LIFE TABLES FOR *Earias vittella* (Fabricius) AND ASSESSMENT OF CROP LOSSES DUE TO MAJOR PESTS IN OKRA

BY

Dadarao Shankarrao Suryawanshi
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CANDIDATE'S DECLARATION

I hereby declare that the entire work embodied in this thesis or any part thereof has not been previously submitted by me for a degree of any University.

(D.S. Suryawanshi)

Parbhani
June 30, 1986.

Dr V.M. Pawar
Senior Insect Toxicologist
Pesticide Research Centre
Marathwada Agricultural University
Parbhani 431 402 (Maharashtra).

CERTIFICATE - I

Shri Dadarao Shankarrao Suryawanshi has satisfactorily prosecuted his course of research for the period of not less than four semesters and that the thesis entitled "Life Tables for *Earias vittella* (Fabricius) and Assessment of Crop Losses due to Major Pests in Okra", submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

(V.M. PAWAR)
Guide

Parbhani
June 30, 1986

CERTIFICATE - II

This is to certify that the thesis entitled "Life Tables for Earias vittella (Fabricius) and Assessment of Crop Losses due to Major Pests in Okra", submitted by Shri Dadarao Shankarrao Suryawanshi to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the subject of AGRICULTURAL ENTOMOLOGY has been approved by the student's Advisory Committee after oral examination in collaboration with the external examiner.

External Examiner 17/1/87

(V.M. PAWAR)
Guide

Members:

(S.N. PURI)

(A.K. RAODEO)

(C.P. GHONSIKAR)

Associate Dean & Principal,
College of Agriculture,
Parbhani.

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Chapter 1

INTRODUCTION

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Okra, *Abelmoschus esculentus* (L.) Moench is an important vegetable crop cultivated throughout India. In Maharashtra State, it is grown on an area of 5,000 hectares (Anonymous, 1985). It is a good source of vitamins, proteins and mineral elements. It is also used in paper industry and in manufacture of *gur* as a clarifying agent. It has high medicinal value and is used in cases of catarrhal infection, fever, irritation of bladder, inflammations and coughs.

This crop is attacked by many pests both in vegetative and fruiting stage; the important amongst them are jassid (*Amrasca biguttula biguttula* Ishida), aphid (*Aphis gossypii* Glover) and fruit borer (*Earias vittella* Fabricius). Jassid and aphid infestation affects the early stage of the crop and can cause reduction in yield. Jassid attack causes the leaves to curl upwards along the tips and margins and to develop necrotic areas which extend over entire leaf surface resulting in hopper burn. Aphids reduce the vigour of the plants. Heavy infestations of these pests in young stage result in stunted growth and gradual death of plants. Caterpillars of *E.vittella* gain entry into tender shoots, flowers, buds and developing fruits and feed therein, causing thereby cessation of shoot growth and shedding of buds and flowers. The affected fruits are rendered unfit for human consumption. Besides okra, it has also been reported to feed on number of malvaceous plants including cotton (Fletcher and Misra, 1920; Haroon Khan *et al.*, 1946).

The food plants play a vital role in development, survival and reproductive potential of insects (Painter, 1951). It is one of the major eco-biological factors in building up its population. The host plants also play an important role in maintaining continuity of the pest throughout the year.

Life tables are one of the tools most useful in the study of insect population dynamics. Life tables can be used to make quantitative and qualitative evaluation of different host plants. Life tables may be analysed to determine the stage in the life cycle which contributes the most to the population trend when a series of life tables is available (Birch, 1948). Perusal of literature reveals that very scanty information is available on the aspect of reproductive potential of *E. vittella* on different hosts (Ambegaonkar and Bilapate, 1982).

Completion of a given stage in the development of insect requires an accumulation of a definite amount of heat energy known as the thermal constant (Uvarov, 1931). The knowledge of thermal constant of a pest gives information regarding the number of generations that a pest will complete and its abundance within a given period.

Insect injury consists of the detrimental acts of insects which cause damage to the plants. This would involve insect population and insect behaviour. Plant damage is the effect of the insect injury on the plant. Plant damage may or may not result in crop loss. In some cases, the damage may even be beneficial. The term 'crop losses' implies qualitative and quantitative reduction in yields, and the loss which can be avoided by applying chemical control measures against pests and diseases may be termed as 'avoidable loss' (Khosla, 1980).

The assessment of crop losses due to pests is a pre-requisite for any planned programme of crop protection. It helps in the prediction of crop production and development planning for future production. It also helps to guide research programmes.

In India, the efforts made to assess the losses due to pests and diseases of major crops are almost negligible. The picture remains much the same from the time Pradhan (1964) advocated assessment of losses due to pests, inspite of the attempts made by several workers. Appreciable crop losses are caused by insect pests in okra (Rawat and Sahu, 1973; Singh and Chopra, 1979; Krishnaiah, 1980). But the reliable and objective estimates of their incidence and consequent crop losses in respect of biometric parameters and yield contributing factors are not available.

Keeping in mind the above points, the present investigations were carried out on the following aspects:

1. Life table studies of *E. vittella* on okra and cotton in laboratory

2. Determination of thermal constant for *E. vittella*

3. Assessment of crop losses due to major pests in okra

4. Crop loss assessment due to major pests during various growth periods of okra.

Chapter 2

REVIEW OF LITERATURE

Chapter 2

REVIEW OF LITERATURE

The review of literature here covers the biology and life fecundity tables of *Earias vittella* Fab., methods and techniques in general for assessing crop losses, crop loss assessment techniques and losses due to insect pests in okra and their impact on various plant characters.

2.1 Biology of *E. vittella*

2.1.1 Egg

Fletcher and Misra (1920) reported that the incubation period of *E. fabia* was about 3 days during April to September. Hussain and Lal (1922) found that the incubation period of *E. insulana* was 2 to 4 days during summer and upto 9 days in winter.

According to Deshpande and Nadkarny (1936) the incubation period of the eggs of *E. fabia* and *E. insulana* was 4 days almost throughout the year except during the cold months of December and January, when it occupied about 5 to 7 days.

The incubation period of *E. fabia* was 11, 6.6, 4, 2.91 and 2.66 days at 16°, 20°, 25°, 30° and 35°C temperatures, respectively (Ahmad and Ullah, 1939).

Pruthi (1939) reported that the egg period of _E. fabia_ and _E. insulana_ on cotton lasted for 11 to 12 days at 16°C temperature.

Patel _et al._ (1956) observed that the incubation period of _E. fabia_ and _E. insulana_ ranged from 4 to 7 days.

Yathom (1956) stated that the incubation period of _E. insulana_ eggs was 3 days at 26-29°C temperature. The incubation period of _E. vittella_ was 3 to 4 days in July to September and 8 to 9 days in January and February at Kanpur (Pant, 1960).

Pruthi (1969) reported that the eggs are minute in size and green in colour, laid singly at night on the tender parts of plant and hatched in 4 to 5 days.

Grewal and Atwal (1969) observed that the incubation period of the eggs of _E. insulana_ lasted for 4.6, 2.9, 2.4 and 2.1 days at 25°, 30°, 35° and 40°C respectively. There was 61.4, 65.2, 59.2 and 51.8 per cent hatching of eggs at different temperatures, respectively.

Moradashaghi (1971) reported that the egg stage of _E. insulana_ lasted for 4 days. Assem _et al._ (1973) found that the incubation period of _E. insulana_ was

4 to 5 days at 30°C and 70 per cent relative humidity and 5 to 10 days at 15°C and 50 per cent relative humidity.

According to Atwal (1976), incubation period of E. insulana and E. fabia was 3 to 4 days. Senapati et al. (1978) observed that the egg stage on fruit and shoots of okra and bolls and shoots of cotton lasted for 3 days at 29 ± 2°C and 2 days at room temperature (30.8 to 32.3°C).

Hafeez and Ali (1983) found that the egg stage of E. vittella lasted 3-4 days under semi-natural conditions in the laboratory.

2.1.2 Larva

Fletcher and Misra (1920) reported that the larval duration of E. fabia was 9 to 11 days on cotton. While Deshpande and Nadkarny (1936) stated that the larval duration was 10 to 12 days on cotton and it extended upto 14 to 16 days during December and January.

Ahmad and Ullah (1939) reported that the larval duration was 34.96, 19.86, 11.92, 9.93 and 8.90 days at 16, 20, 25, 30 and 35°C temperature, respectively. According to Pruthi (1939) larval period was 35 days on cotton at 16°C.

Yathom (1956) reported 9-10 days larval period of *E. insulana* at 26 to 29°C temperature. The larval period ranged from 9 to 16 days (Patel *et al*., 1956). Pant (1960) stated that the larval period of *E. vittella* ranged from 10 to 12 days and 15 to 19 days in laboratory and field conditions, respectively.

The larval duration of *E. insulana* varied from about a week to more than two months (Pradhan, 1969). Grewal and Atwal (1969) found that the larval development was faster at 35°C than at 30° or 25°C temperature and the same was 10.62, 10.99 and 11.48 days, respectively.

Under Punjab conditions, Pruthi (1969) reported that the larval period of *E. insulana* lasted from 10 to 16 days in summer and 50 to 60 days in winter. Moradeshaghi (1971) found that the larval stage of *E. insulana* lasted for 14 days. Larval duration was 9 to 16 days on cotton bolls and 18 to 20 days on cotton twigs (Senapati *et al*., 1978).

Hafeez and Ali (1983) stated that the larval stage of *E. vittella* lasted for 5-16 days in semi-natural conditions.

Ambegaonkar and Bilapate (1984) reported that the mean larval duration of *E. vittella* was shorter (9.26 days) on okra fruits and longest (11.34 days) on cotton flowers. The larval duration on other foods viz. cotton bolls, okra seeds, and okra epicarp was 9.49, 9.81 and 9.98 days, respectively.

2.1.3 Pupa

According to Deshpande and Nadkarny (1936), pupation of E. fabia and E. insulana generally occurs in soil. In normal field conditions, the pupa occurred to a maximum depth of about 10 to 12 inches below the soil surface. The pupal period varied from 8-14 days. The pupal period of E. fabia was 7 to 9 days in April and October at Pusa (Ahmad and Ullah, 1939).

Yathom (1956) stated that life duration of different stages depends upon climatic conditions. The pupal duration of E. insulana lasted for 8 to 10 days at 26 to 29°C temperature. Patel et al. (1956) reported that full fed larva pupated in silken cocoon outside the bolls in which it remained for 8 to 14 days.

Grewal and Atwal (1969) recorded pupal duration of 11.64, 8.98 and 7.52 days at 25, 30 and 35°C temperature, respectively. Murtuza and Waheed (1969) reported that pupal duration of male and female was 9 and 8 days in July and 11 and 10 days in November.

Assem et al. (1973) observed that the pupal stage lasted for 9 to 10 days at 30°C and 70 per cent relative humidity and 10 to 15 days at 15°C temperature and 50 per cent relative humidity. The pupal duration of *E. insulana* was 10.1, 10.6 and 11.3 days on unripe cotton seeds, unripe okra seeds and milky maize seeds, respectively (Megahed *et al.*, 1974).

Atwal (1976) reported that larvae pupated either in the plants or in the ground among fallen leaves and the moths emerged in 4 to 9 days. The pupal stage was prolonged in winter and occupied 6 to 12 weeks. Senapati *et al.* (1978) found 10 to 12 days pupal duration on cotton bolls.

Hafeez and Ali (1983) stated that the pupal stage of *E. vittella* lasted for 6 to 13 days.

Ambegaonkar and Bilapate (1984) observed that the pupal stage of *E. vittella* lasted for 6.63, 8.49, 8.97, 10.58 and 11.41 days when the larvae were reared on cotton bolls, okra seeds, okra fruits, cotton flowers and okra epicarp, respectively.

2.1.4 Life Cycle

Deshpande and Nadkarny (1936) reported that the life cycle duration of *E. insulana* and *E. fabia* was 22 days during January. Christidis and Harrison (1955) observed that the whole life cycle of *E. insulana* was completed in 40 days on cotton.

Khan and Rao (1960) stated that the entire life cycle of *E. insulana* and *E. vittella* on cotton occupied 22 to 35 days in Gujarat, 18 to 46 days in Maharashtra and about 25 days in South India.

Megahed *et al*. (1973) found that the life cycle duration of *E. insulana* was 21 to 28 days in August-September on cotton and 74 to 97 days in December-March. Rao (1980) observed that the threshold temperature of development for various stages ranged from 13.33 to 14.04°C, requiring 323.8 day degrees for completing a life cycle. The pest was computed to complete 13 generations in a year.

Ambegaonkar (1981) recorded that the life cycle duration of *E. vittella* when reared on cotton flowers, cotton bolls, okra fruits, okra seeds and okra epicarp was 25.03, 19.05, 21.37, 20.83 and 23.86 days, respectively. Hafeez and Ali (1983) found that the life span of *E. vittella* was 24 to 45 days in semi-natural conditions.

2.1.5 Adult

2.1.5.1 Preoviposition

Deshpande and Nadkarny (1936) stated that preoviposition period of *E. insulana* and *E. fabia* took 3 to 7 days on cotton. Ahmad and Ullah (1941) reported that the preoviposition period of E. fabia was 9 to 10 days (16°C), 4 to 6 days (20°C); 3 days (25°C) and 3.5 days (30°C) on cotton.

Yathom (1956) reported that preoviposition period of E. insulana was 3 to 6 days at 26-29°C temperature. Eggs were usually laid 2 to 11 days after emergence on fruits of okra (Murtuza and Waheed, 1969).

Anwar et al. (1973) found that E. vittella required 2 to 4 days, for the start of oviposition. The preoviposition period of E. insulana on okra lasted for 3 to 7 days at 15°C and 50 per cent relative humidity and 3-4 days at 30°C and 70 per cent relative humdity (Assem et al., 1973).

The preoviposition period was 9, 5.2 and 12.4 days in unripe cotton seeds, unripe okra seeds and maize seeds, respectively (Megahed et al., 1974). According to Vishwpremi and Krishna (1974) the preoviposition period of E. fabia ranged from 24 to 48 hours after mating. Kehat and Gordon (1977) stated that the preoviposition period of E. insulana was prolonged upto 9 days in unmated females.

Ambegaonkar (1981) reported that the mean preoviposition period of E. vittella on cotton flowers, cotton bolls, okra fruits, okra seeds and okra epicarp was 1.2, 1.8, 1.2, 1.2 and 1.4 days, respectively.

2.1.5.2 Oviposition

Deshpande and Nadkarny (1936) stated that the moths of *E. insulana* and *E. fabia* did not lay eggs during the day time irrespective of light or darkness and the average oviposition period ranged from 5 to 15 days in August-September.

Yathom (1956) reported that 25-28°C temperature range was optimum for oviposition in *E. insulana*. The females of *E. vittella* started laying eggs on either the second night after emergence or the first night following mating and the most oviposition occurred from 2 to 7 days after emergence (Anwar *et al*., 1973).

Megahed *et al*. (1974) observed that the mean oviposition period was 19.6 days on unripe cotton seeds, 17.5 days on unripe okra seeds and 24 days on milky maize seeds. Vishwapremi and Krishna (1974) reported that the oviposition period of *E. fabia* was 10 days on whole fruit of okra, 13 days on epicarp, 10 days on mesocarp and 14 days on okra seeds respectively.

Ambegaonkar (1981) stated that the oviposition period of *E. vittella* when reared on cotton flowers, cotton bolls, okra fruits, okra seeds and epicarp was 6.8, 6.4, 6.5, 6.5 and 6.4 days, respectively.

2.1.5.3 Fecundity

Deshpande and Nadkarny (1936) found that the fecundity of *Earias* spp. was 196, 342 and 451 from the moths emerged when larvae were reared on cotton flower buds, cotton bolls and okra fruit, respectively. Ahmad and Ullah (1941) reported that the fecundity of *E. fabia* was 29 at 16°C, 136 at 20°C, 253 at 25°C and 163 eggs at 30°C temperature respectively.

Chao *et al*. (1965) noted that *E. cupreoviridis* laid 102-275 eggs in each generation. Entwistle (1969) reported that *E. biplaga* adults when reared on Cacao (*Theobroma cacao*) and fed with sucrose laid 95 eggs per female and the greatest number of eggs laid by a single female was 461.

Grewal and Atwal (1969) observed that fecundity of *E. insulana* was maximum (89) at 30°C and 70 per cent relative humidity and minimum (49) at 25°C and 100 per cent relative humidity.

Moradeshaghi (1971) reported that the number of eggs laid by *E. insulana* varied from 1 to 173. Mehta (1971) found that the number of eggs laid by *E. fabia* was higher in moths that had developed on okra than those reared on other foods.

Megahed et al. (1973) found that the E. insulana laid maximum number of eggs (422) in September-October while the minimum (164 eggs) in July-August. Anwar et al. (1973) observed that the mated females of E. vittella laid on an average 259 eggs during its life time.

Vishwapremi and Krishna (1974) noted that the average fecundity of E. fabia when reared on whole fruits of okra, okra epicarp, okra mesocarp and seeds of okra was 515, 136, 342 and 838 eggs, respectively. The mean numbers of eggs per mated females of E. insulana, were 164 for unripe cotton seeds, 168 for unripe okra seeds and 152 for milky seeds (Megahed et al., 1974).

Ambegaonkar and Bilapate (1984) found that the fecundity of E. vittella when reared on cotton flowers, cotton bolls, okra fruits, okra seeds and okra epicarp was 272.8, 310.8, 293.2, 283.63 and 242.80, respectively.

2.1.5.4 Longevity and Sex Differentiation

Deshpande and Nadkarny (1936) stated that the average life of moths fed on honey or sugar solution was found to vary from 8 to 22 days.

Ahmad and Ullah (1941) observed that the longevity of E. fabia at 16, 20, 25, 30 and 35°C temperature was 20, 16.9, 16, 12.4 and 5.7 days, respectively and the longevity of females was more than males.

The *E. vittella* moths differed from *E. insulana* in being slightly bigger (13.14 mm long) and having fore wings with broad white stripes along coastal and anal margins. Thus leaving only a wedge shaped green band in middle (Butani, 1976).

Ambegaonkar (1981) reported that the longevity of the adults on cotton flowers and cotton bolls was 6.4 days, on okra fruits and okra seeds, 6.00 days and on okra epicarp, 6.1 days.

Sexes of the fledging moths were distinguished easily on the basis of certain variations in the colour bands of their fore wings (Vishwapremi and Krishna, 1974). In both males and females, there is a conspicuous green band running along the centre of the fore wing. In males, a distinct white strip flanks this band on its upper portion all along its course while the lower side of the green band is bordered by a faintly brown or pinkish-red strip. But in females, the portions of the forewing above and below the green band are distinctly light brown or pinkish-red in colour, the intensity of which is greater than that observed in the lower part of the fore wing of males.

Gupta (1978) noted that the main difference in the pupae of *E. fabia* is the well developed conical knob at the anteriodorsal end of the male cocoon, which does not exist in the females.

2.2 Life Fecundity Tables of *E. vittella*

The population parameter known as the intrinsic rate of natural increase was first devised for the study of human population by Lotka (1925). The parameter was later adapted for a more general use in animal ecology and was applied to studies on vole *Microtus agrestis* (Leslie and Ranson, 1940) and the brown rat *Rattus norvegicus* (Leslie, 1945). Birch (1948) introduced this useful concept to the study of insect populations. He defined the intrinsic rate of increase as the actual rate of increase of a population under specified constant environmental condition in which space and food are unlimited when there are no mortality factors other than physiological ones. He further suggested that the term intrinsic rate of natural increase might be considered more appropriate than an alternative term 'biotic potential' which is more frequently used in relation to insect population.

Howe (1953) stated that a life table can be constructed by following the life history of a group of insects from their birth (egg laying) to emergence of adults and recording all deaths as they occur together with sex of those which die as adult.

It is not possible to know exactly the parameters, the intrinsic rate of natural increase, but an estimate of its value can be made. This estimated value (statistics) was called the innate capacity for increase (rm) by Andrewartha and Birch (1954).

Watson (1964) stated that the range of climatic and biotic(food type) factors will influence the value of 'rm' and suggested that because of the variations in the climatic conditions 'rm' could be used as bio-climatic index in assessing the pest potentialities of an insect when introduced into a new area.

Ambegaonkar and Bilapate (1982) reported that the net reproductive rate of E. vittella when reared on cotton flowers, bolls, okra fruits, seeds and epicarp was 93.17, 93.96, 114.50, 140.23 and 112.71 females per female per generation, respectively. They further stated that on the basis of innate capacity for increase in numbers 'rm', the host plants could be arranged as okra seeds (0.1569), okra epicarp (0.1384), okra fruits (0.1369), cotton bolls (0.1365) and cotton flowers (0.1151). The maximum contribution towards stable age distribution was made by the immature stages.

2.3 Assessment of Crop Losses due to Insect Pests in Okra

2.3.1 Methods and Techniques in General for Assessing Crop Losses

Techniques for assessment of crop losses due to pests have been outlined by several workers (Pradhan, 1964; Judenko, 1965, 1972; Smith, 1967; Strickland and Bardner, 1967; Krishnaiah, 1980; Veeresh, 1980; Kulkarni, 1983). Various techniques of estimating losses due to insect pests adopted by different workers are as follows:

2.3.1.1 Comparison of Yields from a Mechanically Protected Pest Free Crop with a Naturally Pest Infested Crop

The ideal méthod for estimating crop loss would be to compare yields under pest infested and pest free conditions. Attempts were made by several workers to get pest frée plots by different methods as indicated below:

(a) Cage Studies

Technique involving cages is useful for containing the infestation of specific pests while eliminating others and in critical experiments to establish the relationship between insect intensity and yields. Cages of great variaties were used to either exclude or contain pest infestation (Judenko, 1965), to cover a portion of field or plant (Smith, 1967; Krishnaiah, 1980) to prevent the oviposition (Raw and Loety, 1957) or to cover the soil to prevent the entrance of insects into soil (Bardner and Griffiths, 1967).

(b) Artificial Removal of Pests

Hand picking is usually employed to remove the pests from small areas (Judenko, 1958; Judenko et al., 1952). Prasad (1963) used this method for assessing the loss in cabbage plants by imported cabbage worms Pieris rapae L. The same method was adopted by Sheshu Reddy (1973) to estimate loss in red gram due to Heliothis armigera.

(c) Chemical Treatments

Voluminous literature in economic entomology contains many examples of comparisons of treated and untreated insect populations and the effect on crop yield. Indeed, popular technique of crop loss assessment is by using pesticides. In this, an effort is made to protect the experimental crop by best control schedule known for a particular pest and the yield of such crop is compared with the one which has been exposed to normal insect infestation. Though pesticides cannot give true estimates of losses from specific pests, this method has been adopted by several investigators. Hunter (1924) estimated losses due to Anthonomus grandis Bohman using this method.

LeClerg (1971) suggested paired plot experiments and multiple treatments experiments to know the increment of loss per unit increase of pest intensity and the competitive or interaction effects of more than one pest on yield loss. Suryawanshi and Pawar (1980) used the paired plot technique for estimating the losses due to the aphid, Dactynotus sonchi L. in safflower. Krishnaiah (1980) suggested a randomised block design instead of paired plot experiment, if the programme aims at assessing the loss at different crop stages or due to more than one pests. Kulkarni (1983) modified the method suggested by LeClerg (1971) and used factorial randomised block design instead of paired plot for estimating the losses due to cotton pest complex in two cotton hybrids.

2.3.1.2 Evaluation of Damage Before and After Introduction of a Pest into an Area

Hunter (1924) and Smith (1959) have used this method for boll weevil and spotted alfalfa aphid, respectively.

2.3.1.3 Comparison of Yields from Artificially Infested Crops with Pest Free Crops

Artificial infestation can be established at the different points on a plant (Chiang and Holdaway, 1959), on different dates (Deay et al., 1949; Prasad, 1963), on different sizes of the plant (Deay et al., 1949) and for different length of the time (Ortman and Painter, 1960). This method was adopted for estimating the losses due to H. armigera in sorghum (Buckley and Burkhardt, 1962), Spodoptera frugiperda (Smith) on maize (Morril and Greene, 1974); H. armigera on red gram (Sheshu Reddy, 1973), *Empoasca fabae* on soybean (Ogunlana and Pedigo, 1974) and *E. vittella* on cotton (Zaghoul, 1982).

2.3.1.4 Comparison of Naturally Infested Plants with Naturally Uninfested Plants

Pradhan (1964) described that, in this technique the plants from the same field are examined for the degree of infestation and their individual yields are determined.

Judenko (1972) suggested an analytical method of calculating loss based on comparison of yield from two sets of plants that are precisely identical in all respects except that one is unattacked and the other is attacked by specific pest. The economic loss was computed by the following procedure:

Coefficient of harmfulness (C) $= \frac{a-b}{a} \times 100$

where, a = Mean yield per uninfested plant

b = mean yield per infested plant

Percentage of economic loss (L) $= \frac{C \times P}{100}$

where, p = percentage of plants infested

Expected yield in the absence of Pest (W) $= \frac{100\ (ACT)}{100-L}$

where, ACT = actual yield

The economic loss (LOS) = W - ACT

2.3.1.5 Simulated Damage

A number of investigators have attempted to simulate pest injury either by removing leaves, reproductive parts in a manner caused by pest themselves to determine its effect on the crop losses caused (Dunnam *et al.*, 1943; Kincade *et al.*, 1967; Wilson *et al.*, 1972; Baldwin *et al.*, 1974; Rehman, 1977; Wilson and Gutierrez, 1980; Wilson *et al.*, 1982).

2.3.1.6 Manipulation of Natural Enemies

The feasibility of this method is limited by many potential secondary interactions (Smith, 1967).

2.3.1.7 Average Amount of Damage Caused by Individual Insect

This method is utilised by Pradhan and Peswani (1961) to assess the losses caused by *Hieroglyphus nigroleptus* (Boliver) in maize and by *Plusia orichalcea* F. in cauliflower by Basu and Chatterjee (1969).

2.3.1.8 Subjective Estimates of Yield Loss

Estimation of losses over large areas are often made from the opinions of farmers and extension workers. This method may be useful when damage is heavy.

Although, none of the foregoing methods and techniques of assessing losses gives unequivocal results, estimates of losses can be obtained that are of practical value and that show the benefits of controlling pests.

2.3.2 Crop Loss Assessment Techniques and Losses Caused due to Major Pests in Okra

Rawat and Sahu (1973) carried out field tests to estimate losses in growth and yield of okra caused by Amrasca (Empoasca) devastans Dist. and Earias sp. In one set of plots, the pests were controlled by the application of granules containing 5 per cent dimethoate at a rate of 20 kg/ha below the seed in the furrow followed by 2 sprays of 0.02 per cent endrin and six sprays of 0.02 per cent carbaryl at 10 days interval starting 5 weeks after sowing, another set was left untreated. Average losses in plant height, the number of leaves per plant and the weight of healthy fruits were 49.8, 45.1 and 69 per cent, respectively.

Singh and Chopra (1979) reported that the per cent reduction in the average plant height, average number of leaves/plant, average number of total fruit(s)/5 plants, average weight of total fruits/5 plants, average number of healthy fruits/5 plants and average weight of healthy fruits/5 plants in control plots in comparison with malathion and leptophos treated plots was 18.30, 28.57, 27.61, 27.0, 40.65 and 37.58 and 21.62, 28.57, 30.27, 29.67, 44.89 and 43.24, respectively.

Krishnaiah (1980) conducted different insecticidal trials in paired plots for assessment of losses due to major pests in okra from 1972-74. From the yield data collected from different insecticidal trials he calculated per cent avoidable loss,

$$\left(\text{Per cent avoidable loss} = \frac{\text{mean yield of protected plots} - \text{mean yield of unprotected plots}}{\text{mean yield of protected plots}} \times 100 \right)$$

due to major pests in okra and recorded 40-56 per cent and 49-74 per cent yield loss due to leaf hopper and fruit borer, respectively.

In another experiment to compare the losses due to fruit borer on okra by different methods viz. cage method, chemical protection and individual plant yield assessment the yield losses worked out were 46.1, 45.5 and 38.9 per cent, respectively. Thus he found that other methods are also useful. His efforts to assess the yield loss from naturally infested plots were not successful, as the variation in fruit borer infestation was very narrow with a range of 29 to 45 per cent.

