BIOECOLOGY AND MANAGEMENT OF HADDA BEETLE, *Henosepilachna vigintioctopunctata* (Fabricius)

THESIS

By

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Submitted to

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Is there anything I can say,

anything I can give

or do for you…..

Because all that I'm

all that I have

I owe to you…..

Affectionately Dedicated

to my

Revered Parents

who sacrificed

their present

to make my future better

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CERTIFICATE – I

This is to certify that the thesis entitled, **"Bioecology and management of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius)"**, submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms. Ruchi Kanwar (Admission No. A-2004-30-24)** daughter of **Shri S.P. Kanwar** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

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Chairman
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Place : Palampur
Dated: 20 October, 2006

CERTIFICATE – II

This is to certify that the thesis entitled, **"Bioecology and management of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius)"**, submitted by **Ms. Ruchi Kanwar (Admission No. A-2004-30-24)** daughter of **Shri S.P. Kanwar** to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Entomology**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Ruchi Kanwar

Place: Palampur
Dated: 20 October, 2006

(RUCHI KANWAR)

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Introduction

Chapter I

INTRODUCTION

Bitter gourd, *Momordica charantia* L. is one of the most important cucurbitaceous crops grown throughout India owing to its nutritive value and medicinal properties. But it is subjected to the ravages of a wide array of insect pests right from the germination upto harvesting stage (Thomas and Jacob, 1991). The epilachna beetle, *Henosepilachna vigintioctopunctata* (Fabricius) has been found to be a serious pest of this crop throughout the growth stages, causing great debilitation to the crop and resulting in considerable reduction of yield. Epilachnids are phytophagous beetles belonging to family Coccinellidae, and occur mainly in tropical and semitropical parts of the world.

Epilachna beetle is a pest of many plants of agricultural importance in Asia. Besides this, the species has also been reported from other parts of the world *viz.* Australia, America, East Indies and Japan (Rajagopal and Trivedi, 1989; Hirano,1993). It is an important pest of solanaceous and cucurbitaceous crops (Pandey and Shankar, 1975; Anand *et al.*, 1988, Mala *et al.*, 1992) in mid hills and plains of India (Kumar and Kumar, 1996).

Beetles are metallic brown in colour and usually have 7-14 black spots on each elytron with somewhat pointed abdominal tip. Being polyphagous in nature, the pest devours several host plants. Both the grubs as well as adults of the pest scrap and feed voraciously on the green matter of the leaf and skeletonize it (Kumar and Kumar, 1998; Rath *et al.*, 2002; Mohasin and De, 1994) in a characteristic manner leaving the upper epidermal tissue intact. The adults being strong fliers damage large crop areas during their peak activity (Nagia *et al.*, 1992). These usually feed on the upper surface while the grubs confine their attack to lower surface of leaves. The pest eats out regular areas of the leaf tissue leaving parallel bands of uneaten portions in between. The affected leaves present a lace-like appearance, turn brown, dry up and drop prematurely resulting in retardation of plant growth and thereby reduce the bearing of the plants (Ghosh and Senapati, 2001). Under severe infestation the plants may be completely defoliated.

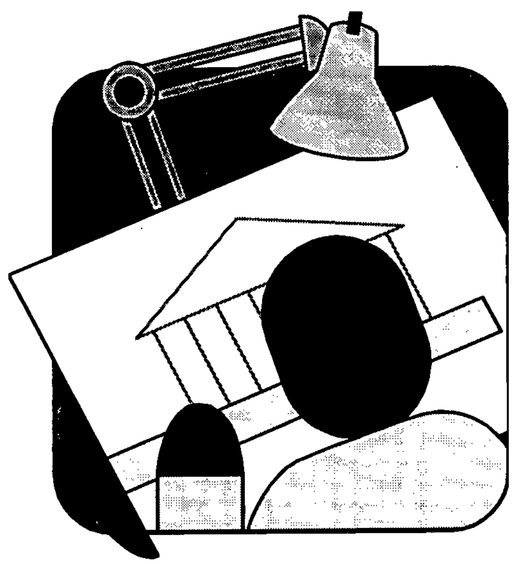
Population of the pest varies from region to region and the pest passes through several broods, but peak activity is generally recorded in July-August (Rajagopal and Trivedi, 1989). High temperature and low relative humidity coupled with scarcity of food plants had an adverse effect on fecundity, egg hatchability and newly hatched larvae (Grewal, 1988).

Thus, the damage done by the pest necessitates the studies on incidence, biology and population dynamics on bitter gourd in Himachal Pradesh in order to formulate the strategies for the management of the pest in the most effective way.

Application of insecticides against this pest is imperative to get economic returns since the pest has developed considerable levels of resistance to endosulfan and malathion in Himachal Pradesh (Kumar, 1995). So there is a need to evaluate other insecticides for the effective control of this pest.

Keeping in view the damage done by this pest, it was pertinent to undertake studies on bioecology and management of hadda beetle with the following objectives:-

1. To study the host range of hadda beetle, *Henosepilachna vigintioctopunctata* in low and mid hill conditions of Himachal Pradesh.
2. To study the biology and population dynamics of *H. vigintioctopunctata* on bitter gourd, *Momordica charantia* L.
3. To evaluate some insecticides and biopesticides against the pest.



Review of Literature

Chapter II

REVIEW OF LITERATURE

The literature pertaining to the present investigations with regard to different aspects on epilachna (*hadda*) beetle is reviewed in this chapter under the following heads:

2.1 Host range

2.2 Incidence

2.3 Biology

2.4 Population dynamics

2.5 Bioefficacy of insecticides

2.1 Host range

The host plants of *Henosepilachna* (*Epilachna*) *vigintioctopunctata* (Fabricius) have been recorded by various workers, who found most of them belonging to Cucurbitaceae and Solanaceae families (Pandey and Shankar, 1975; Anand *et al.*, 1988; Rajagopal and Trivedi, 1989). Singh and Mukherjee (1987) reported the oligophagous nature of *H. vigintioctopunctata*. They showed that 0-24 hours old grubs of *H. vigintioctopunctata* failed to survive on cucurbit plants such as pumpkin (*Cucurbita moschata* Duch.), sponge gourd (*Luffa cylindrica* Roem.), ridge gourd (*Luffa acutangula* (L.) Roxb.) and *Cucumis* sp.However they survived and developed well on various solanaceous plants tested. Katakura *et al.* (1988) recorded *H. vigintioctopunctata* feeding on brinjal

(*Solanum melongena* L.), potato (*S. tuberosum* L.), *rimbang* (*S. torvum* Linn.) and thorn apple (*Datura metel* Linn.) whereas, *E. septima* Dieke on bitter gourd (*Momordica charantia* L.), *E. dodecastigma* (Wiedemann) on squash gourd, wax gourd (*Benincasa cerifera* Savi [*B. hispida* (Thumb.) Cogn.]), cucumber (*Cucumis sativus* L.) and sponge gourd (*Luffa cylindrica* Roem.) and *E. enneasticta* on brinjal (aubergine), *S. torvum* L. and potato from Sumatra, Indonesia.

Chen *et al.* (1989) reported *H. vigintioctopunctata* as a destructive pest of vegetables from China. Dhamdhere *et al.* (1990) reported that tomato and brinjal were the most suitable and *Datura alba* (*D. metel* Linn.) the least suitable to *H. vigintioctopunctata*.

H. vigintioctopunctata was recorded as a new pest of solanaceous crops *viz.*, brinjal (*Solanum melongena* L.), *S. bonariense* and tomato (*Lycopersicon esculentum* Mill.) from Argentina (Folcia *et al.*, 1996). Sreekala and Ushakumari (1999) found brinjal as a host for *H. vigintioctopunctata* whereas *H. septima* Dieke was found on bitter gourd. Shirai and Katakura (1999) examined larval survival and development of *H. vigintioctopunctata* and observed that the largest adult body size and highest emergence rate of the pest was recorded when reared on the genus *Solanum* (Solanaceae). They concluded that the major host plants of *H. vigintioctopunctata* are solanaceous plants and this species is unable to complete its life cycle solely on cucurbits. Shirai and Katakura (2000) reported *Centrosema pubescens* Benth (Fabales; Leguminosae) as a host for *H. vigintioctopunctata.* Newly emerged adults showed 62 to 72 per cent hatchability when reared on *C. pubescens*.

Patel and Purohit (2000) reported that *H. vigintioctopunctata* damaged mainly brinjal and tomato and showed that the average number of days required to complete entire larval stage was slightly longer (15.95 $\pm$ 0.86 days) on tomato leaves as compared to brinjal leaves (15.60 $\pm$ 0.73). This indicated that the brinjal leaves were preferred by larva and adult as compared to tomato leaves.

E. vigintioctomaculata Motschulsky and *E. vigintioctopunctata* were stimulated to feed by cucurbitacins and not by solanine and tomatine, which are usually contained in solanaceous plants (Abe and Matsuda, 2000).

Mukhtar *et al.* (2001) recorded *H. vigintioctopunctata* feeding on poplar foliage. Keot *et al.* (2002) reported *H. vigintioctopunctata* to be a minor pest of vegetables in *Brassica* genus. The epilachnid can discriminate between varieties, and the degree of preference is influenced by 'non-preference' mechanism of resistance (Rath *et al.*, 2002). According to Chandra (2004) *ashwagandha* (*Withania somnifera* (L.) Dunal) was preferred by *H. vigintioctopunctata* among the medicinal plants studied.

H. vigintioctopunctata was recorded as a regular and dominant pest of brinjal in Jammu that attacked the crop during vegetative and reproductive phase of plant growth (Bhagat and Munshi, 2004).

2.2 Incidence

According to Iftekhar and Khan (1980), the pest remained active from July to November on brinjal and was more prevalent at temperature 27-29°C and relative humidity more than 80 per cent during the month of August. Singh and Kavadia (1989) also found the maximum infestation of epilachna beetle in August to October on July planted crop. The potato crop was attacked by the coccinellid *H. vigintioctopunctata* during both the *Kharif* and *Rabi* seasons in Orissa (Sonatakke *et al.,* 1989).

Rajagopal and Trivedi (1989) reported that the peak period of infestation of the pest varies with region, but the peak is generally in July-August. Ramzan *et al.* (1990) studied the comparative development and seasonal abundance of *H. vigintioctopunctata* on some solanaceous host plants and reported that all the stages of the pest were available during May-June and from May to August on potato and *W. somnifera*, respectively.

According to Mall *et al.* (1992) epilachna beetle was recorded from third week of August to middle of October on brinjal crop in Kanpur. The incidence of grubs of spotted beetle was maximum during the vegetative stage of brinjal (Veeravel and Bhaskaran, 1994). *H. vigintioctopunctata* appeared in the middle of May and its activity peaked in the first week of August in Manipur (Suresh *et al.,* 1996).

Solanum macrocarpon L. plants were severely damaged during Decemebr-January by *H. vigintioctopunctata* but incidence was not noticed on *S. viarum* Dunal in Bangalore (Kumar *et al.*, 1998). According to Karmakar and Bhattacharya (2000) *H. vigintioctopunctata* was found to be the destructive pest of brinjal in terai zone of West Bengal. Nayak and Rath (2001) evaluated the reaction of some brinjal varieties to epilachna beetle and showed that cultivars CHBR 3 and DPLB 5 had the highest leaf damage of 59.8 and 58.5 per cent, respectively. In Karnataka, the incidence of *H. vigintioctopunctata* was recorded by Reddy and Srinivasa (2001) on brinjal only during *Kharif* as compared to summer season.

The beetles were recorded between April to mid-October on brinjal from West Bengal (Ghosh and Senapati, 2001). Singh and Singh (2002) recorded *H. vigintioctopunctata* as the moderate pest of brinjal in Barapani, Meghalaya which appeared in the last week of June and remained throughout the cropping season.

According to Banerjee *et al.* (2003) the incidence of both epilachna beetles and grubs on bitter gourd in West Bengal was maximum during first and second week of September with minimum and maximum temperature varying from 25.2°C to 26°C and 31.5°C to 32.7°C, respectively and minimum and maximum relative humidity ranged from 76.0-79.0 and 97-98 per cent, respectively. The incidence was low to moderate in October and was very low in November. In Tamil Nadu, the peak incidence was recorded on brinjal during March-April (Muthukumar and Kalyanasundaram, 2003).

2.3 Biology

Grewal (1988) reported that high temperature and low relative humidity had an adverse effect on egg hatchability, viability of newly hatched larvae and fecundity. According to Sinha and Chandra (1988) the fruit and leaf of sponge gourd *Luffa* (*aegyptiaca*) *cylindrica* Roem. were the most suitable as larval food of the pest while the flower was less suitable in terms of the mean life span, percentage survival, frequency of moulting in the immature stages and adult emergence. The fruits of brinjal were the most suitable food of larvae with respect to mean life span and frequency of moulting, while the leaves and flowers were unsuitable. All three plant parts of brinjal failed to support pupation of the coccinellid.

According to Rajagopal and Trivedi (1989) the egg, larval, pupal and adult stages lasted for 3-4, 8-10, 3-6 and 21-28 days, respectively on potato. Chen *et al.* (1989) reported that the pest completes 4-5 generations annually on different vegetables in China. The generation was completed in 35.7 days at 24°C, 30.1 days at 26°C, 23.9 days at 28°C and 23.1 days at 32°C.

Shirai (1990) studied the reproductive ability of epilachna beetles on potato and reported that out of the two species *E. vigintioctomaculata* and *E. yasutomii* (Katakura) reproduction by individuals of first species reared on potato was about 14-fold that of individuals reared on deadly nightshade (*Scopolia japonica*) in Ina area of Japan.

In New South Wales, *E. cucurbitae* Rich. survived on a diet of wild weeds namely, *Cucumis myriocarpus* Naud. and watermelon, *Citrullus lanatus* (Thumb.) Mansf. but the fecundity was reduced and the number of generations produced was half as compared to cucurbit crop plants in a year (Richards and Filewood, 1990).

According to Ramzan *et al.* (1990) the coccinellid, *H. vigintioctopunctata* completed its life cycle successfully on brinjal and potato, but most quickly on *Solanum nigrum* (22.4 days) whereas the pest could not complete its life cycle on *Dhatura* and tomato.

The egg, larval and pupal periods of *H. elaterii* (Rossi) were 5.0 $\pm$ 0.45, 13.54 $\pm$ 0.16 and 6.47 $\pm$ 0.33 days, respectively. The adult life span was 38.05 $\pm$ 3.01 days and each female laid a total of 405 $\pm$ 46.0 eggs (El Abdin and Siragelnour, 1991).

The duration of development of *E. dodecastigma* (*E. pusillanima*) on *ghia torai* was longest at 20°C and shortest at 40°C whereas the optimum temperature for larval development and survival was 25°C (Tripathi and Misra, 1991).

Marinoni and Giambarresi (1992) reported that the pre-oviposition period of *E. clandestine* Mulsant lasted for 53-62 days and the oviposition period lasted for 11.9 days and each female laid an average of 28.1 eggs.

The larval and pupal periods of *H. vigintioctopunctata* on *Physalis minima* Linn. (wild gooseberry) were 11.54 ± 0.69 and 3.57 ± 0.50 days and on brinjal were 14.20 ± 0.65 and 4.65 ± 0.49 days. Egg laying by each female was 194.06 ± 20.99 and 147.40 ± 23.48 eggs, respectively (Nagia *et al.,* 1992).

Takeuchi (1994) studied the life cycle of two populations of *E. admirabilis* Crotch feeding on different host plants and reported that the larval period of the population feeding on *Trichosanthes kirilowii* Maxim. was shorter than that of the population feeding on *Gynostemma pentaphyllum* (Thumb.) Makino and *T. cucumeroides* (*T. ovigera*).

According to Folcia *et al.* (1996) the larval and pupal stages on brinjal leaves in the laboratory were 24.4 ± 4.52 and 4.7 ± 0.826 days, respectively. Amongst solanaceous plants tested for their suitability to epilachna beetle brinjal and potato were shown to be superior with regard to survival and duration of larval development as compared to *makoi* (*Solanum nigrum* Linn.), *jharpota* (*Nicandra physaloides* (L.), *aswagandha* and tomato (Parjhar *et al.*, 1997). Kumar and Kumar (1997) studied the comparative biology of laboratory selected malathion and endosulfan resistant strains *vis-à-vis* susceptible strain of *H. vigintioctopunctata* on potato and reported that resistant strains had significantly longer incubation periods and a lower egg viability compared to the susceptible strain. The fecundity was also less in malathion resistant (331.93) and endosulfan resistant (328.93) strains compared to the susceptible strain (391.07).

Within species, *E. enneasticta* showed less fecundity, more pre-reproductive period, and low intrinsic rate of natural increase when compared to other species namely, *E. vigintioctopunctata, E. septima* and *E. dodecastigma* (Nakano *et al.,* 1997). Duration of life cycle of *H. vigintioctopunctata* was shortest (26.74 days) in June-July and longest (33.52 days) in September-October, but highest fecundity (272.32 eggs) was recorded during March-April on brinjal in West Bengal (Ghosh and Senapati, 2001).

Shanmugapriyan and Kingsly (2003) studied the biology of the beetle *H. vigintioctopunctata* on bitter gourd, *Momordica charantia*, in Tamil Nadu and reported that life cycle was completed on an average of 22.1 days with the incubation period ranging from 3 to 4 days and the average larval and pupal period of 12.9 and 5.5 days, respectively.

