DEVELOPMENT AND PREDATION EFFICACY OF *Chrysoperla carnea* (STEPHENS) ON SUCKING PESTS OF COTTON.

by

VIJAY KUMAR

(L-94-A-147-M)

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of
MASTER OF SCIENCE
in
ENTOMOLOGY

(Minor Field : Plant Pathology)

Department of Entomology
College of Agriculture
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA-141004

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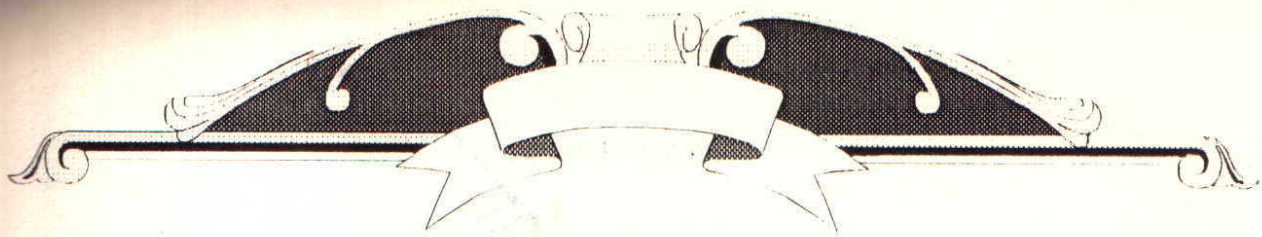

DEDICATED
TO THOSE, WHOM
I CARE MOST....

Dean PG

27.10.97

CERTIFICATE-I

This is to certify that this thesis entitled **"Development and predation efficacy of Chrysoperla carnea (Stephens) on sucking pests of cotton"** submitted for the degree of Master of Science in the subject of **Entomology** [Minor subject: **Plant Pathology**] to the Punjab Agricultural University, is a bonafide research work carried out by **Mr. VIJAY KUMAR (L-94-A-147-M)**, under my supervision and that no part of this thesis has been submitted for any other degree.

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

Ranjit Singh Gill 6-6-97

Major Advisor
(Dr Ranjit Singh Gill)
Assistant Entomologist(Cotton)
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CERTIFICATE-II

This is to certify that this thesis entitled **"Development and predation efficacy of Chrysoperla carnea (Stephens) on sucking pests of cotton"** submitted by **Mr. VIJAY KUMAR (L-94-A-147-M)** to the Punjab Agricultural University, in partial fulfilment of the requirements for the degree of **Master of Science** in the subject of **Entomology** (Minor subject: **Plant Pathology**) has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with an external examiner.

11.8.97

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ABSTRACT

Studies on the development and predation efficacy of Chrysoperla carnea (Stephens) were carried out on nymphs of Aphis gossypii Glover, Amrasca biguttula biguttula (Ishida) and adults of Bemisia tabaci (Gennadius) at a mean minimum and maximum temperature of 21.23 and 26.72°C, respectively in the Biological Control laboratory, Department of Entomology, PAU, Ludhiana during 1995-96. The effect of insecticidal application on larval mortality of C. carnea was also studied. The mean larval period of C. carnea on A. gossypii, A. biguttula biguttula and B. tabaci was 9.47, 10.40 and 9.77 days, respectively. The duration of 1st, 2nd and 3rd larval instars of C. carnea were found to be 3.46, 2.68, 3.30; 3.70, 2.80, 3.90 and 3.42, 2.70, 3.65 days on aphid, jassid and white fly, respectively. The mean pupal period was 8.67, 7.62 and 7.67 days, when aphid, jassid and white fly were provided as prey species. However, the total larval plus pupal period was 18.13, 18.03 and 17.45 days on aphid, jassid and white fly, respectively. C. carnea consumed significantly more number of aphid (447.00) than jassid (284.25) which in turn was significantly higher than white fly (250.40) during its larval development. The average number of aphid, jassid and white fly consumed by 1st, 2nd and 3rd instar larvae of C. carnea were 72.95, 140.67, 233.30; 40.65, 80.02, 163.32 and 33.15, 62.75, 153.70, respectively. Each successive instar consumed more number of preys than the previous one. The prey consumption of 3rd instar larvae was more than the combined consumption of first two instars. Per day consumption of C. carnea larvae on aphid, jassid and white fly was 47.03, 27.34 and 25.69, respectively. Studies

on feeding preference of C. carnea larvae revealed high preference for aphid followed by jassid and white fly. Among the different insecticides, tested for their toxicity to C. carnea, cypermethrin, dimethoate, carbaryl and imidacloprid proved comparatively less toxic to all instars, when exposed to treated host (eggs of Corcyra cephalonica) as well as by direct spray on cotton plants. Endosulfan, chlorpyriphos, monocrotophos, phosphamidon, ethion, and fenitrothion were highly toxic to different instars of C. carnea.

Signature of Major Advisor

Vijay Kumar
Signature of the Student

C O N T E N T S

CHAPTER I

INTRODUCTION

Cotton is India's principal commercial crop with an area of 9.1 million hectare and production of 13.1 million bales (Anonymous, 1996). But its productivity is largely affected by a number of insect pests and diseases. As many as 130 species of insects and few species of mites have been found associated with cotton in India (Sohi, 1964). Among them sucking pests and bollworms are most important as they cause losses in yield and quality of lint and oil. The unwarranted and improper use of pesticides for the control of these pests has led to disturbance in natural ecosystem, leading to resurgence of pests, secondary pest outbreaks, development of resistance among pests to pesticides (e.g. Helicoverpa), toxic hazards and residues besides environmental pollution (Huffaker and Messenger, 1976). Thus, there is a need to follow the integrated pest management approach for the control of pests.