He had also undertaken studies to establish pest density of jassids and okra yield relationship for the 15 days old crop. Jassid nymphs at 1,3,5 and 7 per leaf were released on plants grown in field and covered by 6" x 4" x 6" field cages. Insect numbers were maintained for a fortnight by releasing nymphs of 2nd and 3rd instars. Later, the plants were protected from jassids by monocrotophos (0.05 per cent) spray and okra fruit yields were recorded. Correlation between the insect number and yield (gm/plant) was highly significant with a correlation coefficient of -0.717. The regression equation (for yield 'y' on insect number 'x') was worked out to be Y = 121.925 - 5.521 x. The yield loss in okra due to 7 nymphs per leaf for a period of fortnight at this growth stage was of the order of 32 per cent. In his studies to establish relationship between intensity of fruit borer and yield loss, he found that the relationship of fruit borer infestation (x) and yield loss (y) follow a linear regression. The regression equation worked out was:

$$Y = 1.624 + 1.149\,x \quad (r = 0.814)$$

Rao (1980) conducted studies on crop loss due to insect pests of okra by differential protection, by using two insecticides viz. formothion (against sucking insects) and carbaryl (against fruit borer) and observed that fruit borers inflicted greater losses (33.10 to 45.03 per cent by number and 21.11 to 39.26 per cent by weight with 5.40 to 13.24 q/ha reduction in yield) as compared to sucking insects (1.5 per cent by number and 3.76 per cent by weight with 7.2 q/ha reduction in yield).

Srinivasan and Krishnakumar (1983) conducted field trials in randomised block design with four replications for assessment of losses caused by sucking pests and fruit borer in okra. They observed that the percentage yield losses following the treatments with carbaryl (4.2 per cent), carbofuran + phosalone (4.1 per cent) and disulfoton + carbaryl (2.9 per cent) were lowest and were not significantly different from one another. The same treatments produced maximum marketable yields. The loss caused in the unprotected control plot was 13.5 per cent and this was on par with losses resulting from the application of carbofuran followed by disulfoton. The application of granular insecticides to control sucking pests without controlling fruit borer did not significantly increase marketable yields. Of the total yield, 19 per cent was lost to jassids and aphids and 45 per cent was lost to the fruit borer.

2.3.2.1 Plant Characters as Influenced by Pest Infestation

Palaniswamy et al. (1965) stated that the growth rate of plants as indicated by daily weight gains for 30 days was higher following treatment with aldicarb and carbofuran for the control of aphids on okra.

Perumal et al. (1971) found increase in the total dry matter production per plant, shoot weight/ root weight, petiole length, leaf area and dry weight and advanced flowering by 3 days, following carbaryl spraying against okra pests. The shoot length/root length was greatest in plants sprayed with endrin. Fruit length and weight were greater in the thiodemeton treatment.

Rawat and Sahu (1973) reported that the average loss in unprotected okra crop in plant height, the number of leaves per plant and in the weight of healthy fruits were 49.8, 45.1 and 69 per cent respectively. Shantakumar et al. (1975) observed vigorous growth, early flowering by 2-9 days and higher yields by protecting the okra crop with carbofuran seed treatment.

Saimbhi et al (1979) stated that both fresh and dry weights of okra leaves, stem and fruits per plant and seed yield per hectare increased by application of phorate at 1.25 kg a.i./ha. Singh and Chopra (1979) observed significantly more height, number of leaves and yield in okra plots treated with 0.1 per cent malathion and leptophos 0.05 per cent for jassid control.

Chapter 3

MATERIAL AND METHODS

Chapter 3

MATERIAL AND METHODS

The details of the material used and methods followed during the present investigation are described hereunder:

3.1 Laboratory Studies

3.1.1 Rearing Technique of Fruit Borer, *Earias vittella*

The initial culture of fruit borer, *E. vittella* was obtained by collecting a large number of larvae in the month of September, 1978 from the okra fields. The larvae were reared individually in 5 x 5 cm round plastic boxes and fresh okra fruits were provided as food. The boxes were kept clean and fresh food was provided to the larvae every day until pupation. Sexing was done in the adult stage (Vishwapremi and Krishna, 1974). The newly emerged male and female moths (1:1) were placed in an oviposition cage (30 x 30 x 30 cm) having a glass in the front and muslin cloth on three sides with sleaves on the two lateral sides and the wooden base. The bottom of the cage was covered with one cm thick urethane foam. Cotton wool swabs dipped in five per cent honey solution were suspended with the help of U pins from the top and sides of the cage and also kept in the petri-dish placed on the floor of the cage. The cotton wool swabs were replaced daily. Tender okra fruits were kept in petri-dish as oviposition site. Soon after egg laying, the eggs were collected in the petri-dishes (10 cm diameter). The neonate larvae were carefully removed with the help of wet camel hair brush and released on different fresh foods viz. okra fruits, okra seeds, cotton squares and cotton bolls. All the larvae were reared individually on different hosts. Food was renewed daily in the morning until pupation. The rearing was conducted through two consecutive generations on respective hosts to acclimatise and thus the nucleus culture was maintained on respective hosts. From third generation, culture was used for laboratory investigations. All the laboratory experiments were conducted in the Division of Entomology, Marathwada Agricultural University, Parbhani at 27 ± 2°C temperature.

3.1.2 Life Fecundity Tables

In order to construct the life fecundity tables, 100 eggs were placed in ten plastic boxes in batches of ten each. The eggs were glued with the help of soft wet camel hair brush on the white paper in one row to facilitate observation on hatching. After hatching, all the larvae were reared individually on respective hosts. Fresh food was supplied daily. Observations on hatching, larval and pupal development, successful adult emergence, fecundity and age specific mortality in eggs, larvae, pupae and adults were recorded daily. For determining the age specific fecundity, the total number of adults emerged on a particular day were transferred to a separate cage for egg laying. The healthy twigs of respective host plants kept in the containers containing water were put into the cages as oviposition site. As the sex ratio was 1:1 the number of eggs laid per female was divided by two to get the number of female births (m_x).

The following column headings proposed by Birch (1948), elaborated by Howe (1953) and Atwal and Bains (1974) were used for the construction of life fecundity tables under laboratory conditions.

x = Pivotal age in days

l_x = Survival of females at age 'x'

m_x = Age schedule for female births at age 'x'

3.1.2.1 Net Reproductive Rate

The values of 'x', 'l_x' and 'm_x' were calculated from the data on life tables. The sum of the products '$l_x m_x$' is the net reproductive rate (R_o) (Lotka, 1925). 'R_o' is the rate of multiplication of the population in each generation measured in terms of females produced per generation. The number of times a population would multiply per generation was calculated by the formula,

$$R_o = \sum l_x m_x$$

3.1.2.2 Mean Generation Time

The approximate value of cohort generation time (T_c) (the mean age of the mothers in a cohort at the birth of female offspring) was calculated as follows

$$T_c = \frac{\sum x \, l_x m_x}{R_o}$$

3.1.2.3 The Innate Capacity for Increase in Numbers

The number of individuals survived at each age interval and also the mean number of female offsprings produced at each age interval were recorded. From the data on life table, the arbitrary value of r_m (r_c) was calculated by using the formula (Laughlin, 1965):

$$r_c = \frac{\log_e R_o}{T_c}$$

The intrinsic rate of natural increase (r_m) was then calculated from the value of arbitrary 'r_m' by taking two trial values arbitrarily selected on either side of it, differing in the second decimal places by interpolation with the formula:

$$\sum e^{-r_m x} \, l_x m_x = 1$$

The values of the negative exponent of $e^{-r_m x}$ ascertained from this experiment often lay outside the range given in the tables found in most mathematical handbooks. For this reason, both sides of the above equation were multiplied by factor e^7 to give an equation (Birch, 1948; Watson, 1964):

$$\sum e^{7-r_m x} \; l_x m_x = e^7 = 1096.6$$

where,

$$e = 2.71828$$

Tables were then constructed for each host plant with columns 'x' and '$l_x m_x$' for each trial 'r_m'. The two trial values of $\sum e^{7-r_m x} \; l_x m_x$ were then plotted on the horizontal axis against their respective arbitrary r_m's on the vertical axis. The points were joined to give a line which intersected a vertical line drawn from the desired value of $\sum e^{7-r_m x} \; l_x m_x = 1096.6$. The point of intersection gave the value of the true 'r_m', accurate to four decimal places. The precise generation time (T) was then calculated from the formula:

$$T = \frac{\log_e R_o}{r_m}$$

3.1.2.4 The Finite Rate of Natural Increase (λ)

The finite rate of natural increase (λ) i.e. females per female per day was calculated as:

$$\lambda = \text{anti} \log_e r_m$$

and thus, the weekly multiplication of the population was calculated. The number of days required to double the population as well as the hypothetical F_2 females were also worked out.

3.1.2.5 Stable Age Distribution

The stable age distribution (per cent distribution of various age groups) is the distribution which would be approached by a population of stable age schedule of birth rate and death rate (i.e. m_x and l_x are constant) when growing in unlimited space (Andrewartha and Birch, 1954). The stable age distribution was worked out with the knowledge of 'r_m' and the life table (age specific mortality of immature as well as mature stages). The L_x (life table age distribution) was worked out from the 'l_x' table with the formula:

$$L_x = \frac{l_x + (l_x + 1)}{2}$$

The L_x was multiplied with $e^{-r_m (x + 1)}$ and the percentage distribution of each pivotal age (x) was worked out. By putting together the percentage under each stage, viz. egg, larval, pupal and adult, the expected percentage contribution of each group (stage) in a stable age distribution was calculated.

3.1.3 Determination of Thermal Constant for *E. vittella*

The fruit borer, *E. vittella* was reared on okra fruits at constant temperature of 20 and 30°C and at constant relative humidity of 75 per cent obtained by using sulphuric acid solution (Solomon, 1951). The period of development of different stages as well as total developmental period was recorded. Using this data, threshold temperature of development of *E. vittella* was worked out as per the method described by Atwal and Bains (1974). Similarly, the developmental period was studied at ambient temperature and relative humidity in the laboratory. The prevailing temperature during the period of study was recorded. From this, the effective temperature for each day of development was calculated. The summation of daily effective temperature for the number of days taken by a particular stage gave the thermal constant for that stage and similarly for all the stages of the pest over the total developmental period. Summation of effective temperature of each day for one year gave the heat availability in terms of day degrees which when divided by day degrees required for the total development, gave the number of generations that the pest could complete within a year.

3.2 Field Experiments

The field experiments were conducted at Agricultural School Farm, Marathwada Agricultural University, Parbhani. The city has sub-tropical climate where the mean annual rainfall is about 828.28 mm, mostly during June-September. The mean maximum temperature ranges from 28.7°C during December to 41.2°C in May. The minimum temperature varies from 11.32° to 25.77°C in winter and summer, respectively. Summer is hot and dry while winter is cool. The mean relative humidity ranges from 30-90 per cent.

The investigations were undertaken in kharif seasons of 1978, 1979 and 1981. The experiments were laid out on black cotton soil having medium fertility and fairly good drainage. Fields were well prepared by giving one ploughing and two harrowings to bring the soil to proper tilth. The crop was fertilised with 50 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare as a basal dose and top dressed with 50 kg N/ha after a month. Certified seed of Pusa Sawani variety of okra was obtained from National Seeds Corporation. Seeds were sown by dibbling 2-3 seeds per hill in a row 45 cm apart by keeping 30 cm distance between plants. Two hoeings and three hand weedings were done to keep the plots free from weeds. The crop was grown under protective irrigation.

3.2.1 Assessment of Crop Losses due to Okra Pest Complex

Popular technique of crop loss assessment by using pesticides as per LeClerg (1971) was followed with modifications in design to suit the requirements of the present experiment i.e. instead of adopting paired plot, randomised block design was used to calculate the losses due to okra pest complex.

Two field trials were laid out during the rainy season of 1978 and 1979 (June-September) in a randomised block design with ten treatments each replicated four times. The individual plot size was 5.4 x 3.0 m with twelve rows and ten dibbles in each row. Net plot size was 4.5 x 2.4 m with 10 rows and 8 dibbles in each row. The experiment consisted of following treatments

- T_1 Carbofuran 5 per cent seed treatment to protect the crop during vegetative stage
- T_2 Disulfoton at 1 kg a.i./ha applied at the time of sowing to protect the crop during vegetative stage
- T_3 Monocrotophos 0.04 per cent applied at 40, 50, 60 and 70 days after germination with commencement of flowering
- T_4 Carbaryl 0.2 per cent applied as T_3 above
- T_5 Carbofuran 5 per cent seed treatment and monocrotophos 0.04 per cent sprayed at the commencement of flowering as T_3 above

T_6 Disulfoton at 1 kg a.i./ha applied at the time of sowing and carbaryl 0.2 per cent applied at the commencement of flowering as T_3 above

T_7 Carbofuran 5 per cent seed treatment and malathion 0.1 per cent applied as T_3 above

T_8 Malathion 0.1 per cent applied throughout the growth period at an interval of 10 days commencing from 20 days of sowing, the time of pest appearance

T_9 Carbaryl 0.2 per cent applied as T_8 above

T_{10} Untreated throughout the growth period.

The details of the insecticides used in the above treatments are given in Table 1.

3.2.1.1 Method of Recording Observations

Observations were recorded on ten plants randomly selected in each net plot. The observations recorded during the experimentation are given here under.

3.2.1.1.1 Population of Sucking Pests

Counts of Jassid nymphs and aphids were taken at weekly interval from six leaves (two each from top, middle and bottom) on ten tagged plants selected at random commencing from 15 to 40 days of sowing. The data on the number of jassids and aphids were subjected to log (insect number + 2) transformation before statistical analysis (Krishnaiah et al., 1976). The incidence of other pests was negligible, hence not recorded.

3.2.1.1.2 Infestation of Fruit Borer

During each harvest carried out at four days interval borer affected and healthy fruits from individual plots were counted. The percentage borer infestation was calculated on the basis of cumulative data for all the pickings. The data on percentage fruit borer infestation were transformed to arcsin values before statistical analysis (Little and Hills, 1978; Nageswar Rao, 1983).

3.2.1.1.3 Biometrical Observations

Observations on the plant height and number of leaves per plant were recorded at weekly interval throughout the crop life. The observations on the leaf area per plant, fresh leaf weight per plant and fresh stem weight per plant were recorded 40 days after sowing. The leaf area per plant was recorded with digital leaf area meter.

3.2.1.1.4 Yield and Yield Components

Observations on the number of healthy fruits per plant and those infested by fruit borer were recorded

Table 1. Details of the insecticides used

Sr. No.	Common name	Trade name	Formulation	Chemical name	Source of supply
1.	Carbofuran	Furadan	50 SP	2,3-Dihydro 2,2 dimethyl 7-Benzofuranyl methyl carbamate	Rallis India Ltd., Bombay
2.	Disulfoton	Solvirex	5 G	O-O-Dimethyl-s-2 (ethyl-thio) ethyl Phosphorodithioate	Bayer (India) Ltd., Bombay
3.	Carbaryl	Sevin	50 WP	1-Napthyl N-methyl Carbamate	Union Carbide Ltd., Bombay
4.	Monocrotophos	Nuvacron	36 EC	Dimethyl Phosphate of 3-hydroxy-N-methyl ciscrotonomide	CIBA GIEGY of India Ltd., Bombay
5.	Endosulfan	Thiodan	35 EC	6, 7, 8, 9, 10, 10-Hexa-chloro-1,5,5a,6,9,9a-hexahydro-6, 9-methano-2-3-benzo (c)-dioxathie-pin-3-oxide	Hoechest Pharmaceuticals Ltd., Bombay
6.	Malathion	Cythion	50 EC	O,O-dimethyl S-(1,2-dicarbethoxyethyl) Phosphorodithioate	Cynamid India Ltd., Bombay

from the cumulative data for all the pickings. Similarly, the observations were recorded on the length and girth of the fruits at each harvest from 10 randomly selected plants. Observations on the weight of healthy fruits per plot were recorded from the cumulative data for all the pickings.

3.2.1.2 Method used for Assessing per cent Crop Loss

Judenko (1972) expressed the percentage yield loss per plant by the coefficient of harmfulness (C):

$$C = \frac{(a-b) \times 100}{a}$$

where,

a = mean yield of unattacked plants

b = mean yield of attacked plants

The same method was adopted to assess the losses in various parameters studied. The per cent loss was calculated by comparing the various treatments to the treatment that afforded maximum protection and maximum increase in plant characters and yield. In such a treatment the avoidable loss was considered as nil.

3.2.1.3 Statistical Analysis

The data were statistically analysed by standard "Analysis of variance" method (Panse and Sukhatme, 1967;

Snedecor and Cochran, 1967). The null hypothesis was tested by 'F' test of significance to know whether the observed treatment effects were real or not. From the data in which treatment effects were significant the appropriate standard error (S.E.) and critical difference (C.D.) at five per cent level of probability were calculated for comparing the means of treatments.

3.2.1.3.1 Pooled Analysis

The simple technique of analysis of variance may not be valid under two different seasonal conditions, if the error variance in the seasons are not of the same order and interaction (treatment x season) is also significantly different. Hence, pooled analysis of the data of two years was carried out as per the method described by Panse and Sukhatme (1967).

3.2.1.3.2 Correlation and Regression Studies

The correlations between okra pest complex (jassids, aphids and fruit borer), different plant characters and marketable fruit yield were worked out as per the method given by Panse and Sukhatme (1967).

Simple regression coefficients (b) were worked out between the characters mentioned as under as per the method of Panse and Sukhatme (1967).

1. Number of jassids/leaf (x) and yield (Y)
2. Per cent fruit borer infestation (x) and yield (Y)

The values of regression coefficients (b) were tested for their significance. The regression equation $Y = a + b_x$ was set up for above relationships and the values of constant (a) were computed for prediction of 'Y' on 'x'.

3.2.1.3.2.1 Multiple Regression Studies

Since the yield of marketable fruits (Y) is the resultant of the effect of more than one independent variable (x_n), the relations obtained by simple regression analysis may not furnish so satisfactory information. Hence, an attempt was made to study the problem of multiple regression analysis.

The yield contributing characters such as plant height, leaf area, number of fruits/plant, etc. have a direct bearing on the crop yield. These characters though directly affect yield, but are in turn affected by pest incidences during the crop growth. Hence, the yield contributing characters cannot be regarded as 'independent' variables in formulating a yield relationship and hence the conventional regression approach cannot be applied in this situation.

The problem can be viewed through the simultaneous equation approach. The approach involves formulating a system of equations in the first stage and then applying suitable method of estimation based on the identifiability of the system. In the present case, the system can be developed as:

The major pests are jassids (x_1), aphids (x_2) and fruit borer (x_3). These variables affect the yield contributing characters, which in the present case are identified to be plant height (y_1), leaf area (y_2) and number of fruits (y_3).

The other variables viz. plant height at 45 days of sowing, number of leaves, leaf weight, stem weight, fruit length and fruit girth were not selected for the multiple regression studies as they exhibited strong correlation between final plant height, leaf area and number of healthy fruits per plant. This inter-correlation would cause the estimation problem "multicollinearity". The joint impact of the selected variables on crop yield can now be described as follows:

$$Y = f(y_1, y_2, y_3) \quad .. \quad 1$$
$$y_1 = f(x_1, x_2, x_3) \quad .. \quad 2$$
$$y_2 = f(x_1, x_2 \quad) \quad .. \quad 3$$
$$y_3 = f(x_1, x_2, x_3) \quad .. \quad 4$$

The above system of equations can be readily verified for identification as per the order condition given by Koutisoyiannis (1978).

As the yield equation is exactly identified, its estimation can be carried out by applying the method of Indirect Least Squares (ILS). The procedure involves estimating the equations (2, 3 and 4) which contain only one dependent and 3 independent variables by ordinary least squares (OLS) method. The estimates of the dependent variables i.e. y_1, y_2 and y_3 are then obtained from the estimated equations. These estimated values which are no longer dependent variables are then regressed on the yield (equation 1) for obtaining the yield equation i.e. the procedure contains the following steps:

(1) Estimation of $\hat{y}_1$, $\hat{y}_2$ and $\hat{y}_3$ from:

$$\hat{y}_1 = a_0 + a_1x_1 + a_2x_2 + a_3x_3$$

$$\hat{y}_2 = b_0 + b_1x_1 + b_2x_2$$

$$\hat{y}_3 = c_0 + c_1x_1 + c_2x_2 + c_3x_3$$

(2) Estimation of $\hat{Y}$ from:

$$\hat{Y} = d_0 + d_1\hat{y}_1 + d_2\hat{y}_2 + d_2\hat{y}_3$$

3.2.2 Crop Loss Assessment due to Major Pests During Various Plant Growth Periods of Okra

This experiment was conducted with Pusa Sawani variety of okra in randomised block design during the kharif season of 1981 (June-September). There were 12 treatments each replicated thrice. The plot size was 5.4 x 3.0 m with 12 rows and 10 dibbles in each row. The net plot size was 4.5 x 2.4 m with 10 rows and 8 dibbles in each row. The treatments were designed to protect okra crop with insecticide during different plant growth periods. Each treated growth period had a complementary treatment during which no insecticide was applied. Chemical protection during a particular growth period consisted of spraying with monocrotophos 0.04 per cent. The details of the treatments are given in Table 2.

3.2.2.1 Method of Recording Observations

Observations were recorded on the population of jassids (nymphs), aphids, per cent fruit borer infestation, height of the plant, number of leaves per plant, number of fruits per plant, length and girth of fruit and yield of okra fruits. The method of recording observations was same as given in earlier experiment.

3.2.2.2 Statistical Analysis

The data were statistically analysed by standard Analysis of variance method (Panse and Sukhatme, 1967; Snedecor and Cochran, 1967). The variance due to treatments was compared against variance due to error to test the null hypothesis by 'F' test of significance at P = 0.05.

Table 2. Details of the treatments

Treatment	Period with insecticidal applications (days after sowing)	No. of insecticidal applications	Schedule of insecticidal application (days after sowing)
T_1	15-90	5	15
T_2	15-74	4	
T_3	15-59	3	
T_4	15-44	2	30
T_5	15-29	1	
T_6	Untreated	0	45
T_7	30-90	4	
T_8	45-90	3	60
T_9	60-90	2	
T_{10}	75-90	1	75
T_{11}	30-74	3	
T_{12}	15-29 and 75-90	2	

Chapter 4

RESULTS

Chapter 4

RESULTS

The results obtained in the present investigations are presented under the following heads:

4.1 Life fecundity tables of Earias vittella (F.) on okra and cotton

4.2 Determination of thermal constant for E. vittella

4.3 Assessment of crop losses due to major pests in okra

4.4 Crop loss assessment due to major pests during various plant growth periods of okra

4.1 Life Fecundity Tables of E. vittella

4.1.1 Okra

4.1.1.1 Okra Fruits

The data regarding the survival of different stages of E. vittella during development on okra fruits are presented in Table 3. It was observed that the maximum duration of egg, larva and pupa was 4, 13 and 12 days, respectively. The number which survived between egg and adult emergence was 80 out of 100.

The data regarding the life table showing the survival (l_x) and age specific fecundity for E. vittella when reared on okra fruits are presented in Table 4 and Fig. 1.

Table 3. The survival of different stages of E. *vittella* on okra fruits

Sr. No.	Eggs kept (0 days)	Number surviving		
		Egg stage (0-4 days)	Larval stage (5-17 days)	Pupal stage (18-29 days)
1	10	9	8	8
2	10	8	8	7
3	10	10	9	9
4	10	10	10	9
5	10	8	7	7
6	10	9	8	8
7	10	8	8	8
8	10	10	9	9
9	10	10	10	8
10	10	7	7	7
Total	100	89	84	80

Table 4. Life table (for females) and age specific fecundity for E. vittella on okra fruits

Pivotal age in days x	Survival of females at different age intervals l_x	Age schedule for female births m_x	$l_x m_x$	$x l_x m_x$
0-29	0.80	..	Immature stages	
30-31	0.80	..	Preoviposition period	
32	0.80	6.8	5.44	174.08
33	0.80	24.1	19.28	636.24
34	0.80	33.5	26.80	911.20
35	0.80	35.1	28.08	982.80
36	0.78	28.7	22.38	805.89
37	0.68	23.5	15.98	591.26
38	0.54	11.5	6.21	235.98
39	0.32	0.0	0.00	0.00
			$\Sigma l_x m_x (R_0)$ = 124.17	$\Sigma x l_x m_x$ = 4337.45

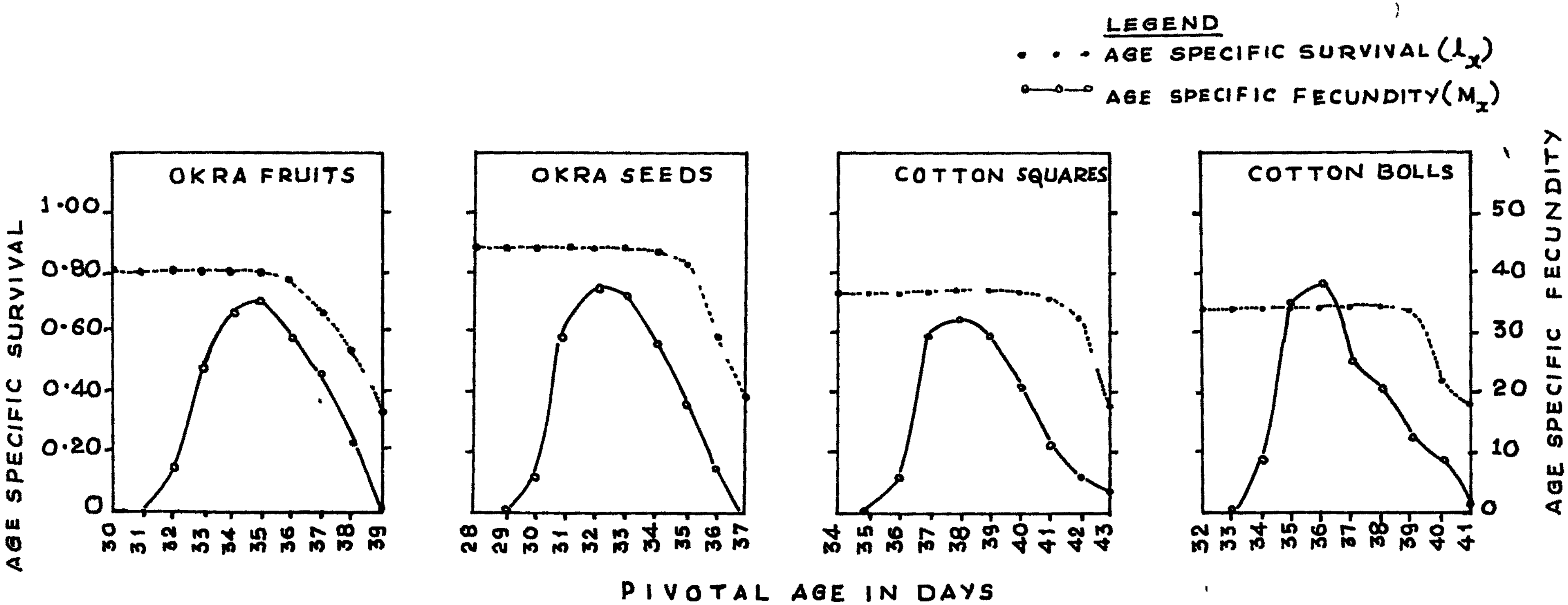

Figure 1. DAILY AGE SPECIFIC SURVIVAL AND FECUNDITY OF *E. vittella* ON OKRA FRUITS, OKRA SEEDS, COTTON SQUARES AND COTTON BOLLS

It is evident from Table 4 that the preoviposition period ranged from 30th to 31st day of pivotal age. The survival of immature stages (l_x) from egg to adult emergence was 0.80 adults per individual. The first female mortality was observed on 36th day (l_x = 0.78) of pivotal age. The highest contribution of females (m_x = 35.1) was observed on 35th day of pivotal age in the life cycle. The net reproductive rate (R_0) representing the total female births was 124.17. Thus the population of E. vittella would be able to multiply 124.17 times per generation on okra fruits.

The data on innate rate of natural increase (r_m), generation time (T) and finite rate of increase in numbers of E. vittella are presented in Table 5 and Fig. 2.

It is apparent from the Table 5 that the innate capacity for increase in numbers (r_m) was 0.1385 females per female per day and with a daily finite rate of increase (λ) 1.148 females per female per day, the population would multiply 2.63 times every week. It took 5.004 days to double the population. The mean generation time (T) was 34.81 days. The hypothetical female population in F_2 generation was 15418.18.