According to Araujo Siqueira and Almeida (2004),the average life cycle of the pest was 41.44 days on tomato,with the larval and pupal period of 26.19 and 8.19 days, respectively. The pre-oviposition, oviposition and post-oviposition period was 23.57, 17.86 and 53.86 days, respectively. The fecundity of the females was 59.78 eggs and the average longevity of male and female was 81.44 and 97.89 days, respectively.

2.4 Population dynamics

The foliage of *Solanum hermanii* was attacked by the chrysomelids *Chaetocnema sp.*, *Conchyloctenia tigrina* and the coccinellid, *H. hirta* and *S. mauritianum* Scop. was attacked to a lesser extent by *H. hirta* only. The occurrence and damage caused by these insects was seasonal, with the greatest numbers of adults and larvae occurring on *S. hermanii* in December in Cape Province, Southern Africa (Olckers and Hulley, 1989).

Ramzan *et al.* (1990) observed that the highest number of *H. vigintioctopunctata* were found on *S. xanthocarpum* Schard and Wendl., reaching a maximum of 526.3 individuals per 10 plants in March. Tripathi and Misra (1991) showed that populations of *E. dodecastigma* in fields of *Luffa cylindrica* increased in the 1st and 2nd generation and declined in the 3rd and 4th generations in Uttar Pradesh.

Epilachna beetle had its maximum population of 0.22 beetle per leaf of brinjal in the middle of September in Kanpur, Uttar Pradesh when the average temperature and humidity were about 28°C and 80 per cent, respectively (Mall *et al.,* 1992). Population increase of *H. vigintioctopunctata* was suppressed in months of normal rainfall ($\geq$ 300 mm) in Indonesia but unable to suppress when rainfall dropped to 50 per cent of the long-term average (Inoue *et al.,* 1993).

Mukhopadhyay and Mandal (1994) did the screening of brinjal cultivars for resistance to insect pests and reported that the population of spotted leaf beetle *H. vigintioctopunctata* was less (0.09) on tolerant cultivar 'Shyamla Bhangar' as compared to 2.84 on highly susceptible 'Banaras Long Purple' whereas 'R 14' and 'Agora' cultivars showed 2.17 and 2.03 beetles, respectively, which may be considered susceptible. The remaining cultivars were moderately tolerant, registering 0.43-1.77 pest population. The population life tables of *H. vigintioctomaculata* were studied under 5 constant temperatures and which showed that the mortalities were highest at the 1^{st} and 4^{th} instar growth periods (Zhang and Liu, 1994).

Veeravel and Bhaskaran (1994) recorded the population of grubs of spotted beetle *H. vigintioctopunctata* during flowering and bearing stages of brinjal in Tamil Nadu. Raghuraman and Veeravel (1999) revealed that the *H. vigintioctopunctata* population in brinjal was greatest in February (24.2 insects/plant) and March (27.4 insects / plant). The highest population of the beetles (8.14 beetles per plant) was observed in mid-September when the average temperature, relative humidity and weekly rainfall were 28.59°C, 85.24 per cent and 67.45 mm, respectively and minimum (0.59 beetle / plant) in early November at 24.22°C temperature, 75.92 per cent relative humidity and without any rainfall on brinjal in West Bengal (Ghosh and Senapati, 2001). Gill (2003) screened four melon cultivars under field conditions against hadda beetles, *H. dodecastigma* and *E. vigintioctopunctata* and recorded the highest adult population on cultivars Punjab Rasila and Hara Madhu and lowest on MM-28. The peak pest population density for all stages of the pest was recorded in March on brinjal in Assam (Shaw *et al.*, 2004).

2.5 Bioefficacy of insecticides

2.5.1 Intrinsic toxicity

According to Krishnaia and Bhaskaran (1988) mixing malathion with 0.25, 0.2 and 1 per cent dicofol, Zineb and urea, respectively did not adversely affect its effectiveness against *H. vigintioctopunctata* on brinjal. The leaves of winter squash *Cucurbita maxima* Duch. when treated with methomyl (0.07%) and fed to 4^{th} instar larvae, caused 72.5 and 100 per cent mortality after 24 and 48 hours, respectively. Dimethoate (0.025%) caused 60.0 and 92.5 per cent mortality and malathion (0.05%) caused 55.0 and 75.0 per cent mortality, respectively (El Abdin and Siragelnour, 1991). Kumar and Kumar (1996) showed that the LC_{50} of malathion and endosulfan to the third instar larvae were 0.032 and 0.018 per cent and 0.022 and 0.013 per cent to adults, respectively, using the direct spray method. The selection of third instar grubs of the beetle with malathion by applying a selection pressure of 60-80 per cent kill in every generation resulted into 7.79 times resistance after nine generations of selection (Kumar and Kumar, 1998).

Laboratory selection of a strain of hadda beetle *H. vigintioctopunctata* resistant to endosulfan showed that a selection pressure of 60-80 per cent mortality of third-instar larvae of the beetle in every generation resulted in 6.59 times resistance after 9 generations in comparison to the non-selected strain (Kumar and Kumar, 1997).

Chlorfenvinphos (Birlane 35 EC) and monocrotophos (Nuvacron 40 WSC) at 0.05% were the most effective and were toxic to 2^{nd} instar larvae of *H. vigintioctopunctata* upto 15 days after treatment whereas leptophos (Phosvel 34

EC), chlorpyriphos (Dursban 20 EC), phenthoate (Elsan 50EC), fenthion (Lebycid 100 EC), DDT, dicrotophos (Bidrin 35 EC) and a mixture of carbaryl (Sevimol 40 LV) and molasses were less effective (Bhalla *et al.,* 1988). Umapathy and Baskaran (1991) showed that cypermethrin and carbaryl were effective against larvae of *H. vigintioctopunctata* while cypermethrin was effective against adults on brinjal. According to Nagia *et al.* (1992) carbaryl, quinalphos, endosulfan, cypermethrin, deltamethrin and fenvalerate were effective against grubs and adults. Dimethoate, fenpropathrin and fluvalinate were effective against grubs only. Liu *et al.* (2003) tested fipronil and phoxim against *H. vigintioctopunctata* on brinjal. They reported that fipronil had high efficacy (86.44-94.03%) in controlling grubs and adults three days after treatment and also had long residual effect in controlling grubs upto 14 days after treatment.

Steets (1975) observed cent per cent mortality of grubs of *E. varivestis* (Mulsant) which were fed on leaves of cabbage and beans treated with 2-5 per cent extracts of neem *Azadirachta indica* and *Melia azedarach* L. According to Tewari and Krishnamoorthy (1985), petroleum ether extracts of *M. azedarach* drupes, rhizomes of *Acorus calamus* and seed oil of *A. indica* at 0.05 to 0.5 per cent concentrations showed varying degrees of antifeedant activity against the grubs and adults of *H. vigintioctopunctata.* Schmutterer (1989) tested crude extracts of three insecticidal trees at concentration of 50-800 ppm against *E. varivestis* and found leaf extracts of *Azadirachta integrifoliola* Merr. superior to those from *M. azedarach* L. whereas, extracts from leaves of *A. indica* were the least effective. Feeding of the brinjal leaves treated with 0.05 per cent neem oil to females of *Henosepilachna* (Epilachna) *sparsa* (Hbst.) resulted in 21.09 per cent longer pre-oviposition period than those fed on untreated leaves. Oviposition period and fecundity was reduced when fed on treated leaves in comparison to the untreated controls (Mishra *et al.,* 1989). According to Mishra *et al.* (1990), feeding of brinjal leaves treated with 0.025 and 0.05 per cent neem oil to *H. sparsa* increased the duration and reduced the weight of treated insects compared with the untreated leaves. The antifeedant activity of neem seed extracts against the fourth instar grubs and adults of *H. vigintioctopunctata* was tested by Jeyarajan and Babu (1990). They reported that Neem-75 at 1000 ppm proved to be the best antifeedant for the grubs followed by NK-100 and Nemidin. However, NK-100 had the highest antifeedant activity against adults. Petroleum ether extracts of *Bougainvillea spectabilis* Willd., *Parthenium hysterophorous* L. and *A. indica* at 0.5 per cent gave cent per cent protection to brinjal leaves against third instar larvae of *H. vigintioctopunctata* after 24 hours of treatment (Janardhan Rao *et al.,* 1992). According to Mehta *et al.* (1995) 1 per cent extract of each of billgoat weed (*Ageratum conyzoides*) and yellow sage (*Lantana camara*) gave complete protection to brinjal leaves avoiding feeding by grubs whereas in adults, the greatest antifeedant effect was observed with 1 per cent *L. camara* extract, followed by cromfton weed, *Chromolaena* (*Eupatorium*) *adenophorum* L. (1%). Kumar and Babu (1998) found that the Neem Azal-T/S (1% Azadirachtin) and Neem Azal-F (5% Azadirachtin) had adverse effect on fecundity and moderate growth regulatory effects in *H. vigintioctopunctata*. Patel and Purohit (1998) reported strong antifeedant properties of azadirachtin and neem seed kernel extract (NSKE) both for grubs and adults of *H. vigintioctopunctata*. The adults when fed on brinjal leaves treated with leaf extracts of *Ageratum houstonianum* Mill., *Artemisia brevifolia* Wall. and leaf and drupe extracts of *Melia azedarach* resulted in substantial prolongation in development of the progeny of the pest. Adults emerging from the treatments *viz.,* 4 and 6 per cent concentrations leaf extract of both *M. azedarach* and *A. houstonianum* were found to be deformed (Mehta *et al.,* 1999).

Brinjal leaves treated with 4000 ppm steam distillate extract of *Solanum aethiopicum* Linn. reduced settling of adults and larvae of the pest by 54.75 and 35.28 per cent, respectively. The extract also reduced egg hatchability from 84 per cent in the untreated check to 62 per cent in the treatment whereas larvae fed with leaves treated with steam distillate extract experienced 50 per cent mortality (Rajendran, 1999). Neem oil at 1.5 per cent produced the highest mortality of second and third instars (95.23%) and fourth instars (76.19%). Neem oil at lower concentrations produced varying degrees of mortality in different instars. Monocrotophos (Nuphos 36 at 0.025%) and quinalphos (Quinaal X at 0.025%) resulted in 95.24 per cent larval mortality (Shanmugapriyan and Kingsly, 2001a, b). They also evaluated neem oil and neem cake extract for their phagodeterrent effect on the grubs and adults of *H. vigintioctopunctata* and indicated that feeding inhibition by neem oil (0.25 to 2.50%) varied from 97.64 to 99.01 per cent in second instar and from 88.86 to 96.54 per cent in the third instar. At a similar concentration range, the feeding inhibition by neem cake extract ranged from 89.13 to 97.08 per cent in second instar and from 98.82 to 90.45 per cent in third instar. In the fourth instar, however, the average leaf area protection varied between 72.80 and 92.33 per cent in neem oil and between 66.71 to 90.71 per cent in neem cake extract with concentration ranging from 0.25 to 5.50 per cent. At similar concentrations the feeding deterrent effect against adults varied from 65.61 to 89.90 per cent with neem and from 61.70 to 84.84 per cent with neem cake extract. Among the synthetic insecticides, endosulfan (0.025%) gave the maximum feeding inhibition in second instar (96.19%), quinalphos in third instar (90.97%) and adult stage (78.23%) and malathion in fourth instar (84.76%) larvae. According to Carpinella *et al.* (2002), the isomeric mixture of meliartenin (a limonoid antifeedant) at concentration of 4 $\mu g/cm^2$ and 1 $\mu g/cm^2$ was as active as azadirachtin in strongly inhibiting the larval feeding of *Epilachna paenulata* Germ. and *Spodoptera eridania* Cram.,respectively. Shanmugapriyan and Kingsly (2003) reported that neem oil, neem cake extract and NSKE had the maximum ovicidal effect on the 24 and 48 h old eggs of *H. vigintioctopunctata* at the highest concentration of 5.5 per cent whereas endosulfan, monocrorotphos and malathion (each at 0.025%) resulted in less than 50% egg mortality. Quinalphos treatment resulted in 74.33 per cent mortality in 24 h old eggs.

According to Hanif and Abida (1997), *Beauveria bassiana* (Balsamo) Vuill. proved to be effective against all the stages of *H. dodecastigma* except for the eggs. For the grubs, 100 per cent mortality occurred after 120 h with concentration of 0.8 x 10^4 spores / ml, for pupae 100 per cent mortality in 168 h whereas in case of adults, mortality was 100 per cent after 192 h at the same dose.

Padmaja and Kaur (1998) studied the pathogenicity of *B. bassiana* isolates of brinjal spotted beetle, *H. vigintioctopunctata* and reported that pathogenic strains showing rapid germination and profuse sporulation were found to be more virulent to the pest with LT_{50} values ranging from 1.33 to 4.8 days of the second instar larvae in the different isolates. According to Rajendran and Gopalan (1999) direct spraying of the white muscardine fungus, *B. bassiana* (2×10^8 conidia / cm^2) killed 58.1 per cent first instar and 35.2 per cent pre-pupal stage grubs. The adults were less affected with the maximum mortality being 10.3 per cent of newly emerged adults. *B. bassiana* treated one-day old eggs resulted in 54.6 per cent hatchability.

Garcia Gutierrez *et al.* (1999) evaluated spore toxicity of ten *B. bassiana* strains against three-day old larvae of *Epilachna varivestis* (Mulsant) and found that all the strains showed toxicity to the pest with the highest mortality (96.6%) in the strain isolated from western corn rootworm, *Diabrotica* sp. and lowest mortality (66 %) in that isolated from *Cydia pomonella* (L.) Mycotrol, a commercial *B. bassiana* formulation was most toxic, with 96 per cent larval mean mortality while unformulated *B. bassiana* resulted in 77.3 per cent and microencapsulated formulation of *B. bassiana* (5 %) yielded 72 per cent larval mortality (Garcia Gutierrez *et al.*, 2002).

Treatment of newly emerged adults of *H. vigintioctopunctata* with insect growth regulator, diflubenzuron had reduced adult longevity and fecundity while penfluron inhibited egg hatch (Gupta and Dogra, 1990). Novaluron, a modern insect growth regulator had a wide spectrum of activity and suitable for integrated pest management strategies as reported by Castagna *et al.* (2002).

2.5.2 Field efficacy

According to Singh and Kavadia (1989) pests attacking brinjal including *Henosepilachna* sp. were most effectively controlled by the application of granular aldicarb or disulfoton at 1.5 kg a.i./ha as a side-dressing 8 days after transplanting, followed by 2-3 sprays of endosulfan (0.07%) or carbaryl (0.1%) whereas malathion and fenitrothion showed little effectiveness against the pests. Sprays of 0.5 per cent carbaryl + molasses and quinalphos were found to be effective against the pest on potato (Rajagopal and Trivedi, 1989). Application of carbofuran and phorate granules at 0.5 and 1.0 kg a.i./ha, respectively followed by need based application of carbaryl (0.2%), quinalphos (0.05%) or malathion (0.1%) was effective in controlling the major pests of brinjal and in increasing yield (Reghunath *et al.,* 1989). Carbofuran granules applied to bitter gourds at 1.5 kg a.i./ha at sowing, vining and flowering gave an effective control of *H. vigintioctopunctata.* Petroleum ether extract (0.1%) of leaves of mexican poppy, *Argemome mexicana* L. was more effective (76.18% control) than 0.07 per cent endosulfan (75.46%). An extract of *A. indica* leaves (0.1%) and formulation Neknool (0.1%) gave 69.55 and 69.02 per cent control, respectively. Neemguard (0.5%) and allitin (0.1%) were the least effective (55.92 and 55.56%, respectively) (Chitra *et al.,* 1993). According to Mohasin (1994) dichlorvos, quinalphos and demeton-methyl (each at 0.03%) gave an effective level of control of *H. vigintioctopunctata* on potato. Fenvalerate was the most effective insecticide against the *H. vigintioctopunctata* and *Amrasca biguttula biguttula* amongst eight tested insecticides on bitter gourd at fortnightly intervals between 30 and 105 days after sowing (Reddy, 1997).

According to Rajendran *et al.* (1998) *H. vigintioctopunctata* was partially controlled with neem oil 4 per cent on brinjal whereas the application of neem oil (2%) + endosulfan (0.035%) reduced the pest population by over 63 per cent.

Rajendran (1998) examined the effects of neem oil on the fecundity and egg hatchability of *H. vigintioctopunctata* and reported that neem oil (4%) reduced fecundity by 62.8 per cent over control and neem oil (2%) + endosulfan (0.035%) reduced it by 74.7 per cent.

Quinalphos @ 500, 750 and 1000 g a.i./ha and its mixture with monocrotophos (500+360 g a.i./ha) gave excellent control of brinjal pests including *H. vigintioctopunctata* along with a significantly higher crop yield (Samanta *et al.,* 1999). Mandal and Kumar (2001) evaluated the efficiency of monocrotophos, quinalphos, cypermethrin and fenvalerate against *H. vigintioctopunctata* infesting brinjal and reported that cypermethrin recorded the highest reduction in the pest population at all stages of plant growth.

Materials and Methods

Chapter III

MATERIALS AND METHODS

The present investigation entitled, "Bioecology and management of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius)" were carried out at 'Entomological Research Farm' and 'Post Graduate Laboratory' of the Department of Entomology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.), during 2005-2006.

The details of materials used and methods employed during the present investigations are presented in this chapter.