Biological control is one of the important components of IPM, which is safe, economical and self perpetuating method of controlling pests. A number of parasitoids and predators have been reported feeding on insect pests of cotton. Chrysoperla carnea (Stephens) commonly referred as green lacewing, is of particular interest for biological control of insect pests of cotton, as this is the most predominant among various predacious insect species (van den Bosch and Hagen, 1966). It is active throughout the year in India, feeding on various insect pests on

different crops (Singh and Jalali, 1991).

C. carnea has been found feeding on various insect pests like eggs and early larval instars of Heliothis virescens (Fabricius), pupae of Bemisia tabaci (Gennadius), Aphis gossypii Glover, eggs of Corcyra cephalonica (Stainton) and nymphs of Amarsca biguttula biguttula (Ishida) (Balasubramani and Swamiappan, 1994). This predator has also been found feeding on a variety of other insect pests like Thrips tabaci Lindeman, Aphis punicae Passerini, eggs and nymphs of Aphis laburni, eggs of Ephestia kuehniella Zeller, eggs of Spodoptera littoralis (Boisduval), eggs of Brathra brassicae Linnaeus (Awadallah et al., 1975; Megahed et al., 1982 and Sengonca and Grooterhorst, 1985) and Myzus persicae (Sulzer) (Kharizanov and Dimitrov, 1972 and Mannan, 1994).

C. carnea has many desirable attributes for use in biological control. They inhabit many diverse agroecosystems and are tolerant to many insecticides (Bartlett, 1964; Rajakulendran and Plapp, 1982) and can be mass reared easily (Ridgway et al., 1970).

Keeping in view the importance of C. carnea as a predator, the present studies were undertaken with the following objectives:

1. To study development of C. carnea on different prey species.
2. To study predation efficacy of C. carnea on different prey species.
3. To study effect of insecticidal application on C. carnea.

CHAPTER II

REVIEW OF LITERATURE

Chrysoperla carnea (Stephens) (Chrysopidae:Neuroptera), commonly called as green lacewing, is mainly a predator on aphids, jassids, whitefly, thrips, mealy bug and eggs of Heliothis. The pertinent literature has been reviewed under the following heads:

1. Distribution
2. Rearing technique
3. Development of C. carnea on different prey species
4. Predation efficacy of C. carnea larvae on different prey species
5. Effect of insecticidal application on C. carnea

2.1. Distribution

The predator, C. carnea is widely distributed and has been reported from Australia, Bulgaria, England, Egypt, India, Iran, Iraq, Italy, Norway, Pakistan, Poland, Rhodesia, Switzerland, Turkey, USA, USSR. In India, many species of natural enemies have been recorded from various crop ecosystems. Amongst them, Chrysoperla carnea and Mallada boninensis (Okamoto) are most common (Singh and Jalali, 1991).

2.2. Rearing techniques of C. carnea

Maurice and Catherine (1975) fed the adults on wheast diet which consisted of wheat, protein hydrolysate of yeast, sugar and honey (1:1:1:1 ratio) for rearing of Chrysoperla carnea. Hassan and Hagen (1978) developed artificial diet for rearing larvae of C. carnea consisting of 5g honey, 5g sugar, 5g food

yeast flakes, 6g yeast enzymatic hydrolysate, 1g casein enzymatic hydrolysate, 10g egg yolk and 68 ml of distilled water.

The females of C. carnea that had been fed on nutritionally complete food produced eggs at higher rate than those fed on sugar alone or with those feeding on naturally occurring food i.e. honey dew and pollen (Tassan et al., 1979).

Kismir and Sengonca (1981) reared C. carnea on eggs of Sitotroga cerealella (Ol.) at 25°C and 70-80% R.H.

Krishnamoorthy and Nagarkatti (1981) developed a technique of rearing Chrysopa sclestes Banks on the frozen eggs of Corcyra cephalonica.

Dry diet for adults of common lacewing based on brewer's yeast hydrolysate and saccharose was more suitable diet in comparison with liquid artificial diet. Fecundity was increased 2.2-2.8 folds in comparison with liquid diet (Makarenko, 1988). Hasegawa et al. (1989) developed a technique for rearing C. carnea on chemically defined diets. The diet were composed of 23 amino acid, sucrose, trehalose, 17 vitamins, 6 fatty acid etc. The adult of C. carnea on best diet produced more than 1000 eggs over two months.

Letardi and Caffarelli (1989) developed a liquid artificial diet for feeding C. carnea. However, larval development was slightly extended on the liquid diet (an average of 18.2 and 14.4 days, respectively) compared with individuals reared on eggs of E. kuehniella (10.2 days).

The artificial diets for rearing larvae of C. carnea cannot be used efficiently until encapsulated in an artificial eggs. The cannibalism in the larvae can be inhibited by using polystyrene chips which when used to fill the rearing box to 75 per cent of its capacity (Singh and Jalali, 1991). Kubota and Shiga (1995) developed a method of successive rearing of chrysopids on eggs of Tribolium castaenum (larval diet) and on 2:3 mixture (by weight) of commercially available yeast autolysate and honey (adult diet).

2.3. Development of C. carnea on different prey species

2.3.1. **Larval period**

The duration of larval stages of C. carnea on different hosts as reported by different workers ranged from 7.53 to 16.96 days.

The larval stage of C. carnea lasted 9.5 days at 20°C on eggs of Sitotroga carealella (Ol.) (Kowalska, 1968). Butler and Ritchie (1970) reported that the duration of larval stage varied from about 4 week at 15°C to 1 week at 30°C on eggs of Sitotroga cerealella. Generally, the Ist instar was the longest, the 3rd was next longest and the 2nd was the shortest.

The larval stage of C. carnea found to last for 16-17 days at an average daily temperature of 18°C, 12-15 days at 18.5°C, 14 days at 18.6°C, 13 days at 18.8°C, 12 days at 20.6°C and 4-10 days at 24.6°C (Kharizanov and Dimitrov, 1972).