Table 5. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *E. vittella* on okra fruits

Population growth statistics	
Mean length of generation (T_c)	
$T_c = \frac{\sum x l_x m_x}{R_o}$	34.93 days
Innate capacity for increase in numbers (r_c)	
$r_c = \frac{\log_e R_o}{T_c}$	0.1380 females/female/day
Arbitrary r_m 0.13 and 0.14 corrected r_m $\sum e^{7-r_m x} l_x m_x = 1096.6$	0.1385 females/female/day
Corrected generation time (T)	
$T = \frac{\log_e R_o}{r_m}$	34.81 days
Finite rate of increase in numbers (λ)	
$(\lambda) = \text{antilog}_e\, r_m$	1.148 females/female/day
Weekly multiplication of population	2.63
Doubling time	5.004 days
Hypothetical F_2 females	15418.18

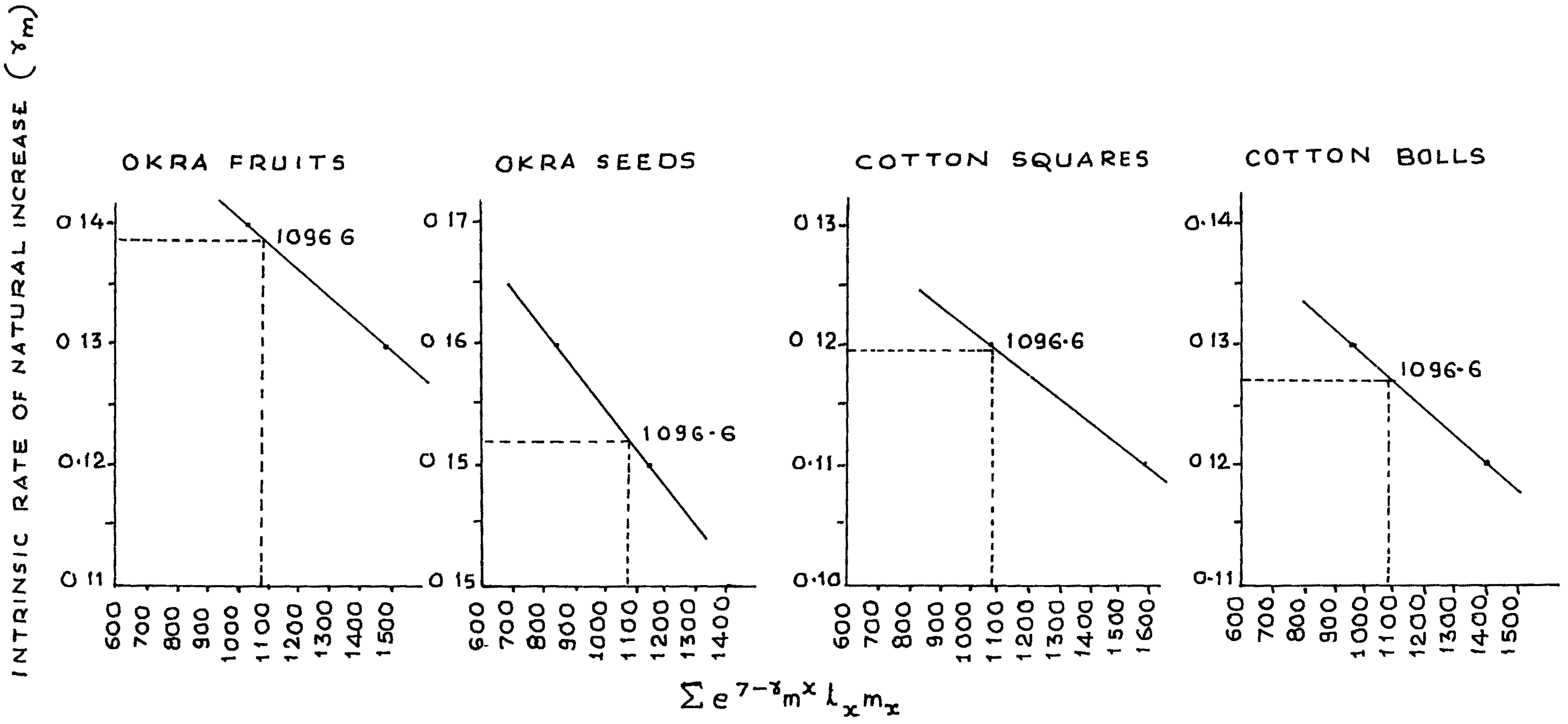

Figure 2. DETERMINATION OF THE INTRINSIC RATES OF INCREASE (γ_m) OF *E. vittella* ON OKRA FRUITS, OKRA SEEDS, COTTON SQUARES AND COTTON BOLLS

The contribution made by different developmental stages towards the stable age distribution of E. vittella was determined and the results obtained are presented in Table 6 and Fig. 3.

Table 6. Stable age distribution of E. vittella on okra fruits (r_m = 0.1385)

Pivotal age in days x	Life table age distribution L_x	$e^{-r_m(x+1)}$	$L_x\ e^{-r_m(x+1)}$	Percentage distribution	
1	2	3	4	5	
0	1.00	0.8706	0.8706	14.183	
1	1.00	0.7580	0.7580	12.349	
2	1.00	0.6600	0.6600	10.752	Eggs 53.33
3	0.94	0.5746	0.5401	8.799	
4	0.89	0.5003	0.4452	7.253	
5	0.89	0.4356	0.3876	6.314	
6	0.88	0.3792	0.3337	5.436	
7	0.87	0.3302	0.2872	4.679	
8	0.87	0.2875	0.2501	4.074	
9	0.86	0.2503	0.2152	3.506	Larvae 39.64
10	0.86	0.2177	0.1874	3.053	
11	0.86	0.1897	0.1631	2.657	
12	0.85	0.1652	0.1404	2.287	
13	0.85	0.1438	0.1222	1.990	

Table 6 contd.

1	2	3	4	5	
14	0.85	0.1252	0.1064	1.733	
15	0.84	0.1090	0.0915	1.490	
16	0.84	0.0949	0.0797	1.298	
17	0.84	0.0826	0.0694	1.130	
18	0.84	0.0719	0.0604	0.984	
19	0.84	0.0626	0.0526	0.856	
20	0.84	0.0545	0.0458	0.746	
21	0.83	0.0475	0.0394	0.641	
22	0.82	0.0413	0.0339	0.552	
23	0.82	0.0360	0.0295	0.480	Pupae 6.07
24	0.82	0.0313	0.0257	0.418	
25	0.82	0.272	0.0223	0.363	
26	0.82	0.0237	0.0194	0.316	
27	0.82	0.0206	0.0169	0.275	
28	0.81	0.0180	0.1450	0.236	
29	0.80	0.0156	0.1250	0.203	
30	0.80	0.0136	0.0109	0.177	
31	0.80	0.0118	0.0095	0.154	
32	0.80	0.0103	0.0082	0.133	
33	0.80	0.0090	0.0072	0.117	Adults 0.92
34	0.80	0.0078	0.0062	0.101	
35	0.79	0.0068	0.0053	0.086	
36	0.73	0.0059	0.0043	0.070	
37	0.61	0.0051	0.0031	0.050	
38	0.43	0.0045	0.0019	0.031	
39	0.16	0.0039	0.0006	0.009	

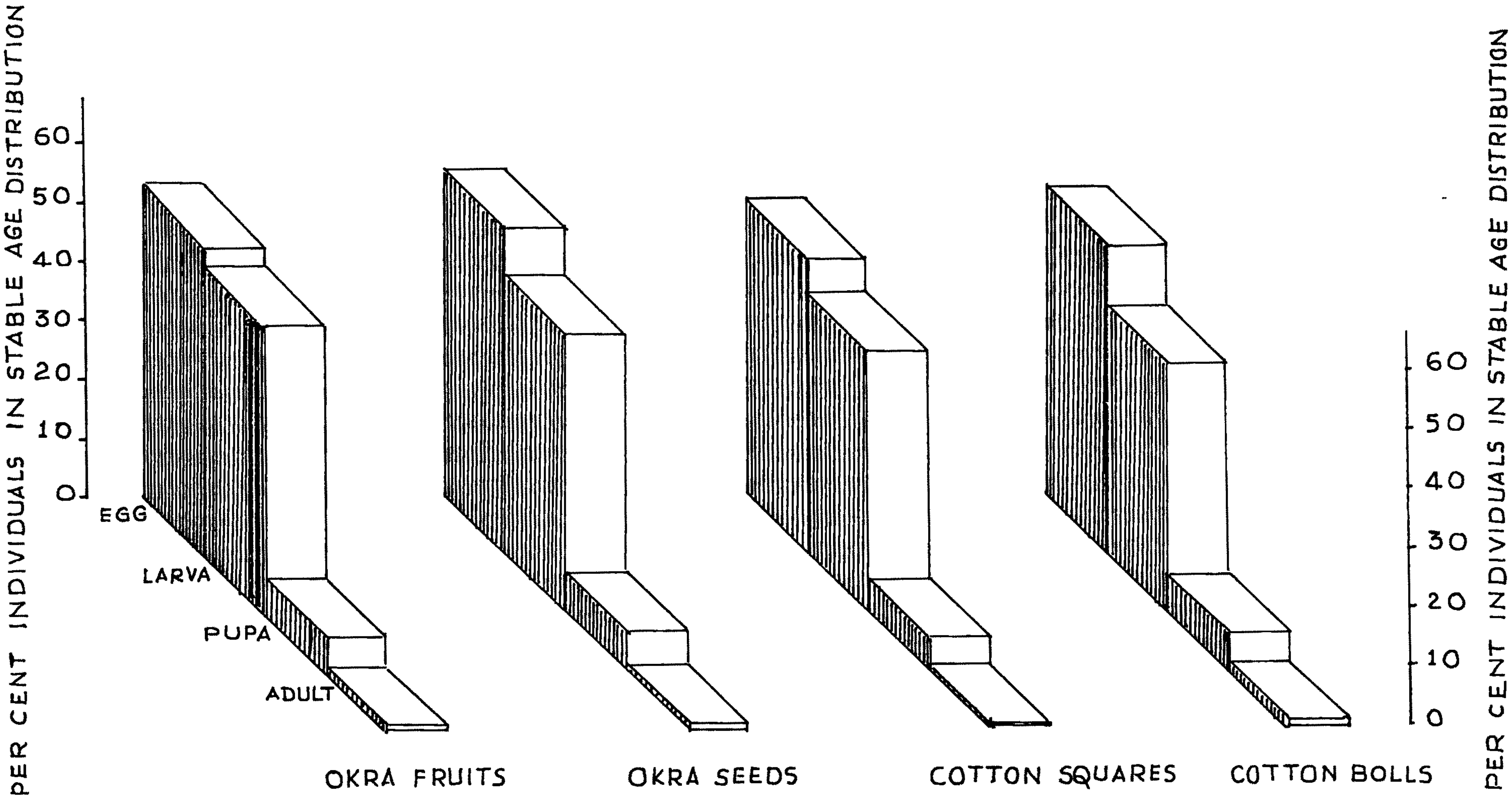

Figure 3. PER CENT INDIVIDUALS IN THE STABLE AGE DISTRIBUTION OF <u>E. vittella</u> ON OKRA FRUITS, OKRA SEEDS, COTTON SQUARES AND COTTON BOLLS

It is evident from Table 6 that the population of *E. vittella* on reaching stable age distribution comprised 99.04 per cent of immature stages. The contribution of various stages viz. egg, larva, pupa and adult towards the stable age distribution was 53.33, 39.64, 6.07 and 0.92 per cent, respectively.

4.1.1.2 Okra Seeds

The data on survival of different stages of *E. vittella* during development on okra seeds are presented in Table 7. The maximum duration of egg, larva and pupa was 4, 11 and 12 days, respectively. The number which survived between egg and adult emergence was 89 out of 100.

Table 7. The survival of different stages of *E. vittella* on okra seeds

Sr. No.	Eggs kept (0 days)	Number surviving		
		Egg stage (0-4 days)	Larval stage (5-15 days)	Pupal stage (16-27 days)
1	10	10	10	10
2	10	9	9	9
3	10	8	8	8
4	10	10	9	8
5	10	9	9	9
6	10	10	9	9
7	10	10	10	10
8	10	9	9	8
9	10	9	9	9
10	10	10	9	9
Total	100	94	91	89

The data on life table showing the survival (l_x) and age specific fecundity (m_x) of E. vittella when reared on okra seeds are presented in Table 8 and Fig.1.

Table 8. Life table (for females) and age specific fecundity for E. vittella on okra seeds

Pivotal age in days x	Survival of females at different age intervals l_x	Age schedule for female births m_x	$l_x m_x$	$x\ l_x m_x$
0-27	0.89	..	Immature stages	
28-29	0.89	..	Preoviposition period	
30	0.89	5.5	4.89	146.70
31	0.89	28.5	25.36	786.31
32	0.89	37.6	33.46	1070.84
33	0.89	36.8	32.75	1080.81
34	0.89	28.4	25.27	859.38
35	0.84	18.7	15.70	549.78
36	0.59	6.9	4.07	146.55
37	0.38	0.0	0.00	0.00
			$\Sigma l_x m_x$ (R_o) = 141.50	$\Sigma x\ l_x m_x$ = 4640.37

The preoviposition period ranged from 28th to 29th day of pivotal age. The females started depositing eggs from 30th day of pivotal age. The highest mean progeny production per day of females (m_x) was 37.6 females per female and was observed on 32nd day of pivotal age. The ovipositional period was 7 days. The first female mortality occured on 35th day (l_x = 0.84) of pivotal age after the emergence of females. The net reproductive rate (R_o) representing the total female births was 141.50. It was observed that the population of E. vittella would multiply 141.50 times at the end of each generation.

The mean generation time, innate capacity for increase in numbers and finite rate of increase in numbers of E. vittella on okra seeds are presented in Table 9 and Fig. 2.

The mean duration of a generation (T) i.e. the mean length of developmental and reproductive stages was found to be 32.51 days for this cohort. The innate capacity (r_m) and finite rate (λ) for increase in numbers were 0.1523 and 1.164 females per female per day, respectively. At this rate the population of E. vittella was capable of multiplying 2.895 times per week under the given set of conditions. The doubling time was 4.55 days. The hypothetical F_2 female population was 20022.25.

Table 9. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *E. vittella* on okra seeds

Population growth statistics	
Mean length of generation (T_c)	
$T_c = \frac{\Sigma x\, l_x m_x}{R_o}$	32.79 days
Innate capacity for increase in numbers (r_c)	
$r_c = \frac{\log_e R_o}{T_c}$	0.1510 females/female/day
Arbitrary r_m 0.15 and 0.16	
corrected r_m $\Sigma e^{7-r_m x}\, l_x m_x = 1096.6$	0.1523 females/female/day
Corrected generation time (T)	
$T = \frac{\log_e R_o}{r_m}$	32.51 days
Finite rate of increase in numbers (λ)	
$(\lambda) = \text{antilog}_e r_m$	1.164 females/female/day
Weekly multiplication of population	2.895
Doubling time	4.55 days
Hypothetical F_2 females	20022.25

The stable age distribution of _E._ _vittella_ was worked out by observing the population schedule of birth rate and death rate (m_x and l_x) under the given set of conditions. The results obtained are presented in Table 10 and Fig. 3.

Table 10. Stable age distribution of _E._ _vittella_ on okra seeds (r_m = 0.1523)

Pivotal age in days x	Life table age distribution L_x	$e^{-r_m (x+1)}$	$L_x\ e^{-r_m (x+1)}$	Percentage distribution	
1	2	3	4	5	
0	1.00	0.8587	0.8587	14.778	
1	1.00	0.7374	0.7374	12.690	
2	1.00	0.6332	0.6332	10.897	Eggs 54.99
3	0.97	0.5437	0.5274	9.076	
4	0.94	0.4669	0.4389	7.553	
5	0.94	0.4009	0.3769	6.486	
6	0.94	0.3443	0.3236	6.486	
7	0.94	0.2957	0.2779	5.569	
8	0.94	0.2539	0.2386	4.782	
9	0.93	0.2180	0.2027	4.106	
10	0.93	0.1872	0.1741	3.488	Larvae 37.08
11	0.93	0.1607	0.1495	2.996	
12	0.93	0.1380	0.1284	2.572	

Table 10 contd.

1	2	3	4	5	
13	0.93	0.1185	0.1102	2.209	
14	0.92	0.1185	0.0936	1.896	
15	0.91	0.0874	0.0795	1.368	
16	0.91	0.0750	0.0683	1.175	
17	0.91	0.0644	0.0586	1.008	
18	0.91	0.0553	0.0503	0.865	
19	0.91	0.0475	0.0432	0.743	
20	0.91	0.0408	0.0371	0.638	
21	0.91	0.0350	0.0319	0.548	
22	0.91	0.0301	0.0274	0.471	Pupae 6.96
23	0.91	0.0258	0.0235	0.404	
24	0.91	0.0222	0.0202	0.347	
25	0.91	0.0190	0.0173	0.297	
26	0.90	0.0163	0.0147	0.252	
27	0.89	0.0140	0.0125	0.215	
28	0.89	0.0120	0.0107	0.184	
29	0.89	0.0103	0.0092	0.158	
30	0.89	0.0089	0.0079	0.135	
31	0.89	0.0076	0.0068	0.117	
32	0.89	0.0065	0.0058	0.099	Adults 0.93
33	0.89	0.0056	0.0050	0.086	
34	0.86	0.0048	0.0041	0.070	
35	0.71	0.0041	0.0029	0.049	
36	0.48	0.0035	0.0017	0.029	
37	0.19	0.0030	0.0005	0.008	

Table 10 reveals that the adults contributed only 0.93 per cent to the population of stable age whereas eggs, larvae and pupae contributed 54.99, 37.08 and 6.96 per cent, respectively. The population comprised approximately more than 99 per cent of immature stages.

4.1.2 Cotton

4.1.2.1 Cotton Squares

The maximum duration of egg, larva and pupa when reared on cotton squares was 4, 16 and 13 days respectively. The number which survived from 100 eggs to adult stage was 73 (Table 11).

Table 11. The survival of different stages of *E. vittella* on cotton squares

Sr. No.	Eggs kept (0 days)	Number surviving		
		Egg stage (0-4 days)	Larval stage (5-20 days)	Pupal stage (21-33 days)
1	10	7	6	6
2	10	9	9	7
3	10	9	8	8
4	10	8	8	8
5	10	9	8	7
6	10	10	9	9
7	10	7	7	6
8	10	8	7	7
9	10	7	7	7
10	10	10	8	8
Total	100	84	77	73

The life table showing the survival (l_x) and the age specific fecundity (m_x) of E. vittella when reared on cotton squares are presented in Table 12 and Fig. 1.

Table 12. Life table (for females) and age specific fecundity for E. vittella on cotton squares

Pivotal age in days x	Survival of females at different age intervals l_x	Age schedule for female births m_x	$l_x m_x$	$x\ l_x m_x$
0-33	0.73	..	Immature stages	
34-35	0.73	..	Preoviposition period	
36	0.73	5.6	4.08	146.88
37	0.73	29.5	21.53	796.61
38	0.73	32.3	23.57	895.66
39	0.73	30.1	21.97	856.83
40	0.73	21.2	15.47	618.80
41	0.73	11.7	8.54	350.14
42	0.65	6.4	4.16	174.72
43	0.35	0.0	0.00	0.00
			$\Sigma\ l_x m_x\ (R_0)$ = 99.32	$\Sigma x\ l_x m_x$ = 3839.64

The preoviposition period ranged from 34th to 35th day of pivotal age. The oviposition reached a peak (m_x = 32.3 females per female per day) on 38th day of pivotal age and then declined. The first female mortality was observed on 10th day of adult emergence. The net reproductive rate (R_o) representing the total female births per generation was 99.32.

The results obtained on mean generation time and innate capacity for increase in numbers of E. vittella are presented in Table 13 and Fig. 2.

Table 13 reveals that the mean time for completing a generation (T) was 38.48 days. The innate capacity (r_m) and finite rate (λ) for increase in numbers were 0.1195 and 1.127 females per female per day, respectively. At this rate the population of E. vittella was capable of multiplying 2.31 times every week. It took 5.8 days to multiply the population to two folds. The hypothetical F_2 females were 9864.46.

The stable age distribution of E. vittella was calculated when reared on cotton squares. The data presented in Table 14 (Fig. 3) indicated that the contribution made by adults was only 0.92 per cent of the population of stable age. The contribution made by other immature stages viz. egg, larva and pupa was 49.65, 43.76 and 5.60 per cent, respectively.

Table 13. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of E. vittella on cotton squares

Population growth statistics	
Mean length of generation (T_c)	
$T_c = \frac{\Sigma x\, l_x m_x}{R_o}$	38.65 days
Innate capacity for increase in numbers (r_c)	
$r_c = \frac{\log_e R_o}{T_c}$	0.1189 females/ female /day
Arbitrary r_m 0.11 and 0.12	
corrected $r_m \Sigma e^{7-r_m x}\ l_x m_x = 1096.6$	0.1195 females/ female/day
Corrected generation time (T)	
$T = \frac{\log_e R_o}{r_m}$	38.48 days
Finite rate of increase in numbers (λ)	
$(\lambda) =$ anti $\log_e r_m$	1.127 females/ female/day
Weekly multiplication of population	2.31
Doubling time	5.80 days
Hypothetical F_2 females	9864.46

Table 14. Stable age distribution of E. *vittella* on cotton squares ($r_m = 0.1195$)

Pivotal age in days x	Life table age distribution L_x	$e^{-r_m (x+1)}$	$L_x e^{-r_m (x+1)}$	Percentage distribution	
1	2	3	4	5	
0	1.00	0.8873	0.8873	12.936	
1	1.00	0.7874	0.7874	11.480	
2	1.00	0.6987	0.6987	10.187	Eggs 49.65
3	0.92	0.6200	0.5704	8.316	
4	0.84	0.5501	0.4621	6.737	
5	0.84	0.4882	0.4101	5.979	
6	0.84	0.4332	0.3639	5.305	
7	0.83	0.3844	0.3190	4.651	
8	0.82	0.3411	0.2797	4.078	
9	0.81	0.3027	0.2451	3.573	Larvae 43.76
10	0.80	0.2686	0.2148	3.131	
11	0.80	0.2383	0.1906	2.778	
12	0.80	0.2115	0.1692	2.466	
13	0.80	0.1876	0.1501	2.188	
14	0.80	0.1665	0.1332	1.942	
15	0.80	0.1477	0.1182	1.723	
16	0.80	0.1311	0.1049	1.529	
17	0.78	0.1163	0.0907	1.322	
18	0.77	0.1032	0.0795	1.159	
19	0.77	0.0916	0.0705	1.027	
20	0.77	0.0813	0.0626	0.912	

Table 14 contd

1	2	3	4	5	
21	0.77	0.0721	0.0555	0.809	
22	0.77	0.0640	0.0492	0.717	
23	0.77	0.0568	0.0437	0.637	
24	0.77	0.0504	0.0388	0.565	
25	0.77	0.0447	0.0344	0.501	Pupae 5.60
26	0.76	0.0396	0.0301	0.438	
27	0.76	0.0352	0.0267	0.389	
28	0.76	0.0312	0.0237	0.345	
29	0.76	0.0277	0.0210	0.306	
30	0.76	0.0246	0.0187	0.272	
31	0.76	0.0218	0.0165	0.240	
32	0.74	0.0193	0.0143	0.208	
33	0.73	0.0171	0.0125	0.182	
34	0.73	0.0152	0.0111	0.161	
35	0.73	0.0135	0.0098	0.142	
36	0.73	0.0120	0.0087	0.126	
37	0.73	0.0106	0.0077	0.112	Adults 0.92
38	0.73	0.0094	0.0069	0.100	
39	0.73	0.0083	0.0061	0.088	
40	0.73	0.0074	0.0054	0.078	
41	0.69	0.0066	0.0045	0.065	
42	0.50	0.0058	0.0029	0.042	
43	0.17	0.0052	0.0008	0.011	

4.1.2.2 Cotton Bolls

The observations on the survival of different stages of *E. vittella* during development on cotton bolls are presented in Table 15.

Table 15. The survival of different stages of *E. vittella* on cotton bolls

Sr. No.	Eggs kept (0 days)	Number surviving		
		Egg stage (0-4 days)	Larval stage (5-18 days)	Pupal stage (19-30 days)
1	10	7	6	6
2	10	8	7	7
3	10	10	9	9
4	10	9	7	5
5	10	7	7	6
6	10	10	9	7
7	10	8	8	8
8	10	9	7	7
9	10	8	7	6
10	10	9	8	7
Total	100	85	75	68

The maximum duration of egg, larva and pupa was 4, 14 and 12 days respectively. The number which survived from egg to adult was 68 out of 100.

The data regarding the life table and age specific fecundity for E. vittella when reared on cotton bolls are given in Table 16 and in Fig. 1.

Table 16. Life table (for females) and age specific fecundity for E. vittella on cotton bolls

Pivotal age in days x	Survival of females at different age intervals l_x	Age schedule for female births	$l_x m_x$	$x\, l_x m_x$
0-30	0.68	..	Immature stages	
31-33	0.68	..	Preoviposition period	
34	0.68	8.5	5.78	196.52
35	0.68	35.8	24.34	851.90
36	0.68	38.5	26.18	942.48
37	0.68	25.3	17.20	636.54
38	0.68	21.7	14.75	560.72
39	0.68	12.5	8.50	331.50
40	0.44	8.8	3.87	154.88
41	0.35	0.0	0.00	0.00
			$\Sigma\, l_x m_x$ (R_o) = 100.62	$\Sigma\, x\, l_x m_x$ = 3674.54

The survival of immature stages (l_x) from egg to adult emergence was 0.68. The substantial contribution (m_x = 38.5 female births) in the life cycle was made by the females on 36th day of pivotal age. The first female mortality occurred on 40th day (l_x = 0.44) of pivotal age. The net reproductive rate (R_0) representing the total female births was 100.62. This indicated that 100.62 females were produced per female during one generation (Table 16).

Table 17 and Fig. 2 depict the results obtained on mean generation time, innate capacity (r_m) and finite rate for increase in numbers of E. vittella.

It is evident from the Table 17 that the mean time required to complete one generation (T) was 35.77 days. The innate capacity (r_m) and finite rate (λ) for increase in numbers were 0.1289 and 1.137 females per female per day, respectively. At this rate, the population of E. vittella was capable of multiplying 2.456 times per week. The population would multiply two folds within 5.37 days. The hypothetical female population in F_2 generation was 10124.38.

The observations were recorded on the contribution of respective stages towards stable age distribution of E. vittella by calculating the population schedule of birth rate and death rate (m_x and l_x) (Table 18 and Fig. 3).

Table 17. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *E. vittella* on cotton bolls

Population growth statistics	
Mean length of generation (T_o)	
$T_o = \frac{\Sigma x\, l_x m_x}{R_o}$	36.51 days
Innate capacity for increase in numbers (r_o)	
$r_o = \frac{\log_e R_o}{T_o}$	0.1263 females/female/day
Arbitrary r_m 0.12 and 0.13	
corrected $r_m \Sigma e^{7-r_m x}\ l_x m_x$ = 1096.6	0.1289 females/female/day
Corrected generation time (T)	
$T = \frac{\mathrm{Log}_e R_o}{r_m}$	35.77 days
Finite rate of increase in numbers (λ)	
(λ) = anti $\log_e r_m$	1.137 females/female/day
Weekly multiplication of population	2.456
Doubling time	5.37 days
Hypothetical F_2 females	10124.38

Table 18. Stable age distribution of E. vittella on cotton bolls (r_m = 0.1289)

Pivotal age in days x	Life table age distribution L_x	$e^{-r_m (x+1)}$	$L_x e^{-r_m (x+1)}$	Percentage distribution	
1	2	3	4	5	
0	1.00	0.8790	0.8790	13.668	
1	1.00	0.7727	0.7727	12.015	
2	1.00	0.6792	0.6792	10.561	Eggs 51.72
3	0.92	0.5971	0.5493	8.541	
4	0.85	0.5249	0.4461	6.936	
5	0.85	0.4614	0.3922	6.098	
6	0.85	0.4056	0.3447	5.360	
7	0.85	0.3565	0.3030	4.711	
8	0.85	0.3134	0.2664	4.142	
9	0.85	0.2755	0.2342	3.641	Larvae 41.55
10	0.85	0.2422	0.2058	3.200	
11	0.84	0.2129	0.1788	2.780	
12	0.83	0.1871	0.1553	2.414	
13	0.83	0.1645	0.1365	2.122	
14	0.83	0.1446	0.1200	1.866	
15	0.82	0.1271	0.1042	1.620	
16	0.81	0.1117	0.0905	1.407	
17	0.78	0.0982	0.0766	1.191	
18	0.75	0.0863	0.0647	1.006	

Table 18 contd.