3.1 Chemicals and other materials

The information regarding different insecticides and other chemicals used in the present study has been given in Table 3.1. In addition, other materials *viz.* beakers (250 and 500 ml), conical flasks (250 ml), measuring cylinders (50 and 100 ml), Petri plates (7 and 8 cm dia.), pipettes (1 ml, 5 ml), plastic jars (18 x 15 cm, 15 x 13 cm, 18 x 10 cm, 8 x 6.5 cm and 7 x 4.5 cm dia.), polythene bags (250 g), cages (45 x 45 x 55 cm), camel hair brush, forceps, filter papers, cotton, muslin cloth, rubber bands, fresh leaves and ocular micrometer were also used.

3.2 Survey for host range and collection of test insect

The hosts on which the epilachna beetle, *H. vigintioctopunctata* feeds were recorded by surveying extensively the localities around Palampur. Besides this, localities/areas in low and mid hills comprising Kangra, Hamirpur and Una

Table 3.1 Information of the insecticides used in the present study

Common Name	Trade Name	Range of concentration Used (%)	Formulator
Endosulfan	Thiodan 35 EC	0.00625 – 0.2	Agro Pack, Panoli, Gujarat
Malathion	Jythion 50EC	0.0015625 – 0.1	Jyoti Insecticides Naya Bazaar, Delhi-110006
Cypermethrin	Cymbush 25EC	0.00009765 – 0.02	Syngenta Crop Protection Private Limited,14,J.Tata Road, Mumbai-400020
Carbaryl	Sevin 50WDP	0.000391 – 0.2	S.S.Crop Care Ltd.,10,Idustrial Area, Govindpura, Bhopal 462023
Azadirachtin	Nimbecidine 0.03 EC	0.0075 – 0.024	T Stanes and Company Ltd. 8/23-24,Race Course Road, PO Box No. 2709, Coimbatore, Tamil Nadu – 641018
Beauveria bassiana	Biopower 1x 10^8cfu / g	1 x 10^4 – 2 x 10^6 cfu / ml	T Stanes and Company Ltd. 8/23-24,Race Course Road, PO Box No. 2709, Coimbatore, Tamil Nadu - 641018
Novaluron	Rimon 10 EC	0.000078125 – 0.02	Indofil Chemicals Company, Nirlon House,Dr. Annie Besant Road, Worli, Mumbai 400025

districts were also surveyed to record the host range of the pest. All the stages of the pest were collected from different areas using polythene bags and rubber bands. Host range was also recorded for *H. dodecastigma*. Details of different areas from where the collections were made are given in Table 3.2.

Table 3.2 Localities surveyed for the host range of *H. vigintioctopunctata*

District	Locations	Host crop
Kangra	Kachhiari	Potato, Brinjal, Bitter gourd
	Samloti	Potato, Bitter gourd
	Mundla	Bitter gourd, Bottle gourd
	Kuthma	Potato
	Gaggal	Potato
	Palampur	Brinjal, Bitter gourd, Ridge gourd, Cucumber, *Ashwagandha*, Sponge gourd, Wild cucumber, Potato
	Tanda	Bitter gourd, Tomato, *makoi*
	Baijnath	Bitter gourd
	Ghuggar	Tomato
	Banuri	Bitter gourd
	Rajpur	Bitter gourd
	Bhawarna	Bitter gourd
	Samula	Bitter gourd
	Thakurdwara	Bitter gourd
Hamirpur	Chauki, Baragaon	Sponge gourd, *makoi*, Brinjal
Una	Takka	Pumpkin, Brinjal, Bitter gourd, Ridge gourd
	Rampur	Ridge gourd
	Malahat Nagar	Ridge gourd
	Nangal Jariyalan	Bottle gourd, Bitter gourd, Sponge gourd, Pumpkin
Mandi	Tikkari, Bhambla Gadwa (Keolidhar)	Brinjal, Bottle gourd, Bitter gourd, Cucumber, Pumpkin, *makoi* , Sponge gourd, Potato
Bilaspur	Berthin	Bottle gourd, Bitter gourd

3.3 Rearing of test insect

Egg masses, grubs, pupae and adult beetles were collected from field especially from solanaceous crops and brought to laboratory for rearing. The insect culture was maintained in plastic jars (18 x 15 cm, 15 x 13 cm, 18 x 10 cm and 8.0 x 6.5 cm) with a perforated lid or muslin cloth tied with a rubber band on the top. Earlier fresh potato, tomato and brinjal leaves were provided daily as food to the pest. But from May end onwards the field collected individuals of the pest from different solanaceous and cucurbitaceous crops were fed on their respective hosts and the culture was maintained and reared on bitter gourd, bottle gourd, ridge gourd, sponge gourd, tomato, brinjal, potato, cucumber and also *H. dodecastigma* on *Solanum nigrum,* till the cropping season. Moist cotton plug was wrapped around the petiole of the leaves in order to keep them fresh. The food was changed daily, the containers were washed and the filter paper was replaced daily to maintain hygiene.

The leaves were examined daily and leaf portion with yellowish egg masses were clipped off and placed in Petri plate (7 cm dia.) having a fresh leaf with a moistened filter paper at the bottom. These eggs were observed daily for hatching and newly hatched larvae (grubs) were transferred to fresh leaves with the help of camel hair brush. The larvae were maintained and reared in plastic jars upto the pupal stage. The pupae were separately placed in plastic jars for adult emergence so as to get regular supply of various developmental stages.

3.4 Multiple choice test

The epilachna beetle was collected from bitter gourd and reared under laboratory conditions on the same host for one generation and was designated as bitter gourd population. The host preference of this population was then determined by multiple choice test. For this, ten adults and equal number of grubs (in each of three replications) were preconditioned for 3-4 hours and given fresh leaves of twelve different hosts to feed upon in cages (45 x 45 x 55 cm).

The observations on feeding by the pest were taken after 24 hours. The leaves on which maximum feeding was done were removed and other leaves were replaced with fresh ones and observations were taken after 48 hours and similarly after 72 hours. Similar choice test was conducted to know the host preference of the adult beetles collected from different hosts (bottle gourd, ridge gourd and brinjal) and were reared on their host for one generation and designated as population of that host.

To show the extent of damage to leaf area scoring was done as per the method given by Mehta and Sandhu (1989) with slight modifications.

Score	Extent of damage to leaf area
0	Nil – Healthy leaf
1	Approximately upto 1/4th
2	Approximately upto 1/2
3	Approximately upto 3/4th
4	Approximately more than 3/4th

3.5 Biology

3.5.1 Description and Measurements of Developmental stages

Colour, shape, and size of different developmental stages of *H. vigintioctopunctata* was observed. The length and breadth of egg, first instar and *second instar grub were measured using an ocular micrometer whereas those of* third instar onwards were measured using scale.

The biology of *H. vigintioctopunctata* was studied on bitter gourd under laboratory conditions. The field collected adults were reared on leaves and the number of generations completed by the pest were worked out in the laboratory. During different generations the data was recorded on the number of eggs laid per female, duration of each developing stage and other biological characters.

The procedure for studying the various biological parameters was as follows:

3.5.1.1 Egg stage

One pair of adults (male and female, selected on the basis of abdominal tip) were released on bitter gourd leaves in plastic jars (8 x 6.5 cm) and observed daily for egg laying. Pieces of bitter gourd leaves containing egg masses were removed and kept over a moist filter paper in a Petri dish. The eggs were observed daily to record the date of hatching. Total incubation period and per cent survival was worked out. Mean incubation period was established as the period between oviposition and 50 per cent egg hatching.

3.5.1.2 Grub stage

Freshly hatched grubs were transferred into plastic jars (8 x 6.5 cm) containing fresh bitter gourd leaves and daily observations were recorded on the number, moulting and duration of different instars. Grubs were provided daily with fresh bitter gourd leaves as food.

The duration of each instar was worked out by recording the data on moulting, which was confirmed by the presence of exuviae on the leaf. Time interval between date of egg hatching and formation of pupa was recorded as the total larval period. The mean duration was established when 50 per cent of the individuals moulted to the next stage and total larval period and survival percentage was worked out.

3.5.1.3 Pupal stage

Total pupal period was recorded as the period between the formation of pupa and emergence of adult. The mean duration of the pupal period was established as the period between pupal formation to 50 per cent adult emergence. Survival percentage of the pupa was also worked out.

3.5.1.4 Total developmental period

Total time spent to complete development from egg to adult emergence was recorded as total developmental period.

3.5.2 Pre-oviposition and oviposition periods and fecundity

The adult emerged from pupae were kept separately according to their date of emergence and observed for copulation. Observations on the date of start of egg laying and subsequently number of eggs laid per female till cessation of egg laying were taken. Period between the emergence of adults and start of egg laying was considered as pre-oviposition period. Total duration (in days) of egg-laying was taken as oviposition period and total number of eggs laid per female during entire oviposition period was taken as its fecundity.

3.5.3 Percentage survival of different developmental stages

Per cent survival of eggs was worked out by counting the number of eggs hatched from the total number kept for studying the biology. The newly hatched grubs were reared in plastic jars (8 x 6.5 cm) upto the adult emergence and observations were recorded on mortality of grubs instar wise and pupa.

3.6 Population dynamics

3.6.1 Raising of the crop

Sowing of bitter gourd seeds was done on April 8, 2005. For this, polythene bags (250 g capacity) were filled with the mixture of soil, sand, FYM and German mixture (IFFCO 12:32:16) and the seeds were sown in them. Water was sprinkled on them and were covered with dry grass and polythene sheet to ensure optimum temperature for germination. The transplanting of seedlings was done in the field on May 16, 2005 at the Entomological Research Farm as per the package of practices (Anonymous,2005). The crop was laid in Randomized Block Design with 4 plants each in the plots of 3 x 3 m^2. The plants were stacked and monitored regularly to note the first incidence of the pest.

3.6.2 Population build-up

The population build-up of *H. vigintioctopunctata* was studied by taking the observations on the number of adults, grubs, pupae and egg masses at weekly interval by observing all 48 plants and was continued throughout the season. The observations on population build-up per plant were worked out. Similarly the level of infestation was also recorded by observing 48 plants. Per cent infestation plant was calculated as per the formula given by Koul (1998) as:-

$$\text{\% plant infestation} = \frac{\text{Number of plants infested}}{\text{Total number of plants}} \times 100$$

These observations were utilized to work out infestation index as per the method outlined by Sharma (1995).

$$\text{Infestation index} = \log \left(\frac{\text{Population / plant} \times \text{\% plant infestation}}{100} + 1 \right)$$

3.6.3 Relationship of abiotic factors

Relationship of population counts of the hadda beetle with abiotic factors of the environment namely, minimum and maximum temperature and relative humidity was worked out. Correlation of infestation index with the weather parameters was also worked out.

3.7 Evaluation of insecticides and biopesticides

Insecticides and biopesticides comprising endosulfan, carbaryl, malathion, cypermethrin, novaluron, neem and *Beauveria bassiana* were evaluated against the grubs and adults of the pest in the laboratory as well as under the field conditions on bitter gourd crop.

3.7.1 Laboratory evaluation

3.7.1.1 Preparation of stock solution

Stock solutions of all the above mentioned chemicals were prepared in distilled water, using Triton X-100 wherever required. The chemicals in emulsifiable concentrate (EC) formulations were measured using the pipette pump whereas the powdered formulations were weighed according to the dose using electronic weighing balance. These solutions were used for the preparation of different concentrations of the insecticides and biopesticides.

3.7.1.2 Method of bioassay

Leaf dip method of bioassay was used against the grubs and adults of the pest. In this method, counted number of third instar grubs/adults (10 per replicate) was released in clean and dry plastic jars having appropriate filter papers inside before preconditioning (starved for 2-3 hours). Third instar grubs were selected for the bioassay studies to make handling of the culture easy while conducting experiments. The fresh bitter gourd leaves were taken and dipped inside the solutions of different concentrations for each insecticide for 30 seconds, shade dried and then placed in the plastic jars for feeding of the grubs and adults separately. Initial trials were run to adjust the range of insecticidal concentrations which could give mortality between 20 and 80 per cent. A complete test for each insecticide finally comprised different concentrations alongwith untreated check replicated thrice. Mortality counts were taken after 24 hours of treatment in case of synthetic insecticides and 72 hours of treatment in case of neem, *B. bassiana* and novaluron. Insects which were unable to move or had uncoordinated movements were counted as dead. The treated leaves were replaced after 24 hours with the fresh leaves and observations were taken on the feeding in different concentrations. Similarly, the leaves and filter paper were replaced after 48 and 72 hours, wherever necessary, after taking the mortality counts. Water soaked cotton plug was wrapped around the petiole of the bitter gourd leaf in order to keep it fresh.

3.7.2 Field efficacy

Sowing of bitter gourd seeds was done on April 25, 2006. Seeds were soaked in water for 24 hours before sowing. The method of sowing was the same as explained in section 3.6.1.

Transplanting of the seedlings was done on May 22, 2006 in 24 plots. All the insecticides and biopesticides were evaluated under the field conditions on bitter gourd crop in Randomized Block Design during August 2006. The pre-treatment counts of immature stages and adults were taken from each plant in every plot. Post treatment counts of immature stages and adults were recorded at 1, 3, 7 and 15 days of application of insecticides. The experiment was replicated thrice comprising four plants each in the plots of 3 x 3 m^2. Three plots were kept as untreated check. Reduction in population over untreated check was worked out as per the modified formula of Abbott given by Fleming and Retnakaran (1985):

$$\text{Per cent reduction in population} = 1 - \left[\frac{\text{Post-treatment population in treatment}}{\text{Pre-treatment population in treatment}} \times \frac{\text{Pre-treatment population in check}}{\text{Post-treatment population in check}} \right] \times 100$$

3.7.3 Presentation and analysis of data

The average per cent mortality for each concentration was calculated and corrected with Abbott's formula (Abbott,1925) wherever necessary. This corrected per cent mortality was subjected to probit analysis (Finney, 1971) to find out LC_{50} and LC_{90} values for different insecticides. The results have been presented in the tables under each experiment.

Results

Chapter IV

RESULTS

The present investigation entitled "Bioecology and management of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius)" was undertaken to study the host range, biology and population dynamics of hadda beetle alongwith the evaluation of some insecticides for its management. The results obtained on these aspects are being presented in this chapter.

4.1 Host Range

Field surveys conducted during 2005-06 in low - and mid - hill areas of Himachal Pradesh to study the occurrence and host range of *H. vigintioctopunctata* revealed a total of ten plant species belonging to two families including Cucurbitaceae (6 species) and Solanaceae (4 species) (Table 4.1) as hosts of this species.

Table 4.1 Host plants of *H. vigintioctopunctata* in Himachal Pradesh

Family	Common name	Scientific name
Cucurbitaceae	Bitter gourd	*Momordica charantia* L.
	Bottle gourd	*Lagenaria siceraria* (Molina) Standl.
	Cucumber	*Cucumis sativus* L.
	Pumpkin	*Cucurbita moschata* (Duch.) Poir
	Ridge gourd	*Luffa acutangula* (L.) Roxb.
	Sponge gourd	*Luffa cylindrica* Roem.
Solanaceae	Ashwagandha	*Withania somnifera* (L.) Dunal
	Brinjal	*Solanum melongena* L.
	Potato	*Solanum tuberosum* L.
	Tomato	*Lycopersicon esculentum* Mill.

The hosts comprised nine vegetable crops and one medicinal plant. However, during the study another species, *H. dodecastigma* (Wiedemann) (Plate 3d) was found to infest five plant species belonging to three families *viz.* Solanaceae (3 species), Leguminoseae (1 species) and Cucurbitaceae (1 species) (Table 4.2).

Table 4.2 Host plants of *H. dodecastigma*

Family	Common name	Scientific name
Cucurbitaceae	Pumpkin	*Cucurbita moschata* (Duch.) Poir
Leguminoseae	Cowpea	*Vigna unguiculata* (L.) Walp
Solanaceae	Black night shade	*Solanum nigrum* L.
	Brinjal	*Solanum melongena* L.
	Potato	*Solanun tuberosum* L.

4.2 Population Dynamics

4.2.1 Seasonal Abundance

Seasonal abundance of *H. vigintioctopunctata* was studied on bitter gourd in the field during, 2005. The observations recorded are summarized in Table 4.3.

The adult beetles were first observed on August 10 on bitter gourd at Palampur with a population level of 0.1 beetle / plant which increased afterwards to reach the peak level of 1.8 adults per plant on September 28, thereafter a declining trend was set in. Eggs appeared on August 17 with the peak of 26.1 eggs / plant on August 31. The grubs were first observed a week later to the appearance of adults on August 17 with the population level of 1.4 grubs / plant. The population was at its peak on September 7 (7.5 grubs /

plant) with the total population of 8.4 / plant thereafter declined sharply upto September 28. The grub population again increased abruptly to 3.3 / plant on October 5 and declined thereafter whereas the pupae appeared 4 weeks after the appearance of adults with their peak population (0.7 / plant) on September 7.