Larvae of C. carnea survived even when starved for a period of 4 days. There were two moults (Egger, 1974).

Awadallah et al. (1975) reported that at 28°C of temperature and 63-70% relative humidity, larvae of C. carnea lasted for 14.18, 11.32 and 8.50 days on Thrips tabaci, Aphis punicae and eggs of Spodoptera litura, respectively. Development was faster on S. litura followed by an A. punicae and T. tabaci.

The duration of 3 larval instars was 2.6, 2.9, 4.4 days on egg diet and 3.3, 3.9, 8.4 days on larval diet of Heliothis armigera (El-Daksoury et al 1977).

Afzal and Khan (1978) reported that total duration of larval stages of C. carnea was 12.9 days on the pupae of Bemisia tabaci (Gennadius). Babrikova (1981) reported that duration of larval stages of C. carnea averaged 9.82 (7-16) days at mean daily temperature of 25.1°C and mean RH of 75.1% but at 17.5°C and 80.3% RH, it averaged 19.96 (8-31) days.

The larval period of C. carnea which was collected from aphid infested maize field averaged 8.3 days at 27°C and 65.8% RH (Varma and Shenhmar, 1983). Sengonca et al. (1987) studied the effect of feeding different prey species on the development of C. carnea. The results indicated that Tetranychus urticae Koch compared unfavourably with eggs of Myzus persicae and Mamestra brassicae and led to a longer period of larval development and 85% mortality. There were minor differences in the development time between larvae fed on Myzus persicae, Aphis fabae Scopoli and Bravicoryne brassica (Linnaeus), high mortality occuring only with Mamestra brassicae. The combination of feeding on unfavourable and favourable prey at different larval stages

revealed that development time was shorter and mortality higher when Ist and 2nd instar larvae were fed on unfavourable T. uritcae and third instar larvae on the unfavourable Myzus persicae.

Kaya and Oncuer (1988) studied the effect of combination of two prey species on development of C. carnea under laboratory conditions at temperature of 24-26°C and 60-70 per cent relative humidity. It was observed that Chrysoperla larvae fed on eggs of the Ephestia kuehniella had more rapid development, greater adult fecundity and lower mortality rate during all stages than larvae fed on nymph and adults of the aphid Acryrthosiphon pisum (Harris). Chrysopids fed on combination of these prey species showed intermediate results.

Total duration of development period from egg to adult emergence in C. carnea was found to be 19.15, 19.95, 20.15, 20.60 and 22.50 days when larvae were fed on Bemisia tabaci, eggs of Corcyra cephalonica and Helicoverpa armigera, Aphis gossypii, Amrasca biguttula biguttula, neonate larvae of Heliothis armigera (Balasubramani and Swamiappan, 1994). It was further reported that the larval development was 8.2 and 11.1 days on eggs of Corcyra cephalonica and on neonate larvae of H. armigera, respectively.

Mannan (1994) reported that the duration of first, second and third instar larvae were 2.60, 2.55, 2.38 days and 3.75, 2.78, 3.35 days, when Aphis gossypii and Myzus persicae were given as food, respectively.

2.3.2. **Pupal period**

The pupal period of C. carnea on different hosts as reported by different workers ranged from 7.24 to 15.Ø days.

Kowalska (1968) reported that pupal stage of C. carnea lasted 12 days at 2Ø°C on eggs of Sitotroga cerealella (Ol.). Butler and Ritchie (197Ø) found that duration of pupal stage for both males and females varied from 13-14 days at 2Ø°C and 6-7 days at temperature between 2Ø° and 35°C on eggs of Sitotroga cerealella.

Pupal stage of C. carnea lasts for 14 days at temperature of 17.8°C, 1Ø days at 22.5°C, 9 days at 21.8, 24.Ø and 25°C and 8 days at 22.6 and 25°C (Kharizanov and Dimitrov, 1972).

Awadallah et al. (1975) found that pupal stages of C. carnea lasted 8.37, 8.3Ø and 8.Ø8 days respectively on Thrips tabaci, Aphis punicae and on eggs of Spodoptera litura.

Total duration of pupal stages was 6.7 and 7.9 days on egg diet and larval diets of Heliothis armigera (El-Daksoury, 1977). Afzal and Khan (1978) reported that the duration of pre-pupal and pupal stages of C. carnea were 4.2 and 7.8 days on pupae of Bemisia tabaci, respectively.

The duration of pupal stage varied between 8.76 (7-13) days and 15.11 (9-23) days in a temperature range of 24.8 and 18.9°C (Babrikova, 1981).

Varma and Shenhmar (1983) reported that pupal period of C. carnea which was collected from aphid infested maize field average 8.5 days at 27°C and 65.8% relative humidity.

Balasubramani and Swammiappan (1994) reported that pupal development period was shorter on Bemisia tabaci (7.40 days) and Amrasca biguttula biguttula (7.40 days) and longer on neonate larvae of Heliothis armigera (8.40 days).

Mannan (1994) reported that pupal period of C. carnea was 9.43 and 11.40 days on Aphis gossypii and Myzus persicae, respectively.

2.4. Predation efficacy of C. carnea on different prey species

The information on the feeding capacity of larva and different larval instars as reported by different workers ranged from 173.75 to 952.4 preys.

The chrysopid consumed more aphids at higher temperature than at the lower or variable ones. It has been found that the minimum food requirements for development was considerably less than the actual amount consumed. C. carnea appeared to be the most efficient predator at 21°C (Sundby, 1966). Third instar larvae were most voracious feeder (Shuvakhina, 1975).

El-Daksoury (1977) reported that the number of eggs of Heliothis armigera consumed per predator during three larval instars averaged 24.1, 40.5 and 113.7, respectively and number of larvae of Heliothis armigera was 37.9, 95.8 and 757.7. The average daily consumption of eggs per larvae of C. carnea was 9.8, 14.3 and 26.2 in the 3 instars respectively and that of larvae of H. armigera was 11.8, 24.0 and 90.3, respectively.