1	2	3	4	5	
19	0.75	0.0759	0.0569	0.884	
20	0.75	0.0667	0.0500	0.777	
21	0.75	0.0586	0.0440	0.684	
22	0.75	0.0515	0.0386	0.600	Pupae 5.69
23	0.75	0.0453	0.0340	0.528	
24	0.75	0.0398	0.0298	0.463	
25	0.75	0.0350	0.0262	0.407	
26	0.75	0.0307	0.0230	0.357	
27	0.73	0.0270	0.0197	0.306	
28	0.72	0.0237	0.0171	0.265	
29	0.70	0.0209	0.0146	0.227	
30	0.68	0.0183	0.0125	0.194	
31	0.68	0.0161	0.0109	0.169	
32	0.68	0.0142	0.0096	0.149	
33	0.68	0.0124	0.0084	0.130	
34	0.68	0.0109	0.0074	0.115	
35	0.68	0.0096	0.0065	0.101	Adults 0.98
36	0.68	0.0084	0.0057	0.088	
37	0.68	0.0074	0.0050	0.077	
38	0.68	0.0065	0.0044	0.068	
39	0.56	0.0057	0.0032	0.049	
40	0.39	0.0050	0.0019	0.029	
41	0.17	0.0044	0.0007	0.010	

The data indicate that the adults shared only 0.98 per cent of the population of stable age, while eggs, larvae and pupae contributed 51.72, 41.55 and 5.69 per cent, respectively.

4.2 Determination of Thermal Constant for *E. vittella*

The data on the mean developmental period, temperature threshold and day degrees required for completion of various developmental stages and for total life are presented in Table 19.

Table 19. Determination of thermal constant for the different stages of *E. vittella*

Stage	Mean developmental period (days)			Temperature threshold °C	Day degrees
	20°C	30°C	Room temperature		
Egg	8.10	3.20	4.2	13.46	41.31
Larva	23.20	9.5	12.5	13.06	113.36
Pupa	22.1	8.9	12.0	13.25	135.87
Total life	53.4	21.6	28.7	13.20	292.77

The mean developmental period for completion of egg, larva and pupa and for total life at 20°C was longer than at 30°C and room temperature. The threshold temperature for development of egg, larva, pupa and for total life was 13.46, 13.06, 13.25 and 13.20°C, respectively.

Day degrees (thermal constants) required for completion of egg, larva, pupa and for total life were 41.31, 113.36, 135.87 and 292.77, respectively. Thus, E. vittella would complete 17 generations per year.

4.3 Assessment of Crop Losses due to Major Pests in Okra

4.3.1 Population of Jassids

The data on the population of jassids are presented in Table 20.

The results indicated significant differences in the insecticidal treatments during both the seasons in respect of jassid incidence. Significantly lowest population of jassid nymphs was observed in the plots treated throughout the growth period (T_5, T_6, T_7, T_8 and T_9) and in the plots where the crop was protected during vegetative stage (T_1 and T_2) for control of sucking pests in both the seasons. The jassid population was significantly low in the treatments with carbaryl 0.2 per cent (T_9) and disulfoton (T_2 and T_6) followed by carbofuran (T_5, T_1 and T_7) and malathion 0.1 per cent (T_8). The treatments viz. monocrotophos 0.04 per cent (T_3)

Table 20. Effect of various treatments on the population of jassids

Treatments	Mean number of jassids/leaf at 40 days after sowing		
	1978	1979	Average
T_1 Carbofuran 5% seed treatment	1.512 (0.545)	1.362 (0.526)	1.437 (0.535)
T_2 Disulfoton 1 kg a.i./ha	0.657 (0.422)	0.605 (0.415)	0.631 (0.418)
T_3 Monocrotophos 0.04% during fruiting stage	5.270 (0.857)	4.125 (0.780)	4.697 (0.818)
T_4 Carbaryl 0.2% during fruiting stage	5.470 (0.871)	4.225 (0.791)	4.847 (0.831)
T_5 Carbofuran 5% seed treatment + Monocrotophos 0.04%	1.452 (0.537)	1.365 (0.526)	1.408 (0.531)
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	0.655 (0.423)	0.527 (0.401)	0.591 (0.412)
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	1.887 (0.586)	1.495 (0.541)	1.691 (0.563)
T_8 Malathion 0.1% spray throughout	1.650 (0.559)	1.920 (0.592)	1.785 (0.575)
T_9 Carbaryl 0.2% spray throughout	0.502 (0.398)	0.482 (0.394)	0.492 (0.396)
T_{10} Untreated check	5.450 (0.871)	4.302 (0.797)	4.876 (0.834)
S.E. ±	0.031	0.032	0.015
C.D. (P = 0.05)	0.064	0.065	0.045

Figures in parentheses are log (x+2) values

and carbaryl 0.2 per cent (T_4) receiving no protection during vegetative stage and the untreated control (T_{10}) were at par with each other.

The pooled analysis revealed significantly low population of jassid nymphs in the treatments with carbaryl 0.2 per cent (T_9), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and disulfoton 1 kg a.i./ha (T_2) over all other treatments and were at par with each other. The treatments with carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbofuran 5 per cent (T_1), carbofuran 5 per cent + malathion 0.1 per cent (T_7) and malathion 0.2 per cent (T_8) were significantly superior over the treatments with no protection during vegetative stage (T_3, T_4 and T_{10}).

4.3.2 Population of Aphids

The data presented in Table 21 reveals that during both the seasons, the treatment differences were not significant among the plots receiving protection during vegetative stage. The treatments with disulfoton 1 kg a.i./ha (T_2) and carbaryl 0.2 per cent (T_9) recorded comparatively low aphid population than all other treatments. The incidence of aphid was lower in both the seasons.

Table 21. Effect of various treatments on the population of aphids

Treatments	Mean number of aphids/leaf at 40 days after sowing		
	1978	1979	Average
T_1 Carbofuran 5% seed treatment	0.143 (0.329)	0.068 (0.313)	0.105 (0.323)
T_2 Disulfoton 1 kg a.i./ha	0.009 (0.303)	0.007 (0.302)	0.008 (0.302)
T_3 Monocrotophos 0.04% during fruiting stage	0.302 (0.362)	0.175 (0.337)	0.238 (0.358)
T_4 Carbaryl 0.2% during fruiting stage	0.433 (0.384)	0.223 (0.346)	0.328 (0.379)
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	0.014 (0.304)	0.047 (0.311)	0.030 (0.304)
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	0.016 (0.304)	0.008 (0.311)	0.012 (0.305)
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	0.096 (0.320)	0.075 (0.316)	0.085 (0.320)
T_8 Malathion 0.1% spray throughout	0.033 (0.308)	0.026 (0.306)	0.029 (0.307)
T_9 Carbaryl 0.2% spray throughout	0.003 (0.301)	0.025 (0.306)	0.014 (0.302)
T_{10} Untreated check	0.273 (0.354)	0.195 (0.341)	0.234 (0.352)
S.E. ±	0.019	0.007	0.004
C.D. (P = 0.05)	0.039	0.015	0.013

Figures in parentheses are log (x+2) values

The pooled analysis indicated that the average population of aphids was minimum in the treatment with carbaryl 0.2 per cent (T_9), but it did not differ significantly from disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and malathion 0.1 per cent (T_8). These treatments were significantly superior in lowering the aphid population over carbofuran 5 per cent (T_1) and the treatments with no protection during vegetative stage (T_3 and T_4) and control (T_{10}). Maximum number of aphids (0.328/plant) was recorded in the treatment with no protection during vegetative stage + carbaryl 0.2 per cent (T_4).

4.3.3 Infestation of Fruit Borer, *E. vittella*

The data pertaining to the percentage fruit borer infestation are presented in Table 22 and graphically depicted in Fig. 4.

The results indicated that the percentage fruit borer infestation in all the insecticidal treatments including the plots untreated during fruiting stage (T_1 and T_2) was significantly low as compared to untreated control in both the seasons. The treatments receiving protection with monocrotophos 0.04 per cent (T_3 and T_5) and carbaryl 0.2 per cent (T_6, T_9 and T_4)

Table 22. Effect of various treatments on infestation of fruit borer

Treatments	Percentage fruit borer infestation		
	1978	1979	Average
T_1 Carbofuran 5% seed treatment	10.32 (18.62)	12.67 (20.80)	11.49 (19.71)
T_2 Disulfoton 1 kg a.i./ha	7.90 (16.25)	9.50 (17.91)	8.70 (17.08)
T_3 Monocrotophos 0.04% during fruiting stage	2.32 (8.75)	1.40 (6.77)	1.86 (7.76)
T_4 Carbaryl 0.2% during fruiting stage	3.85 (11.30)	2.65 (9.35)	3.25 (10.32)
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	2.75 (9.54)	1.80 (7.70)	2.27 (8.62)
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	3.37 (10.56)	2.20 (8.50	2.78 (9.53)
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	7.65 (15.99)	9.62 (18.03)	8.63 (17.01)
T_8 Malathion 0.1% spray throughout	8.85 (17.23)	7.95 (16.31)	8.40 (16.77)
T_9 Carbaryl 0.2% spray throughout	3.70 (11.08)	3.12 (10.17)	3.41 (10.63)
T_{10} Untreated check	17.12 (24.42)	23.62 (29.05)	20.37 (26.74)
S.E. ±	1.016	0.824	0.467
C.D. (P = 0.05)	2.086	1.691	1.327

Figures in parentheses are angular transformations

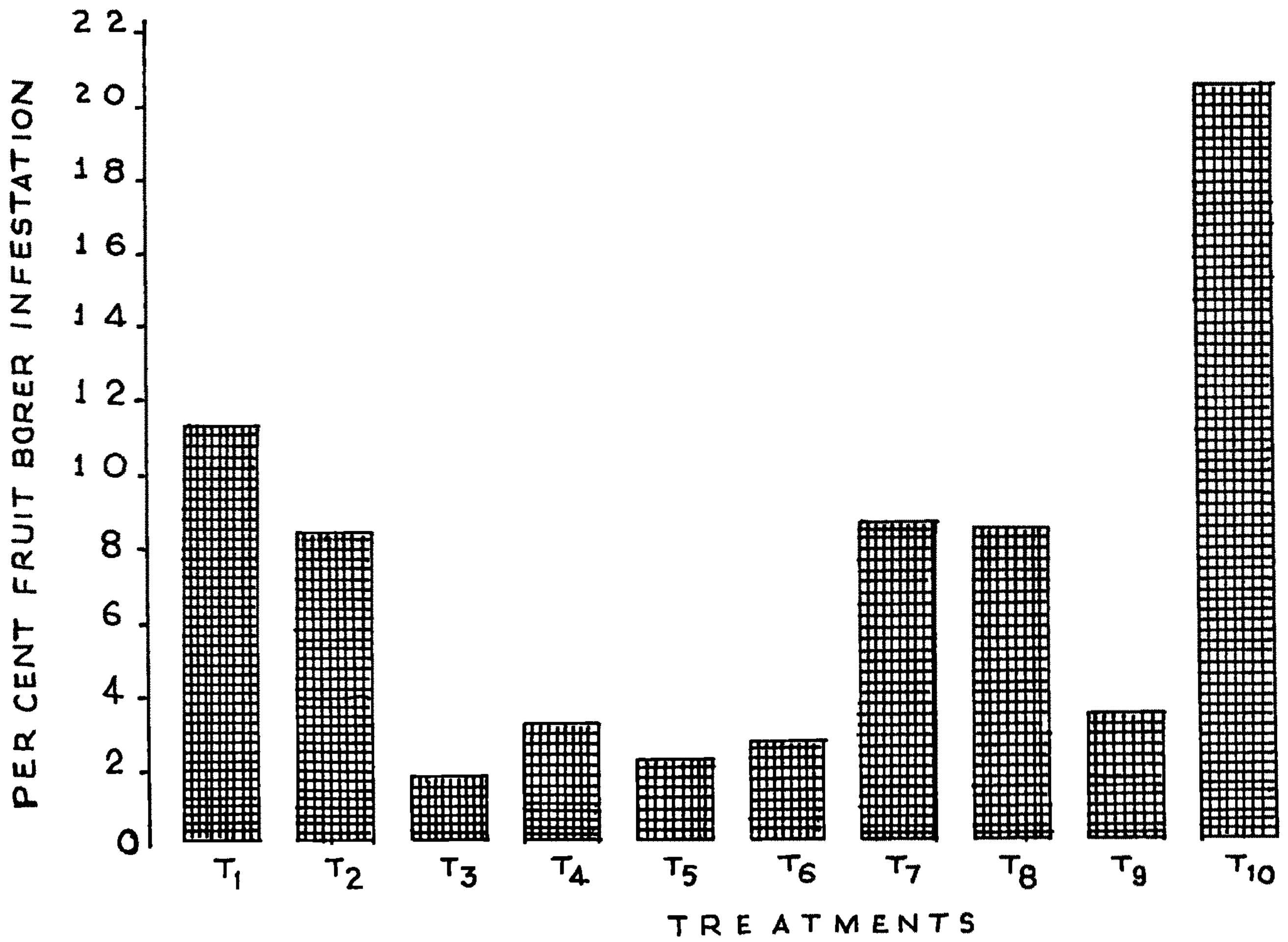

Figure 4 . INFESTATION OF FRUIT BORER AS INFLUENCED BY VARIOUS TREATMENTS

during fruiting stage had significantly less infestation of fruit borer than all other treatments during 1978. The treatments with malathion (T_7) and T_8) were at par with the treatment with disulfoton 1 kg a.i./ha (T_2) which was not protected during fruiting stage. The treatment with malathion 0.1 per cent (T_8) was at par with carbofuran 5 per cent seed treatment (T_1) during 1978.

During 1979, the treatments with malathion 0.1 per cent (T_7 and T_8) were at par with disulfoton 1 kg a.i./ha (T_2) but were significantly superior over carbofuran 5 per cent (T_1) in reducing the fruit borer infestation.

The pooled analysis revealed that the average per cent fruit borer infestation was minimum in the treatment with no protection during vegetative stage + monocrotophos 0.04 per cent (T_3) and maximum in untreated control (T_{10}). The treatments with monocrotophos 0.04 per cent (T_3), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbaryl 0.2 per cent during fruiting stage (T_4) and carbaryl 0.2 per cent (T_9) were significantly superior over rest of the treatments in reducing the fruit borer infestation in order of their merit.

4.3.4 Plant Height and per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The data on the plant height and per cent avoidable loss due to jassids and aphids during vegetative stage are given in Table 23 and graphically depicted in Fig. 5.

4.3.4.1 Effect on Plant Height

The effect of the insecticidal treatments on plant height during vegetative stage was significant in both the seasons. The plant height in the treatments with disulfoton 1 kg a.i./ha (T_2 and T_6) and carbaryl 0.2 per cent (T_9) was significantly more than rest of the treatments during 1978. The treatments with carbofuran 5 per cent (T_1), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and malathion 0.1 per cent (T_8) were significantly superior over carbaryl 0.2 per cent during fruiting stage (T_4), but did not differ significantly from monocrotophos 0.04 per cent during fruiting stage (T_3), carbofuran 5 per cent + malathion 0.1 per cent (T_7) and untreated control (T_{10}) during 1978. The above treatments (T_1, T_5 and T_8) were significantly superior over carbaryl 0.2 per cent during fruiting stage (T_4) and untreated control (T_{10}) during 1979.

Table 23. Per cent avoidable loss due to jassids and aphids in plant height during vegetative stage

Treatments	Plant height (cm) at 40 days after sowing			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	1840	19.97	19.18	36.92
T_2 Disulfoton 1 kg a.i./ha	29.75	31.07	30.41	Nil
T_3 Monocrotophos 0.04% during fruiting stage	14.70	16.30	15.50	49.02
T_4 Carbaryl 0.2% during fruiting stage	13.72	14.82	14.27	53.07
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	18.67	19.77	19.22	36.79
T_6 Disulfoton 1 kg ai/ha + Carbaryl 0.2%	28.82	30.77	29.80	2.00
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	16.87	16.72	16.80	44.75
T_8 Malathion 0.1% spray throughout	18.20	19.77	18.98	37.58
T_9 Carbaryl 0.2% spray throughout	29.07	29.47	29.27	3.74
T_{10} Untreated check	14.50	15.35	14.92	50.93
S.E. ±	2.096	1.900	0.923	
C.D. (P = 0.05)	4.302	3.917	2.621	

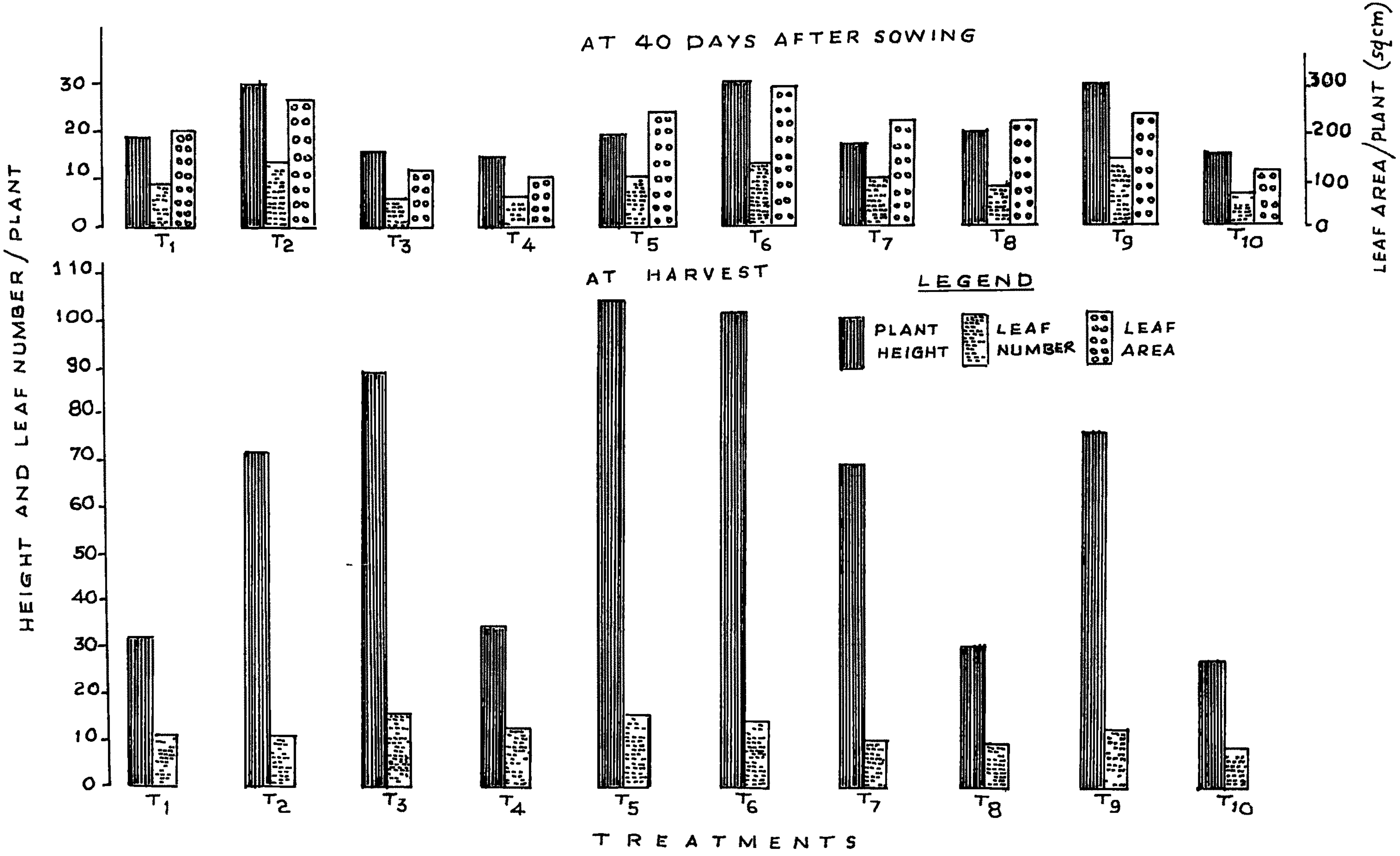

Figure 5. HEIGHT, NUMBER OF LEAVES AND LEAF AREA PER PLANT AS INFLUENCED BY VARIOUS TREATMENTS

The pooled analysis indicated significantly more height in the treatments with disulfoton 1 kg a.i./ha (T_2), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9) over all other treatments. The treatments with carbofuran 5 per cent (T_1 and T_5) and malathion 0.1 per cent (T_8) were significantly superior over the treatments not protected during vegetative stage (T_3 and T_4) and control (T_{10}), but were at par with carbofuran 5 per cent + malathion 0.1 per cent (T_7).

4.3.4.2 Per cent Avoidable Loss in Plant Height due to Jassids and Aphids

The maximum per cent avoidable loss was recorded in the treatments with no protection during vegetative stage viz. carbaryl 0.2 per cent during fruiting stage (T_4) (53.07), untreated control (T_{10}) (50.93) and monocrotophos 0.04 per cent during fruting stage (T_3) (49.02). The per cent loss was minimum in the treatment with disulfoton 1 kg a.i./ha (T_2) followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbaryl 0.2 per cent (T_9), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbofuran 5 per cent (T_1), malathion 0.1 per cent (T_8) and carbofuran 5 per cent + malathion 0.1 per cent (T_7) in order of their merit.

4.3.5 Final Plant Height and Per cent Avoidable Loss due to Pest Complex in Okra

The data on the final plant height and per cent avoidable loss due to pest complex in okra are presented in Table 24 and graphically depicted in Fig. 5.

4.3.5.1 Effect on Final Plant Height

The results indicated that the differences in the plant height were significant in both the seasons. Plant height in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) was significantly more than all other treatments in both the seasons, however, these treatments were at par with monocrotophos 0.04 per cent during fruiting stage (T_3) in 1978. The treatments monocrotophos 0.04 per cent (T_3), disulfoton 1 kg a.i./ha (T_2), carbaryl 0.2 per cent (T_9) and carbofuran 5 per cent + malathion 0.1 per cent (T_7) were significantly superior over carbofuran 5 per cent (T_1), carbaryl 0.2 per cent (T_4), malathion 0.1 per cent (T_8) and untreated control (T_{10}), in increasing the plant height.

The pooled analysis revealed similar trend as in 1979 except that the treatment carbaryl 0.2 per cent during fruiting stage (T_4) was significantly superior over untreated control (T_{10}) but was at par with carbofuran 5 per cent (T_1) and malathion 0.1 per cent (T_8).

Table 24. Per cent avoidable loss in plant height at final harvest due to pest complex in okra

Treatments	Mean plant height at final harvest (cm)			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	31.02	31.85	31.72	69.56
T_2 Disulfoton 1 kg a.i./ha	76.36	70.57	71.45	31.44
T_3 Monocrotophos 0.04% during fruiting stage	91.27	88.10	88.58	15.01
T_4 Carbaryl 0.2% during fruiting stage	32.97	35.02	34.70	66.70
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	108.30	103.50	104.23	Nil
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	97.47	102.65	101.85	2.28
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	67.05	69.50	69.12	33.68
T_8 Malathion 0.1% spray throughout	29.62	30.22	30.12	71.10
T_9 Carbaryl 0.2% spray throughout	71.45	76.72	75.91	27.17
T_{10} Untreated check	25.30	27.32	27.01	74.08
S.E. ±	9.714	4.147	2.701	
C.D. (P = 0.05)	19.933	8.511	7.488	

4.3.5.2 Per cent Avoidable Loss in Final Plant Height

The per cent avoidable loss due to okra pest complex in untreated control (T_{10}) was to the tune of 74.08 per cent followed by malathion 0.1 per cent (T_8) (71.19), carbofuran 5 per cent (T_1) (69.56) and carbaryl 0.2 per cent during fruiting stage (T_4) (66.70). The reduction in plant height was minimum in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), monocrotophos 0.04 per cent (T_3), carbaryl 0.2 per cent (T_9).

4.3.6 Number of Leaves Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The data pertaining to the number of leaves per plant and per cent avoidable loss due to jassids and aphids during vegetative stage are given in Table 25 and graphically presented in Fig. 5.

4.3.6.1 Effect on Number of Leaves Per Plant During Vegetative Stage

The results revealed that the treatments with disulfoton (T_2 and T_6) and carbaryl 0.2 per cent (T_9) were significantly superior over all other treatments in increasing the number of leaves per plant in both the seasons. The treatments T_1, T_5 and T_7 which included

Table 25. Per cent avoidable loss due to jassids and aphids in number of leaves per plant during vegetative stage

Treatments	Number of leaves/plant at 40 days after sowing			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	8.12	9.75	8.93	34.19
T_2 Disulfoton 1 kg a.i./ha	13.45	13.70	13.57	Nil
T_3 Monocrotophos 0.04% during fruiting stage	5.20	5.82	5.51	59.39
T_4 Carbaryl 0.2% during fruiting stage	6.02	6.22	6.12	54.90
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	9.85	10.57	10.21	24.76
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	12.92	13.30	13.11	3.38
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	9.35	9.85	9.60	29.25
T_8 Malathion 0.1% spray throughout	7.47	7.97	7.72	43.10
T_9 Carbaryl 0.2% spray throughout	13.62	13.52	13.57	Nil
T_{10} Untreated check	6.37	6.67	6.52	51.95
S.E. ±	0.905	0.888	0.593	
C.D. (P = 0.05)	1.859	1.822	1.682	

carbofuran 5 per cent as seed treatment were at par with each other and significantly superior over the treatments not protected during vegetative stage (T_3 and T_4) and untreated control (T_{10}) in both the seasons. However, the treatment with malathion 0.1 per cent (T_8) was at par with untreated control (T_{10}) and carbofuran 5 per cent (T_1) in 1978, but it was also equal to carbaryl 0.2 per cent during fruiting stage (T_4) in 1979.

The pooled analysis indicated similar observations as in 1979.

4.3.6.2 Per cent Avoidable Loss in Leaf Number Per Plant

The incidence of jassids and aphids had also affected the number of leaves per plant. The maximum number of leaves per plant was observed in the treatment with disulfoton 1 kg a.i./ha (T_2) (13.57) and carbaryl 0.2 per cent (T_9) (13.57). Maximum reduction in leaf number per plant due to jassids and aphids was observed to be 59.39, 54.90 and 51.95 per cent in the treatments with no protection during vegetative stage viz. monocrotophos 0.04 per cent during fruiting stage (T_3), carbaryl 0.2 per cent during fruiting stage (T_4) and untreated control (T_{10}), respectively. The per cent avoidable loss was minimum in disulfoton 1 kg a.i./ha (T_2) (nil) and in carbaryl 0.2 per cent (T_9) (nil), followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent

(T_6) (3.38), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (24.76) in order of their merit.

4.3.7 Number of Leaves Per Plant at Final Harvest and Per cent Avoidable Loss due to Okra Pest Complex

The data on the number of leaves per plant at final harvest and per cent avoidable loss due to okra pest complex are presented in Table 26 and graphically depicted in Fig. 5.

4.3.7.1 Effect on Number of Leaves Per Plant at Final Harvest

The results indicated that all the treated plots were significantly superior over untreated control in increasing the number of leaves per plant in both the seasons. The treatments, carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and monocrotophos 0.04 per cent (T_3) exhibited significantly increased number of leaves per plant than all other treatments in both the seasons. The treatment with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) was significantly superior over rest of the treatments except carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and monocrotophos 0.04 per cent (T_3) in both the seasons but however, it was at par with carbaryl 0.2 per cent during fruiting stage (T_4) in 1978.

Table 26. Per cent avoidable loss in number of leaves per plant at final harvest due to okra pest complex

Treatments	Mean number of leaves per plant at final harvest			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	10.05	10.62	10.49	32.79
T_2 Disulfoton 1 kg a.i./ha	9.75	10.70	10.33	33.82
T_3 Monocrotophos 0.04% during fruiting stage	15.42	15.25	15.28	2.11
T_4 Carbaryl 0.2% during fruiting stage	12.57	12.60	12.59	19.34
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	15.42	15.67	15.61	Nil
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	13.45	14.25	14.07	9.86
T_7 Carbofuran 5% seed treatment + malathion 0.1%	10.05	10.20	10.16	34.91
T_8 Malathion 0.1% spray throughout	9.95	9.57	9.65	38.18
T_9 Carbaryl 0.2% spray throughout	11.55	12.65	12.40	20.56
T_{10} Untreated check	8.00	8.52	8.39	46.25
S.E. ±	0.840	0.444	0.277	
C.D. (P = 0.05)	1.723	0.911	0.769	

The pooled analysis revealed similar results as in 1979 except that the treatment with malathion 0.1 per cent (T_8) was at par with disulfoton 1 kg a.i./ha (T_2) besides carbofuran 5 per cent + malathion 0.1 per cent (T_7).