Table 4.3 Seasonal abundance of *H. vigintioctopunctata* on bitter gourd at Palampur during 2005

Sampling Date	Eggs	Grubs	Pupae	Adult	Mean population* (grubs, pupae and adult)	Per cent plant infestation	Infestation index
August 10	0.0	0.0	0.0	0.1	0.1	2.1	0.10
17	11.1	1.4	0.0	0.1	1.5	14.6	0.09
24	15.6	4.9	0.0	0.1	5.0	18.8	0.29
31	26.1	5.5	0.0	0.2	5.7	58.3	0.64
September 7	8.9	7.5	0.7	0.2	8.4	100.0	0.97
14	0.1	4.3	0.3	0.5	5.1	83.3	0.72
21	0.0	1.1	0.6	1.2	2.9	91.7	0.56
28	2.3	1.0	0.5	1.8	3.3	97.9	0.63
October 5	2.2	3.3	0.3	1.3	4.9	91.7	0.74
12	1.9	0.2	0.2	1.0	1.4	56.3	0.25
19	0.0	0.0	0.1	0.7	0.8	33.3	0.10

*** Based on 48 observations**

During first observation period (August 10) per cent plant infestation was observed to be 2.1 with the corresponding infestation index of 0.10. The number of plants infested increased gradually reaching upto 100 per cent with the highest infestation index of 0.97 on September 7 (Table 4.3 & Fig. 4.1).

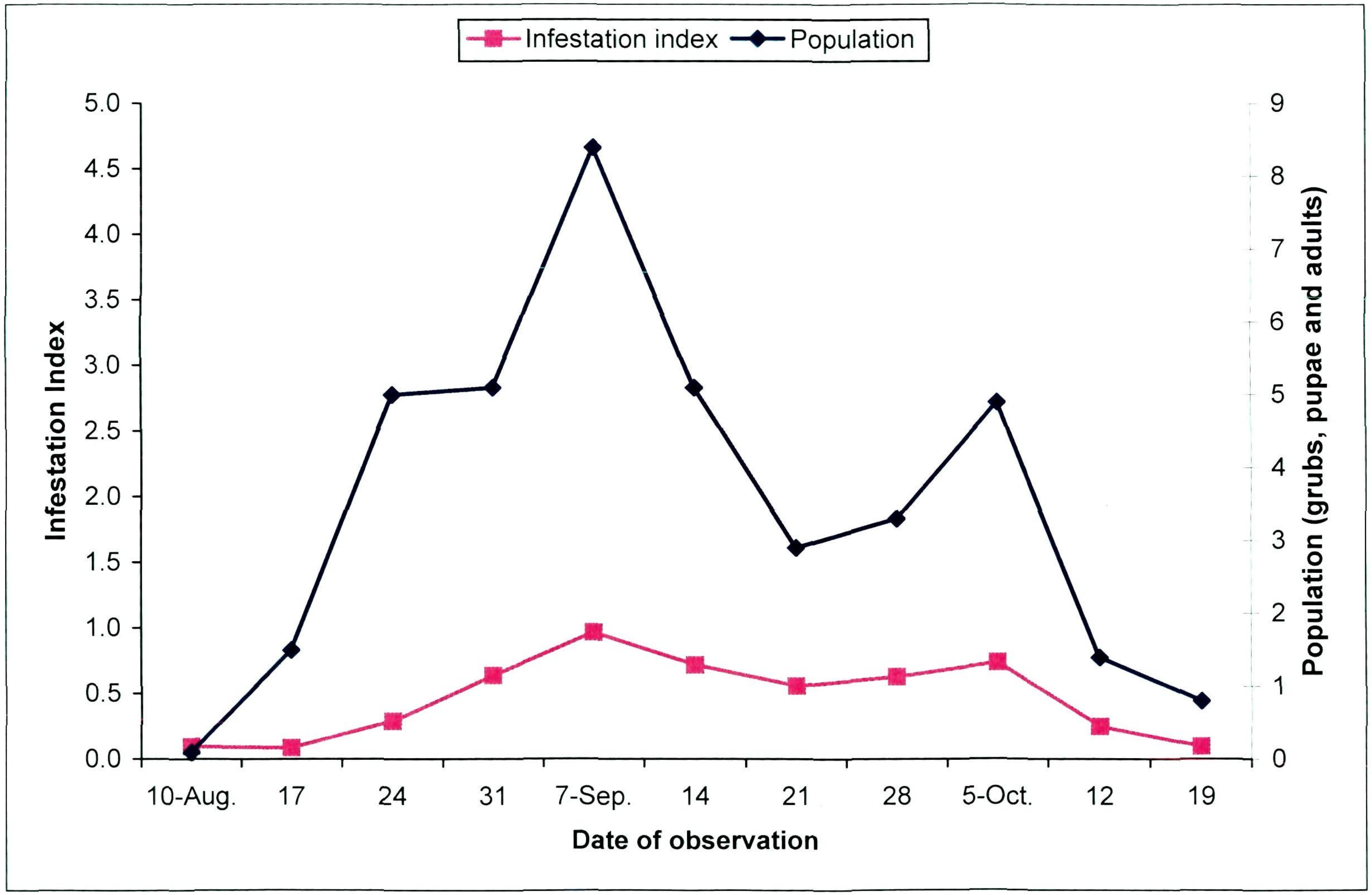


Fig. 4.1 Population build-up of *H. vigintioctopunctata* on bitter gourd

4.2.2 Relationship of population with abiotic factors

The correlation between the abiotic factors namely, minimum and maximum temperature (^{0}C), relative humidity (%), rainfall (mm), wind velocity (kmph) and sunshine (hours) and population of different developmental stages as well as infestation index was worked out.

Data presented in Table 4.4 revealed a positive and significant correlation between minimum temperature and number of eggs as well as grubs. A negative relationship between adult population and minimum temperature, relative humidity as well as rainfall was established, the value of 'r' being significant (-0.5764) with relative humidity only. The correlation analysis also revealed that the adult population had a positive but statistically non-significant correlation with maximum temperature and rainfall whereas sunshine (hours) were correlated positively and significantly (r = 0.6448).

Table 4.4 Correlation coefficient (r) of the population and infestation index of *H. vigintioctopunctata* with the abiotic factors

Factors	Population of Developmental Stage					Infestation index
	Eggs	Grub	Pupa	Adult	Total Population	
Temperature (^{0}C)						
Minimum	0.5247*	0.5601*	0.0971	-0.4955	0.4584	0.3003
Maximum	0.0722	0.0729	0.3618	0.2853	0.1862	0.1683
RH (%)	0.2407	0.5053	0.0547	-0.5764*	0.3909	0.2487
Rainfall (mm)	0.0824	-0.0614	-0.2581	-0.3375	-0.1607	-0.2713
Wind Velocity (kmph)	-0.5212	-0.4086	-0.1484	0.3286	-0.3376	-0.3240
Sunshine (hours)	-0.2566	-0.4091	0.1003	0.6448*	-0.2597	-0.0847

*** Significant at 5% level of significance**

The total population and infestation index had a non-significant correlation with different abiotic factors of the environment.

4.3 Biology of *H. vigintioctopunctata*

4.3.1 Description and measurement of developmental stages

Egg

The females deposited eggs in clusters of 5-85 eggs on the underside of the leaves. The freshly laid eggs were yellow, cigar-shaped, oval in shape (Plate 2a) and turned pale prior to hatching. The eggs were pointed distally and placed vertically in clusters. The length of eggs ranged between 1.295 to 1.540 mm with the mean value of 1.390 mm and that of breadth from 0.420 to 0.490 mm with the mean of 0.469 mm (Table 4.5).

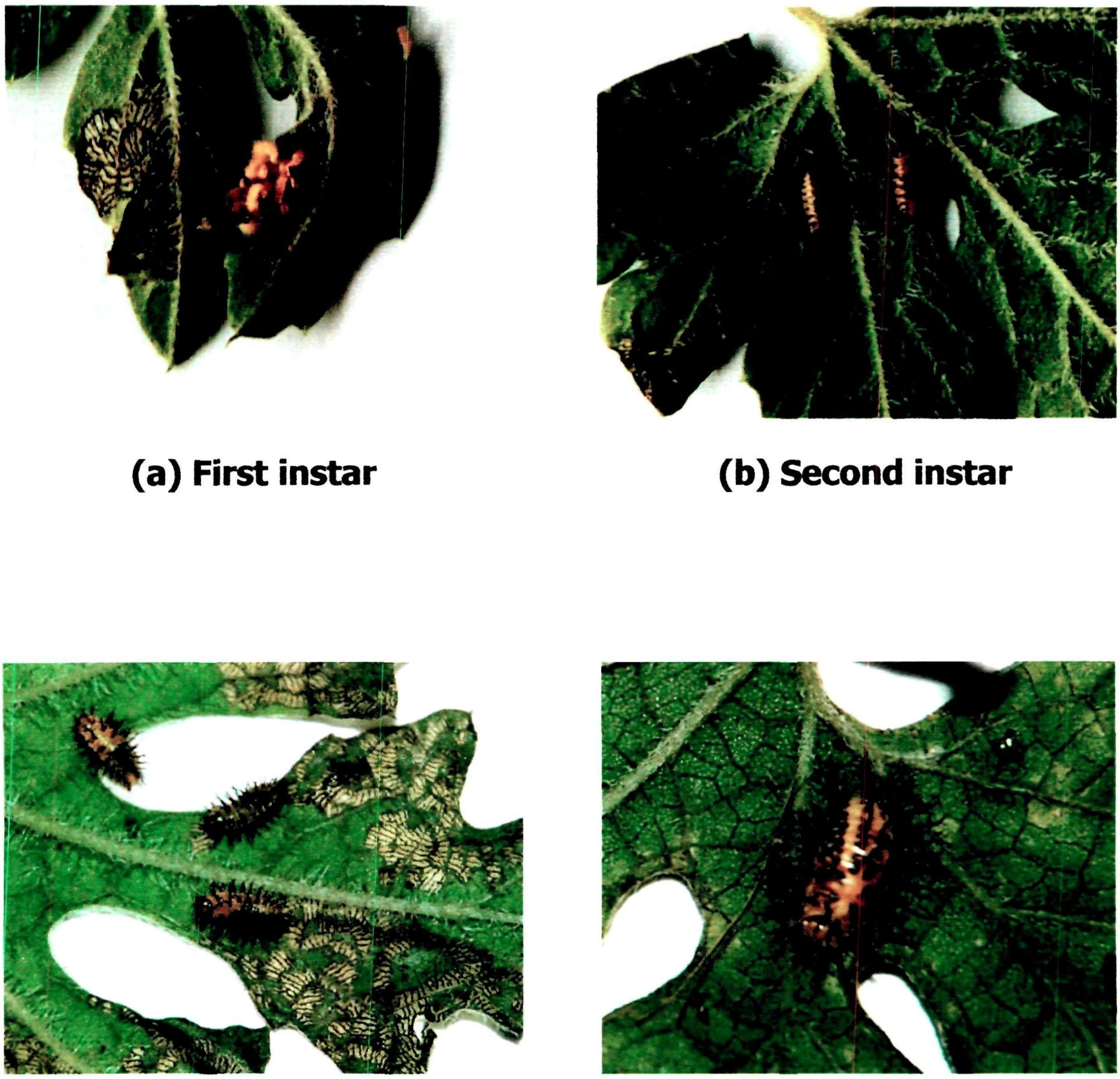
Table 4.5 Morphometric studies on different developmental stages of *H. vigintioctopunctata*

Stage	Length (mm)		Breadth (mm)	
	Range	Mean ± S.E.	Range	Mean ± S.E.
Eggs	1.295-1.540	1.390±0.024	0.420-0.490	0.469±0.008
Grubs				
I	0.945-1.680	1.411±0.086	0.455-0.560	0.501±0.011
II	2.310-2.485	2.433±0.022	0.470-0.875	0.840±0.012
III	4.000-5.000	4.500±0.167	2.000-3.000	2.500±0.167
IV	9.000-12.000	9.800±0.416	4.000-5.000	4.400±0.163
Pupae	8.000-10.000	8.700±0.213	4.000-5.000	4.900±0.100
Adult				
Male	6.000-7.000	6.800±0.133	4.000-5.000	4.800±0.133
Female	7.000-8.000	7.600±0.163	5.000-6.000	5.400±0.163

*** Based on 10 observations**

Grubs

There were four larval instars. The freshly hatched grubs were light yellow in colour, elongate and oval (Plate 1a). They possessed functional legs and crawled throughout the leaf on which they hatched. The first and second



(a) First instar

(b) Second instar

(c) Third instar

(d) Fourth instar

Plate 1. Different larval instars of *H. vigintioctopunctata*

instar grubs made pin hole injuries whereas the later instars were voracious feeders. The thoracic and abdominal segments were covered with six rows of branched spines which were further divided into 3-7 sub-branches (Plate 1b, c, d). The length and breadth of the first instar grubs ranged from 0.945 to 1.680 mm (mean : 1.411 mm) and 0.455 to 0.560 mm (mean : 0.501), respectively. The average length and breadth of second instar was 2.433 and 0.840 mm, of third was 4.500 and 2.500 mm and that of fourth instar was 9.800 and 4.400 mm, respectively.

Pupa

The newly formed pupae were yellowish but later turned to creamish brown, being hemispherical in shape (Plate 2b). The exuviae of last instar remained attached to the tail end of the pupa. The length and breadth of the pupa varied from 8.000 to 10.000 mm (8.700 mm) and 4.000 to 5.000 mm (4.900 mm), respectively.

Adult

The adult beetles were yellowish-brown dorsally and paler ventrally and were hemispherical in shape (Plate 2c). Each elytron of both the sexes had 9-14 spots. The adults were pubescent. The females were larger than the males and measured 7.600 mm in length and 5.400 mm in breadth, whereas in males, the corresponding values were 6.800 mm and 4.800 mm, respectively.

4.3.2 Life-cycle

4.3.2.1 Number of generations

Under laboratory conditions, the hadda beetle when reared on bitter gourd completed 4 overlapping generations during July– November lasting from July 1 – July 28, August 3 – August 27, September 2 – October 7 and October 13 – November 19 during the year 2005 (Table 4.6).

(a) Eggs

(b) Pupa

(c) Adults

Plate 2. Egg, pupa and adult of *H. vigintioctopunctata*

Table 4.6 Number of generations of *H. vigintioctopunctata* on bitter gourd under laboratory conditions

Generation	Period	Mean temperature (°C)		Mean RH
		Minimum	Maximum	(%)
I	July 1- July 28	19.8	26.2	87.0
		(17.5-22.5)	(23.0-29.0)	(74.0-100.0)
II	August 3- August 27	21.4	27.3	83.7
		(17.4-25.3)	(24.0-32.5)	(68.0-98.0)
III	September 2-October 7	17.9	25.5	79.3
		(15.2-20.8)	(19.5-29.5)	(61.0-99.0)
IV	October 13-November 19	10.7	23.1	55.0
		(6.6-13.6)	(20.0-26.8)	(33.0-73.0)

Figures in parentheses are the range values

4.3.2.2 Developmental biology

Biology of different developmental stages of *H. vigintioctopunctata* was studied on bitter gourd under laboratory conditions and the observations recorded on duration and survival are being presented in Table 4.7 and 4.8.

Among the different developmental stages, larva occupied the longest duration (mean: 19.1days) followed by pupa (mean: 8.0 days) and egg (mean: 3.9 days) whereas, the survival was maximum in the egg stage (mean: 90.9%) followed by pupa (mean: 28.2%) and larva (mean: 21.5%) but the survival from pupal stage to adult emergence was recorded to be the least with the mean survival of 5.4 per cent.

Egg

The incubation period ranged between 3.3-5.0 days and was influenced by the prevailing temperature during different generations, but non-significantly.

Table 4.7 Developmental biology of *H. vigintioctopunctata* during different generations on bitter gourd

Generation	Duration of developmental stage (Days)							
	Egg	Larval instar					Pupa	Total development (egg-adult emergence)
		I	II	III	IV	Total larval period		
I	3.3 (3-4)	3.7 (3-4)	3.0 (3-4)	3.0 (3-4)	6.0 (5-7)	15.7 (15-16)	7.7 (7-9)	27.3 (26-29)
II	3.3 (3-4)	3.0 (3-4)	3.7 (3-5)	2.3 (2-3)	5.3 (3-7)	14.0 (13-15)	7.3 (7-8)	24.3 (23-26)
III	4.3 (3-6)	3.3 (3-4)	5.0 (3-7)	5.7 (5-7)	7.7 (7-8)	22.3 (21-23)	8.3 (8-9)	35.0 (28-41)
IV	5.0 (4-6)	3.7 (3-5)	5.7 (5-7)	6.0 (5-7)	8.7 (8-9)	24.3 (22-26)	8.7 (8-9)	38.3 (38-40)
Mean	3.9	3.4	4.4	4.3	6.9	19.1	8.0	31.2
$CD_{(p=0.05)}$	N.S.	N.S.	N.S.	1.54	1.63	2.03	N.S.	6.66

*** Figures in parentheses are the range values**
N.S.: Non – significant

Table 4.8 **Survival of developmental stages of *H. vigintioctopunctata* during different generations**

Generation	Survival (%)							
	Egg	Larva				Total larval survival	Pupal survival	Adult emergence
		I	II	III	IV			
I	97.2 (80.43)	90.3 (72.12)	66.4 (54.59)	58.7 (49.99)	56.2 (48.57)	19.9 (26.45)	29.9 (33.07)	6.3 (14.52)
II	91.7 (73.66)	96.2 (78.79)	93.2 (75.44)	77.2 (61.55)	55.6 (48.19)	38.4 (38.29)	21.7 (27.65)	7.6 (15.92)
III	81.9 (64.96)	81.2 (64.29)	72.2 (58.13)	73.2 (58.83)	37.7 (37.87)	16.2 (23.75)	42.8 (40.8)	5.7 (13.78)
IV	92.9 (74.53)	82.4 (65.15)	75.5 (60.31)	63.5 (52.78)	28.9 (32.39)	11.5 (19.64)	18.7 (25.43)	1.9 (7.91)
Mean	90.9 (73.39)	87.5 (70.09)	76.8 (62.18)	68.2 (55.79)	44.6 (41.76)	21.5 (27.03)	28.2 (31.74)	5.4 (13.03)
C.D.$_{(p=0.05)}$	(6.53)	(4.36)	(5.59)	(3.44)	(6.48)	(4.61)	(5.68)	(2.14)

*** Figures in parentheses are the angular transformed values**

Variation in hatchability of eggs was evident during different generations, which ranged between 81.9 to 97.2 per cent (Table 4.8). It was comparatively more in the generations occurring during the period having high temperature and high relative humidity regimes. Highest hatchability was recorded during July (I) generation followed by August (II) generation which was statistically at par with October- November (generation IV), whereas lowest (81.9%) hatchability was observed in September – October (III) generation.