Afzal and Khan (1978) reported that the number of Aphis gossypii Glover consumed averaged 487.2 per larvae and pupae of

Bemisia tabaci averaged 510.8 per larvae of C. carnea. Aphids were more preferred than the pupae of whitefly by C. carnea.

The release of C. carnea into a population of A. gossypii Glover at a ratio of 1:50 or 1:55 reduced number of aphids by 99.5% whereas untreated population of A. gossypii doubled in size (Ishankulieva, 1979).

Three releases of C. carnea made at the predator prey ratio of 1:1 reduced the abundance of Aphis gossypii by 98.5% and that of thrips by 95.6% and that of spider mite (Tetranychus spp.) by 100% and that of young larvae of Heliothis armigera by 50% (Gurbanov, 1982).

Megahed et al. (1982) observed that larvae of C. carnea increased their prey consumption in the laboratory as they grew older. Sengonca and Grooterhorst (1985) reported that number of prey consumed by C. carnea increased slowly and reached a peak in the 3rd larval instar. A single larvae consumed 982.9 eggs of Spodoptera littorallis (Boisduval) as compared to 426.2 eggs of Bratha brassicae Linnaeus during total larval development. However, the weight of prey consumed was same since eggs of B. brassicae was 2.33 times heavier than those of S. littoralis.

The consumption rate of C. carnea increased with the decrease in relative humidity and there was a marked increase in the consumption at a higher temperature of 30°C. The average number of aphids consumed at a temperature of 30°C and 40% RH during the larval stage was about 424.6 per larvae, while at 85% RH, this was reduced to 273.4 per larvae. At 20°C and 40 and 85%

RH these values were 382.6 and 232.6, respectively (Zaki, 1987). Butler and Henneberry (1988) investigated the predation of Bemisia tabaci (Gennadius) by C. carnea. Adults of C. carnea do not feed on B. tabaci adults or eggs. First instar larvae of C. carnea consumed eggs and pupae of Bemisia tabaci in about the same time, while the 2nd instar larvae of C. carnea consumed eggs more rapidly than 1st instar larvae. Third instar larvae consumed pupa in 33-78 seconds.

Obrycki et al. (1989) reported the suitability of corn insect pests for development of C. carnea. The number of eggs of Ostrinia nubilalis and Agrotis ipsilon consumed averaged 377.Ø and 641.Ø per larvae.

The 3rd instar larvae of C. carnea has been found to prey on pupae of Bemisia tabaci (Kapodia and Puri, 199Ø). Yuksel and Gocman (1992) reported that Aphis gossypii consumption by 1st instar larvae of C. carnea was 53.6 and 6Ø.3 at 25°C and 3Ø°C, respectively while that of 2nd instar larvae was 724.4 and 5Ø6.7.

The number of aphids i.e. Aphis gossypii and Myzus persicae consumed during the larval development were 449.43 and 173.75, respectively. The three larval instars consumed 85.3Ø, 12Ø.85, 243.4Ø Aphis gossypii and 3Ø.65, 49.35 and 93.75 Myzus persicae. The number of aphids consumed by a larva increased with age (Mannan, 1994).

2.5. Effect of insecticides on C. carnea

Bartlett (1964) reported that day old residues of dimethoate were not appreciably toxic to C. carnea but phosphamidon and

endosulfan were highly toxic to the larvae of C. carnea.

Most of the organophosphate insecticides and the carbamate methomyl were highly toxic to the predator. Another carbamate, carbaryl, formamidine, chlordemiform, several pyrethroids and several organochlorines were much less toxic to C. carnea. Phosphorothionate (P = S) insecticides were selective against C. carnea in comparison with synthetic pyrethroid and endosulphan (Plapp and Bull, 1978).

Hafez et al. (1979) studied the effect of 3 ULV sprays of Nuvacron and low volume sprays of several insecticides including Nuvacron from aircraft and ground equipment on abundance of predator in cotton field. The population of predator were considerably lower in former field than later. Babrikova (1979) studied the effect of pesticides on adult and pre-adult stages of C. carnea. The egg, larvae and pupae were for the most part resistant to pesticides, while the adult were most sensitive. Out of 22 pesticides tetrachlorvinphos, phosalone, ethiofencarb, primicarb and menazon were the least toxic.

Permethrin, cypermethrin, fenvalrate, bioresmethrin and Decis were found to be very toxic to larvae of C. carnea and low toxicity to larvae of Episyrphus balteatus (Deg.) (Niemczyk et al., 1979).

Among the various insecticides tested, DDT, monocrotophos and Decis has little effect on eggs of C. carnea while the cypermethrin, permethrin and fenvalerate caused 1-70% kill. DDT and especially monocrotophos caused heavy larval mortality (upto

84%) but the synthetic pyrethroids especially Decis and fenvalerate were much less harmful. The adults of C. carnea proved very susceptible to all the compounds tested except fenvalrate which had no effect and cypermethrin which caused 40% mortality (Kismir and Sengonca, 1980).

Larvae of C. carnea has shown remarkable natural tolerance to pyrethroids in laboratory which is attributed to detoxification by pyrethroid esterases. This nymphal enzyme had usually high activity and unique specificity for hydrolysing cispermethrin and cypermethrin 2-3 times as fast as the corresponding trans-isomers. Deltamethrin was also hydrolysed rapidly (Ishaaya and Casida, 1981).