4.3.7.2 Per cent Avoidable Loss in Number of Leaves Per Plant at Final Harvest

The per cent avoidable loss in leaf number per plant was minimum in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5)(nil) followed by monocrotophos 0.04 per cent (T_3)(2.11), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (9.86) and carbaryl 0.2 per cent during fruiting stage (T_4) (19.34). The plots not protected throughout the growth period (T_{10}) recorded 46.25 per cent reduction in leaf number/plant due to okra pest complex.

4.3.8 Leaf Area Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The data on leaf area per plant and per cent avoidable loss due to jassids and aphids in vegetative stage are given in Table 27 and graphically presented in Fig. 5.

Table 27. Per cent avoidable loss in leaf area per plant due to jassids and aphids during vegetative stage

Treatments	Mean leaf area/plant (sq cm) at 40 days after sowing			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	184.63	219.97	202.30	29.77
T_2 Disulfoton 1 kg a.i./ha	258.61	272.90	265.75	7.75
T_3 Monocrotophos 0.04% during fruiting stage	116.13	122.97	119.55	58.50
T_4 Carbaryl 0.2% during fruiting stage	104.54	104.27	104.39	63.76
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	239.92	236.76	238.34	17.26
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	289.59	286.57	288.08	Nil
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	208.50	223.50	216.03	25.01
T_8 Malathion 0.1% spray throughout	215.46	217.91	216.68	24.78
T_9 Carbaryl 0.2% spray throguhout	230.06	231.62	230.84	19.86
T_{10} Untreated check	111.06	111.47	111.26	61.37
S.E. ±	34.614	27.248	15.573	
C.D. (P = 0.05)	71.029	55.913	44.185	

4.3.8.1 Effect on Leaf Area

The leaf area per plant was increased significantly in all the insecticidal treatments as compared to treatments not protected during vegetative stage (T_3 and T_4) and the untreated control in both the seasons. Maximum leaf area per plant was observed in disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (2.88.08 sq cm) and it was at par with disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and carbaryl 0.2 per cent (T_9). The treatments with carbofuran 5 per cent + monocrotophos 004 per cent (T_5), carbaryl 0.2 per cent (T_9), malathion 0.1 per cent (T_8), carbofuran 5 per cent + malathion 0.1 per cent (T_7) and carbofuran 5 per cent (T_1) were at par with each other during both the seasons but these treatments were also equal to disulfoton 1 kg a.i./ha (T_2) in 1979.

The pooled analysis indicated that the treatments with disulfoton (T_6 and T_2) recorded maximum leaf area and were significantly superior over rest of the treatments except carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and carbaryl 0.2 per cent (T_9).

4.3.8.2 Per cent Avoidable Loss in Leaf Area Per Plant

The influence of sucking pests in reducing the leaf area was drastic. The reduction in leaf area per plant in the plots not protected from jassids and aphids was 63.76, 61.37 and 58.5 per cent in carbaryl 0.2 per cent (T_4), untreated control (T_{10}) and monocrotophos 0.04 per cent (T_3) respectively. The per cent avoidable loss in leaf area per plant was minimum in the treatment with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) followed by disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and carbaryl 0.2 per cent (T_9).

4.3.9 Leaf Weight Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The data on the leaf weight per plant and per cent avoidable loss due to jassids and aphids during vegetative stage are presented in Table 28 and graphically depicted in Fig. 6.

4.3.9.1 Effect on Leaf Weight Per plant

The results indicated that the plots treated during vegetative stage recorded significantly higher leaf weight compared to the plots not protected during vegetative stage (T_3, T_4 and T_{10}) in both the seasons; however, the treatment carbofuran 5 per cent (T_1) was equal to monocrotophos 0.04 per cent during fruiting stage (T_3) in 1978. The treatment with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6)

Table 28. Per cent avoidable loss in leaf weight per plant due to jassids and aphids during vegetative stage

Treatments	Mean leaf weight/plant (g) at 40 days after sowing			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	6.38	6.57	6.50	32.78
T_2 Disulfoton 1 kg a.i./ha	8.25	8.32	8.29	14.27
T_3 Monocrotophos 0.04% during fruiting stage	4.10	3.80	3.90	59.66
T_4 Carbaryl 0.2% during fruiting stage	3.41	3.67	3.57	63.08
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	8.80	7.47	7.93	17.99
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	10.05	9.47	9.67	Nil
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	6.75	6.60	6.65	31.23
T_8 Malathion 0.1% spray throughout	7.70	7.65	7.66	20.78
T_9 Carbaryl 0.2% spray throughout	8.52	8.67	8.61	10.96
T_{10} Untreated check	3.73	3.82	3.79	60.80
S.E. ±	1.278	0.938	0.534	
C.D. (P = 0.05)	2.622	1.924	1.482	

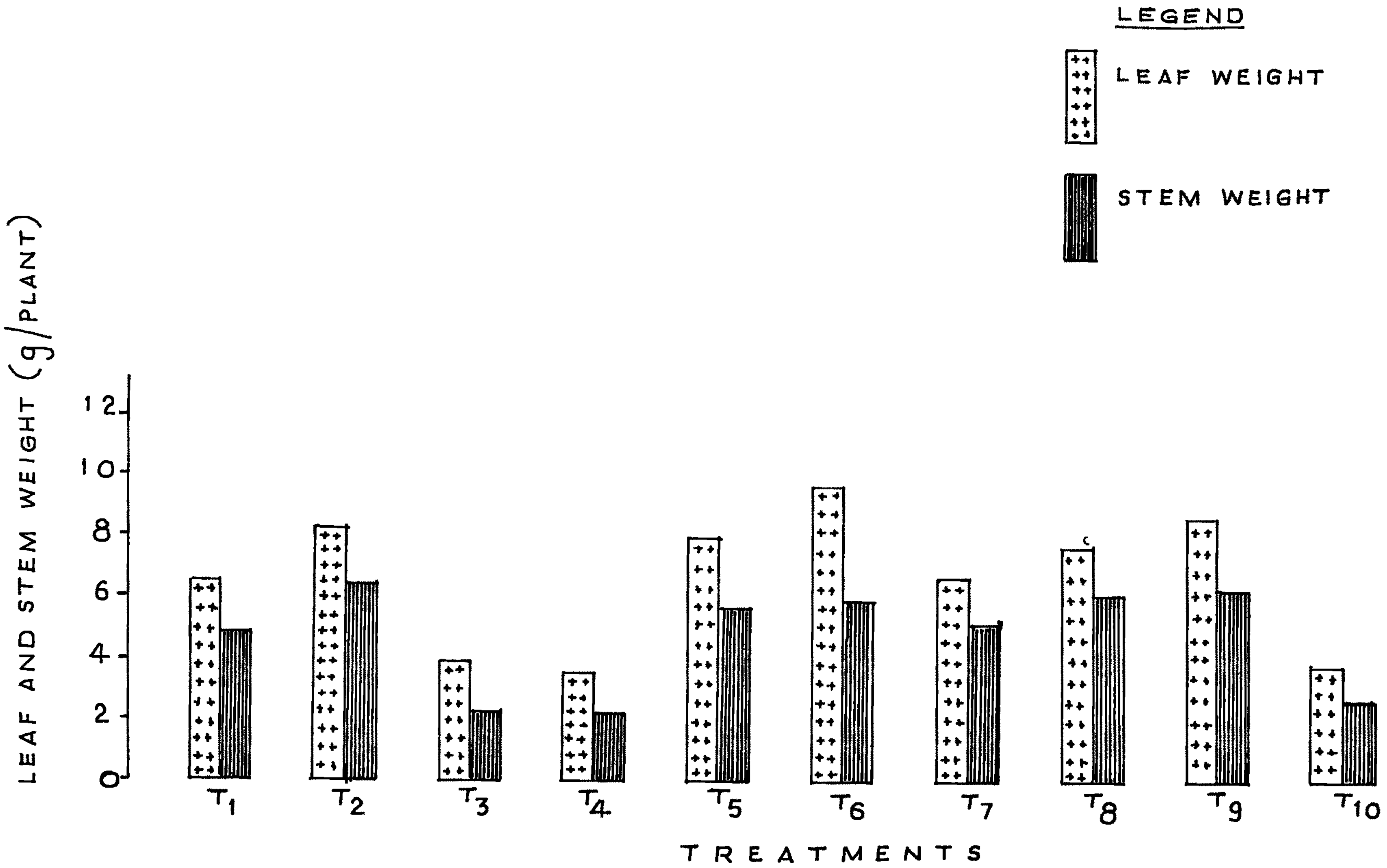

Figure 6. LEAF AND STEM WEIGHT AS INFLUENCED BY VARIOUS TREATMENTS AT 40 DAYS AFTER SOWING

recorded significantly increased leaf weight per plant over all other treatments but it was at par with carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbaryl 0.2 per cent (T_9), disulfoton 1 kg a.i./ha (T_2) and malathion 0.1 per cent (T_8) in 1978; however, it was also significantly superior over carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) during 1979.

The pooled analysis revealed that the treatments disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2) were at par with each other and significantly superior over rest of the treatments except carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and malathion 0.1 per cent (T_8). The plots unprotected during vegetative stage (T_3, T_4 and T_{10}) recorded significantly reduced leaf weight per plant than all other treatments.

4.3.9.2 Per cent Avoidable Loss in Leaf Weight Per Plant due to Jassids and Aphids

The per cent avoidable loss in leaf weight per plant was maximum (63.08) in carbaryl 0.2 per cent during fruiting stage (T_4), followed by untreated control (60.80) and monocrotophos 0.04 per cent during fruiting stage (59.66). The per cent avoidable loss in leaf weight per plant was minimum in the treatment with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) followed by carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2).

4.3.10 Stem weight Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The data on the stem weight per plant and per cent avoidable loss as influenced by jassids and aphids during vegetative stage are presented in Table 29 and graphically depicted in Fig. 6.

4.3.10.1 Stem Weight Per Plant

The stem weight was significantly increased in the plots protected during vegetative stage than the plots untreated during vegetative stage (T_3 and T_4) and untreated control (T_{10}). The treatments carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2) were significantly superior over all other treatments except malathion 0.1 per cent (T_8), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) in both the seasons. The treatments monocrotophos 0.04 per cent (T_3), carbaryl 0.2 per cent during fruiting stage (T_4) and untreated control registered significantly reduced stem weight than all other treatments and were at par with each other.

The pooled analysis indicated similar results.

4.3.10.2 Per cent Avoidable Loss in Stem weight Per Plant

The per cent avoidable loss in stem weight per plant in the treatments not protected during vegetative stage viz. T_3 and T_4 and untreated control was 65.63,

Table 29. Per cent avoidable loss in stem weight per plant due to jassids and aphids during vegetative stage

Treatments	Mean stem weight/plant (g) at 40 days after sowing			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	4.70	4.87	4.81	25.88
T_2 Disulfoton 1 kg a.i./ha	6.35	6.57	6.49	Nil
T_3 Monocrotophos 0.04% during fruiting stage	2,15	2.27	2.23	65.63
T_4 Carbaryl 0.2% during fruiting stage	2.05	2.32	2.23	65.63
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	5.70	5.57	5.61	13.55
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	5.60	6.17	5.98	7.85
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	4.85	5.25	5.11	21.26
T_8 Malathion 0.1% spray throughout	6.05	6.12	6.09	6.16
T_9 Carbaryl 0.2% spray throughout	6.60	6.10	6.26	3.54
T_{10} Untreated check	2.52	2.65	2.60	59.93
S.E. ±	0.624	0.438	0.253	
C.D. (P = 0.05)	1.281	0.900	0.703	

65.63 and 59.93 per cent, respectively. The per cent avoidable loss in stem weight per plant was minimum in disulfoton 1 kg a.i./ha (T_2) followed by carbaryl 0.2 per cent (T_9), malathion 0.1 per cent (T_8) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6).

4.3.11 Fruit Number Per Plant and Per cent Avoidable Loss due to Okra Pest Complex

The data on fruit number per plant and per cent avoidable loss due to okra pests are presented in Table 30.

4.3.11.1 Fruit Number Per Plant

The results indicated that the treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9) were significantly superior over all other treatments in increasing the number of fruits per plant and were at par with each other in both the seasons. Treatments with monocrotophos 0.04 per cent (T_3), disulfoton 1 kg a.i./ha (T_2) and carbaryl 0.2 per cent during fruiting stage (T_4) recorded significantly higher number of fruits per plant than carbofuran 5 per cent (T_1) and untreated control (T_{10}) but did not differ significantly among themselves during 1978, but these treatments were also significantly superior over carbofuran 5 per cent + malathion 0.1 per cent (T_7) and

Table 30. Per cent avoidable loss in number of fruits per plant due to okra pest complex

Treatments	Mean number of healthy fruits per plant			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	2.40 (1.54)	3.22 (1.79)	2.81 (1.72)	46.74
T_2 Disulfoton 1 kg a.i./ha	5.72 (2.38)	6.25 (2.49)	5.98 (2.46)	23.83
T_3 Monocrotophos 0.04% during fruiting stage	6.40 (2.48)	7.00 (2.63)	6.70 (2.58)	20.12
T_4 Carbaryl 0.2% during fruiting stage	5.37 (2.30)	6.17 (2.47)	5.77 (2.42)	25.07
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	10.20 (3.18)	10.62 (3.25)	10.41 (3.23)	Nil
T_6 Disulfoton 1 kg a.i./ha + Carbaryl 0.2%	9.72 (3.10)	10.72 (3.26)	10.22 (3.21)	0.61
T_7 Carbofuran 5% seed treatment + malathion 0.1%	4.00 (1.97)	4.45 (2.10)	4.22 (2.06)	36.22
T_8 Malathion 0.1% spray throughout	3.80 (1.92)	4.37 (2.08)	4.08 (2.04)	36.84
T_9 Carbaryl 0.2% spray throughout	8.87 (2.97)	9.22 (3.02)	9.04 (3.00)	7.12
T_{10} Untreated check	1.95 (1.39)	2.85 (1.66)	2.40 (1.59)	50.77
S.E. ±	0.207	0.126	0.076	
C.D. (P = 0.05)	0.426	0.259	0.212	

Figures in parentheses are $\sqrt{n}$ transformed values malathion 0.1 per cent (T_8) besides carbofuran 5 per cent (T_1) and untreated control (T_{10}) in 1979. The treatment carbofuran 5 per cent (T_1) registered significantly less number of fruits per plant and was at par with untreated control (T_{10}) in both the seasons.

The pooled analysis indicated that all the insecticidal treatments were significantly superior over untreated control except carbofuran 5 per cent (T_1). The treatment carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) recorded significantly higher number of fruits per plant than rest of the treatments and was at par with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6). No significant differences were observed between carbofuran 5 per cent (T_1) and untreated control (T_{10}).

4.3.11.2 Per cent Avoidable Loss in Fruit Number Per Plant

The results indicated that the per cent avoidable loss in fruit number per plant in the untreated check due to okra pest complex was to the extent of 50.77 per cent. The per cent avoidable loss due to okra pest complex in other treatments viz. carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbofuran 5 per cent + malathion 0.1 per cent (T_7), malathion 0.1 per cent (T_8) and carbaryl 0.2 per cent (T_9) was nil, 0.61, 36.22, 36.84 and 7.12 per cent, respectively.

The per cent avoidable loss in fruit number per plant due to jassids and aphids in the plots unprotected during vegetative stage viz. monocrotophos 0.04 per cent during fruiting stage (T_3) and carbaryl 0.2 per cent during fruiting stage (T_4) was to the extent of 20.12 and 25.07 per cent, respectively.

The per cent avoidable loss in fruit number per plant due to fruit borer in the treatments unprotected during fruiting stage viz. carbofuran 5 per cent (T_1) and disulfoton 1 kg a.i./ha (T_2) was to the extent of 46.74 and 23.83 per cent.

4.3.12 Fruit Length and Per cent Avoidable Loss due to Okra Pest Complex

The data on the effect on fruit length and per cent avoidable loss due to okra pests are presented in Table 31.

4.3.12.1 Fruit Length

Differences among various treatments in influencing the fruit length were not evident in both the seasons.

The pooled analysis indicated that the differences among various treatments in influencing the fruit length were significant. The treatments disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and disulfoton 1 kg a.i./ha (T_2) were significantly superior over

Table 31. Per cent avoidable loss in fruit length due to okra pest complex

Treatments	Mean fruit length (cm)			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	11.88	12.12	12.06	2.26
T_2 Disulfoton 1 kg a.i./ha	12.43	12.32	12.34	Nil
T_3 Monocrotophos 0.04% during fruiting stage	12.25	12.20	12.21	1.05
T_4 Carbaryl 0.2% during fruiting stage	12.17	12.20	12.19	1.21
T_5 Carbofuran 5% seed treatment + Monocrotophos 0.04%	12.26	12.22	12.22	1.78
T_6 Disulfoton 1 kg a.i./ha + carbaryl 0.2%	12.49	12.30	12.34	Nil
T_7 Carbofuran 5% seed treatment + malathion 0.1%	12.13	12.07	12.08	2.10
T_8 Malathion 0.1% spray throughout	11.67	11.90	11.84	4.05
T_9 Carbaryl 0.2% spray throughout	11.89	11.95	11.93	3.32
T_{10} Untreated check	11.42	11.87	11.76	4.70
S.E. ±	0.384	0.215	0.133	
C.D. (P = 0.05)	N.S	N.S	0.368	

carbaryl 0.2 per cent (T_9), malathion 0.1 per cent (T_8) and untreated control (T_{10}) in increasing the fruit length, but they were at par with rest of the treatments. The treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent during fruiting stage (T_4) were significantly superior to untreated control (T_{10}). The treatments carbofuran 5 per cent + malathion 0.1 per cent (T_7), carbofuran 5 per cent (T_1), carbaryl 0.2 per cent (T_9) and malathion 0.1 per cent (T_8) recorded minimum fruit length and were equal to untreated control (T_{10}).

4.3.12.2 Per cent Avoidable Loss in Fruit Length due to Okra Pests

The per cent avoidable loss in fruit length due to okra pest complex in untreated control (T_{10}) was to the extent of 4.70 per cent followed by malathion 0.1 per cent (T_8) (4.05), carbaryl 0.2 per cent (T_9) (3.32), carbofuran 5 per cent + malathion 0.1 per cent (T_7) (2.1), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (1.78) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (nil).

The per cent avoidable loss in fruit length due to jassids and aphids in the treatments unprotected during vegetative stage viz. monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent (T_4) was 1.05 and 1.21 per cent, respectively.

The treatments without protection during fruiting stage viz. carbofuran 5 per cent (T_1) and disulfoton 1 kg a.i./ha (T_2) registered per cent avoidable loss in fruit length to the extent of 2.26 and nil respectively due to fruit borer.

4.3.13 Fruit Girth and Per cent Avoidable Loss due to Okra Pests

The data on fruit girth and per cent avoidable loss due to okra pests are presented in Table 32.

4.3.13.1 Fruit Girth

The treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9) recorded significantly increased fruit girth than all other treatments, but were at par with disulfoton 1 kg a.i./ha (T_2) and among themselves in both the seasons. The treatment carbofuran 5 per cent + malathion 0.1 per cent (T_7) was significantly superior over untreated control (T_{10}) during 1978 but it was at par with untreated control (T_{10}) during 1979. No significant differences were observed among the treatments with monocrotophos 0.04 per cent (T_3), malathion 0.1 per cent (T_8), carbaryl 0.2 per cent during fruiting stage (T_4), carbofuran 5 per cent (T_1) and untreated control (T_{10}) in both the seasons.

Table 32. Per cent avoidable loss in fruit girth due to okra pest complex

Treatments	Mean fruit girth (cm)			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	3.59	4.19	4.03	26.45
T_2 Disulfoton 1 kg a.i./ha	4.92	5.02	5.00	8.75
T_3 Monocrotophos 0.04% during fruiting stage	4.14	4.39	4.32	21.16
T_4 Carbaryl 0.2% during fruiting stage	4.10	4.15	4.13	24.63
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	5.62	5.41	5.47	0.18
T_6 Disulfoton 1 kg a.i./ha + carbaryl 0.2%	5.61	5.43	5.48	Nil
T_7 Carbofuran 5% seed treatment + Malathion 0.1%	4.34	4.48	4.44	18.97
T_8 Malathion 0.1% spray throughout	4.12	4.40	4.33	20.98
T_9 Carbaryl 0.2% spray throughout	5.37	5.42	5.40	1.45
T_{10} Untreated check	3.20	3.89	3.71	32.29
S.E. ±	0.499	0.293	0.179	
C.D. (P = 0.05)	1.025	0.602	0.496	

The pooled analysis indicated that the treatment with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2) were significantly superior to all other treatments and were at par with each other. The treatments carbofuran 5 per cent + malathion 0.1 per cent (T_7), malathion 0.1 per cent (T_8) and monocrotophos 0.04 per cent (T_3) were significantly superior over control (T_{10}) and equal among themselves. The differences in the treatments with carbaryl 0.2 per cent during fruiting stage (T_4), carbofuran 5 per cent (T_1) and untreated control (T_{10}) were not evident.

4.3.13.2 The Per cent Avoidable Loss in Fruit Girth due to Okra Pests

The per cent avoidable loss due to okra pest complex in untreated control (T_{10}) in fruit girth was to the extent of 32.29 per cent. The treatments with complete protection viz. malathion 0.1 per cent (T_8), carbofuran 5 per cent + malathion 0.1 per cent (T_7), carbaryl 0.2 per cent (T_9), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) recorded 20.98, 18.97, 1.45, 0.18 and nil per cent loss, respectively in fruit girth due to okra pest complex.

The treatments monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent during fruiting stage (T_4) which were unprotected during vegetative stage recorded 21.16 and 24.63 per cent loss in fruit girth due to jassids and aphids.

The per cent loss in the treatments without protection during fruiting stage viz. carbofuran 5 per cent (T_1) and disulfoton 1 kg a.i./ha (T_2) were 26.45 and 8.75 per cent respectively in fruit girth due to fruit borer.

4.3.14 Yield of Marketable Fruits and Per cent Avoidable Loss due to Okra Pests

The data on the marketable fruit yield and per cent avoidable loss due to okra pests are presented in Table 33 and graphically depicted in Fig. 7.

4.3.14.1 Yield of Marketable Fruits

The results indicated that significantly increased yield of marketable fruits was recorded in the treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) than all other treatments and were at par with each other during 1978. The treatments carbaryl 0.2 per cent (T_9) monocrotophos 0.04 per cent (T_3) and disulfoton 1 kg a.i./ha (T_2) were equal among

Table 33. Per cent avoidable loss in marketable fruit yield due to okra pest complex

Treatments	Marketable fruit yield (q/ha)			Per cent avoidable loss
	1978	1979	Average	
T_1 Carbofuran 5% seed treatment	17.34	23.97	20.66	78.22
T_2 Disulfoton 1 kg a.i./ha	45.79	49.92	47.85	49.57
T_3 Monocrotophos 0.04% during fruiting stage	50.37	55.50	52.93	44.21
T_4 Carbaryl 0.2% during fruiting stage	40.94	47.10	44.02	53.60
T_5 Carbofuran 5% seed treatment + monocrotophos 0.04%	92.84	96.95	94.89	Nil
T_6 Disulfoton 1 kg a.i./ha + carbaryl 0.2%	80.59	88.50	84.54	10.90
T_7 Carbofuran 5% seed treatment + malathion 0.1%	30.05	32.92	31.48	66.82
T_8 Malathion 0.1% spray throughout	20.06	24.15	22.10	76.70
T_9 Carbaryl 0.2% spray throughout	57.40	61.50	59.45	37.34
T_{10} Untreated check	10.66	15.90	13.28	86.00
S.E. $\pm$	6.041	5.352	2.860	
C.D. (P = 0.05)	12.396	10.983	8.116	

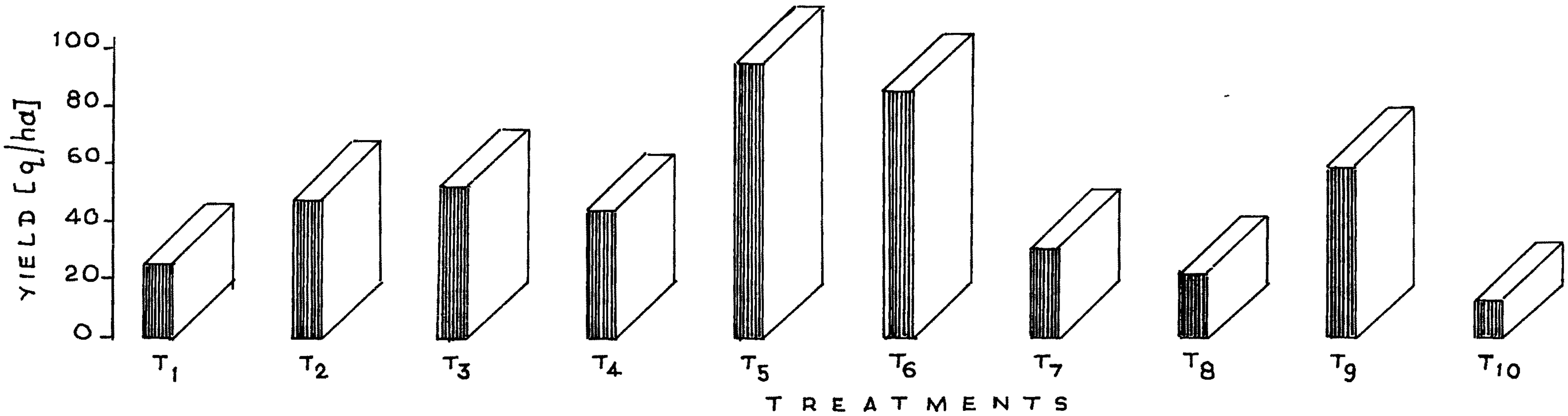

Figure 7. YIELD OF OKRA AS INFLUENCED BY VARIOUS TREATMENTS

themselves and were significantly superior over the treatments with carbofuran 5 per cent + malathion 0.1 per cent (T_7), malathion 0.1 per cent (T_8), carbofuran 5 per cent (T_1) and untreated control (T_{10}). The treatments malathion 0.1 per cent (T_8) and carbofuran 5 per cent (T_1) recorded significantly low yield of fruits and were equal to untreated control (T_{10}) during 1978. Similar trend was observed in 1979.

The pooled analysis indicated that maximum yield of 94.89 q/ha was recorded in the treatment with carbofuran 5 per cent seed treatment + monocrotophos 0.04 per cent (T_5) and it was significantly superior over all other treatments. The treatment disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) was the next best treatment in increasing fruit yield and was also significantly superior to rest of the treatments. The treatment carbaryl 0.2 per cent (T_9) and monocrotophos 0.04 per cent (T_3) yielded significantly more than the carbofuran 5 per cent + malathion 0.1 per cent (T_7), malathion 0.1 per cent (T_8), carbofuran 5 per cent (T_1) and untreated control (T_{10}) and were equal among themselves. The treatment disulfoton 1 kg a.i./ha (T_2), carbaryl 0.2 per cent during fruiting stage (T_4) and carbofuran 5 per cent + malathion 0.1 per cent (T_7) were significantly superior over malathion 0.1 per cent (T_8), carbofuran 5 per cent (T_1) and untreated control(T_{10}).

The treatment carbofuran 5 per cent (T_1) yielded significantly less and was at par with untreated control (T_{10}).

4.3.14.2 Per cent Avoidable Loss in the Yield of Marketable Fruits due to Okra Pests

The yield of marketable fruits was drastically reduced due to okra pests in the plots unprotected during vegetative stage (T_3 and T_4) and fruiting stage (T_1 and T_2) and untreated control (T_{10}). The per cent avoidable loss due to okra pest complex in untreated control (T_{10}) in fruit yield was to the tune of 86.00 per cent.

The treatments with carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbofuran 5 per cent + malathion 0.1 per cent (T_7), malathion 0.1 per cent (T_8) and carbaryl 0.2 per cent (T_9) recorded nil, 10.90, 66.82, 76.70 and 37.34 per cent loss, respectively in fruit yield due to okra pest complex.

The per cent avoidable loss due to jassids and aphids alone in the treatments unprotected during vegetative stage viz. monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent (T_4) was 44.21 and 53.60 per cent, respectively.