Grub

Observations recorded on the duration of grubs revealed that the fourth instar occupied the maximum period (mean of different generations being 6.9 days) followed by second and third whereas the mean duration occupied by the first instar was minimum (3.4 days). Among the different generations the duration of first instar was recorded maximum (3.7 days) in first (July) and fourth (October - November) generations followed by September – October (III) generation and was least in August (generation II). All the durations differed non-significantly among the different generations. The second instar occupied the maximum duration (5.7 days) in the October – November (IV) generation whereas it was minimum in the July (I) generation. The differences between the generations being non-significant. The third instar occupied 2.3-6.0 days in different generations and was maximum during fourth (October - November) generation being at par with September-October (generation III), whereas the lowest duration coincided to August (II) generation which in turn was at par with generation occurring during July (generation I). In case of fourth instar, the duration ranged between 3.0-9.0 days. The maximum duration (8.7 days) was recorded in fourth generation occuring during October – November which was significantly at par with the third generation (September – October). The lowest duration (5.3 days) was observed in August (generation II) which was significantly at par with the July (I) generation.

Among the larval instars, the fourth instar experienced the highest mortality as depicted from the minimum mean survival rate of 44.6 per cent followed by third, second and first instar, respectively (Table 4.8). Survival among the first instar grubs varied between 81.2 and 96.2 per cent in different generations, the maximum corresponded to second (August) generation which was significantly more than others. This was followed by the July (generation I) whereas the lowest survival was observed in the September-October (III) generation which was significantly at par with October-November (generation IV). In case of second instar grubs, the maximum survival (93.2%) was observed in August (II) generation which was significantly higher over the other generations followed by October - November (generation IV) with the survival of 75.5 per cent which was statistically at par with the third (September - October) and first (July) generations. The survival ranged between 58.7 to 77.2 per cent, in third instar, the maximum survival was observed in August (generation II) which was significantly at par with the September-October (III) generation whereas, the lowest survival was recorded in first (July) generation which was at par with the October-November (IV) generation with the survival of 63.5 per cent. Survival among the fourth instar grubs varied between different generations and the highest survival (56.2%) was observed in first (July) generation which was statistically at par with August (generation II) followed by third (September-October) generation which in turn was at par with October-November (generation IV).

Total larval period

The total larval period ranged between 13.0 to 26.0 days during different generations, being maximum (24.3 days) in fourth (October - November) generation being statistically at par with the September – October (generation III) followed by first (July) generation which in turn was at par with the August (generation II)

The total larval survival ranged between 11.5 and 38.4 per cent and was maximum during August (generation II) being significantly higher over the other generations. It was minimum in October-November (IV) generation which was statistically at par with the third (September-October) generation.

Pupa

The pupal period varied between 7 to 9 days amongst different generations. The maximum duration (8.7 days) was found in October – November (IV) generation followed by 8.3, 7.7 and 7.3 days in third (September – October), first (July) and second (August) generation, respectively. The differences in duration were non – significant.

Pupal stage experienced survival ranging between 18.7 and 42.8 per cent in different generations. The highest survival was observed in September-October (generation III) which was significantly higher over the other generations and the lowest survival was recorded in October-November (IV) generation being statistically at par with that in August (II) generation.

Total Developmental Period

The total developmental period from egg deposition to adult emergence ranged between 23 - 41 days amongst different generations being minimum (24.3 days) in the second generation which was at par with the duration recorded in first generation. The total developmental period was significantly *maximum in fourth generation occurring* during October – November which was at par with the September – October (III) generation.

Data contained in Table 4.8 revealed very low rate of generation survival as evident from the adult emergence which varied between 1.9 to 7.6 per cent in different generations. The highest adult emergence was observed in August (generation II) being statistically at par with the first (July) and third (September-October) generations whereas the minimum survival was recorded during October-November (IV) generation.

Adult

The temperature influenced the adult longevity greatly being comparatively more in the generations during September-November (Table 4.9). The females lived longer than the males with a life span of 33.7 - 47.0 days in different generations, whereas the male longevity was of 30.3-39.3 days. The female longevity was significantly higher in September – October (III) generation as compared to other generations followed by October – November (generation IV) whereas, it was minimum (33.7 days) in first generation (July) being significantly at par with the August (II) generation.

The pre-oviposition period ranged between 5.7 to 8.7 days during different generations, however, the variation being non-significant (Table 4.9). The oviposition period was highest (32.3 days) during the September-October

Table 4.9 Adult longevity and fecundity of *H. vigintioctopunctata* during different generations

Generation	Duration (Days)					Fecundity (Number of eggs/female)
	Male	Female				
		Pre-oviposition period	Oviposition period	Post-oviposition period	Total longevity	
I	36.0	6.3	11.3	17.0	33.7	290.3
II	30.3	8.7	17.7	10.0	35.3	449.3
III	39.3	5.7	32.3	15.0	47.0	579.7
IV	37.0	6.0	22.7	21.3	41.3	395.3
Mean	35.7	6.7	21.0	15.8	39.3	428.7
$CD_{(p=0.05)}$	3.9	N.S.	4.6	3.6	2.3	85.4

(generation III) being significantly higher over other generations followed by that in October-November (IV) generation whereas the minimum oviposition period (11.3 days) was recorded in July (generation I). The post oviposition period ranged between 10.0 – 21.3 days and was maximum and significantly higher in October – November (IV) generation whereas it was minimum during August (generation II).

The female on an average laid 290.3-579.7 eggs in different generations. Fecundity was comparatively more during the generations occurring from August to October. The maximum egg laying was recorded during September-October (III) generation which was significantly higher than the other generations whereas minimum fecundity corresponded to first (July) generation as presented in Table 4.9.

4.3 Feeding preference

Feeding preference of grubs and adults of bitter gourd population was studied on different hosts in a multiple choice test. Data contained in Table 4.10 on the utilization of different hosts by the bitter gourd population (Plate 3a) of *H. vigintioctopunctata* showed that the population responded differently in utilizing them as host and bitter gourd itself was the most preferred host with the maximum mean scoring (4.0), on the basis of leaf area consumed after 72 hours of feeding, both for the grubs and adults. The solanaceous plants were not at all preferred by the grubs as well as the adults even in the absence of other host plants. Thus the order of preference for grubs was observed as, bitter gourd > cucumber > sponge gourd > pumpkin = ridge gourd > bottle gourd = ash gourd = brinjal = tomato = potato = black night shade and cowpea (Fig. 4.2). Likewise, the order of preference

Table 4.10 Preference of bitter gourd population of *H. vigintioctopunctata* to different hosts on the basis of multiple choice test

Host Plants	Scoring on the basis of extent of damage to leaf area after hours of feeding*							
	Grubs				Adults			
	24	48	72	Average	24	48	72	Average
Ash gourd	0	0	0	0.0	0	0	0	0.0
Bitter gourd	4	Removed	Removed	4.0	4	Removed	Removed	4.0
Black night shade	0	0	0	0.0	0	0	0	0.0
Bottle gourd	0	0	0	0.0	0	0	0	0.0
Brinjal	0	0	0	0.0	0	0	0	0.0
Cowpea	0	0	0	0.0	0	0	0	0.0
Cucumber	1	3	Removed	2.0	0	3	Removed	1.5
Potato	0	0	0	0.0	0	0	0	0.0
Pumpkin	0	1	1	0.7	1	1	1	1.0
Ridge gourd	0	0	2	0.7	0	1	2	1.0
Sponge gourd	0	0	4	1.3	1	0	4	1.7
Tomato	0	0	0	0.0	0	0	0	0.0

***Based on 10 individuals replicated thrice**

Order of preference
Adults: Bitter gourd > sponge gourd > cucumber > pumpkin = ridge gourd > bottle gourd = ash gourd = brinjal = tomato = potato = black night shade = cowpea
Grubs: Bitter gourd > cucumber > sponge gourd > pumpkin = ridge gourd > bottle gourd = ash gourd = brinjal = tomato = potato = black night shade = cowpea

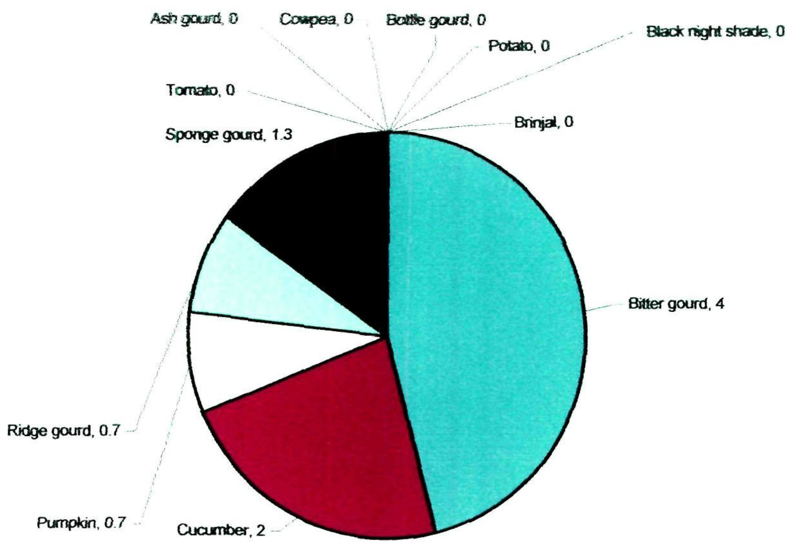


Fig. 4.2 Host preference of grubs of Bitter gourd population of *H. vigintioctopunctata*

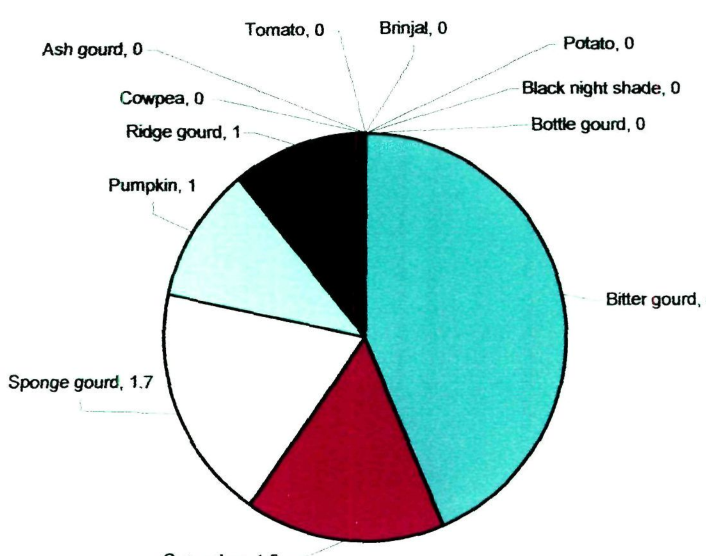
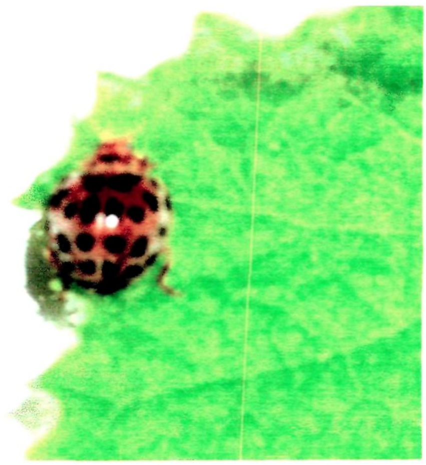


Fig. 4.3 Host preference of adults of bitter gourd population of *H. vigintioctopunctata*

(a) ***H. vigintioctopunctata*** **on bitter gourd**



(b) ***H. vigintioctopunctata*** **on bottle gourd**

(c) ***H. vigintioctopunctata*** **on brinjal**

(d) ***H. dodecastigma*** **on black night shade**

Plate 3. Adults of *H. vigintioctopunctata* and *H. dodecastigma*

worked out for adults was, bitter gourd > sponge gourd > cucumber > pumpkin = ridge gourd > bottle gourd = ash gourd = brinjal = tomato = potato = black night shade and cowpea (Fig. 4.3).

Preference of different populations of *H. vigintioctopunctata* adults to the hosts on the basis of multiple choice test (Table 4.11) revealed the following order of preferences and for bitter gourd population it was, bitter gourd > cucumber > ridge gourd > bottle gourd = tomato = potato = brinjal = black night shade. In case of bottle gourd population (Plate 3b) it was, cucumber > ridge gourd = potato > bottle gourd > bitter gourd = tomato = brinjal = black night shade (Fig. 4.4). The sequence of preference of ridge gourd population was cucumber > ridge gourd > tomato > bitter gourd > bottle gourd = potato = brinjal = black night shade (Fig. 4.5) and that for brinjal population (Plate 3c) was black night shade > brinjal > tomato = potato > bitter gourd = cucumber = ridge gourd = bottle gourd (Fig. 4.6).

4.4 Bioefficacy of insecticides

4.4.1 Intrinsic toxicity

Results pertaining to laboratory bioassay studies of seven insecticides namely, endosulfan (Thiodan 35 EC), malathion (Jythion 50 EC), cypermethrin (Cymbush 25 EC), carbaryl (Sevin 50 WDP), neem (Nimbecidine 0.03%), *Beauveria bassiana* (Biopower $1x10^8$ cfu/g) and novaluron (Rimon 10 EC) using leaf dip method against the third instar grubs and adults of *H. vigintioctopunctata* are being presented in Tables 4.12 - 4.18.

Endosulfan

Bitter gourd leaves dipped in endosulfan concentrations of 0.00625, 0.0125, 0.025, 0.05 and 0.1 per cent when offered to the third instar grubs resulted in mortality of 24.1, 34.5, 51.7, 65.5 and 75.9 per cent in the

Table 4.11 **Preference of different populations of *H. vigintioctopunctata* to the hosts on the basis of multiple choice test**

Host plants	Different adult population of *H. vigintioctopunctata*											
	Scoring of host plants on the basis of extent of damage to leaf area*											
	Bitter gourd adults			Bottle gourd adults			Ridge gourd adults			Brinjal adults		
	24	48	Mean	24	48	Mean	24	48	Mean	24	48	Mean
Bitter gourd	4	Removed	4.0	0	0	0.0	1	0	0.5	0	0	0.0
Black night shade	0	0	0.0	0	0	0.0	0	0	0.0	4	Removed	4.0
Bottle gourd	0	0	0.0	0	1	0.5	0	0	0.0	0	0	0.0
Brinjal	0	0	0.0	0	0	0.0	0	0	0.0	0	3	1.5
Cucumber	1	1	1.0	4	Removed	4.0	4	Removed	4.0	0	0	0.0
Potato	0	0	0.0	1	1	1.0	0	0	0.0	1	1	1.0
Ridge gourd	1	0	0.5	1	1	1.0	1	2	1.5	0	0	0.0
Tomato	0	0	0.0	0	0	0.0	1	1	1.0	1	1	1.0

* **Averaged for 24 and 48 hours of feeding**

Order of preference
Bitter gourd adults: Bitter gourd > cucumber > ridge gourd > bottle gourd = tomato = potato = brinjal = black night shade
Bottle gourd adults: Cucumber > ridge gourd = potato > bottle gourd > bitter gourd = tomato = brinjal = black night shade
Ridge gourd adults: Cucumber > ridge gourd > tomato > bitter gourd > bottle gourd = potato = brinjal = black night shade
Brinjal adults: Black night shade > brinjal > tomato = potato > bitter gourd = cucumber = ridge gourd =bottle gourd

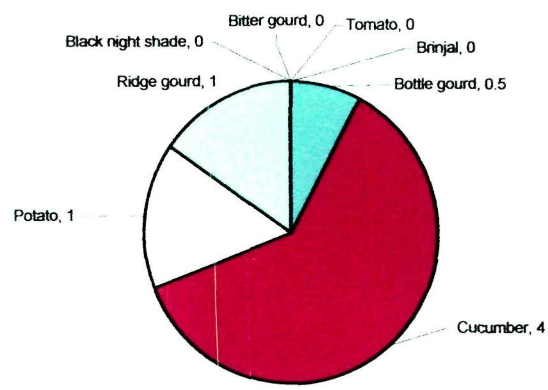


Fig. 4.4 Host preference of bottle gourd population *H. vigintioctopunctata*

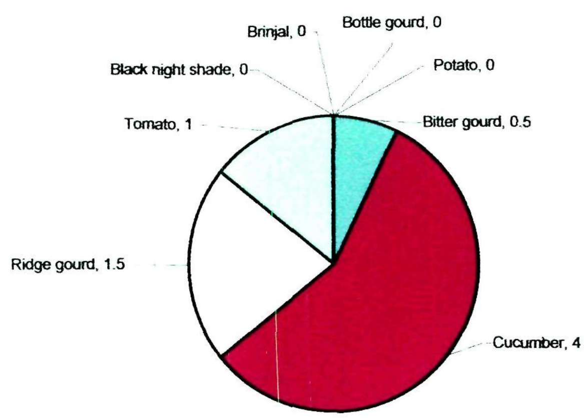


Fig. 4.5 Host preference of ridge gourd population *H. vigintioctopunctata*

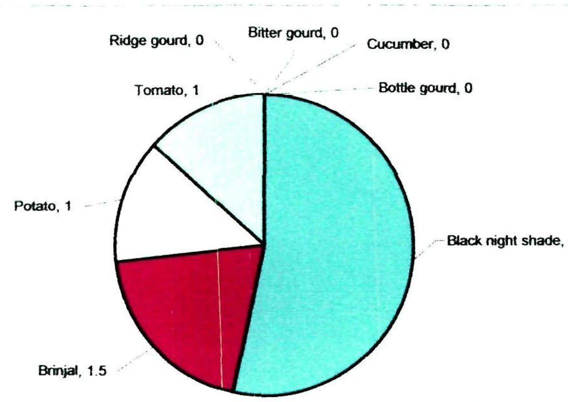


Fig. 4.6 Host preference of brinjal population *H. vigintioctopunctata*

respective concentrations (Table 4.12) after 24 hours of exposure. The data were subjected to probit analysis. The χ^2 (0.0886) test showed the homogeneity of the test population. The regression equation obtained from the data had a slope of 1.2059 (Fig. 4.7a). The LC_{50} value worked out was 0.0242 per cent with fiducial limits of 0.0227 and 0.0257 per cent, the LC_{90} value being 0.2799 per cent with fiducial limits of 0.2769 and 0.2829 per cent.