Adults and larvae of C. carnea and Coccinella septumpunctata were exposed in the laboratory to films of primicarb at 300 g/ha, oxydemeton methyl at 300 ml/ha, ethiofencarb at 600 ml/ha, HOE 25682 at 300 g/ha and heptenophos at 300 ml/ha and then provided with Acryrthosiphon pisum (Harris) as prey (Grapel, 1981). Ethiofencarb, oxydemeton methyl and heptenophos reduced predation and fecundity of both predators by 100 per cent. Oxydemeton methyl caused nearly 100 per cent mortality to both species in 5 days and heptenophos caused about 30% in 2 days. HOE 25682 was less injurious to Coccinella septumpunctata but reduced feeding by C. carnea considerably. Only primicarb could be considered safe for use against aphid in the presence of predators.

Rajakulendran and Plapp (1982) studied the comparative toxicity of 5 synthetic pyrethroids viz. phenothrin,

cypermethrin, tralomethin, fluvalinate and flucythrinate to C. carnea and tralomethrin was least toxic. Singh and Varma (1984) reported that endosulphan, quinalphos, monocrotophos and fenitrothion caused 74-89% larval mortality of C. carena after 72 hour of feeding on insecticide treated food (eggs of rice moth). Carbaryl and cypermethrin were moderately toxic (34.1-38.1% mortality) and fenvalerate proved least toxic (19.1% mortality).

Zhumanov et al. (1988) studied the effect of pesticides on common lacewing, C. carnea. The compound Bi 58 (Dimethoate) was harmless to C. carnea but was highly toxic to the other predators. Surulivelu and Kumarswami (1989) studied the effect of 'skip row coverage' of insecticide application on sucking pests and their predators in cotton. Deltamethrin, endosulphan and monocrotophos as skip row coverage in a field resulted in larger population of C. carena.

Darwish and Farghal (1990) reported that Beta cyfluthrin was most effective insecticide against Bemisia tabaci and least toxic to C. carena. Natarajan (1990) reported that activity and abundance of C. carnea was reduced significantly more when triazophos, monocrotophos were sprayed than when endosulphan was used.

Pyrethroids were highly detrimental to C. carnea and resulted in a lowest number of 2.0-4.3 of predator per 10 leaves occurring early in the year and 0.3-1.2 of later occurring predator per 10 leaves (Rao and Reddy, 1990).

Wetzel et al. (1991) developed a technique for monitoring non target effect of pesticide on larvae of C. carnea. Larvae were released in a large numbers on the plants and pesticides applied on the same day. After 24 hours, survival of larvae is assessed for 3 days using bait card with eggs of Sitotroga cerealella as prey. Parathion was shown to be harmful, heptenophos moderately harmful and triforine harmless to the C. carnea.

Baspinar and Uygun (1992) studied the side effects of fluvalinate and fenitrothion on adult of C. carnea and on egg, larvae, pupa and adult of Leptomastix dactylopii. Fenitrothion had a greater effects on adults of C. carnea than fluvalinate. Although there were no effect on larvae and pupae of L. dactylopii but it has effect on adults.

CHAPTER III

MATERIAL AND METHODS

The present studies were carried out in the Biological Control Laboratory of Department of Entomology as well as at the Entomological Research Farm of Punjab Agricultural University, Ludhiana during 1995-96.

3.1. Source of insects and their rearing

3.1.1. Chrysoperla carnea (Stephens)

The adults of C. carnea were collected from unsprayed cotton crop grown at the Entomological Research Farm, PAU Ludhiana and were compared with the already identified specimen in the Biological Control Laboratory. These adult insects were kept in a battery jar (15 x 10 cm). The bottom and inner sides of jar were covered with brown paper for oviposition. The mouth of jar was also covered with brown paper which was held with a rubber band [Fig.1(a)]. Adults were provided with food by hanging a cotton swab dipped in honey from top of the jar. The brown paper was provided daily for oviposition. When the eggs were laid, they were removed along with brown paper. The eggs were then transferred to glass vials (15 x 2.5 cm) singly with small portion of brown paper which was cut along the egg. Mouth of these vials were covered with surgical cotton wool [Fig.(1b)]. The vials were kept vertically in a plastic tray. Eggs in the vials were examined daily for hatching. The larvae produced were provided with eggs of Corcyra cephalonica till pupation. The pupae were kept in glass vials till the emergence of adults. The

Fig 1. (a) Battery jar (15 X 10 cm) for egg laying.

(b) Glass vial used for studying development and predation efficacy of C. carnea.


(a)
(b)

larvae and adults produced in this way were used for various studies.

3.1.2. **Cotton aphid, Aphis gossypii Glover**

To maintain a continuous supply of A. gossypii, the colonies of aphids were raised on cucurbit plants. The cucurbits were sown in the earthen pots at different intervals and were allowed to grow in the open. The aphid collected from unsprayed cucurbit plants in the field were transferred to the potted plants with the help of camel hair brush, where they multiplied. Immediately after releasing the aphids, these potted plants were kept covered in the screen house. This species was used for studying development and predation efficacy of C. carnea.

3.1.3. **White fly, Bemisia tabaci (Gennadius)**

To obtain information on the development and predation efficacy C. carnea, the colonies of B. tabaci were reared on brinjal and cotton plants. These plants were raised in the pots at different interval and were kept in the open. Adults of B. tabaci were collected from the unsprayed plants of cotton with the help of a aspirator and were released on potted plants of brinjal and cotton for multiplication. These potted plants were shifted to screen house immediately after release of cotton white fly. The adult white flies produced this way were used for different studies.

3.1.4. **Cotton jassid, Amrasca biguttula biguttula (Ishida)**

To maintain continuous supply of A. biguttula biguttula for different experiments on development and predation efficacy of C.

carnea, the colonies of cotton jassid were raised on okra (Abelmoschus esculentus) plants. The seeds of the okra were sown in the earthen pots at different intervals and were allowed to grow in the open. The adults of cotton jassid were collected from unsprayed plants of cotton with the help of a aspirator and transferred to the potted plants, where they multiplied. The plants were kept covered in the screen house. The nymphs produced this way were used for conducting different experiments on development and predation efficacy of C. carnea.