The per cent loss in fruit yield due to fruit borer in the treatments without protection during fruiting stage viz. carbofuran 5 per cent (T_1) and disulfoton 1 kg a.i./ha (T_2) was to the extent of 78.22 and 49.57 per cent, respectively.

4.3.15 Correlation Studies Between Okra Pests, Plant Characters and Yield of Okra

The data on the inter-correlation between okra pests, plant characters and yield of okra are presented in Table 34.

The results indicated that significant negative correlations were observed for all the pests and yield relationships. The highest significant negative correlation was observed in the case of percentage fruit borer incidence followed by jassids and aphids.

In case of mean height of the plant, jassids and aphids exerted negatively significant impact.

The effect of jassids was more prominent than that of aphids. Similar trend was observed in the case of number of leaves per plant at 40 days but effect of jassids and aphids was non-significant at final harvest. It was observed that the jassids and aphids significantly affected the leaf area per plant, the effect being higher in case of jassids than that of the latter.

Table 54. Inter-correlations between insect pests, plant characters and yield of okra

	Mean height of the plant at 40 days after sowing	Mean number of leaves/plant at 40 days after sowing	Mean plant height at final harvest	Mean number of leaves/plant at final harvest	Leaf area/plant at 40 days after sowing	Leaf weight/plant at 40 days after sowing	Stem weight/plant at 40 days after sowing	No.of healthy fruits per plant	Average fruit length	Average fruit girth	Yield of healthy fruits
Mean number of jassids/leaf	-0.857**	-0.907**	-0.408**	-0.04	-0.859**	-0.855**	-0.902**	-0.496**	-0.271*	-0.669**	-0.425**
Mean number of aphids/leaf	-0.445**	-0.525**	-0.297**	-0.048	-0.515**	-0.515**	-0.589**	-0.217*	0.086	-0.314**	-0.255*
Per cent fruit borer incidence								-0.685**			-0.759**
Mean plant height at 40 days after sowing		0.927**			0.775**	0.770**	0.760**	0.563**			0.486**
Mean number of leaves/plant at 40 days after sowing					0.827**	0.812**	0.819**	0.569**			0.564**
Mean plant height at final harvest				0.706**				0.678**			0.840**
Mean number of leaves/plant at final harvest								0.647**			0.789**
Leaf area/plant at 40 days after sowing						0.958**	0.890**	0.554**			0.485**
Leaf weight/plant at 40 days after sowing							0.890**	0.575**			0.494**
Stem weight/plant at 40 days after sowing								0.414**			0.538**
Number of healthy fruits/plant									0.514**	0.809**	0.864**
Average fruit length											
Average fruit girth										0.624**	0.495**
											0.772**

* and ** significant for P ∠ 0.05 and P ∠ 0.01, respectively.

Similar trend was also observed in case of leaf weight and stem weight of plant.

All the three insects viz. jassids, aphids and fruit borer, indicated significantly negative correlationship with number of healthy fruits per plant. The highest correlation was observed due to per cent fruit borer incidence followed by jassids and aphids. In case of average fruit length, the aphid did not affect the fruit length whereas, the effect of jassids was significantly negative. Significant negative correlationship was observed between the incidence of jassids and aphids and the fruit girth.

4.3.16 Simple Regression Studies Between Okra Pests and Yield of Okra

Simple regression studies were carried out between jassids, per cent fruit borer infestation and yield of okra. The regression coefficient 'b' and constant 'a' were worked out and simple regression equations were set up.

4.3.16.1 Jassids and Yield

The relationship between jassid incidence (x) and yield of okra (Y) was found to be negative and highly significant ($r = -0.425^{**}$) (Table 34 and Fig.8a).

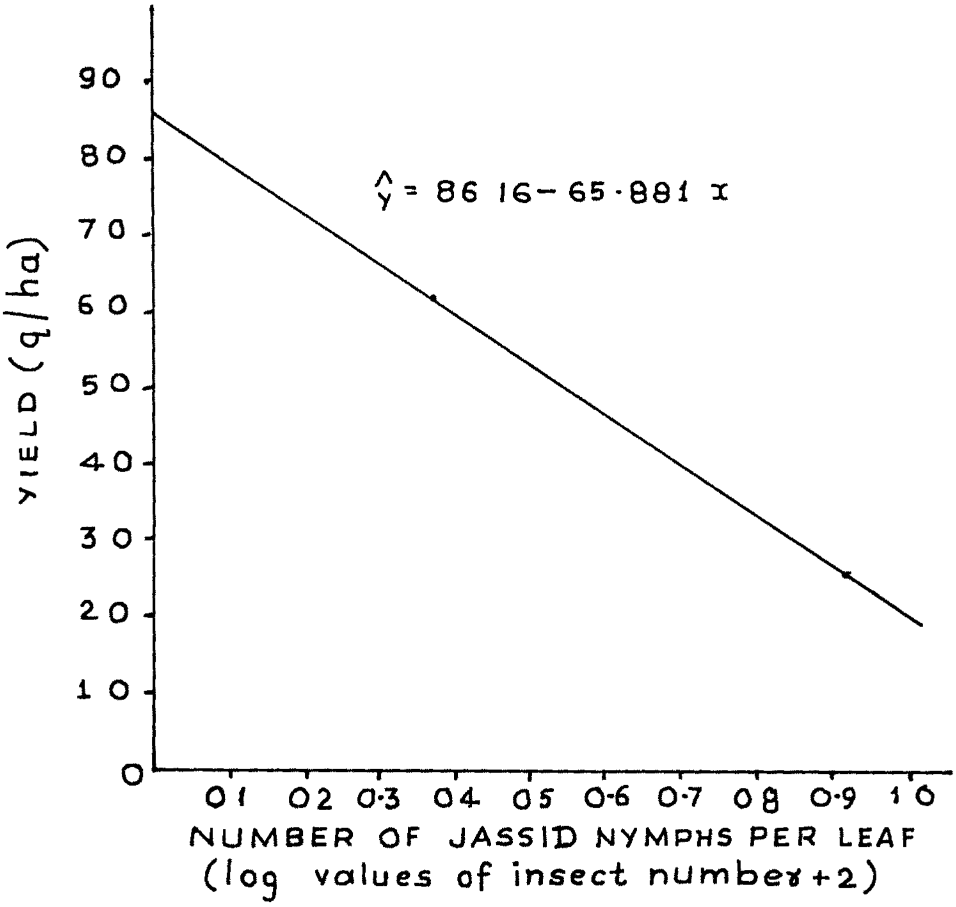

Figure 8a SIMPLE REGRESSION BETWEEN NUMBER OF JASSIDS PER LEAF AND YIELD OF OKRA

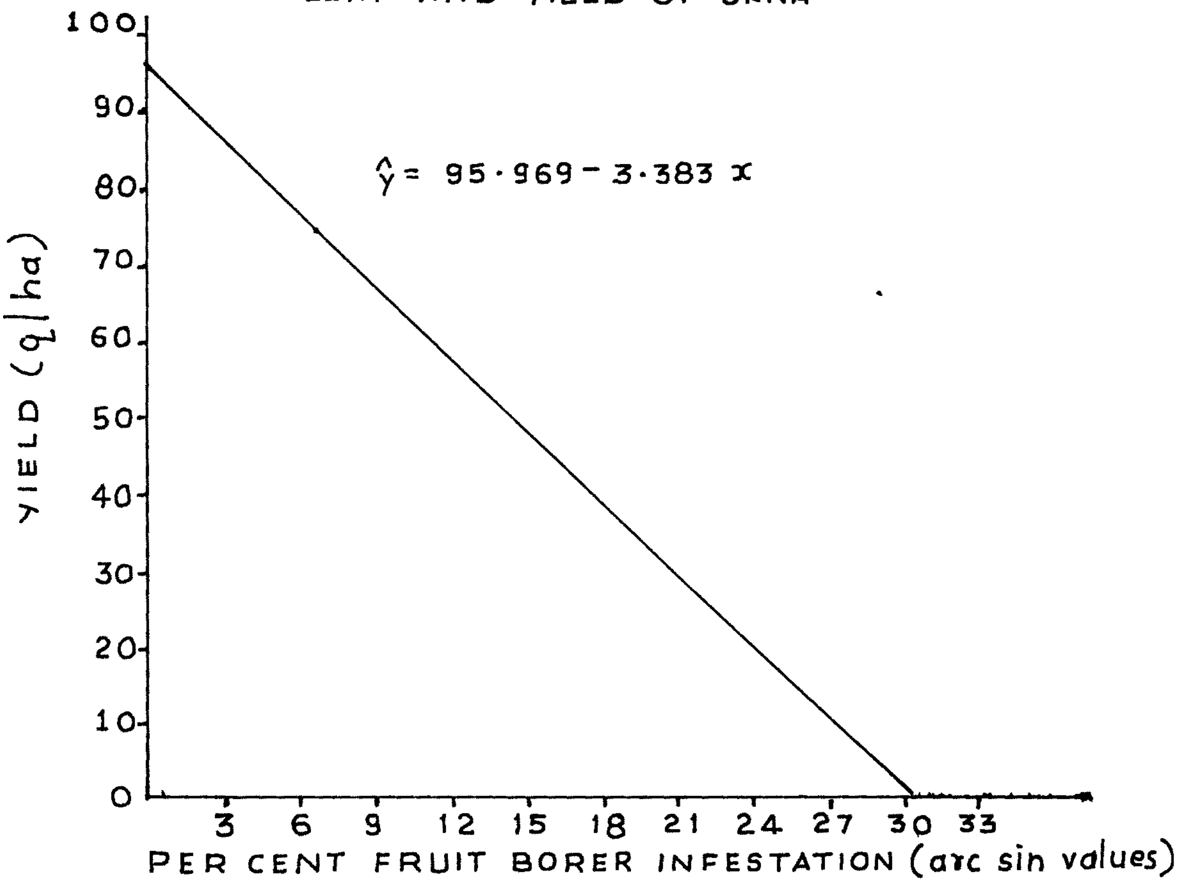

Figure 8b. SIMPLE REGRESSION BETWEEN PER CENT FRUIT BORER INFESTATION AND YIELD OF OKRA

The regression equation worked out was Y = 86.162 - 65.881x indicating that for every one jassid nymph per leaf the yield decreased by 65.88 q/ha.

4.3.16.2 Per cent Fruit Borer Infestation and Yield

The relationship between per cent fruit borer infestation (x) and yield of okra (Y) was found to be negative and highly significant (r = -0.759**) (Table 34 and Fig. 8b). The regression equation worked out was Y = 95.969 - 3.383x indicating that for every one per cent fruit borer infestation, yield decreased by 3.38 q/ha.

4.3.17 Multiple Regression Studies Between Okra Pest Complex, Plant Height, Leaf Area, Fruit Number and Marketable Fruit Yield

The results of the multiple regression studies between okra pest complex (jassids, aphids and fruit borer), plant height, leaf area, fruit number and marketable fruit yield are presented in Table 35.

The multiple regression analysis between jassids, aphids and fruit borer as explanatory variables (independent variables) and plant height, leaf area and fruit yield taking as dependent variables; were estimated. The linear multiple regression analysis revealed significant coefficient of multiple determination (R^2 = 0.16, 0.74, 0.61 and 0.68 respectively for height,

Table 35. Functional relationship between okra pest complex, final plant height, leaf area, number of healthy fruits and yield of okra

Equation No.	Regression equation	R^2
1.	$y_1 = 57.085 - 67.243^{*} x_1 - 51.727 x_2$ (24.716) (148.597)	0.16**
2.	$y_2 = 357.197 - 398.72^{**} x_1 + 241.542 x_2$ (33.286) (200.000)	0.74**
3.	$y_3 = 3.853 - 1.690^{**} x_1 + 1.574 x_2 - 0.068^{**} x_3$ (0.379) (2.244) (0.008)	0.61**
4.	$Y = 4421.471 + 0.443^{*} y_1 - 0.052 y_2 + 28.423^{*} y_3$ (0.217) (0.035) (11.140)	0.68**

Figures in parentheses are standard errors of the estimates.

*, ** Significant at 5 and 1 per cent level of significance respectively.

y_1 Final plant height

y_2 Leaf area

y_3 Fruit number per plant

Y Yield

x_1 Number of jassids

x_2 Number of aphids

x_3 Per cent fruit borer infestation

R^2 Coefficient of multiple determination leaf area, fruit number and yield) causing thereby 16.8, 74.3, 61.7 and 68.3 per cent variation in final plant height, leaf area, fruit number per plant and yield due to jassids, aphids and fruit borer.

In case of final plant height, the jassid has given significant negative impact at 5 per cent level of significance whereas, the contribution of aphids was non-significant.

The leaf area was significantly affected by jassids whereas, the effect of aphids was nonsignificant.

In case of number of fruits per plant, the effect of jassids and fruit borer was significantly negative whereas the effect of aphids was not significant

The plant height and number of fruits per plant have positively contributed to the yield, whereas, the effect of leaf area was not evident. This indicates that the contribution of number of healthy fruits per plant to the yield was highest followed by plant height, implying thereby that if losses in fruit number are minimised, the yield could be increased.

It is evident from yield equation that yield is dependent upon plant height (y_1) and number of fruits per plant (y_3). The plant height (y_1) is dependent upon number of jassids (x_1) per leaf whereas fruit number per plant (y_3) is dependent upon both the number of jassids (x_1) and percentage incidence of fruit borer (x_3). Thus, we see that the jassid (x_1) and fruit borer (x_3) are the factors which ultimately affect the yield. Though leaf area per plant (y_2) is dependent upon jassids (x_1), since yield (Y) does not depend upon leaf area (y_2), the jassids affect the yield only through plant height (y_1) and fruit number per plant (y_3), but not the leaf area (y_2). The jassid tends to decrease plant height (y_1) and fruit number per plant (y_3) and the fruit borer tends to decrease fruit number per plant (y_3) which in turn decrease the yield.

4.4 <u>Crop Loss Assessment due to Major Pests During Various Growth Periods of Okra</u>

4.4.1 Incidence of Jassids

It is evident from the Table 36 that significant differences were observed in various treatments. The incidence of jassid population was significantly low in all the treatments receiving protection during 15-90 days (T_1, T_2, T_3, T_4, T_5, T_7, T_{11} and T_{12}) of crop growth. The treatments receiving protection during 45-90 days of crop growth (T_8, T_9 and T_{10}) were at par with unprotected control recording significantly higher jassid incidence than all other treatments.

Table 36. Incidence of jassids and aphids in different growth periods of okra

Treatments (period with insecticidal applications - days after sowing)	Mean number of jassids/leaf	Mean number of aphids/leaf
T_1 (15-90)	0.009 (0.303)	0.003 (0.301)
T_2 (15-74)	0.012 (0.303)	0.003 (0.301)
T_3 (15-59)	0.009 (0.303)	0.003 (0.301)
T_4 (15-44)	0.009 (0.304)	0.001 (0.301)
T_5 (15-29)	0.103 (0.322)	0.040 (0.309)
T_6 (untreated control)	1.738 (0.571)	1.811 (0.580)
T_7 (30-90)	0.096 (0.321)	0.011 (0.303)
T_8 (45-90)	1.535 (0.548)	1.394 (0.527)
T_9 (60-90)	1.925 (0.592)	1.720 (0.570)
T_{10} (75-90)	1.866 (0.586)	1.624 (0.558)
T_{11} (30-74)	0.116 (0.325)	0.011 (0.303)
T_{12} (15-29 and 75-90)	0.103 (0.322)	0.040 (0.309)
S.E. ±	0.016	0.017
C.D. (P = 0.05)	0.033	0.036

Figures in parentheses are log (x+2) values

4.4.2 Incidence of Aphids

The aphid population was significantly low in all the insecticidal treatments than untreated control (T_6) except the treatments protected during 60-90 days (T_9) and 75-90 days (T_{10}). The treatments protected during 15-90 (T_1), 15-74 (T_2), 15-59 (T_3), 15-44 (T_4), 15-29 (T_5), 30-90 (T_7), 30-74 (T_{11}) and 15-29 and 75-90 days (T_{12}) were at par with each other. No significant differences were observed in treatments receiving protection during 60-90 (T_9), 75-90 days (T_{10}) and untreated control (T_6) (Table 36).

4.4.3 Infestation of Fruit Borer

The observations on the percentage fruit borer infestation are presented in Table 37 and graphically represented in Fig. 9.

The percentage infestation of fruit borer was significantly low during 15-90 (T_1), 45-90 (T_8) and 30-90 days (T_7) than all other treatments. However, the treatments with protection during 30-90 days (T_7) was equal to 15-74 days (T_2). The treatments with 15-74 (T_2) and 30-74 days protection (T_{11}) were significantly superior over the treatments 15-29 and 75-90 (T_{12}), 15-59 (T_3), 15-44 (T_4), 75-90 (T_{10}), 15-29 (T_5) and untreated control (T_6) in reducing fruit borer infestation.

Differences in treatments 15-44 (T_4), 75-90 (T_{10}), untreated control (T_6) and 15-29 (T_5) were not significant.

Table 37. Infestation of fruit borer in different growth periods of okra

Treatments (periods with insecticidal applications - days after sowing)		Percentage fruit borer infestation
T_1	(15-90)	4.10 (11.68)
T_2	(15-74)	7.03 (15-37)
T_3	(15-59)	11.00 (19.30)
T_4	(15-44)	14.73 (22.42)
T_5	(15-29)	15.83 (23.33)
T_6	(untreated control)	15.40 (23.08)
T_7	(30-90)	4.66 (12.47)
T_8	(45-90)	4.40 (12.10)
T_9	(60-90)	9.50 (17.92)
T_{10}	(75-90)	14.70 (22.54)
T_{11}	(30-74)	7.20 (15.55)
T_{12}	(15-29 and 75-90)	10.70 (19.08)
	S.E. $\pm$	1.44
	C.D. (P = 0.05)	2.99

Figures in parentheses are angular transformations

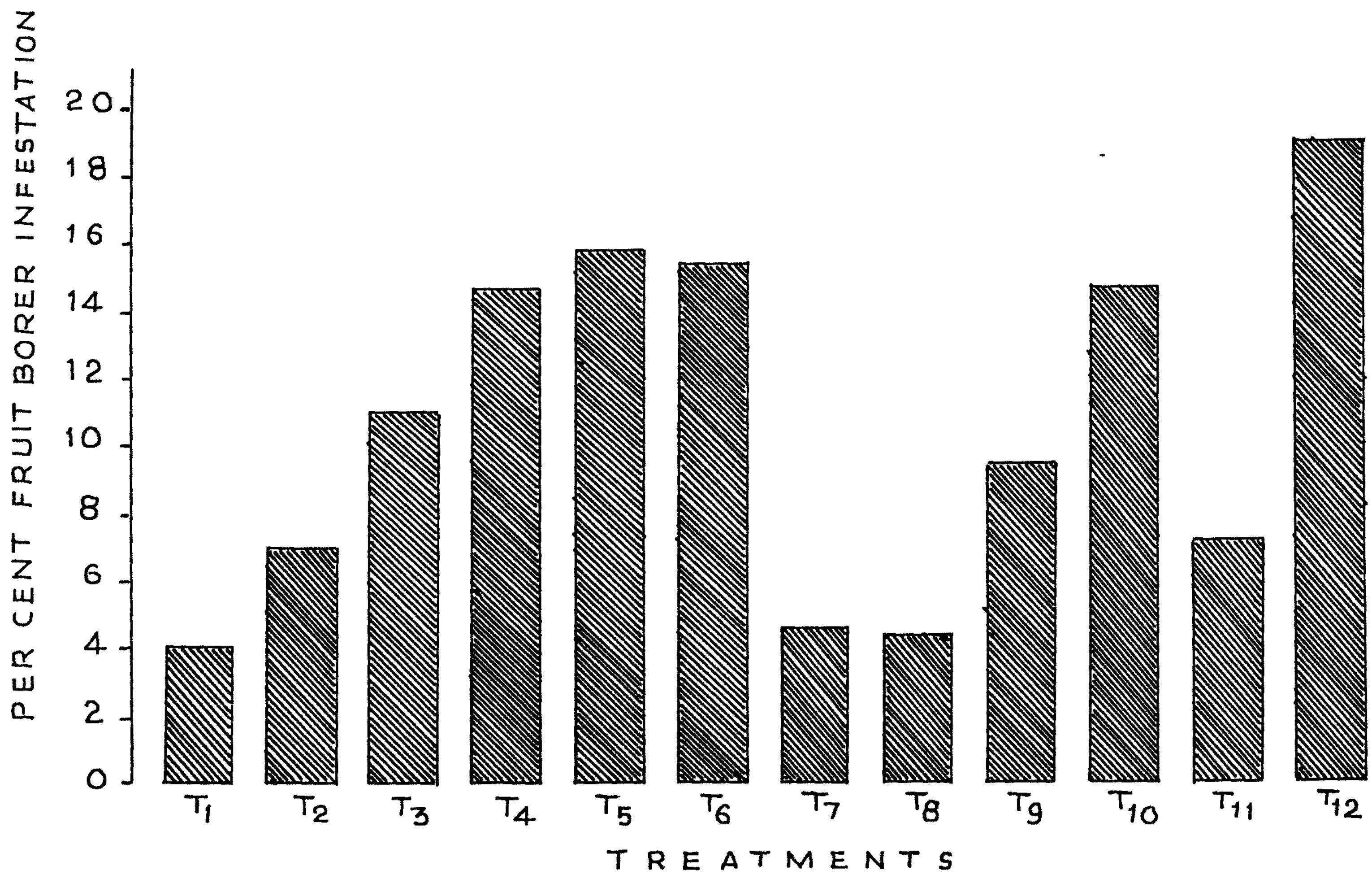

Figure 9. PER CENT INFESTATION OF FRUIT BORER IN OKRA PROTECTED DURING DIFFERENT GROWTH PERIODS

4.4.4 Effect on Plant Height and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The data regarding influence of various treatments on plant height and per cent avoidable loss are presented in Table 38 and graphically depicted in Fig. 10.

4.4.4.1 Plant Height

The results indicated that the height of the plant was significantly increased in treatments with 15-74 (T_2) and 15-90 (T_1) than all other treatments, but they were at par with 30-90 (T_7) and 15-59 (T_3) treatments. Significant increase in plant height, was observed in treatments 30-90 (T_7) and 15-59 (T_3) as compared to others except 15-90 (T_1), 15-74 (T_2) and 15-44 (T_4). No significant differences were observed in 15-29 (T_5), 45-90 (T_8), 15-29 and 75-90 (T_{12}), 60-90 (T_9), 75-90 (T_{10}) and untreated control (T_6).

4.4.4.2 Per cent Avoidable Loss in Plant Height

Table 38 indicates that the reduction in plant height in unprotected plots (T_6) was to the extent of 43.23 per cent. Avoidable loss in plant height was minimum in the treatment receiving protection during 15-74 days (nil) followed by 15-90 (6.30), 30-90 (8.54) and 15-59 days (9.36).

Table 38. Plant height and per cent avoidable loss due to insect pests in different growth periods of okra

Treatments (period with insecticidal applications - days after sowing)	Mean plant height at final harvest (cm)	Per cent avoidable loss
T_1 (15-90)	65.36	6.30
T_2 (15-74)	69.76	Nil
T_3 (15-59)	63.23	9.36
T_4 (15-44)	55.56	20.35
T_5 (15-29)	48.50	30.47
T_6 (untreated control)	39.60	43.23
T_7 (30-90)	63.80	8.54
T_8 (45-90)	43.13	32.43
T_9 (60-90)	42.16	39.56
T_{10} (75-90)	42.03	39.75
T_{11} (30-74)	53.46	23.36
T_{12} (15-29 and 75-90)	46.80	32.91
S.E. ±	4.27	
C.D. (P = 0.05)	8.86	

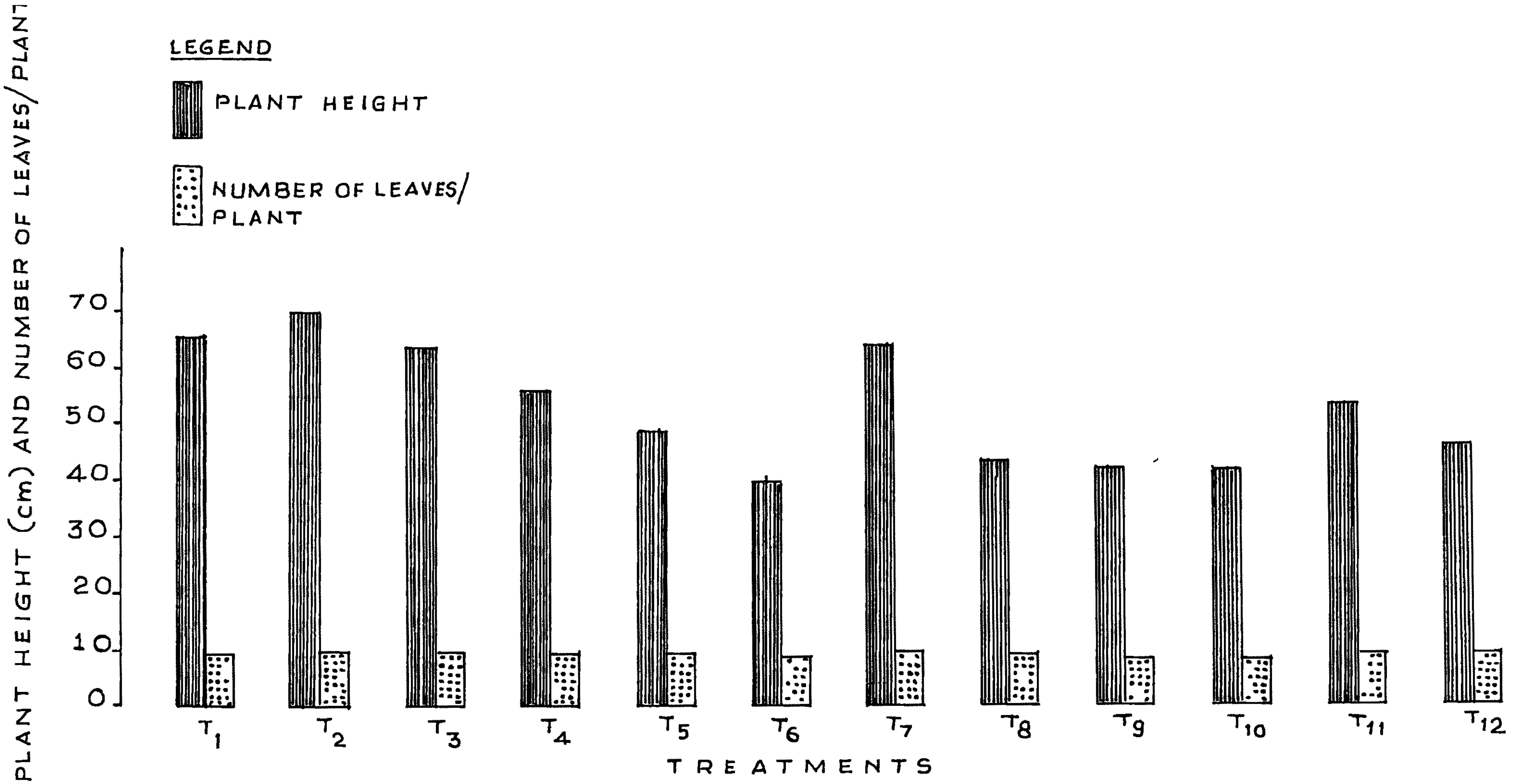

Figure 10. PLANT HEIGHT AND NUMBER OF LEAVES PER PLANT IN OKRA PROTECTED DURING DIFFERENT GROWTH PERIODS

4.4.5 Effect on Number of Leaves Per Plant and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The data on influence of various treatments on number of leaves per plant and per cent avoidable loss are presented in Table 39 and graphically represented in Fig. 10.

4.4.5.1 Effect on Number of Leaves Per Plant

Significantly highest number of leaves were observed in the treatments with 15-74 (T_2), 15-59 (T_3), 30-74 (T_{11}), 15-90 (T_1) and 30-90 (T_7) than untreated control (T_6), 75-90 (T_{10}) and 60-90 (T_9), but these treatments were at par with rest of the treatments. No significant differences were observed in treatments 45-90 (T_8), 15-44 (T_4), 15-29 (T_5), 15-29 and 75-90 (T_{12}) and untreated control (T_6).