Table 4.12 Concentration-mortality response of third instar grubs and adults of *H. vigintioctopunctata* to endosulfan

Grubs			Adults		
Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)	Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)
0.00625	0.7959	24.1	0.0125	1.0969	16.7
0.0125	1.0969	34.5	0.025	1.3979	23.3
0.025	1.3979	51.7	0.05	1.6989	36.7
0.05	1.6990	65.5	0.1	2.0000	60.0
0.1	2.0000	75.9	0.2	2.3010	83.3

	Grubs	Adults
Regression equation	y = 3.3307 + 1.2059x	y = 2.4879 + 1.4062x
χ^2	0.0886	4.2170
χ^2 (p= 3df).	7.8	7.8
LC_{50} (Fiducial limit) (%)	0.0242 (0.0227-0.0257)	0.0612 (0.0597-0.0626)
LC_{90} (Fiducial limit) (%)	0.2799 (0.2769-0.2829)	0.4986 (0.4959-0.5014)

Similar bioassay method was followed for the adults with the concentrations 0.0125, 0.025, 0.05, 0.1 and 0.2 per cent when offered to the adults resulted in mortality of 16.7, 23.3, 36.7, 60.0 and 83.3 per cent, respectively (Table 4.12) after 24 hours. The data were subjected to probit

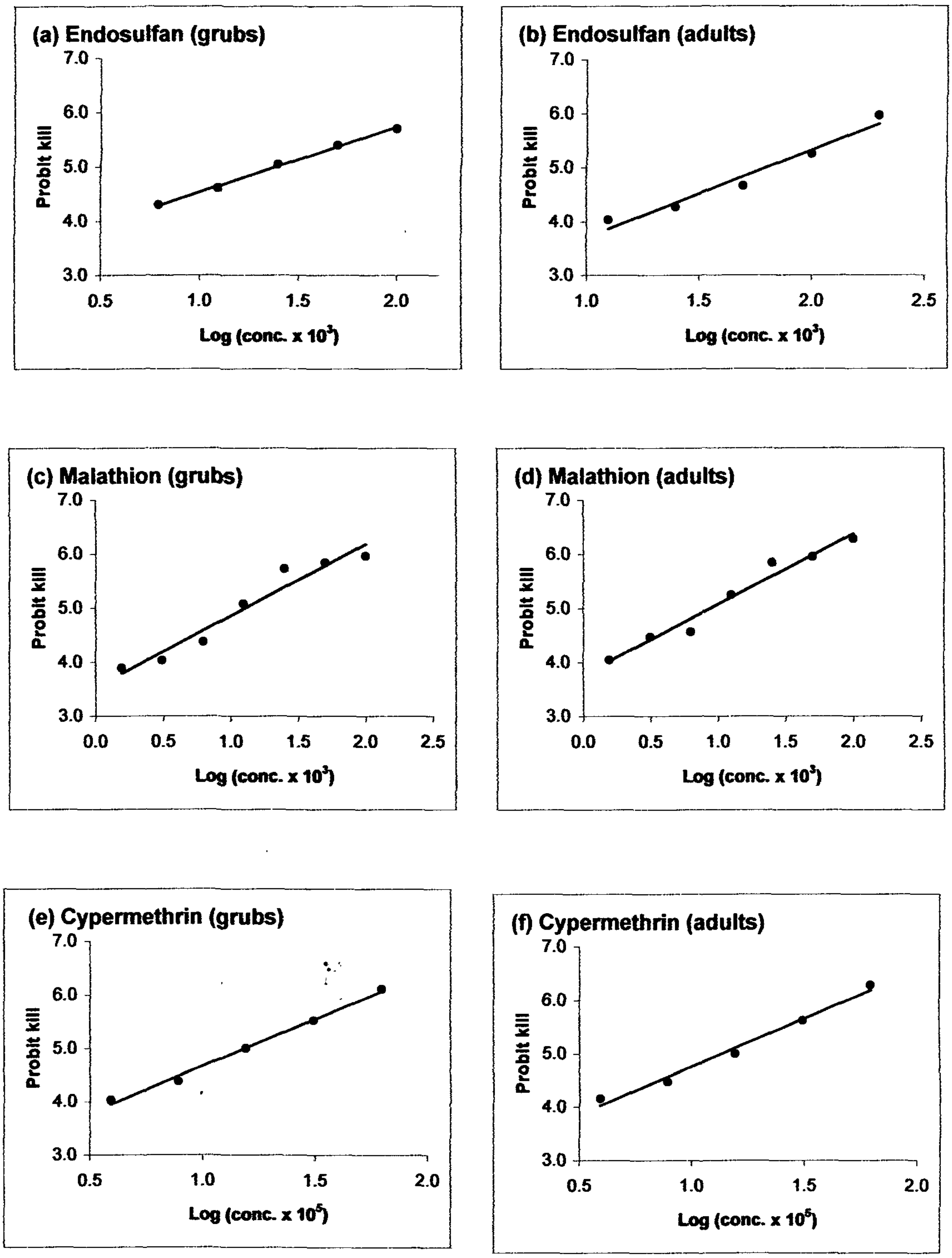


Fig. 4.7 Concentration-mortality response of different insecticides to grubs and adults of hadda beetle

analysis. The χ^2 (4.2170) test showed the homogeneity of the test population .The regression equation (Fig. 4.7b) obtained from the data had a slope of 1.4062. The LC_{50} value worked out was 0.0612 per cent with fiducial limits of 0.0597 and 0.0626 per cent, the LC_{90} value being 0.4986 per cent with fiducial limits of 0.4959 and 0.5014 per cent. No mortality was recorded in control in this case.

Malathion

The third instar grubs of *H. vigintioctopunctata* when fed on bitter gourd leaves dip treated for 30 seconds in malathion concentrations of 0.001563, 0.0031, 0.0063, 0.0125, 0.05 and 0.1 per cent gave 13.3, 16.7, 26.7, 53.3, 76.7, 80.0 and 83.3 per cent mortality, respectively (Table 4.13). The data were homogenous and the LC_{50} value was calculated to be 0.0127 per cent with fiducial limits of 0.0113 to 0.0141 per cent while the LC_{90} value was 0.1171 per cent with the fiducial limits of 0.1153 to 0.1189 per cent. The regression equation obtained from the mortality data had a slope of 1.3299 (Fig. 4.7c).

The adults when fed to the malathion treated leaves at same concentrations gave 16.7, 30.0, 33.3, 60.0, 80.0, 83.3 and 90.0 per cent mortality. The data was homogeneous with χ^2 (2.1957) less than the tabulated value (11.1) (Table 4.13). The LC_{50} value was calculated as 0.0088 per cent with the fiducial limits of 0.0074 to 0.0102 per cent. The LC_{90} value being 0.0823 per cent with fiducial limit of 0.0804 to 0.0841 per cent. The regression equation obtained from the mortality data had a slope of 1.3175 (Fig. 4.7d).

Table 4.13 Concentration-mortality response of third instar grubs and adults of *H. vigintioctopunctata* to malathion

Grubs			Adults		
Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)	Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)
0.0015625	0.1938	13.3	0.0015625	0.1938	16.7
0.003125	0.4949	16.7	0.003125	0.4949	30.0
0.00625	0.7959	26.7	0.00625	0.7959	33.3
0.0125	1.0969	53.3	0.0125	1.0969	60.0
0.025	1.3979	76.7	0.025	1.3979	80.0
0.05	1.6990	80.0	0.05	1.6990	83.3
0.1	2.0000	83.3	0.1	2.0000	90.0

	Grubs	Adults
Regression equation	y = 3.5304 + 1.3299x	y = 3.7583 + 1.3175x
χ^2	3.6168	2.1957
χ^2 (p= 5df).	11.1	11.1
LC_{50} (Fiducial limit) (%)	0.0127 (0.0113-0.0141)	0.0088 (0.0074-0.0102)
LC_{90} (Fiducial limit) (%)	0.1171 (0.1153-0.1189)	0.0823 (0.0804-0.0841)

Cypermethrin

The dose mortality data for the third instar grubs of *H. vigintioctopunctata* is given in Table 4.14 & Fig. 4.7e. It was observed that 0.000039062 per cent cypermethrin gave 16.7 per cent mortality and 0.000625 per cent gave 86.7 per cent mortality. The LC_{50} and LC_{90} values were calculated to be 0.00015 and 0.00083 per cent with fiducial limits of 0.00014 to 0.00017 per cent and 0.00081 to 0.00085 per cent, respectively.

Table 4.14 Concentration-mortality response of third instar grubs and adults of *H. vigintioctopunctata* to cypermethrin

Grubs			Adults		
Concentration (%)	Log (conc.x 10^5) x	Corrected mortality (%)	Concentration (%)	Log (conc.x 10^5) x	Corrected mortality (%)
0.000039062	0.5917	16.7	0.000039062	0.5917	20.0
0.000078125	0.8928	26.7	0.000078125	0.8928	30.0
0.00015625	1.1938	50.0	0.00015625	1.1938	50.0
0.0003125	1.4949	70.0	0.0003125	1.4949	73.3
0.000625	1.7959	86.7	0.000625	1.7959	90.0

	Grubs	Adults
Regression equation	y = 2.9200 +1.7522x	y = 2.9917 +1.7573x
χ^2	0.3847	0.7533
χ^2 (p= 3df).	7.8	7.8
LC_{50} (Fiducial limit) (%)	0.00015 (0.00014-0.00017)	0.00014 (0.00013-0.00015)
LC_{90} (Fiducial limit) (%)	0.00083 (0.00081-0.00085)	0.00075 (0.00073-0.00076)

The adults subjected to same concentrations showed 20.0 and 90.0 per cent mortality at 0.000039062 and 0.000625 per cent concentrations. The data were homogenous with the calculated value of χ^2 being 0.7533.The LC_{50} value was 0.00014 per cent with the fiducial limit of 0.00013 to 0.00015 per cent and LC_{90} value being 0.00075 per cent with the fiducial limit of 0.00073 to 0.00076 per cent (Fig. 4.7f).

Carbaryl

The per cent corrected mortality in carbaryl treatments (ranging from 0.000391 to 0.2 %) was found to vary between 16.7 to 86.7 per cent respectively in case of third instar grubs, 24 hours after treatment (Table 4.15). The data was homogenous and the regression equation had a slope of 0.7218 (Fig. 4.8a). The LC_{50} value was found to be 0.0044 per cent with fiducial limits of 0.0042 to 0.0045 per cent while the LC_{90} value was 0.2594 per cent with fiducial limits of 0.2591 and 0.2597 per cent.

Table 4.15 Concentration-mortality response of third instar grubs and adults of *H. vigintioctopunctata* to carbaryl

Grubs			Adults		
Concentration (%)	Log (conc. x 10^4) x	Corrected mortality (%)	Concentration (%)	Log (conc. x 10^4) x	Corrected mortality (%)
0.00039062	0.5918	16.7	0.000195312	0.2907	23.3
0.00078125	0.8928	26.7	0.00039062	0.5918	33.3
0.0015625	1.1938	43.3	0.00078125	0.8928	46.7
0.003125	1.4949	50.0	0.0015625	1.1938	56.7
0.00625	1.7959	56.7	0.003125	1.4949	73.3
0.0125	2.0969	63.3	0.00625	1.7959	80.0
0.0250	2.3979	66.7	0.0125	2.0969	90.0
0.0500	2.6989	80.0			
0.1000	3.0000	83.3			
0.2000	3.3010	86.7			

Regression equation	y = 3.8172 +0.7218x	y = 3.9249 +1.0951x
χ^2	1.5518	0.1778
χ^2 (p= 8df).	15.5	11.1 (p=5df)
LC_{50} (Fiducial limit) (%)	0.0044 (0.0042-0.0045)	0.0009 (0.0008-0.0011)
LC_{90} (Fiducial limit) (%)	0.2594 (0.2591-0.2597)	0.0142 (0.0139-0.0144)

The per cent corrected mortality in case of adults in treatments (ranging from 0.000195 to 0.0125 %) was found to vary between 23.3 to 90 per cent, respectively, after 24 hours of treatment. The χ^2 calculated value (0.1778) was less than the tabulated value (11.1) and proved the homogeneity of the data. The regression equation had a slope of 1.0951 (Fig. 4.8b). The LC_{50} value was 0.0009 per cent with fiducial limits of 0.0008 to 0.0011 per cent and the LC_{90} values being 0.0142 with the fiducial limits of 0.0139 to 0.0144 per cent.

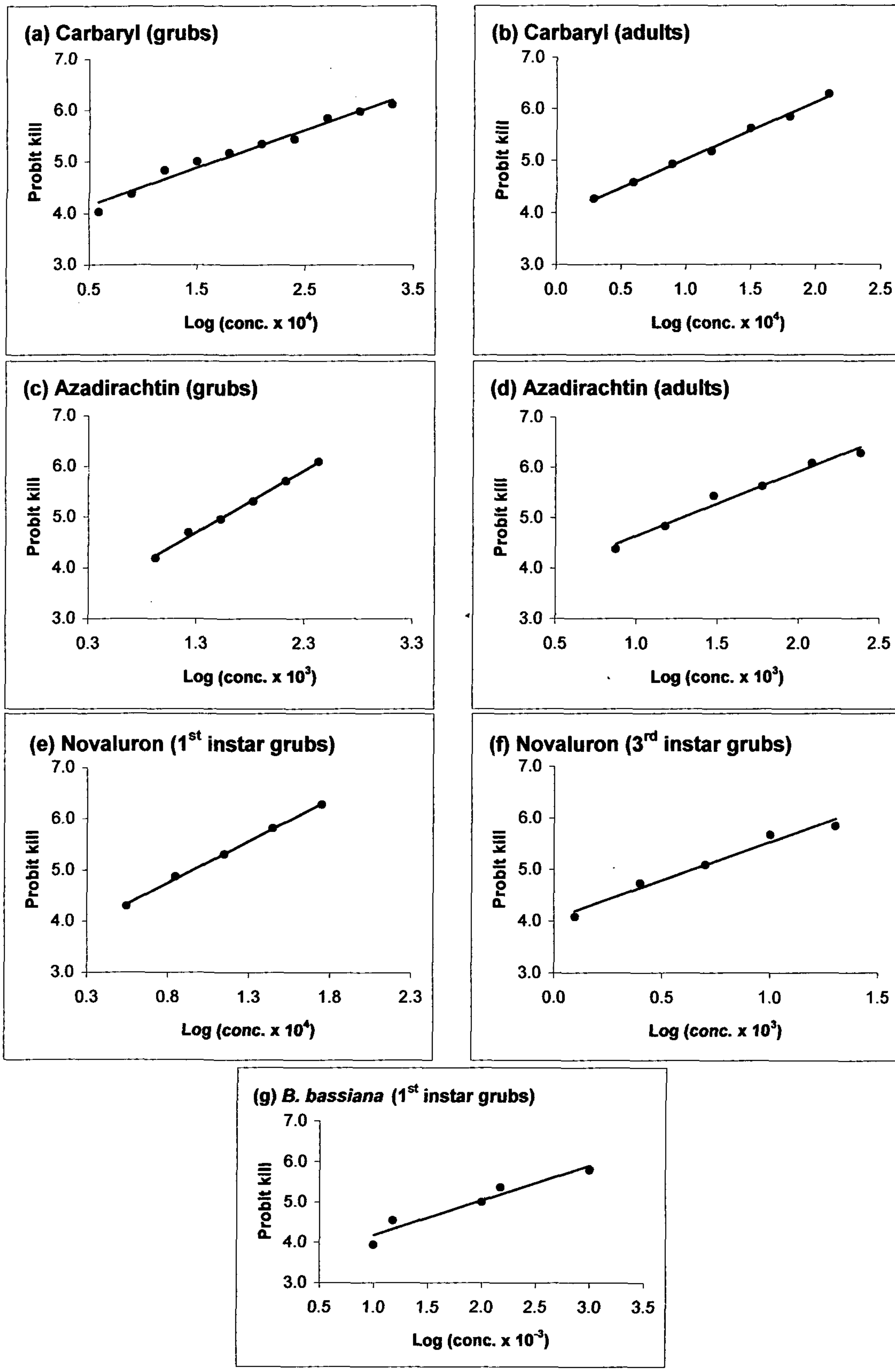


Fig. 4.8 Concentration mortality response of different insecticides to grubs and adults of hadda beetle

Neem

The dose mortality data for the third instar grubs and adults of *H. vigintioctopunctata* revealed a mortality of 20.7, 37.9, 48.2, 62.1, 75.9, 86.2 per cent and 26.7, 43.3, 66.7, 73.3, 86.0 and 90.0 per cent respectively at azadirachtin concentrations of 0.0075, 0.015, 0.03, 0.06, 0.12 and 0.24 per cent, respectively after 72 hours of treatment. The χ^2 test confirmed the homogeneity of the test population. The regression equation had a slope of 1.2101 (Fig. 4.8c) for the grubs and 1.2860 (Fig. 4.8d) for the adults. The LC_{50} and LC_{90} values for the grubs were 0.0316 and 0.3617 per cent with the respective fiducial limits of 0.0301 to 0.0330 and 0.3594 to 0.3639 per cent. The LC_{50} and LC_{90} values for the adults were 0.0189 per cent with fiducial limits of 0.0175 to 0.0205 and 0.1885 per cent with fiducial limit of 0.1865 to 0.1904 per cent, respectively (Table 4.16).