3.2. Temperature record

The laboratory temperature was recorded daily between 9.00 and 9.30 a.m. during the period of study. The temperature in the laboratory was maintained almost constant by using air conditioners and room heaters depending upon the weather.

3.3. Development and predation efficacy of C. carnea

3.3.1. Larval and pupal development

The studies on the larval and pupal development of C. carnea on different prey species were carried out under laboratory conditions in the Biological Control Laboratory of the Department of Entomology. A. gossypii, B. tabaci and A. biguttula biguttula were used as food for development of C. carnea. The duration of first, second and third instar larvae and pupal period of C. carnea were recorded on the above mentioned prey species.

3.3.2. **Larval period**

Ten newly hatched larvae were kept singly in the glass vials (15 x 2.5 cm) to prevent cannibalism. The larvae were daily provided with food in excess to their requirement and the unconsumed food was removed next day. The dates of larval emergence and pupation were recorded regularly to work out the total larval span. To determine the duration of larval instars larvae were observed carefully under the zoom stereoscopic binocular microscope to find out the interval between successive moultings. The larvae were examined twice daily at 9.ØØ a.m. and 5.ØØ p.m. for moulting and pupation. When the exuviae of particular instar was noticed, it was removed with the help of wet camel hair brush. Thus, the duration of all the instar was worked out. These studies were conducted by providing A. gossypii, B. tabaci and A. biguttula biguttula as host separately. The data for larval period and larval instar durations were statistically analysed using randomized block design. This experiment was repeated four times to confirm the observations.

3.3.3. **Pupal period**

The time interval between pupation and adult emergence was considered as pupal period. The pupae were not removed from the vials which were used for larval development till the emergence of adults. For this purpose, the record of pupation and adult emergence of ten pupae was kept to work out the pupal period. The data were statistically analysed to calculate mean pupal period.

This experiment was also repeated for four times to confirm the observations.

3.4. Predation efficacy of C. carnea

3.4.1. Feeding capacity of C. carnea larvae

The feeding capacity of C. carnea larvae during total larval period and individuals larval instars were studied on three prey species i.e. A. gossypii, A. biguttula biguttula and B. tabaci. The consumption of prey by larvae as well as by each instar was studied. For this purpose, ten newly hatched C. carnea larvae were taken and kept separately in glass vials (15 x 2.5 cm) for daily consumption of cotton aphid, jassid and white fly. The larvae were provided with counted number of nymphs of aphid, jassid and adults of white fly in excess to their requirement till pupation. After 24 hours, each vial was examined for actual number of preys consumed and unconsumed preys were removed. The record for daily consumption of above mentioned prey species by larvae of C. carnea was maintained, till they pupated.

Similarly, for determining the feeding capacity of each instar, the number of nymphs of different prey species consumed by larvae of C. carnea till the completion of larval instar were also counted. In addition observation were also taken twice a day at 9.00 a.m. and 5.00 p.m. for changing of larval instar. During these observations, the exuviae of previous instar, if any found along with unconsumed prey species were removed and number of preys consumed daily were counted to determine the total number of prey species i.e. aphid, cotton jassid and cotton white

fly consumed by previous instars. The data were statistically analysed by calculating the mean number of aphid, jassid and white fly consumed during the larval period and each larval instar. This experiment was also repeated for four times.

3.4.2 Comparative preference of A. gossypii, A. biguttula biguttula and B. tabaci by larvae of C. carnea

A replicated experiment was conducted to study the comparative preference of C. carnea larvae for nymphs of cotton aphid, jassid and adults of white fly. For this purpose ten potted plants of cotton (5-6 leaf stage) were taken and covered with glass chimneys. The glass chimneys were darkened from inside by wrapping with black paper. On each plant, ten second instar larvae of C. carnea were released with the help of camel hair brush. After settling of these larvae, on each plant thirty nymphs of Aphis gossypii were released with the help of wet camel hair brush and 30 adults of Bemisia tabaci and 30 nymphs of Amrasca biguttula biguttula were released with aspirator. One such plant constituted one replication. The observations for number of prey species consumed by C. carnea larvae were recorded at an interval of 6 hour after the release of predator and prey species on the potted plant. The data was statistically analysed to work out mean number of preys consumed of each species. This experiment was repeated twice.

3.5. Effect of insecticidal sprays on larval mortality of C. carnea

Ten insecticides viz. dimethoate 30EC (0.075%), phosphamidon 85SL (0.064%), imidacloprid 200SL (0.008%), endosulfan 35EC

(Ø.28%), monocrotophos 36SL (Ø.14%), carbaryl 5ØWP (Ø.4Ø%), cypermethrin 1ØEC (Ø.Ø16%), chlorpyriphos 2ØEC (Ø.32%), fenitrothion 5ØEC (Ø.34%) and ethion 5ØEC (Ø.32%) were tested against 3 larval instars of C. carnea at dosages recommended for the control of cotton pests. The formulations of these insecticides for spray on larvae of C. carnea or on its food i.e. eggs of Corcyra cephalonica were used after appropriate dilution with water.

3.5.1. Effect of different insecticides on C. carnea by direct sprays on food (eggs of C. cephalonica)

For this purpose, Corcyra cephalonica Stainton eggs to be used as treated food were glued on cards and sprayed individually at recommended concentration of these insecticides with the help of a baby sprayer upto the point of run off. The insecticide treated egg cards were allowed to dry in shade at room temperature before being used for toxicity studies. Ten larvae of C. carnea were kept in each glass vial and exposed to strip of cards bearing sprayed eggs for first 24 hours. One such glass vial constituted one replication. The treated egg cards were removed after 24 hour and replaced with untreated egg cards of C. cephalonica. The larvae were provided daily with fresh untreated egg cards till their death or pupation. Observation on larval mortality were recorded at an interval of 3, 6, 12, 24, 36, 48 and 72 hours after release of C. carnea larvae on insecticide treated eggs of C. cephalonica. From these observations cummulative per cent larval mortality of C. carnea was worked out at different time intervals. The data was statistically analysed

using randomized block design.