4.4.5.2 Per cent Avoidable Loss in Number of Leaves Per Plant

The number of leaves per plant was not affected by the okra pest complex. Maximum per cent production in number of leaves per plant was observed in treatments receiving protection during 60-90 (13.17) followed by 75-90 (12.55) and untreated control (10.77). The per cent loss in number of leaves per plant was low in 15-74 (nil) followed by 15-59 (1.04) and 30-74 (1.04).

Table 39. Number of leaves per plant and per cent avoidable loss due to insect pests in different growth periods of okra

Treatments (periods with insecticidal applications - days after sowing)		Mean number of leaves/ plant at final harvest	Per cent avoidable loss
T_1	(15-90)	9.43	1.35
T_2	(15-74)	9.56	Nil
T_3	(15-59)	9.46	1.04
T_4	(15-44)	9.13	4.49
T_5	(15-29)	9.05	5.23
T_6	(untreated control)	8.53	10.77
T_7	(30-90)	9.43	1.35
T_8	(45-90)	9.23	3.45
T_9	(60-90)	8.30	13.17
T_{10}	(75-90)	8.36	12.55
T_{11}	(30-74)	9.46	1.04
T_{12}	(15-29 and 75-90)	9.06	5.23
	S.E. $\pm$	0.37	
	C.D. (P = 0.05)	0.77	

4.4.6 Effect on Number of Fruits Per Plant and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The data pertaining to the number of fruits per plant and per cent avoidable loss as influenced by insect pests during different growth periods of okra are presented in Table 40.

4.4.6.1 Effect on Fruit Number Per Plant

It is evident from the Table 40 that all the insecticidal treatments registered significantly higher number of fruits per plant than the unprotected control (T_6). The treatments 15-90 (T_1), 15-74 (T_2) and 30-74 (T_{11}) were significantly superior over all other treatments except 30-90 (T_7). The treatments 15-59 (T_3), 45-90 (T_8) and 60-90 (T_9) were at par with each other and recorded significantly higher number of fruits per plant than 15-29 (T_5), 75-90 (T_{10}) and untreated control (T_6).

4.4.6.2 Per cent Avoidable Loss in Fruit Number Per Plant

The number of fruits per plant was drastically reduced in unprotected plots due to okra pest complex. The per cent loss in unprotected plots (T_6) was to the extent of 27.73. The per cent reduction in fruit number per plant was minimum in plots receiving protection during 15-90 (nil) followed by 15-74 (0.36), 30-74 (0.36) and 30-90 days (2.55).

Table 40. Number of fruits per plant and per cent avoidable loss due to insect pests during different growth periods of okra

Treatments (period with insecticidal applications - days after sowing)	Mean number of fruits/ plant	Per cent avoidable loss
T_1 (15-90)	7.60 (2.74)	Nil
T_2 (15-74)	7.50 (2.73)	0.36
T_3 (15-59)	6.56 (2.55)	6.93
T_4 (15-44)	5.56 (2.34)	14.59
T_5 (15-29)	5.00 (2.22)	18.97
T_6 (untreated control)	4.00 (1.98)	27.73
T_7 (30-90)	7.20 (2.67)	2.55
T_8 (45-90)	6.13 (2.46)	10.21
T_9 (60-90)	5.86 (2.41)	12.04
T_{10} (75-90)	4.80 (2.18)	20.43
T_{11} (30-74)	7.46 (2.73)	0.36
T_{12} (15-29 and 75-90)	5.06 (2.24)	18.24
S.E. ±	0.08	
C.D. (P = 0.05)	0.17	

Figures in parentheses are $\sqrt{n}$ transformed values

4.4.7 Effect on Fruit Length and Per cent Avoidable Loss due to Insect Pests During Different Growth periods of Okra

The data on the fruit length and per cent avoidable loss due to insect pests during different growth periods of okra are presented in Table 41.

Table 41. Fruit length and per cent avoidable loss due to insect pests during different growth periods of okra

Treatments (period with insecticidal applications - days after sowing)	Mean fruit length (cm)	Per cent avoidable loss
T_1 (15-90)	11.76	0.92
T_2 (15-74)	11.57	2.52
T_3 (15-59)	11.78	0.75
T_4 (15-44)	11.63	2.02
T_5 (15-29)	11.68	1.60
T_6 (untreated control)	11.17	5.89
T_7 (30-90)	11.87	Nil
T_8 (45-90)	11.53	2.36
T_9 (60-90)	11.61	2.19
T_{10} (75-90)	11.44	3.62
T_{11} (30-74)	11.74	1.09
T_{12} (15-29 and 75-90)	11.53	2.86
S.E. $\pm$	0.05	
C.D. (P = 0.05)	N.S	

4.4.7.1 Effect on Fruit Length

Differences in the fruit length in various treatments were not evident. The treatments 30-90 (T_7), 15-59 (T_3) and 15-90 (T_1), registered comparatively higher fruit length than rest of the treatments.

4.4.7.2 Per cent Avoidable Loss in Fruit Length

Comparatively the per cent avoidable loss in fruit length was minimum in the treatments 30-90 (T_7) followed by 15-59 (T_3) and 15-90 (T_1).

4.4.8 Fruit Girth and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The data regarding the fruit girth and per cent avoidable loss due to insect pests during different growth periods of okra are presented in Table 42.

4.4.8.1 Effect on Fruit Girth

No significant differences were observed among various treatments with regard to fruit girth. The treatments 15-59 (T_3), 60-90 (T_9) and 15-29 and 75-90 (T_{12}) registered numerically higher fruit girth than other treatments.

4.4.8.2 Per cent Avoidable Loss in Fruit Girth

The per cent loss in fruit girth was comparatively low in the treatments 15-59 (T_3), 60-90 (T_9) and 15-29 and 60-90 (T_{12}).

Table 42. Fruit girth and per cent avoidable loss due to insect pests during different growth periods of okra

Treatments (periods with insecticidal applications - days after sowing)		Mean fruit girth (cm)	Per cent avoidable loss
T_1	(15-90)	5.95	1.16
T_2	(15-74)	5.85	2.82
T_3	(15-59)	6.02	Nil
T_4	(15-44)	5.86	2.65
T_5	(15-29)	5.88	2.32
T_6	(untreated control)	5.44	9.63
T_7	(30-90)	5.92	1.66
T_8	(45-90)	5.88	2.32
T_9	(60-90)	6.01	0.16
T_{10}	(75-90)	5.89	2.15
T_{11}	(30-74)	5.77	4.15
T_{12}	(15-29 and 75-90)	6.00	0.33
	S.E. ±	0.19	
	C.D. (P = 0.05)	N S	

4.4.9 Marketable Fruit Yield and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The data pertaining to the marketable fruit yield and per cent avoidable loss due to insect pests during different growth periods of okra are presented in Table 43 and graphically depicted in Fig. 11.

4.4.9.1 Marketable Fruit Yield

It is evident from Table 43 that all the protected plots were significantly superior over unprotected control except 75-90 (T_{10}). Significantly highest yields were registered by 15-90 (T_1) and 15-74 (T_2) over all other treatments. The treatments 30-90 (T_7), 30-74 (T_{11}) and 45-90 (T_8) were at par with each other and significantly superior over 60-90 (T_9), 15-44 (T_4), 15-29 and 75-90 (T_{12}) and 15-29 (T_5). No significant differences were observed between 15-59 (T_3), 60-90 (T_9) and 15-44 (T_4) and between 15-29 and 75-90 (T_{12}) and 15-29 (T_5) treatments. The treatment 75-90 (T_{10}) yielded equal to untreated control.

4.4.9.2 Per cent Loss in Marketable Fruit Yield

The per cent loss in marketable fruit yield was to the tune of 58.57 per cent in unprotected plots. The per cent reduction in yield was low in treatments 15-90 (nil), 15-74 (7.46), 30-90 (17.34) and 30-74 (21.28).

Maximum per cent loss in fruit yield was recorded in untreated control (58.57) followed by 75-90 (53.81), 15-29 (44.52), 15-29 and 75-90 (41.32) and 15-44 (33.85) treatments. The yield loss in other treatments viz. 45-90 (T_8), 15-59 (T_3) and 60-90 (T_9) was 24.02, 27.32 and 32.26 per cent, respectively.

Table 43. Marketable fruit yield and per cent avoidable loss due to insect pests during different growth periods of okra

Treatments (period with insecticidal applications - days after sowing)		Marketable fruit yield (q/ha)	Per cent avoidable loss
T_1	(15-90)	72.64	Nil
T_2	(15-74)	67.22	7.46
T_3	(15-59)	52.79	27.32
T_4	(15-44)	48.05	33.85
T_5	(15-29)	40.30	44.52
T_6	(untreated control)	30.09	58.57
T_7	(30-90)	60.04	17.34
T_8	(45-90)	55.19	24.02
T_9	(60-90)	49.20	32.26
T_{10}	(75-90)	33.55	53.81
T_{11}	(30-74)	57.18	21.28
T_{12}	(15-29 and 75-90)	42.62	41.32
	S.E. ±	2.83	
	C.D. (P = 0.05)	5.88	

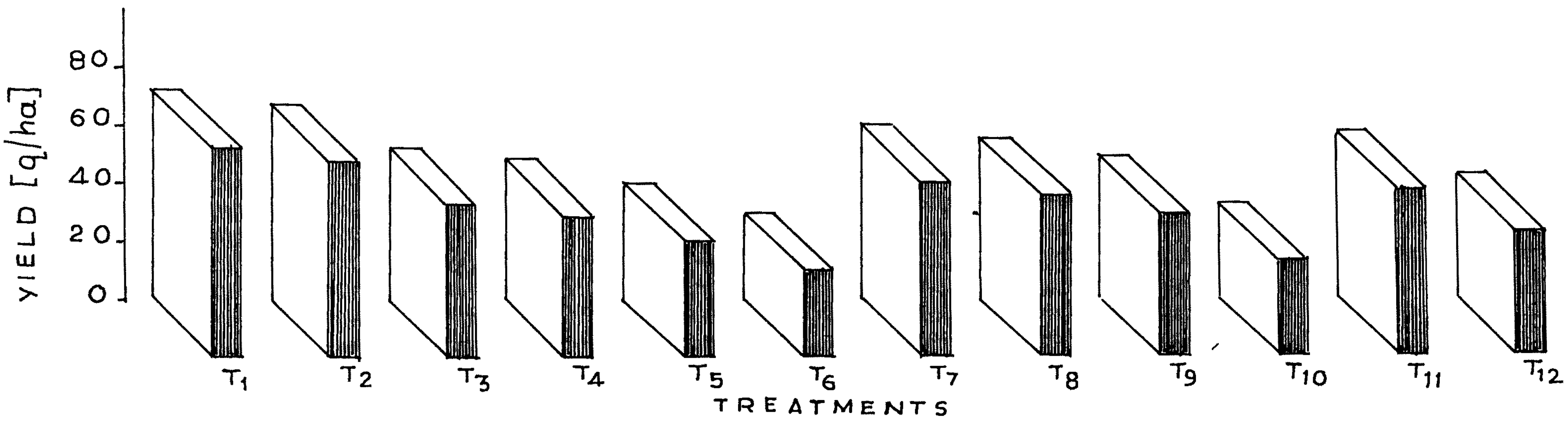

Figure 11. MARKETABLE FRUIT YIELD OF OKRA PROTECTED DURING DIFFERENT GROWTH PERIODS

Chapter 5

DISCUSSION

Chapter 5

D I S C U S S I O N

Okra crop suffers severely from the attack of jassids and aphids in its early stage of development and fruit borer (E. vittella) in the reproductive stage. These pests cause heavy damage and loss in the yield of okra. Present investigations were undertaken to study the life fecundity tables of E. vittella on okra and cotton, determination of thermal constant for E. vittella, assessment of losses in growth and yield of okra due to jassids, aphids and fruit borer, and influence of pest attack during various plant growth periods on growth and yield of okra. The results obtained are discussed in accordance with the previous work in this chapter.

5.1 Life Fecundity Tables of E. vittella

Life tables can be used to make quantitative and qualitative evaluation of different host plants. Thus, the type of table developed by Morris (1963) can be used to estimate the impact of the factors causing mortality in the various life stages of insects under field conditions, the type developed by Birch (1948) can be used to obtain growth statistics that can be used for both qualitative evaluation of the rearing procedures and to estimate the projected potential increase of insects reared on different food commodities. The innate capacity of increase has not been quantified for many insects (Wellik and Pedigo, 1978). In the present investigations, the projected potential rates of increase of E. vittella on different host plants were computed by following the method described by Birch (1948) and elaborated by Howe (1953) and Atwal and Bains (1974).

On the basis of survival values (l_x) of immature stages of E. vittella, the different food plants could be arranged in descending order as: okra seeds (0.89), okra fruits (0.80), cotton squares (0.73) and cotton bolls (0.68).

Ambegaonkar and Bilapate (1982) found 0.96, 0.92, 0.72, 0.68 and 0.59 survivalship values (l_x) of immature stages when reared on okra seeds, okra epicarps, okra fruits, cotton flowers and cotton bolls, respectively.

The net reproductive rate (R_0) of E. vittella was 124.17 on okra fruits, 141.50 on okra seeds, 99.32 on cotton squares and 100.62 on cotton bolls at the end of each generation (Table 44).

On the basis of net reproductive rate (R_0) the host plants could be arranged as okra seeds > okra fruits > cotton bolls > cotton squares. The pattern of female births of E. vittella was similar in

Table 44. The net reproductive rate (R_0), mean generation time (T), intrinsic rate of increase (r_m), finite rate of increase in numbers (λ), weekly multiplication of population, doubling time and hypothetical F_2 females of E. *vittella* on different hosts

Host	Net reproductive rate (R_o)	Innate capacity for increase in numbers (r_m)	Mean length of generation (days) (T)	Finite rate of increase in numbers (λ)	Weekly multiplication of population	Doubling time (days)	Hypothetical F_2 females[2]
Okra fruits	124.17	0.1385	34.81	1.148	2.630	5.004	15418.18
Okra seeds	141.50	0.1523	32.51	1.164	2.895	4.55	20022.25
Cotton squares	99.32	0.1195	38.48	1.127	2.310	5.80	9864.46
Cotton bolls	100.62	0.1289	35.77	1.137	2.456	5.37	10124.38

all the host plants tested, the value of m_x raised gradually and attained a peak followed by gradual decrease (Fig. 1). In general, the contribution of female towards the female birth (m_x) was maximum on the third day of oviposition. It is evident that the okra seed proved to be nutritionally the most superior from the point of view of pest multiplication under the given set of conditions.

Ambegaonkar and Bilapate (1982) observed that the net reproductive rate of E. vittella was 93.17, 93.96, 114.50, 140.23 and 112.71 when reared on cotton flowers, cotton bolls, okra fruits, okra seeds and okra epicarp, respectively.

The mean length of generation differed considerably on different hosts (Table 44). It was maximum (38.48) on cotton squares and minimum (32.51) on okra seeds. The innate capacity for increase in numbers (r_m) ranged between 0.1195 to 0.1523 females per female per day. On the basis of 'r_m' values, the descending order of different foods for E. vittella was: okra seeds (0.1523), okra fruits (0.1385), cotton bolls (0.1289) and cotton squares (0.1195) (Table 44).

According to Birch (1948), the comparison of two or more populations by means of their net reproductive rates may be quite misleading unless the mean lengths of generation are the same. Two or more populations may have the same reproductive rate, but their intrinsic rates of increase may be quite different, because of different lengths of their generation.

The innate capacity of the species for increase in number (r_m) has a number of component variables viz. the length of development of immature stages, the adult life table and the age specific fecundity. These components have their own significance and apply their respective weights (Birch, 1948).

The results obtained in the present investigations are in agreement with the findings of Ambegaonkar and Bilapate (1982).

Life tables giving the statistics on the innate capacity of increase in numbers of a particular species provide insight into the characteristics life patterns of different species. The application of these statistics is as diverse as the insects for which the life tables are developed. The differences observed in the 'r_m' values in the present studies can be attributed to a quantitative and qualitative differences in the food plants tested. However, from the point of view of pest multiplication, okra seed with high 'r_m' value would be the most suitable food. *E. vittella* would multiply 141.50 times per generation on okra seeds while the corresponding increase in okra fruits, cotton squares and cotton bolls will be 124.17, 99.32 and 100.62 times respectively. Several authors stated that, there is a range of innate capacity for individuals of a population (Dewitt, 1954).

The data on stable age distribution of the respective stages; egg, larva, pupa and adult for different host plants are graphically depicted in Fig. 3. The results in Table 45 reveal that on reaching a stable age distribution, the population of E. vittella at egg, larva, pupa and adult stages comprised, 55.33, 39.64, 6.07 and 0.92 per cent on okra fruits, 54.99, 37.08, 6.96 and 0.93 per cent on okra seeds, 49.65, 43.76, 5.60 and 0.92 per cent on cotton squares and 51.72, 41.55, 5.69 and 0.98 per cent on cotton bolls, respectively. A drastic decrease in the percentage individuals occurred at pupal and adult stages.

Ambegaonkar and Bilapate (1982) reported that on reaching a stable age distribution, the population of E. vittella at egg, larva, pupa and adult stages comprised 55.59, 37.15, 3.94, 1.06 on cotton bolls, 55.2, 36.03, 5.62, 0.94 on okra fruits, 47.26, 43.68, 5.45, 1.03 on okra seeds and 49.16, 43.53, 4.80 and 0.87 on cotton flowers, respectively.

Table 45. Percentage contribution of the various stages to the stable age distribution of E. vittella on different hosts

Host	Percentage contribution of various stages			
	Egg stage	Larval stage	Pupal stage	Adult stage
Okra fruits	53.33	39.64	6.07	0.92
Okra seeds	54.99	37.08	6.96	0.93
Cotton squares	49.65	43.76	5.60	0.92
Cotton bolls	51.72	41.55	5.69	0.98

Considering all the factors, it can be concluded that the okra seed provide a more nutritive food for the multiplication of E. vittella than okra fruits, cotton bolls and cotton squares in that order.

Life table studies have also been carried out on zebra caterpiller, Ceramica picta when reared on sugar beet leaves (Tamaki et al., 1972) on Dichrocrocis punctiferalis Guen when reared on castor, maize, brinjal, okra, bottle gourd and pomogranate (Bilapate, 1977, 1978) on H. armigera when reared on lucerne, lima bean, pea sorghum earhead and safflower (Bilapate et al., 1977; Bilapate et al., 1978; Bilapate and Pawar, 1978; Bilapate and Pawar 1980; Bilapate et al., 1980).

5.2 Determination of Thermal Constant for *E. vittella*

The completion of a given stage in the development of an insect requires an accumulation of a definite amount of heat energy known as thermal constant (Uvarov, 1931). It is not practicable to measure this constant in terms of heat calories. Another method of the summation of temperature during a day or 'day-degrees' has been used. For this purpose, the temperature above the threshold of development or the effective temperature is taken into consideration. This concept of 'thermal constant' expressed in 'day degrees' appears to have been probably first developed by Simpson (1903).

In the present investigation, it was observed that the temperature had a positive effect on the various stages of *E. vittella*. The threshold temperature for the development of egg, larva and pupa was 13.46, 13.06 and 13.25°C respectively. Day degrees (thermal constant) required for completion of egg, larva, pupa and for the life cycle were 41.31, 113.36, 135.87 and 292.77, respectively. Thus it required 292.77 day degrees for completing a cycle and with this rate the pest would be able to complete 17 generations in a year.

Rao (1980) reported that the threshold temperature of development for the various stages of

E. vittella ranged from 13.33 to 14.04°C, requiring 323.8 day degrees for completing a cycle. The pest was computed to complete 13 generations in a year under Bangalore conditions. Difference in the number of generations observed in the present study may be due to the higher temperatures in this region.

Glenn (1922 and 1931) employed this concept of thermal constant to predict the appearance of codling moth in nature. Again, Shelford (1927) employed this method for his studies on codling moth. Uvarov (1931) worked out thermal constant for the *Dytiscus marginalis* for his studies on rate of acceleration of development with rising temperature.

5.3 Assessment of Crop Losses due to Insect Pests in Okra

5.3.1 Jassid Incidence

The jassid population was significantly low in the plots treated throughout the growth period and in the plots protected during vegetative stage in both seasons. Significantly low population of jassids was observed in the treatments with carbaryl 0.2 per cent (T_9), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), disulfoton 1 kg a.i./ha (T_2) followed by carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbofuran 5 per cent (T_1), carbofuran 5 per cent + malathion 0.1 per cent (T_7) and malathion 0.1 per cent (T_8). No significant differences were observed among the untreated control and the treatments with no protection during vegetative stage. The pooled analysis indicated similar results.

Effective control of jassid has been obtained with carbaryl, disulfoton, carbofuran and malathion by several workers. Ademuga (1971) found carbaryl to be most effective for the control of jassids. Rathore et al. (1974) stated that application of disulfoton 5 per cent @ 20 kg/ha successfully controlled jassids on okra.

Krishnaiah et al. (1976) reported that soil application of disulfoton and carbofuran 5 per cent seed treatment protected the okra crop from jassids. Effective control of jassids attacking okra with disulfoton has been reported by Rawat and Jakhmola (1976).

Present findings are in accordance with the results of the above workers.

5.3.2 Population of Aphids

The aphid population was comparatively low in both the seasons. Significantly low aphid population was observed in the treated plots than untreated control and the plots unprotected during vegetative stage. No significant differences were observed among the treatments which were protected during vegetative stage. Other treatments with no protection during vegetative stage (T_3 and T_4) were at par with untreated control (T_{10}). The pooled analysis revealed that the treatments carbaryl 0.2 per cent (T_9), disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) were significantly superior over all other treatments but were at par with each other and malathion 0.1 per cent (T_8) in reducing the aphid population.

Gopalan *et al*. (1974) reported good control of aphids with disulfoton and carbofuran. Dadheech *et al*. (1977) reported effective control of aphids on okra with carbaryl and malathion. Kisha (1978) found good control of *A. gossypii* on okra with disulfoton and monocrotophos sprays and increase yields by 97-119 per cent. Sangappa *et al*. (1978) reported effective control of *A. gossypii* with carbaryl 0.1 per cent on okra.

5.3.3 Fruit Borer Infestation

The fruit borer infestation ranged from 2.32 to 17.12 and 1.4 to 23.62 per cent during 1978 and

1979, respectively. The infestation of fruit borer was significantly low in all the insecticidal treatments than untreated control in both the seasons.

The pooled analysis indicated that the per cent infestation was minimum in the treatments with monocrotophos 0.04 per cent (T_3 and T_5) but it was at par with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6). The treatments disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbaryl 0.2 per cent during fruiting stage (T_4) and carbaryl 0.2 per cent (T_9) did not differ significantly among themselves and were significantly superior over malathion 0.1 per cent (T_8), carbofuran 5 per cent + malathion 0.1 per cent (T_7), disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent (T_1) and untreated control (T_{10}).

Effective control of E. vittella with monocrotophos and carbaryl was obtained by several workers (Rathore et al.,1974; Krishnaiah et al., 1976; Daware et al., 1978; Mote, 1980; Gupta and Dhari, 1980).

5.3.4 Plant Height and Per cent Avoidable Loss due to Okra Pests

The treatments disulfoton 1 kg a.i./ha (T_2), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9) recorded significantly more height than rest of the treatments during vegetative stage. No significant differences were observed among the plots unprotected during vegetative stage (T_3 and T_4), carbofuran 5 per cent seed treatments + malathion 0.1 per cent (T_7) and untreated control (T_{10}) during vegetative stage. The pooled analysis also revealed similar results.

The per cent avoidable loss during vegetative stage in plant height due to jassids and aphids was maximum in treatments with carbaryl 0.2 per cent during fruiting stage (T_4) (53.07), untreated control (T_{10}) (50.93) and monocrotophos 0.04 per cent during fruiting (T_3) (49.02). The treatments with disulfoton 1 kg a.i./ha (T_2 and T_6) and carbaryl 0.2 per cent (T_9) recorded minimum loss in plant height during vegetative stage.

As regards plant height at final harvest, the treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) registered significantly more plant height than rest of the treatments but did not differ significantly from monocrotophos 0.04 per cent (T_3) during 1978. Differences in the treatments with carbofuran 5 per cent (T_1), carbaryl 0.2 per cent (T_4), malathion 0.1 per cent (T_8) and untreated control (T_{10}) were not significant.

The per cent avoidable loss in final plant height due to okra pest complex was maximum in the untreated control (T_{10}) (74.08) followed by malathion 0.1 per cent (T_8) (71.10), carbofuran 5 per cent (T_1) (69.56) and carbaryl 0.2 per cent during fruiting stage (T_4) (66.70).

Rawat and Sahu (1973) reported 49.8 per cent loss in plant height in the unprotected okra plots due to the okra pests as compared to complete protection with dimethoate granules and endrin during vegetative stage and carbaryl during fruiting stage.

Singh and Chopra (1979) observed significantly more height in okra plots treated with malathion 0.1 per cent and leptophos 0.05 per cent and reported 18.30 and 21.62 per cent reduction in plant height in control in comparison to malathion and leptophos treated plots, respectively.

5.3.5 Number of Leaves Per Plant and Per cent Avoidable Loss due to Okra Pests

The number of leaves per plant was significantly increased in the treatments with disulfoton 1 kg a.i./ha (T_2 and T_6) and carbaryl 0.2 per cent (T_9) than all other treatments during vegetative stage in both the seasons. The treatments with malathion 0.1 per cent (T_8) and carbaryl 0.2 per cent (T_4) and monocrotophos 0.04 per cent (T_3) during fruiting stage did not differ significantly from the untreated control.

The leaf number per plant was reduced to the extent of 59.39, 54.9 and 51.95 per cent in monocrotophos 0.04 per cent during fruiting stage (T_3), carbaryl 0.2 per cent (T_4) and untreated control (T_{10}), respectively during vegetative stage. The per cent loss was minimum in disulfoton 1 kg a.i./ha (T_2) (nil), carbaryl 0.2 per cent (T_9) (nil), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (3.38) followed by carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (24.76), carbofuran 5 per cent + malathion 0.1 per cent (T_7) (29.25) and carbofuran 5 per cent (T_1) (34.19).

As regards leaf number at final harvest, all the insecticidal treatments were significantly superior to untreated control. The treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), monocrotophos 0.04 per cent (T_3) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) significantly increased the number of leaves per plant over rest of the treatments except carbaryl 0.2 per cent (T_4).

Maximum reduction in the number of leaves per plant at final harvest was 46.25 per cent in the untreated control (T_{10}) due to okra pest complex. Minimum per cent loss in number of leaves per plant was observed in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (nil) followed by monocrotophos 0.04 per cent (T_3)

(2.11), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (9.86) and carbaryl 0.2 per cent (T_4) (19.34).

Rawat and Sahu (1973) reported 45.1 per cent loss in leaf number per plant in the unprotected plots due to the okra pests when compared to complete protection. Singh and Chopra (1979) reported significantly more number of leaves per plant in plots treated with 0.1 per cent malathion and 0.05 per cent leptophos and recorded 28.57 per cent loss in untreated control plots in comparison with 0.1 per cent malathion and 0.05 per cent leptophos treated plots. Results obtained in the present investigations are in agreement with the results of Rawat and Sahu (1973).

5.3.6 Leaf Area Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

All the plots protected during vegetative stage were significantly superior over untreated ones in increasing the leaf area per plot. The maximum leaf area was recorded by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) followed by disulfoton 1 kg a.i./ha (T_2), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and carbaryl 0.2 per cent (T_9) and these treatments were at par with each other during both the seasons. The pooled analysis, indicated that the treatments with disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6)

was significantly superior over all other treatments but did not differ significantly from disulfoton 1 kg a.i./ha (T_2).

The highest reduction in the leaf area due to jassids and aphids was observed to be 63.76 per cent in the treatment with no protection during vegetative stage + carbaryl 0.2 per cent during fruiting stage (T_4) followed by 61.37 per cent and 58.50 per cent in untreated control (T_{10}) and the treatment without protection during vegetative stage + monocrotophos 0.04 per cent (T_3), respectively. The per cent avoidable loss was minimum in disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (nil) followed by disulfoton 1 kg a.i./ha (T_2) (7.75).

Perumal et al. (1971) reported increase in leaf area per plant following carbaryl spraying against okra pests.

5.3.7 Leaf Weight Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

The treatment disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) recorded significantly increased leaf weight per plant over all other treatments but it was at par with carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), carbaryl 0.2 per cent (T_9), disulfoton 1 kg a.i./ha (T_2) and malathion 0.1 per cent (T_8) in

1978 but it was significantly superior over carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) during 1979. Significantly reduced leaf weight was observed in the treatments with no protection during vegetative stage (T_3 and T_4) and untreated control (T_{10}). These treatments were at par with each other.