Table 4.16 Concentration-mortality response of third instar grubs and adults of *H. vigintioctopunctata* to neem (azadirachtin)

Grubs			Adults		
Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)	Concentration (%)	Log (conc. x 10^3) x	Corrected mortality (%)
0.0075	0.8751	20.7	0.0075	0.875	26.7
0.015	1.1761	37.9	0.015	1.176	43.3
0.03	1.4771	48.2	0.03	1.477	66.7
0.06	1.7782	62.1	0.06	1.778	73.3
0.12	2.0792	75.9	0.12	2.079	86.0
0.24	2.3802	86.2	0.24	2.380	90.0

	Grubs	Adults
Regression equation	y = 3.1857 +1.2101x	y = 3.3556 + 1.2860x
χ^2	0.2077	0.9651
χ^2 (p= 4df).	12.6	12.6
LC_{50} (Fiducial limit) (%)	0.0316 (0.0301-0.0330)	0.0189 (0.0175-0.0205)
LC_{90} (Fiducial limit) (%)	0.3617 (0.3594-0.3639)	0.1885 (0.1865-0.1904)

Beauveria bassiana

Bitter gourd leaves treated with *B. bassiana* concentrations of 1 x 10^4, 1.5 x 10^4, 1 x 10^5, 1.5 x 10^5 and 1 x 10^6 cfu/ml and offered to the first instar grubs of *H. vigintioctopunctata* resulted in corresponding mortality of 14.3, 32.1, 49.9, 64.3 and 78.6 per cent respectively after 72 hours. The regression line had a slope of 0.8526. The LC_{50} and LC_{90} values were calculated as 8.7204 x 10^4 and 2.7783 x 10^6 cfu/ml with the fiducial limits of 8.5412 x 10^4 to 8.8997 x 10^4 and 2.7741 x 10^6 to 2.7825 x 10^6 per cent, respectively (Table 4.17 & Fig. 4.8g).

Table 4.17 Concentration- mortality response of first instar grubs of *H. vigintioctopunctata* to *Beauveria bassiana*

Concentration (cfu / ml)	Log (conc. x 10^{-3}) x	Corrected mortality (%)
1 x 10^4	1.0000	14.3
1.5 x 10^4	1.1761	32.1
1 x 10^5	2.0000	49.9
1.5 x 10^5	2.1761	64.3
1 x 10^6	3.0000	78.6

Regression equation	y = 3.3456 +0.8526x
χ^2	2.2275
χ^2 (p= 3df).	7.8
LC_{50} (Fiducial limit) (cfu / ml)	8.7204 x 10^4 (8.5412 x 10^4- 8.8997x 10^4)
LC_{90} (Fiducial limit) (cfu / ml)	2.7783 x10^6 (2.7741x 10^6- 2.7825x10^6)

Novaluron

The dose mortality data for the first and third instar grubs of *H. vigintioctopunctata* is given in Table 4.18. It was observed that 0.000313 per cent novaluron gave 24.1 per cent mortality and 0.005 per cent gave 89.7 per cent mortality in first instar grubs 72 hours after treatment. The χ^2 test confirmed the homogeneity of the test population. The regression equation had a slope of 1.6301 Fig. 4.8e. The LC_{50} and LC_{90} values were calculated to be 0.0008 per cent with fiducial limits of 0.0007 to 0.0009 per cent and 0.0049 per cent with fiducial limits of 0.0047 to 0.0051 per cent, respectively.

Table 4.18 Concentration-mortality response of grubs of *H. vigintioctopunctata* to novaluron (Rimon)

First instar			Third instar		
Concentration (%)	Log (conc. x 10^4) x	Corrected Mortality (%)	Concentration (%)	Log (conc. x 10^3) x	Corrected Mortality (%)
0.0003125	0.4949	24.1	0.00125	0.0969	17.9
0.000625	0.7959	44.8	0.0025	0.3979	39.3
0.00125	1.0969	62.1	0.005	0.6990	53.6
0.0025	1.3979	79.3	0.01	1.0000	75.0
0.0050	1.6990	89.7	0.02	1.3010	80.0

	First instar	Third instar
Regression equation	y = 3.5268 +1.6301x	y = 4.0687 + 1.4671x
χ^2	0.0776	0.8151
χ^2 (p= 3df).	7.8	7.8
LC_{50} (Fiducial limit) (%)	0.0008 (0.0007-0.0009)	0.0043(0.0029-0.0057)
LC_{90} (Fiducial limit) (%)	0.0049 (0.0047-0.0051)	0.0322 (0.0301-0.0343)

The per cent corrected mortality in novaluron treatments (ranging from 0.00125 to 0.02 %), against third instar grubs was found to vary between 17.9 to 80.0 per cent, respectively after 72 hours of treatment. The data were subjected to probit analysis. The χ^2 calculated (0.8151) was found to be less than tabulated value (7.8) and proved the homogeneity of the data. The regression equation had a slope of 1.4671 (Fig. 4.8f). The LC_{50} value was found to be 0.0043 per cent with fiducial limits of 0.0029 to 0.0057 per cent whereas the LC_{90} value was found to be 0.0322 per cent with fiducial limits of 0.0301 to 0.0343 per cent.

4.5.2 Field efficacy

Field efficacy of seven insecticides namely endosulfan (0.05%), malathion (0.05%), cypermethrin (0.0075%), carbaryl (0.1%), azadirachtin (0.03%), *B. bassiana* (1 x 10^9 cfu / l) and novaluron (0.007%) was evaluated against *H. vigintioctopunctata* on bitter gourd.

A perusal of the data presented in Table 4.19 revealed that the pest population (grubs, pupae and adults) at the initiation of the experiment ranged between 15.11 to 36.22 / plant. Among all the treatments, carbaryl was the most effective with the highest mean reduction in population (86.23%) which was statistically at par with endosulfan. Other treatments resulted in significantly lower reduction in population whereas, the lowest mean reduction in population (30.93%) over untreated check corresponded to novaluron. One day after treatment (DAT) all the synthetic insecticides brought about significantly higher reduction in population ranging between 43.12 to 93.59 per cent, the maximum coinciding with cypermethrin followed by carbaryl whereas the mean reduction in population irrespective of treatment was highest (71.26%) and significantly superior than fifteen DAT followed by seven, one, three and five days after treatment.

At Three DAT, cypermethrin treatment reflected highest per cent reduction (85.64%) in population over control which was at par with carbaryl followed by endosulfan. Five DAT endosulfan showed maximum reduction in

Table 4.19 Field efficacy of some insecticides against *H. vigintioctopunctata* on bitter gourd

Insecticide	Concentration (%)	Pre-Count (No. of larvae+ adults/ plant)	Per cent reduction in population over untreated check after days of treatment					
			1	3	5	7	15	Mean
Endosulfan (Thiodan 35 EC)	0.05	30.78	69.77 (56.68)	71.81 (57.93)	87.00 (68.91)	96.43 (79.07)	96.43 (79.07)	84.29 (68.33)
Malathion (Jythion 50 EC)	0.05	28.33	43.12 (41.01)	53.83 (47.18)	54.80 (47.77)	55.38 (48.08)	53.42 (46.97)	52.11 (46.20)
Cypermethrin (Cymbush 25 EC)	0.0075	28.67	93.59 (75.85)	85.64 (67.91)	68.26 (56.04)	73.69 (59.21)	82.22 (65.09)	80.68 (64.82)
Carbaryl (Sevin 50 WDP)	0.1	22.34	88.26 (69.99)	78.78 (69.29)	81.84 (65.28)	84.74 (67.02)	97.55 (80.96)	86.23 (70.51)
Azadiractin (Nimbecidine 0.03 %)	0.03	15.11	67.36 (58.61)	64.45 (53.38)	30.82 (33.63)	78.58 (62.55)	81.90 (64.90)	64.62 (54.61)
B.bassiana (Biopower 1x 10^8 cfu/g)	1x 10^9 cfu/l	26.89	43.68 (41.32)	52.20 (46.25)	74.50 (59.76)	42.54 (40.65)	55.73 (48.29)	53.73 (47.25)
Novaluron (Rimon 10 EC)	0.007	36.22	36.31 (36.97)	33.68 (35.29)	28.78 (32.21)	24.29 (29.39)	31.58 (34.08)	30.93 (33.59)
Mean			63.16 (54.35)	62.91 (53.88)	60.86 (51.94)	65.09 (55.14)	71.26 (59.91)	
Untreated check**		27.78	44.44	54.04	72.93	111.29	152.39	
$CD_{(p=0.05)}$			Treatments		4.99			
			Days after treatment		4.22			
			Treatment x days after treatment		11.15			

*** *Figure in parentheses are the angular transformed values***
**** No. of larvae and adults per plant**

population (87.00 %) which was at par with carbaryl followed by *B. bassiana* and cypermethrin but both were at par with each other. Seven DAT of endosulfan showed 96.43 per cent reduction followed by carbaryl (84.74%) which was at par with neem. At fifteen DAT the highest reduction was in case of carbaryl (97.55%) which was at par with endosulfan (96.43%) followed by cypermethrin which was at par with neem.

In all, cypermethrin was most effective with highest per cent reduction in population over untreated check one and three DAT. Overall, novaluron was found to be least effective with the lowest per cent reduction in population of 31.58 per cent.

Discussion

Chapter V

DISCUSSION

Hadda beetle, *H. vigintioctopunctata* (Fabricius) is an important pest of solanaceous and cucurbitaceous vegetable crops. Both the adults and grubs of the beetle cause extensive damage to the leaves by feeding on the green matter in characteristic manner. The skeletonized leaves ultimately dry up and drop prematurely thus adversely affecting the plant growth and yield. During the present investigation the work has been done on the bioecology and management of this pest. The results obtained are discussed in this chapter.

5.1 Host Range

In surveys conducted in low and mid hills areas of Himachal Pradesh, *H. vigintioctopunctata* was found to infest ten species belonging to two families namely Cucurbitaceae and Solanaceae which included six and four plant species, respectively. Earlier, Anand *et al.* (1988) reviewed 40 host plants for *H. vigintioctopunctata* majority of them belonging to Solanaceae (17 species) and Cucurbitaceae (12 species). Pandey and Shankar (1975) and Rajagopal and Trivedi (1989) had also reported Cucurbitaceae and Solanaceae as the major families infested by *H. vigintioctopunctata*.

5.2 Seasonal abundance

The activity of the pest was found from August to October on bitter gourd at Palampur during 2005. The total population (grubs, pupae and adults) continued to increase and attained its peak in the first week of September

(8.4 / plant). Thereafter the population showed some fluctuation and then a declining trend upto mid of October. There is a lot of variation in the occurrence of pest in different regions of the country as reported by various workers. Ramzan *et al.* (1990) studied the seasonal abundance of the pest on seven solanaceous plants at Ludhiana, Punjab and reported that the population of the grubs started building up on brinjal from April and reached its peak in June, thereafter there was a sharp decline touching to zero in October. Whereas the adults were found from April to November with minimum population in July. The occurrence of the pest at different time periods may be attributed to varied climatic conditions of the regions. Mall *et al.* (1992) also found that epilachna beetle was recorded from third week of August to middle of October at Kanpur with its maximum population of 0.22 beetle per leaf in the middle of September on brinjal when the average temperature and humidity were about 28^0C and 80 per cent, respectively. The population gradually declined and disappeared probably due to fall in temperature and humidity. In West Bengal, the highest average population (8.14 beetle / plant) was recorded in middle of September on brinjal (Ghosh and Senapati 2001). Similarly, Banerjee *et al.* (2003) reported the incidence of epilachna beetle maximum during same period on bitter gourd in West Bengal. The incidence was low to moderate in October and very low in November.

The correlation studies in the present investigation revealed a significantly positive relationship of egg and grub population with the minimum temperature. This indicated that there is a definite increase in number of eggs and grubs with the increase in minimum temperature. Whereas the adult population was negatively and significantly correlated with relative humidity (RH) signifying the influences of lower RH (55-79%) as compared to high RH levels. However, wind velocity had positive and significant correlation with adult population.

5.3 Biology of *H. vigintioctopunctata*

5.3.1 Description and measurements of developmental stages

The females deposited eggs in clusters of 5-85 eggs on the underside of the leaves. The eggs were yellow, oval in shape and turned pale prior to hatching. The eggs were pointed distally and placed vertically in clusters. The average length and breadth of eggs was 1.390 and 0.469 mm respectively. The results on description are fully supported by Kaur and Mavi (2005), however, the measurements recorded by them were towards the lower side (1.09 mm length and breadth 0.32mm) on brinjal.

The pest had four larval instars which were yellow in colour. The thoracic and abdominal segments were covered with branched spines which were further divided into 3 – 7 sub – branches. The average length of the first, second, third and fourth instar were 1.411, 2.433, 4.500 and 9.800 mm with their respective breadths of 0.501, 0.840, 2.500 and 4.400 mm. The results on description are in line with those reported by Kaur and Mavi (2005) with 1.90, 2.97, 4.45 and 6.80 mm in length and 0.71, 1.01, 1.79 and 3.28 mm in breadth on brinjal.

The newly formed pupae were yellowish but later turned to creamish brown. The exuviae of last instar remained attached to the tail end of the pupa and shape was hemispherical. The mean values of length and breadth were 8.7 and 4.9 mm, respectively.

The male and the female were metallic brown in colour and were hemispherical in shape. There were 9 to 14 black spots on each elytron of both the sexes. The adult beetles were pubescent. The females were bigger than the male as they measured 7.6 and 6.8 mm in length and 5.4 and 4.8 mm in breadth, respectively.

5.3.2 Life cycle of the hadda beetle

Number of generations

Under laboratory conditions, *H. vigintioctopunctata* completed four overlapping generations on bitter gourd. Kaur and Mavi (2005) reported that there were eight overlapping generations in a year both under the screen house and field conditions on brinjal at Ludhiana (Punjab). The variation in number of generations may be attributed to the different host plants, long duration of brinjal crop as compared to bitter gourd and differences in ecological conditions. Results are in close proximity to those reported by Chen *et al.* (1989) who reported four to five generations annually on different vegetables in China.

Developmental biology

Egg

The incubation period varied from 3.3 to 5.0 days in different generation thus signifying the impact of low temperature in its prolongation. Rajagopal and Trivedi (1989) reported that the incubation period of the pest is 3-

4 days which support the present findings. Ramzan *et al.* (1990) reported that the incubation period was 3.6 days on brinjal, 3.5 days on potato and 4.3 days on *Solanum nigrum* at Ludhiana. Ghosh and Senapati (2001) also reported that the incubation period ranged from 3.5 days to 4.14 days; average being 3.87 days on brinjal in West Bengal. Rath (2005) reported that the incubation period ranged between 2.63 to 3.50 days on different varieties of brinjal in Orissa and his findings give partial support to the results.

The highest survival was observed in egg stage with 90.9 per cent hatchability. Kaur and Mavi (2005) reported the highest hatchability of 91.07 per cent and that corroborate the present findings.

Grub

The duration of first, second, third and fourth instar larva was found to vary between 3.0-3.7, 3.0-5.7, 2.3-6.0 and 5.3-8.7 days, respectively with the total larval period ranging between 14 – 24.3 days in different generations. The findings of Pandey and Shankar (1975) give partial support to the results as they reported that the average larval period was shortest on brinjal (12.0 days) and longest on pumpkin (18.0 days) at Kanpur. Singh and Mukherjee (1987) also reported that the average larval period ranged between 12.08 and 15.45 days on different solanaceous plants at Pantnagar. Ghosh and Senapati (2001) reported that the larval period ranged from 11.78 to 15.56 days on brinjal and was shortest during the months when temperature was high and longest when the temperature was low. Kaur and Mavi (2005) reported that the durations of first, second, third and fourth instars varied from 2-3, 3-5, 3-4 and 3-5 days, respectively whereas the total duration of grubs was 13.60 ± 1.11 days. All the above finding are in partial proximity to the present results. The variations in the present observations can be attributed to host, varying temperature and relative humidity during the course of the study.