3.5.2. Effect of different insecticides on larvae of C. carnea by direct spray on plants

For this purpose, potted plants of cotton (3-4 week old) free from insect pests were taken. Ten larvae of C. carnea were released on each potted plant with the help of camel hair brush and allowed them to settle. One such plant constituted one replication. These potted plants were sprayed individually at recommended concentration of these insecticides with the help of baby sprayer. After twenty minute, the treated larvae of C. carnea were removed from the plant with the help of camel hair brush and transferred them into glass vials. These larvae were provided daily with fresh food (i.e. nymphs of Aphis gossypii Glover) and examined them until their death or pupation. Observations on larval mortality were recorded at an interval of 3, 6, 12, 24, 36, 48 and 72 hours after transfer of C. carnea larvae into glass vials. The cummulative mortality was worked out at different time intervals. The data was statistically analysed using randomized block design.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Development of C. carnea on different prey species

4.1.1 Larval period

The development of C. carnea larvae was studied under laboratory conditions at mean temperature of 26.72 (maximum) and 21.23°C (minimum) on cotton aphid, jassid and whitefly. The experiment on the development of C. carnea was repeated four times under laboratory conditions. The results of these experiments are given in Table 1 to 4. The larval development was comparatively faster on Aphis gossypii followed by Bemisia tabaci and Amrasca biguttula biguttula. However, the total larval plus pupal period was comparatively shorter on B. tabaci followed by A. biguttula biguttula and A. gossypii. Pooled data of four sets of experiments presented in Table 5 reveals that mean larval period of C. carnea was 9.47, 9.77 and 10.40 days, when A. gossypii, B. tabaci and A. biguttula biguttula were provided as prey species, respectively. However, the difference were non-significant. The present findings are similar to the earlier reports where the larval period has been reported to be 7.23 days when reared on adults of Aphis gossypii at mean temperature of 32.89 (maximum) and 27.49°C (minimum), respectively (Mannan, 1994). Butler and Ritchie (1970) also reported that larval period of C. carnea was 8-11 days when reared on eggs of Sitotroga cerealella (Oliver) at temperature of 25 and 30°C. Similarly, Kharizanov and Dimitrov (1972) reported that three larval instars were completed in 9-10 days at 24.6°C

Table 1. Development of C. carnea on different prey species under laboratory conditions

Set I (13.7.96 to 3.8.96)

Prey species	Duration of larval instars* (days)			Larval period (days)	Pupal period (days)	Larval+ pupal period (days)	Average temp.(°C)	
	Ist	2nd	3rd				Maximum	Minimum
Aphis gossypii	3.75	2.80	3.55	10.10	8.70 (3.11)	18.80	25.76± 2.06	20.89± 1.29
Amarasca biguttula biguttula	3.80	2.90	3.95	10.65	7.60 (2.93)	18.10	25.76± 2.06	20.89± 1.29
Bemisia tabaci	3.50	2.85	3.85	10.20	7.80 (2.96)	18.05	25.76± 2.06	20.89± 1.29
C.D.(P = 0.05)	NS	NS	NS	NS	(0.012)	NS	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 2. Development of C. carnea on different prey species under laboratory conditions

Set II (5.8.96 to 25.8.96)

Prey species	Duration of larval instars* (days)			Larval period (days)	Pupal period (days)	Larval+ pupal period (days)	Average temp.(°C)	
	Ist	2nd	3rd				Maximum	Minimum
Aphis gossypii	3.70	2.85	3.45 (2.10)	10.10 (3.31)	9.10 (3.18)	19.15	25.61± 1.53	19.85± 0.98
Amarasca biguttula biguttula	3.85	3.00	4.10 (2.25)	10.95 (3.45)	7.70 (2.95)	18.85	25.61± 1.53	19.85± 0.98
Bemisia tabaci	3.75	2.90	3.80 (2.19)	10.45 (3.38)	7.90 (2.98)	18.35	25.61± 1.53	19.85± 0.98
C.D.(P = 0.05)	NS	NS	(0.08)	(0.05)	(0.010)	NS	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 3. Development of C. carnea on different prey species under laboratory conditions

Set III (18.8.96 to 10.9.96)

Prey species	Duration of larval instars* (days)			Larval period (days)	Pupal period (days)	Larval+ pupal period (days)	Average temp.(°C)	
	Ist	2nd	3rd				Maximum	Minimum
Aphis gossypii	3.50	2.70	3.45 (2.11)	9.65 (3.26)	8.80 (3.13)	18.45 (4.41)	27.15± 1.45	21.7± 1.45
Amarasca biguttula biguttula	3.65	2.80	3.85 (2.20)	10.30 (3.36)	7.80 (2.96)	18.10 (4.37)	27.15± 1.45	21.7± 1.45
Bemisia tabaci	3.35	2.70	3.75 (2.18)	9.80 (3.28)	7.60 (2.93)	17.40 (4.29)	27.15± 1.45	21.7± 1.45
C.D.(P = 0.05)	NS	NS	(0.08)	(0.06)	(0.08)	(0.07	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 4. Development of C. carnea on different prey species under laboratory conditions

Set IV (12.9.96 to 1.10.96)

Prey species	Duration of larval instars* (days)			Larval period (days)	Pupal period (days)	Larval+ pupal period (days)	Average temp.(°C)	
	Ist	2nd	3rd				Maximum	Minimum
Aphis gossypii	2.90 (1.97)	2.37	2.75 (1.93)	8.05 (3.01)	8.10 (3.01)	16.15 (4.14)	28.38± 1.29	22.5± 1.97
Amarasca biguttula biguttula	3.50 (2.12)	2.50	3.70 (2.17)	9.70 (3.27)	7.40 (2.89)	17.10 (4.25)	28.38± 1.29	22.5± 1.97
Bemisia tabaci	3.10 (2.02)	2.35	3.20 (2.04)	8.60 (3.09)	7.40 (2.89)	16.00 (4.12)	28.38± 1.29	22.5± 1.97
C.D.(P = 0.05)	(0.07)	NS	(0.05)	(0.06)	(0.08)	(0.07)	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

on Myzus persicae. However, the larval period was prolonged to 16-17 days at lower temperature of 18°C. El-Daksoury (1977) also reported that total duration of 3 larval instar was 9.9 days on egg diet of Heliothis armigera.