The pooled analysis indicated that all the plots receiving protection during vegetative stage recorded significantly increased leaf weight per plant than the unprotected plants during vegetative stage (T_3 and T_4) and untreated control (T_{10}). The treatments with disulfoton 1 kg a.i./ha (T_6 and T_2) and carbaryl 0.2 per cent (T_9) were significantly superior to rest of the treatments except carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and malathion 0.1 per cent (T_8).

The per cent avoidable loss was minimum in disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (nil). The leaf weight per plant was reduced to the extent of 63.08 per cent in the treatment with no protection during vegetative stage + carbaryl 0.2 per cent (T_4) followed by untreated control (T_{10}) (60.80) and monocrotophos 0.04 per cent during fruiting stage (T_3) (59.66). The per cent loss in other treatments ranged from 10.96 to 32.78.

Perumal et al. (1971) reported increased leaf area and dry weight following carbaryl spraying against okra pests. Saimbhi et al. (1979) stated that both fresh and dry weights of okra leaves were increased by application of phorate 1.25 kg a.i./ha.

5.3.8 Stem Weight Per Plant and Per cent Avoidable Loss due to Jassids and Aphids During Vegetative Stage

During 1978 the treatments carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2) were significantly superior over all other treatments except malathion 0.1 per cent (T_8), carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) in increasing the stem weight. During 1979, the treatment disulfoton 1 kg a.i./ha (T_2) had also significantly increased the stem weight, over carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5). During both the seasons, the treatments unprotected during vegetative stage (T_3 and T_4) and untreated control recorded significantly reduced stem weight per plant and were at par with each other.

Maximum per cent avoidable loss due to jassids and aphids in stem weight per plant was observed to be 65.63 in the plots unprotected during vegetative stage (T_3 and T_4). The per cent loss in stem weight was minimum in disulfoton 1 kg a.i./ha (T_2) (nil) followed by carbaryl 0.2 per cent (T_9) (3.54).

Perumal *et al.* (1971) reported increase in shoot weight per plant following carbaryl spraying against okra pests.

5.3.9 Fruit Number Per Plant and Per cent Avoidable Loss due to Okra Pest Complex

The treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5), disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9) significantly increased the fruit number per plant than rest of the treatments followed by monocrotophos 0.04 per cent during fruiting stage (T_3), disulfoton 1 kg a.i./ha (T_2) and carbaryl 0.2 per cent during fruiting stage (T_4) in both the seasons. The treatment carbofuran 5 per cent (T_1) recorded reduced number of fruits per plant and was equal to untreated control (T_{10}).

The pooled analysis indicated that the treatment carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) registered significantly higher number of fruits per plant among all the treatments but was equal to disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6). The treatments carbofuran 5 per cent (T_1) and untreated control were at par with each other with lowest fruit number.

The fruit number per plant was reduced to the extent of 50.77 per cent due to okra pests in untreated control (T_{10}). The per cent avoidable loss due to okra pest complex was minimum in the treatment with carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (nil) followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (0.61).

The per cent loss due to sucking pests was 20.12 and 25.07 in monocrotophos 0.04 per cent during fruiting stage (T_3) and carbaryl 0.2 per cent during fruiting stage (T_4), respectively. The loss in fruit number per plant due to fruit borer alone was 46.74 and 23.83 per cent in carbofuran 5 per cent (T_1) and disulfoton 1 kg a.i./ha (T_2), respectively.

Singh and Chopra (1979) reported 40.65 and 44.89 per cent losses in number of fruits/5 plants of okra in untreated control in comparison with 0.1 per cent malathion and 0.05 per cent leptophos treated plots, respectively.

Saimbhi et al. (1979) reported that fruits per plant and seed yield/ha were increased by application of phorate at 1.25 kg a.i./ha.

Rao (1980) stated that the sucking insects and fruit borer accounted for loss in fruit number to the extent of 1.5 and 33.10 to 45.03 per cent, respectively.

5.3.10 Fruit Length and Per cent Avoidable Loss due to Okra Pest Complex

Differences among various treatments in influencing the fruit length were not significant in both the seasons. However, the pooled analysis indicated significant differences among various treatments. The treatments disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and disulfoton 1 kg a.i./ha (T_2) increased fruit length over carbaryl 0.2 per cent (T_9), malathion 0.1 per cent (T_8) and untreated control (T_{10}) and they were at par with each other.

Maximum loss of 4.70 per cent was observed in untreated control due to okra pest complex. The per cent loss due to okra pest complex was minimum in disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (nil) and disulfoton 1 kg a.i./ha (T_2) (nil) followed by carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (1.78) and carbofuran 5 per cent + malathion 0.1 per cent (T_7) (2.1).

The per cent loss due to jassids and aphids was 1.05 and 1.21 in monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent (T_4), respectively.

Perumal et al. (1971) found that fruit length and weight was greatly increased in the thiodemeton treatment against okra pests.

5.3.11 Fruit Girth and Per cent Avoidable Loss due to Okra Pest Complex

The fruit girth was maximum in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) and carbaryl 0.2 per cent (T_9). All these treatments were significantly superior over others except disulfoton 1 kg a.i./ha (T_2). The pooled analysis indicated that the fruit girth in the above treatments i.e. T_5, T_6, T_9 including disulfoton 1 kg a.i./ha (T_2) was significantly more than all other treatments.

Maximum loss due to okra pest complex in the fruit girth was observed to be 32.29 per cent in untreated control (T_{10}). The per cent avoidable loss due to the okra pest complex was minimum in disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (nil) followed by carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (0.18) and carbaryl 0.2 per cent (T_9) (1.45).

The per cent avoidable loss due to jassids and aphids in fruit girth was 21.16 and 24.63 per cent in monocrotophos 0.04 per cent during fruiting stage (T_3) and carbaryl 0.2 per cent (T_4) during fruiting stage.

5.3.12 Fruit Yield and Per cent Avoidable Loss due to Okra Pest Complex

The treatments carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) and disulfoton 1 kg a.i./ha +

carbaryl 0.2 per cent (T_6) recorded maximum yield as compared to rest of the treatments followed by carbaryl 0.2 per cent (T_9), monocrotophos 0.04 per cent (T_3), disulfoton 1 kg a.i./ha (T_2), carbaryl 0.2 per cent (T_4) and carbofuran 5 per cent + malathion 0.1 per cent (T_7). The treatments malathion 0.1 per cent (T_8), carbofuran 5 per cent (T_1) recorded lower yields equal to that of untreated control.

The pooled analysis indicated that the treatment carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) recorded significantly high yield than all other treatments followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6), carbaryl 0.2 per cent (T_9), monocrotophos 0.04 per cent (T_3), disulfoton 1 kg a.i./ha (T_2) and carbaryl 0.2 per cent (T_4).

The per cent avoidable loss due to okra pest complex in the unprotected control (T_{10}) was to the extent of 86.0 per cent. The per cent loss due to okra pest complex was lowest in carbofuran 5 per cent + monocrotophos 0.04 per cent (T_5) (nil) followed by disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6) (10.90), carbaryl 0.2 per cent spray (T_9) (37.34), carbofuran 5 per cent + malathion 0.1 per cent (T_7) (66.82) and malathion 0.1 per cent (T_8) (76.70).

The jassids and aphids caused loss to the extent of 44.21 and 53.60 per cent in monocrotophos 0.04 per cent during fruiting stage (T_3) and carbaryl 0.2 per cent during fruiting stage (T_4), respectively.

The seed treatment of carbofuran 5 per cent (T_1) to control sucking pests without controlling fruit borer did not significantly increase marketable yield. On the other hand, soil application of disulfoton 1 kg a.i./ha (T_2) alone gave equal yield to that of spraying with monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent (T_4) during fruiting stage.

The fruit borer inflicted yield loss to the extent of 78.22 per cent in carbofuran 5 per cent (T_1) and 49.57 per cent in disulfoton 1 kg a.i./ha (T_2).

Rawat and Sahu (1973) reported 69 per cent loss in weight of healthy fruits due to okra pests in untreated control. Krishnaiah (1980) reported 40-56 per cent and 49-74 per cent yield loss due to leaf hopper and fruit borer, respectively. Rao (1980) observed that 3.76 and 21.11 to 39.26 per cent reduction in yield due to sucking pests and fruit borer, respectively. Srinivasan and Krishnakumar (1983) reported that of the total yield, 19 per cent was lost due to jassids and aphids and 45 per cent was lost due to the fruit borer.

In the present investigation it was observed that the maximum loss due to sucking pests, fruit borer and okra pest complex was to the extent of 53.60, 78.22 and 86.00 per cent, respectively in the marketable fruit yield of okra. The yield loss due to fruit borer was higher than that of sucking pest.

5.3.13 Correlation studies Between Okra Pests, Plant Characters and Yield of Okra

The correlation between all the three pests i.e. jassid, aphid and the fruit borer and yield was significant and negative. It was highest in case of fruit borer (-0.759) followed by jassid (-0.425) and aphid (-0.235).

The jassids and aphids exerted negatively significant impact in case of plant height and number of leaves per plant at 40 days of sowing but effect of jassid and aphids was nonsignificant for number of leaves per plant at final harvest. The leaf area, fresh leaf weight and stem weight of plant was significantly affected by jassids and aphids during the vegetative stage.

Significantly higher correlation was observed in case of fruit borer and number of healthy fruits per plant (-0.685) followed by jassids and aphids. In case of fruit length, the impact of jassid was significant and negative whereas the effect of aphid was not significant. The correlation between jassid, aphids and fruit girth was highly significant and negative.

Krishnaiah (1980) reported that the correlation between the jassid number and yield (gm/plant) was highly significant with a correlation coefficient of -0.717.

5.3.14 Simple Regression Studies Between Okra Pests and Yield of Okra

5.3.14.1 Jassids and Yield

The simple regression studies between jassid number (x) and yield of okra was found to be highly significant and negative. The regression equation was worked out to be Y = 86.162 - 65.881 x (r = -0.425) indicating that for every one jassid nymph per leaf the yield decreased by 65.88 q/ha.

Krishnaiah (1980) established a relationship between jassid density and okra yield for 15 days old crop and reported that the correlation between the jassid number and yield (gm/plant) was highly significant with a correlation coefficient of -0.717. The regression equation (for yield 'Y' on insect number x) worked out was Y = 121.975 - 5.521 x. The yield loss due to 7 nymphs per leaf for a period of fortnight at this stage was of the order of 32 per cent.

5.3.14.2 Fruit Borer and Yield

The relationship between per cent fruit borer incidence (x) and yield of okra (Y) was highly significant and negative (r = -0.759). The regression equation worked out was Y = 95.969 - 3.383 x indicating that for every one per cent fruit borer infestation yield decreased by 3.38 q/ha.

Krishnaiah (1980) established a relationship between fruit borer intensity (x) and yield loss (Y). He found that the relationship of fruit borer infestation and yield loss follow a linear regression. The regression equation worked out was Y = 1.624 + 1.149 x (r = 0.814).

5.3.15 Multiple Regression Studies Between Okra Pest Complex, Plant Height, Leaf Area, Fruit Number and Marketable Fruit Yield

The multiple regression analysis between jassids, aphids and fruit borer as explanatory variables (independent variables) and plant height, leaf area and fruit yield as dependent variables were estimated. The linear multiple regression analysis revealed significant coefficient of multiple determination (R^2 = 0.16, 0.74, 0.61, and 0.68 respectively for height, leaf area, fruit number and yield) causing thereby 16.8, 74.3, 61.7 and

68.3 per cent variation in final plant height, leaf area, fruit number per plant and yield due to jassids, aphids and fruit borer.

The jassid incidence indicated significant negative impact on final plant height and leaf area whereas, the effect of aphid was not evident. In case of fruit number per plant, the effect of jassids and fruit borer was significant and negative, whereas, the effect of aphids was not significant.

The plant height and fruit number per plant have positively contributed to the yield, whereas the effect of leaf area was not evident. This indicates that the contribution of fruit number per plant to the yield was highest followed by plant height, implying thereby that if losses in fruit number are minimised the yield could be increased. Indeed the jassid and the fruit borer are the key pests which mainly influence the fruit number and ultimately the yield.

Ajimal et al. (1979) conducted studies on 29 cultivars of okra to furnish the information on the nature of association among different yield attributes and their direct and indirect contribution towards yield. Fruit yield was positively and significantly correlated with number of fruits and number of nodes.

Perusal of literature shows no other pertinent information available on these aspects.

5.4 Crop Loss Assessment due to Major Pests During Various Growth Periods of Okra

Rational use of pesticides is mandatory in todays society both economically and ecologically. DeBach (1974) estimates that 50 per cent or more of the insecticides used in agriculture are unnecessary and cites as an example of cotton production in U.S.A. where the pesticide input can be reduced by 50 per cent without lowering yield. Recent literature emphasises pesticide use only when the pest population has reached a level where economic damage will occur, i.e. the economic threshold (Stern, 1973). However, plants differ in their susceptibility to insect damage according to growth stages. Ogunlana and Pedigo (1974) reported that the economic threshold populations for soybeans were 1 and 18 leaf hopper (Empoasca fabae) adults per plant during the second trifoliate leaf and the pod fill stage, respectively.

The present study was conducted to know the extent of losses during various plant growth periods of okra and to find out the most critical growth period of okra using monocrotophos 0.04 per cent for protecting a particular growth period.

Efficacy of monocrotophos has been proved by several workers for jassid (Gupta and Dhari, 1980; Mote, 1980; Rameshbabu and Azam, 1981; Azam and Balbhaskar, 1983; Awate et al., 1984), aphid (Krishnaiah et al., 1976; Kisha, 1978; Rameshbabu and Azam, 1981) and fruit borer (Rathore et al., 1974; Krishnaiah et al., 1976; Mote, 1980; Gupta and Dhari, 1980).

5.4.1 Incidence of Jassids and Aphids

The jassid population ranged from 0.009 to 1.925 per leaf in various treatments. The lowest jassid population was recorded in the plots protected during 15-90 days (T_1). Rest of the treatments receiving protection during different growth periods were at par with this treatment except that the treatments receiving protection during 45-90 (T_8), 60-90 (T_9) and 75-90 days (T_{10}) which were at par with untreated control.

The aphid population ranged from 0.001 to 1.811 per leaf. It was lowest in the treatment with protection during 15-44 days (T_4) followed by 15-90 (T_1), 15-74 (T_2), 15-59 (T_3), 30-90 (T_7), 30-74 (T_{11}), 15-29 (T_5) and 15-29 and 75-90 days (T_{12}) in order of their merit.

5.4.2 Fruit Borer Infestation

The percentage fruit borer infestation ranged from 4.10 to 15.83. It was minimum in the treatment with protection during 15-90 days (T_1). Protection during 45-90 (T_8) and 30-90 (T_7) days also recorded similar incidence of the fruit borer. The maximum fruit borer infestation was observed in the treatment with protection during 15-29 days (T_5).

5.4.3 Effect on Plant Height and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of okra

Height of the plant varied from 39.60 to 69.76 cm. Maximum plant height was recorded in the treatment protected during 15-74 days (T_2). Protection during 15-74 (T_2), 15-90 (T_1), 30-90 (T_7) and 15-59 days (T_3) did not make any difference in increasing the plant height. Protection during 15-29 (T_5), 45-90 (T_8), 15-29 and 75-90 (T_{12}), 60-90 (T_9) and 75-90 (T_{10}) has not influenced the plant height and these treatments were equal to untreated control (T_6).

Maximum per cent avoidable loss was recorded in untreated control (T_6) (43.23). Protection during 15-74 days indicated minimum per cent avoidable loss (nil) followed by 15-90 (6.30) and 30-90 (8.54).

Rawat and Sahu (1973) reported 49.8 per cent loss in plant height in the unprotected okra plots due to okra pests when compared to complete protection.

Influence of jassid attack on plant height of okra has been reported by Singh and Chopra (1979) and per cent loss to the extent of 18.30 and 21.62 in untreated control was observed in comparison with malathion and leptophos treated plots, respectively.

5.4.4 Effect on Number of Leaves Per Plant and Per cent Avoidable Loss due to Insect Pests During Various Growth Periods of Okra

The treatments protected during 15-74 (T_2), 15-59 (T_3), 30-74 (T_{11}), 15-90 (T_1), 30-90 (T_7), 45-90 (T_8) and 15-44 (T_4) recorded equal number of leaves per plant. Protection during 15-29 (T_5), 15-29 and 75-90 (T_{12}), 75-90 (T_{10}) and 60-90 (T_9) has not influenced the leaf number per plant and these treatments were equal to untreated control.

The per cent loss in leaf number per plant was maximum in the treatment with protection during 60-90 (T_9) (13.17). Protection during 15-74 days (T_2) recorded maximum number of leaves per plant (9.56) and minimum loss (nil) in leaf number per plant followed by 15-59 (T_3), 30-74 (T_{11}), 15-90 (T_1), 30-90 (T_7), 45-90 (T_8), 15-44 (T_4) and 15-29 (T_5).

Rawat and Sahu (1973) reported 45.1 per cent loss in leaf number per plant in the unprotected plots due to okra pests when compared to complete protection.

Singh and Chopra (1979) reported 28.57 per cent loss in leaf number per plant in untreated control when compared to malathion and leptophos treated plots.

5.4.5 Effect on Number of Fruits Per Plant and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The fruit number ranged from 4.00 in untreated control to 7.60 per plant in the treatment receiving protection during 15-90 (T_1) days. Protection during 15-90 days (T_1), 15-74 (T_2), 30-74 (T_{11}), 30-90 days (T_7) did not make any difference in increasing the number of fruits per plant. The treatments protected during 15-59 (T_3), 45-90 (T_8) and 60-90 (T_9) days were equal and recorded significantly higher fruit number than 15-29 (T_5), 75-90 (T_{10}) and untreated control.

The reduction in the fruit number per plant in untreated plots was to the extent of 27.73 per cent. The per cent avoidable loss was minimum in treatment receiving protection during 15-90 days (T_1) followed by 15-74 (T_2), 30-74 (T_{11}) and 30-90 (T_7).

Saimbhi et al (1979) reported increase in the fruit number per plant due to the protection from okra pests. Rao (1980) stated that the sucking insects and fruit borer accounted for the loss in number of fruits per plant to the extent of 1.5 and 33.1 to 45.03 per cent, respectively.

5.4.6 Effect on Fruit Length and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

Protection during various plant growth periods of okra did not significantly influence the fruit length of okra. The fruit length ranged from 11.17 to 11.87 cm. Maximum per cent avoidable loss in fruit length was 5.89 in unprotected control (T_6) and it was minimum in the treatment with protection during 30-90 days (T_7).

Protection against okra pests with thiodometan greatly increased fruit length (Perumal et al., 1971).

5.4.7 Effect on Fruit Girth and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The fruit girth ranged from 5.44 to 6.02 cm in various treatments. No significant differences were observed among various treatments in influencing the fruit girth.

Maximum per cent avoidable loss in fruit girth was 9.63 in untreated control and it was minimum in the treatment with protection during 15-59 days

5.4.8 Effect on Yield of Marketable Fruits and Per cent Avoidable Loss due to Insect Pests During Different Growth Periods of Okra

The marketable fruit yield varied from 30.09 to 72.64 q/ha in various treatments. The maximum yield was recorded in the treatment with protection during 15-90 days (T_1). Protection during 15-90 (T_1) and 15-74 (T_2) did not make any difference in increasing the yield. Similarly, treatments receiving protection during 30-90 (T_7), 30-74 (T_{11}) and 45-90 days (T_8) recorded equal yields and were significantly superior to protection during 60-90 (T_9), 15-44 (T_4), 15-29 and 75-90 (T_{12}) and 15-29 days (T_5). Protection during 15-59 (T_3), 60-90 (T_9) and 15-44 days (T_4) recorded equal yield and also protection during 15-29 and 75-90 (T_{12}), and 15-29 (T_5) did not make any difference. Protection during 75-90 (T_{10}) has not added to the yield and it was equal to untreated control.

The per cent avoidable loss in marketable fruit yield in the untreated control was to the extent of 58.57. Protection during 15-90 days (T_1) recorded minimum per cent loss in yield (nil) followed by protection during 15-74 (7.46) and 30-90 days (17.34).

Perusal of literature shows that no pertinent information is available on yield losses related to different growth periods in okra. However, similar studies have been carried out in other crops (Schoonhoven et al., 1978, Rangaiah and Sehgal, 1984).

It was observed that protection during 15-90 (T_1) and 15-74 days (T_2) recorded minimum per cent avoidable loss in marketable fruit yield of okra. Maximum yield returns could be obtained with four sprays during 15-74 days (T_2) of sowing. Protection after 75 days did not influence the yield. Application of one spray during 15-29 days (T_5) gave increased yield than untreated control (T_6). Application of two sprays during 15-44 days (T_4) yielded equal to the protection during 60-90 (T_9) and 15-29 and 75-90 days (T_{12}) with same number of sprays. Similarly, application of three sprays during 15-59 (T_3), 45-90 (T_8) and 30-74 days (T_{11}) gave equal yields. However, it was observed that application of four sprays during 15-74 days (T_2) yielded significantly higher than same number of sprays during 30-90 days (T_7).

It is evident from the foregoing discussion that protection during 15-74 days is a must to obtain maximum yield returns. Hence, it can be concluded that this growth period (15-74 days) is the critical growth period for the okra crop.

Chapter 6

SUMMARY

Chapter 6

S U M M A R Y

Investigations were carried out at Marathwada Agricultural University, Parbhani to study the life tables of *Earias vittella* on okra and cotton as well as determination of thermal constant for *E. vittella* in laboratory. Similarly, field studies were undertaken to assess the crop losses due to jassids, aphids and fruit borer in growth and yield of okra and to study the influence of pest attack during various plant growth periods on growth and yield of okra.

6.1 Life Table Studies of *E. vittella*

On the basis of survival values (l_x) of immature stages of *E. vittella*, the different food plants could be arranged in descending order as: okra seeds (0.89), okra fruit (0.80), cotton squares (0.73) and cotton bolls (0.68). The net reproductive rate (R_o) of *E. vittella* was highest on okra seeds (141.50), followed by okra fruits (124.17), cotton bolls (100.62) and cotton squares (99.32). The mean length of generation (T) ranged from 32.51 on okra seeds to 38.48 days on cotton squares. The highest value of innate capacity for increase in numbers (r_m) was 0.1523 on okra seeds and lowest (0.1195) on cotton squares. On the basis of r_m the food plants could be arranged in descending order as okra seeds (0.1523), okra fruits (0.1385), cotton bolls (0.1289) and cotton squares (0.1195). On reaching a stable age distribution, the population of E. vittella at egg, larva, pupa and adult stages comprised 53.33, 39.69, 6.07 and 0.92 per cent on okra fruits, 54.99, 37.08, 6.96 and 0.93 per cent on okra seeds, 51.72, 41.55, 5.69 and 0.98 per cent on cotton bolls and 49.65, 43.76, 5.60 and 0.92 per cent on cotton squares, respectively.

Considering all the factors, it can be concluded that the okra seed with high r_m value would be the most suitable food for E. vittella followed by okra fruits, cotton bolls and cotton squares.

6.2 Thermal Constant for E. vittella

The threshold temperature for the development of egg, larva and pupa was 13.46, 13.06 and 13.25°C, respectively. Day degrees (thermal constant) required for completion of egg, larva, pupa and total life were 41.31, 113.36, 135.87 and 292.77, respectively. It required 292.77 day degrees for completing a cycle and with this rate the pest would complete 17 generations per year.

6.3 Assessment of Crop Losses due to Major Pests in Okra

In order to assess the losses caused by major insect pests in okra, field experiments were carried out in two kharif seasons (1978 and 1979) in a randomised block design with ten treatments and four replications. The observations were recorded on the incidence of jassid, aphid and fruit borer, biometric parameters and yield and yield components of okra.

The jassid and aphid population was significantly low in the treatments with carbaryl 0.2 per cent (T_9) and disulfoton 1 kg a.i./ha (T_2). No significant differences were observed among the untreated control and the treatments with no protection during vegetative stage i.e. monocrotophos 0.04 per cent (T_3) and carbaryl 0.2 per cent (T_4). The fruit borer infestation was minimum in the treatments with monocrotophos 0.04 per cent (T_3 and T_5) and disulfoton 1 kg a.i./ha + carbaryl 0.2 per cent (T_6). The pooled analysis indicated similar results.

The per cent avoidable losses due to jassids and aphids in plant height, leaf number per plant, leaf area per plant, leaf weight per plant, stem weight per plant, fruit number per plant, fruit length, fruit girth and yield of okra were to the extent of 53.07, 59.39, 63.76, 63.08, 65.63, 25.07, 4.70, 32.29 and 53.60, respectively. The fruit borer inflicted losses in fruit number per plant and yield of marketable fruits to the tune of 46.74 and 78.22 per cent, respectively. The combined effect of jassids, aphids and fruit borer caused losses in plant height, leaf number per plant, fruit number per plant and yield of okra to the extent of 74.08, 46.25, 50.77 and 86.0 per cent, respectively.

The correlations between jassid, aphid and fruit borer and the yield were significant and negative. The regression equation for yield 'Y' on jassid number 'x' worked out was Y = 86.162 - 65.881 x (r = -0.425) indicating that for every one jassid nymph per leaf the yield decreased by 65.88 q/ha. The regression equation for yield 'Y' on fruit borer infestation 'x' worked out was Y = 95.969 - 3.383 x (r = -0.759) indicating that for every one per cent fruit borer infestation yield decreased by 3.38 q/ha.

The jassids and aphids exerted negatively significant impact in case of plant height, leaf number, leaf area, leaf weight and stem weight per plant during vegetative stage.

The effect of jassids and aphids was non-significant for plant height and leaf number per plant at final harvest. The correlation between all the three pests and number of healthy fruits per plant was significant and negative.

The linear multiple regression analysis revealed significant coefficient of multiple determination (R^2 = 0.16, 0.74, 0.61 and 0.68 respectively for height, leaf area, fruit number and yield) causing thereby 16.8, 74.3, 61.7 and 68.3 per cent variation in final plant height, leaf area, fruit number per plant and yield due to jassid, aphid and fruit borer. The jassid population exerted significantly negative impact on final plant height and leaf area whereas the effect of aphid was not evident. The jassid and fruit borer gave significantly negative impact on fruit number per plant whereas effect of aphids was not significant. The plant height and fruit number per plant positively contributed to the yield, whereas the effect of leaf area was not evident, implying thereby that if losses in fruit number per plant and plant height are minimised the yield could be increased.

6.4 Assessment of Crop Losses due to Major Pests During Various Plant Growth Periods of Okra

A field experiment was conducted in randomised block design with twelve treatments each replicated thrice to assess the losses due to different pests during various plant growth periods of okra. Monocrotophos 0.04 per cent was used to protect the crop during a particular growth period. Observations were recorded on the population of jassids and aphids, fruit borer infestation and various growth and yield parameters of okra.

The jassid and aphid population was significantly higher in the treatments protected during 60-90 (T_9) and 75-90 days (T_{10}). These treatments were at par with untreated check (T_6). All other treatments recorded lower population of jassids and aphids. The infestation of fruit borer ranged from 4.1 to 15.83 per cent. It was minimum in the treatments receiving protection during 15-90 (T_1) and 45-90 days (T_8). Protection during 15-29 (T_5), 75-90 (T_{10}) and 15-44 days (T_4) recorded maximum fruit borer infestation and these treatments were equal to untreated check (T_6).

The per cent avoidable losses due to okra pest complex in plant height, leaf number per plant, fruit number per plant and marketable fruit yield were to the extent of 43.23, 13.17, 27.73 and 58.57, respectively. The fruit length and fruit girth was not significantly influenced by the pest attack.

Protection during 15-90 (T_1) and 15-74 days (T_2) recorded minimum per cent avoidable loss in fruit yield of okra.

It was evident that maximum yield returns could be obtained with four sprays during 15-74 days (T_2). Protection after 75 days did not increase the yield. Application of two sprays during 15-44 days (T_4) yielded equal to the same number of sprays during 60-90 (T_9) and 15-29 and 75-90 days (T_{12}). Similarly, application of three sprays during 30-74 (T_{11}), 45-90 (T_8) and 15-59 days (T_3) gave equal yields. However, it was observed that application of four sprays during 15-74 days (T_2) yielded significantly higher than application of same number of sprays during 30-90 days (T_7). Hence, it can be concluded that the growth period between 15-74 days is the critical growth period for the okra crop from the stand point of damage due to insect pests.

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* Original not seen