Among the larval instars, the fourth instar experienced highest mortality as depicted from the minimum mean survival of 44.6 per cent as compared to 68.2, 76.8 and 87.5 per cent recorded in third, second and first intar, respectively. The low survival rate in later instars may be attributed to unknown infection which caused mortality in them.

Pupa

The pupal period varied between 7.3-8.7 days amongst different generation which were much higher than reported by earlier workers. Singh and Mukherjee (1987) reported it to last for 3.40 to 4.60 days on different solanaceous hosts, at Pantnagar. Ramzan *et al.* (1990) also reported the pupal period to last for 4.3 to 5.5 days on brinjal, potato, *Solanum nigrum* and *Withania somnifera* in Punjab whereas Ghosh and Senapati (2001) reported the pupal period varying from 5.85 to 7.05 days on brinjal during different generation in West Bengal. The pupal period ranged from 4.75 to 5.75 days on brinjal as reported by Rath (2005). The prevailing temperature and relative humidity during the study period *vis-à-vis* host on which the grubs were reared may be responsible for the higher value of pupal period in the present investigation.

The pupal survival was very low ranging between 18.7 to 42.8 per cent and biotic factors responsible for the mortality were the same as in case of grubs.

Total developmental period

The total developmental period indicated a pronounced effect of temperature on the rate of development in different generations. It was found to occupy 24.3 to 38.3 days in different generations. Ghosh and Senapati (2001) reported that the duration of life cycle was recorded minimum (26.74 days) when the temperature ranged from 28.03 to 32.33^{0}C and relative humidity from 65 to 78 per cent whereas longer duration (33.52 days) was recorded in September-October when the temperature ranged from 24.32 to 33.36 ^{0}C and relative humidity 58-70%.

Generation survival was very low as indicated by the adult emergence of 1.9 to 7.6 per cent and this may be due to the unknown infection in pupae which led to less adult emergence.

Adult

The temperature influenced the adult longevity greatly being comparatively more in those generations which experienced low temperature. The females lived longer than the males and their life span irrespective of sex varied from 30.3 to 47.0 days in different generations. Ghosh and Senapati (2001) also reported longer period for females than males on brinjal. Similar findings were reported by Kaur and Mavi (2005) on the longevity of both the sexes which increased during September and October.

The pre-oviposition period ranged between 5.7 to 8.7 days during different generation. The pre-oviposition period as reported by various workers also differed with the host and region. Ramzan *et al.* (1990) reported it 6.0, 8.0

and 15.0 days on *Solanum nigrum,* brinjal and potato, respectively. Ghosh and Senapati (2001) reported the same to vary from 4.96 to 6.95 days on brinjal in different seasons. The pre-ovipostion period was more in the generations which lived through high temperature and vice-versa.

The mean ovipostion period was 21.0 days and was more in the generations where low temperature prevailed whereas Ramzan *et al.* (1990) reported it to vary with the host as they found the oviposition period of 12.7, 15.0 and 35.0 days on brinjal,potato and *Solanum nigrum,* respectively. A lower range of ovipositon period (6.37 to 8.78 days) was reported by Ghosh and Senapati (2001) on brinjal. Kaur and Mavi (2005) reported lower ovipostion period (11.80 days) as obtained in the present study. The post ovipostion period was maximum (21.3 days) in that generation which experienced lowest temperature. Ghosh and Senapati (2001) and Kaur and Mavi (2005) reported a much lower post ovipositon period 5.06 to 6.87 days and 6.00 to 8.00 days, respectively on brinjal.

The fecundity varied from 290.3 to 579.7 eggs in different generations. Ramzan *et al.* (1990) reported that the numbers of eggs laid by the female were 216, 269 and 502 on potato, brinjal and *Solanum nigrum* , respectively. Ghosh and Senapati (2001) reported highest fecundity (272.32 eggs) on brinjal whereas Kaur and Mavi (2005) reported the fecundity to vary from 55 to 237 on the same host.

Feeding preference

Feeding preference of bitter gourd population of *H. vigintioctopunctata* to different hosts revealed that bitter gourd itself was the most preferred host followed by sponge gourd and cucumber. The solanaceous plants were not preferred at all both by grubs and adults of this population. This may be due to the chemical composition of the leaves as cucurbitacins are present in the cucurbit leaves whereas solanaceous leaves have solanine and tomatine contents and are not preferred by those feeding on cucurbit plants which is an indicative of host specific isolated population within this species.

Feeding preference of different populations of *H. vigintioctopunctata* to various hosts revealed that for bottle gourd population cucumber was the most preferred followed by ridge gourd and bottle gourd whereas bitter gourd was not preferred at all. This may be attributed to the presence of momordicasoides in bitter gourd and preference of cucumber and ridge gourd may be due to the texture of leaf. Same is the case with the ridge gourd population. The results find support from the findings of Singh and Mukherjee (1987) who reported that the species feeding on bottle gourd could not feed on brinjal.

Similarly, the population of adults collected from brinjal could not feed on cucurbits and among solanaceous plants the most preferred host was *S. nigrum* followed by brinjal, tomato and potato. The findings of Rajagopal and Trivedi (1989) support the results as they reported that the species feeding on solanaceous plants will not feed on cucurbits.

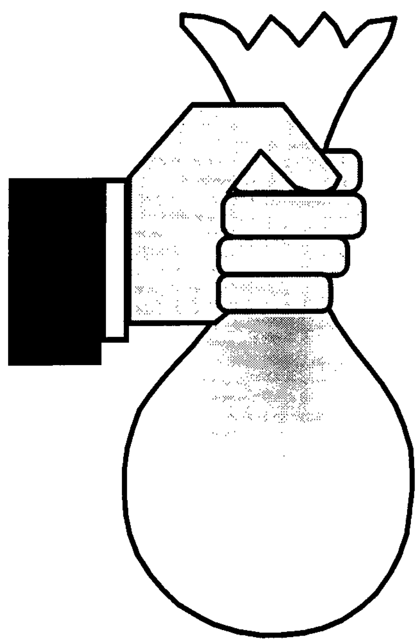
Bioefficacy of Insecticides

Intrinsic toxicity

Bioassay studies were carried out to determine the order of toxicity of seven insecticides following leaf dip method against the third instar grubs as well as adults on the basis of LC_{50} and LC_{90} values. The LC_{50} values for third instar grubs in the decreasing order of toxicity were 0.00015, 0.0043, 0.0044, 0.0127, 0.0242 and 0.0316 per cent for cypermethrin, novaluron, carbaryl, malathion, endosulfan and azadirachtin, respectively whereas it was 8.7204 x 10^4 cfu / ml and 0.0008 per cent for the first instar grubs in case of *B. bassiana* and novaluron, respectively. The LC_{90} values were 0.00083, 0.0322, 0.1171, 0.2594, 0.2799 and 0.3617 percent in case of cypermethrin, novaluron, malathion, carbaryl, endosulfan and azadirachtin, respectively whereas it was 2.7783 x 10^6 cfu / ml and 0.0049 per cent for the first instar grubs in case of *B. bassiana* and novaluron, respectively. The LC_{50} and LC_{90} values for adults in the decreasing order of toxicity were 0.00014, 0.0009, 0.0088, 0.0189 and 0.0612 per cent and 0.00075, 0.0142, 0.0823, 0.1885 and 0.4986 per cent for cypermethrin, carbaryl, malathion, azadirachtin and endosulfan respectively. Kumar and Kumar (1996) reported LC_{50} of malathion and endosulfan to be 0.032 and 0.018 per cent, respectively to the third instar larvae by using direct spray method which slightly differ from those found in the present investigation whereas the LC_{50} of the same insecticides to adults was 0.022 per cent which was 2.5 times higher as compared to that in the present study and 0.013 per cent which was 4.7 times lower as the one obtained in the study. Nagia *et al.* (1992) also reported that mortality to third instar grubs was 100 and 96.67 per cent in cypermethrin (0.005%) and carbaryl (0.05%) 24 hours after treatment on brinjal.

Field Efficacy

The field efficacy of seven insecticides against *H. vigintioctopunctata* revealed carbaryl (0.1%), cypermethrin (0.0075%), endosulfan (0.05%), azadirachtin (0.03%), *B. bassiana* (1 x 10^9 cfu / l), malathion (0.05%) and novaluron (0.007%) to be effective in the decreasing order of toxicity in reducing the population of the pest over untreated check. Rajendran *et al.* (1998) reported that the pest was partially controlled with neem oil 4 per cent on brinjal whereas the application of neem oil (2%) + endosulfan (0.035%) reduced the pest population by over 63 per cent. The findings of Mandal and Kumar (2001) also support the results as they evaluated the efficiency of monocrotophos, quinalphos, cypermethrin and fenvelarate and reported that cypermethrin recorded the highest reduction in pest population at all stages of plant growth of brinjal.



Summary

Chapter VI

SUMMARY

Studies in the present investigation were conducted under laboratory and field conditions during 2005 – 2006 at Palampur. The results obtained are summarized in this chapter.

1. Host range studies revealed that ten plant species belonging to two families were infested by *H. vigintioctopunctata*. Out of these, six plants belonged to family Cucurbitaceae and four to family Solanaceae. The host plants comprised of nine vegetable crops and one medicinal plant.
2. On bitter gourd, the incidence of the pest was first observed on August 10 during 2005 which increased to reach its peak of 8.4 / plant (total population) on September 7. The population of adults was maximum in the last week of September whereas the peak period for grubs and pupae was in the first week of September. The number of eggs were found to be maximum on last week of August. The plant infestation was 100 per cent in the first week of September matching the highest infestation index.
3. The correlation analysis of the population of different developmental stages with the abiotic factors revealed a positive and significant relationship of eggs and grubs with minimum temperature whereas, relative humidity had a negative but significant relationship with the adult population.

4. Biological studies on bitter gourd revealed that *H. vigintioctopunctata* laid eggs on the underside of leaves in clusters of 5-85. The egg length and breadth were 1.390 and 0.469 mm, respectively. There were four larval instars. They were yellow in colour. The thoracic and abdominal segments were covered with branched spines which were further divided into 3 – 7 branches. The average length of the first, second, third and fourth instar larvae was 1.411, 2.433, 4.500 and 9.800 mm with their corresponding breadth of 0.501, 0.840, 2.500 and 4.400 mm. The newly formed pupae were yellowish but later turned to creamish brown. The exuviae of last instar remained attached to the tail end of the pupa and shape was hemispherical. The length and breadth were 8.7 and 4.9 mm, respectively. The male and female were metallic brown in colour and were hemispherical in shape. The spots on each elytron of both the sexes varied from 9 – 14. The adult beetles were pubescent and the females were larger in size as compared to the males with their respective length of 7.6 and 6.8 mm. The corresponding breadth was 5.4 and 4.8 mm.

The pest completed four generations on bitter gourd under laboratory conditions at Palampur. The incubation period varied between 3.3 to 5.0 days in different generations and hatchability was more during July (generation I) when temperature was high. The durations of first, second, third and fourth instar varied between 3.0 – 3.7, 3.0 – 5.7, 2.3 – 6.0 and 5.3 – 8.7 days, respectively in different generations occupying comparatively more period in generations which lived through low temperature conditions. The total larval period was 14.0 – 24.3 days. The fourth instar experienced maximum mortality and was observed least in first instar. The total larval survival varied between 11.5 to 38.4 per cent during different generations. The pupal survival ranged between 18.7 to 42.8 per cent with the pupal period varying between 7.3 to 8.7 days. The total developmental period was from 24.3 to 38.3 days being longer in generations which occurred during September to November and had low temperature regimes being longest in October – November. The adult emergence was found to be very low due to the high mortality rate among the instars and pupa and was found to be 1.9 to 7.6 per cent in different generations and being lowest in generations where temperature was low.

The longevity and fecundity of the adults was influenced by temperature. Females lived for a longer duration as compared to the males and the longevity ranged between 33.7 to 47.0 days for the former and 30.3 to 39.3 days for the latter. The pre - oviposition, oviposition and post – oviposition period ranged between 5.7 – 8.7, 11.3 – 32.3 and 10.0 – 21.3 days, respectively being longer in the generations where temperature was low (September – November). The number of eggs laid per female varied between 290.3 to 579.7 with the mean value of 428.7, being more when temperature was low.

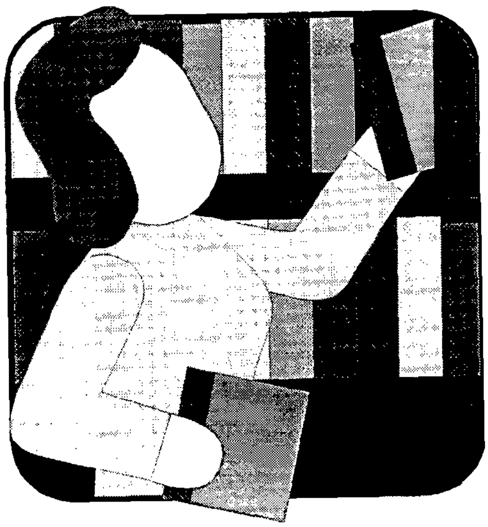
5. Host preference of *H. vigintioctopunctata* on different solanaceous and cucurbitaceous crops in a multiple choice test revealed the order of preference for bitter gourd population for adults as, bitter gourd > sponge gourd > cucumber > ridge gourd = pumpkin > bottle gourd = ash gourd =

potato = tomato = brinjal = black night shade = cowpea. The preference for grubs was bitter gourd > cucumber > sponge gourd > ridge gourd = pumpkin > bottle gourd = ash gourd = potato = tomato = brinjals = black night shade = cowpea.

Host preference of different adult populations was also found to be different. Bottle gourd population had the preference as cucumber > ridge gourd = potato > bottle gourd > bitter gourd = brinjal = tomato = black night shade. The preference of ridge gourd population was cucumber > ridge gourd > tomato > bitter gourd > bottle gourd = brinjal = potato = black night shade whereas brinjal population had the preference as black night shade > brinjal > tomato = potato > bitter gourd = bottle gourd = ridge gourd = cucumber.

6. The toxicity of seven insecticides to grubs and adults of *H. vigintioctopunctata* was evaluated following leaf dip method of bioassay. Cypermethrin was ranked to be the most toxic insecticide followed by novaluron, carbaryl, malathion, endosulfan and azadirachtin with the LC_{50} values for third instar grubs as 0.00015, 0.0043, 0.0044, 0.0127, 0.0242 and 0.0316 per cent whereas it was 8.7204×10^4 cfu / ml and 0.0008 per cent for first instar grubs in case of *Beauveria bassiana* and novaluron, respectively and the LC_{90} values were 0.00083, 0.0322, 0.2594, 0.1171, 0.2799 and 0.3617 per cent and was 2.7783×10^6 cfu / ml and 0.0049 per cent for the first instar grubs in case of *B.bassiana* and novaluron. For adults, the LC_{50} and LC_{90} values were 0.00014, 0.0009, 0.0088, 0.0189 and 0.0612 per cent and 0.00075, 0.0142, 0.0823, 0.1885 and 0.4986 per cent for cypermethrin, carbaryl, malathion, azadirachtin and endosulfan .

The field efficacy of seven insecticides was tested against the pest and revealed that cypermethrin was the most effective which gave maximum per cent reduction of population over untreated check one and three days after treatment whereas the overall reduction fifteen DAT was maximum in case of carbaryl (0.1%) followed by cypermethrin (0.0075%), endosulfan (0.05%), azadirachtin (0.03%), *B. bassiana* (1 x 10^9 cfu / l), malathion (0.05%) and the least effective was novaluron (0.007%).



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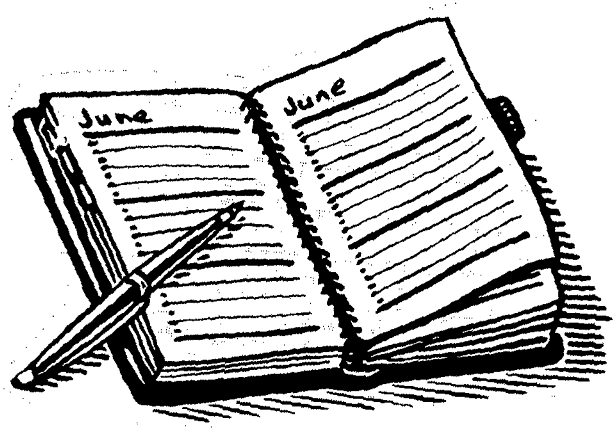

Appendix

Appendix-I

Weekly weather data under field conditions

Date	Temperature (^oC) Minimum	Temperature (^oC) Maximum	Relative humidity (%)	Rainfall (mm)	Wind velocity (kmph)	Bright sunshine (hours)
10-Aug	18.2	26.0	74	0.0	4.2	4.4
17	19.4	24.0	93	55.8	5.0	0.0
24	18.8	28.5	71	1.0	4.5	6.2
31	19.1	26.0	79	0.0	4.0	5.1
7-Sep	20.0	27.5	96	2.9	3.8	1.2
14	16.8	22.0	98	24.0	6.4	0.0
21	18.8	29.5	67	0.0	4.3	9.8
28	15.5	27.0	61	0.0	5.0	7.8
5-Oct	16.0	27.5	64	0.0	5.4	10.0
12	14.8	25.5	80	5.4	6.0	6.0
19	11.2	26.0	57	0.0	6.2	9.9