Afzal and Khan (1978) reported that duration of larval instars of C. carnea was 12.9 days on pupae of Bemisia tabaci (Gennadius). Awadallah et al. (1975) reported that the larval stages of C. carnea lasted 14.18 days on Thrips tabaci, 11.32 days on Aphis punicae and 8.5 days on eggs of Spodoptera litura at 28°C. Babrikova (1981) also reported that duration of larval stages of C. carnea averaged 9.82 days at mean daily temperature of 25.1°C but at 17.5°C it averaged 16.96 days. Varma and Shenhmar (1983) also reported that duration of larval period of C. carnea which was collected from aphid infested maize field averaged 8.3 days at 27°C. These differences in larval duration may be due to different prey species involved and the difference in temperature for rearing larvae of C. carnea in different studies.

The duration of 1st, 2nd and 3rd larval instars (Fig.2) of C. carnea were found to be 3.46, 2.68, 3.30 and 3.70, 2.80, 3.90 days on nymphs of A. gossypii and A. biguttula biguttula and correspondingly it was 3.42, 2.70 and 3.65 days respectively, when adults of B. tabaci were provided as host (Table 5). The present findings are almost in confirmity with the earlier reports where the duration of 1st, 2nd and 3rd larval instar of C. carnea were 2.60, 2.25, 2.38 and 3.75, 2.78, 3.35 days on A. gossypii and M.

Fig. 2 Three larval instars of C. carnea.

persicae, respectively (Mannan, 1994). Butler and Ritchie (1970) also reported that duration of 3 larval instars were 4.2, 3.0 and 3.5 days on eggs of Sitotroga carealella. El-Daksoury et al. (1977) reported that the total duration of 3 larval instar was 2.6, 2.9 and 4.4 days on eggs of Heliothis armigera.

Total larval plus pupal period was 18.13, 18.03 and 17.45 days when nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci were provided as prey species (Table 5). The larval development was comparatively faster on A. gossypii followed by B. tabaci and A. biguttula biguttula. However, the total larval plus pupal period was shorter on B. tabaci followed by A. biguttula biguttula and A. gossypii. Balasubramani and Swamiappan (1994) also reported faster development of C. carnea when pupae of B. tabaci were provided as a prey species.

4.1.2. **Pupal period**

The mean pupal period was 8.67, 7.62 and 7.67 days, at mean temperature of 26.72 (maximum) and 21.23°C (minimum) when C. carnea was reared on nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci, respectively (Table 5). The pupal development was significantly faster on A. biguttula biguttula and B. tabaci as compared to A. gossypii. The present findings corroborate the earlier reports where the duration of pupal stage was 8.5 days at 27°C on eggs of Corcyra cephalonica and 9.43 days on Aphis gossypii at a temperature of 27.4°C (Varma and Shenhmar, 1983 and Mannan, 1994). Balasubramani and Swamiappan (1994) also reported pupal period of C. carnea 7.40 days on B. tabaci and A.

Table 5. Development of C. carnea on different prey species under laboratory conditions

Pooled data (Set I to IV)

Prey species	Duration of larval instars* (days)			Larval period (days)	Pupal period (days)	Larval+ pupal period (days)	Average temp.(°C)	
	Ist	2nd	3rd				Maximum	Minimum
Aphis gossypii	3.46	2.68 (1.92)	3.30 (2.07)	9.47	8.67 (3.11)	18.13	26.72	21.23
Amarasca biguttula biguttula	3.70	2.80 (1.95)	3.90 (2.21)	10.40	7.62 (2.94)	18.03	26.72	21.23
Bemisia tabaci	3.42	2.70 (1.92)	3.65 (2.15)	9.77	7.67 (2.94)	17.45	26.72	21.23
C.D.(P = 0.05)	NS	0.01	0.06	NS	(0.05)	NS	-	-

* Each figure is mean of 40 replications
Figures in parentheses indicate square root transformation

biguttula biguttula. Afzal and Khan (1978) also reported that duration of pupal stage of C. carnea was 7.8 days on pupae of Bemisia tabaci. However, the pupal period has been reported to be 7-9 days when reared on eggs of Sitotroga cerealella (Butler and Ritchie, 1970).

El-Daksoury (1977) observed that total duration of pupal stage was 6.7 days on egg diet and 7.9 days on larval diet of Heliothis armigera. Babrikova (1981) reported that the duration of pupal stage varied between 8.76 (7-13 days) and 15.11 (9-23 days) at a temperature range of 24.8 to 18.9°C. These findings are in confirmation to the present findings on pupal period and the slight differences in pupal period may be due to difference in temperature or prey species involved in rearing of C. carnea.

4.2 Feeding capacity of Chrysoperla carnea larvae on different prey species

The feeding capacity of C. carnea larvae was determined by using nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci as prey species. The experiment on the feeding capacity of C. carnea was repeated four times under laboratory conditions. The results of these experiments presented in Table 6 to 9 reveals that C. carnea larvae has highest feeding potential on A. gossypii followed by A. biguttula biguttula and B. tabaci. Per day prey consumption of C. carnea larvae was also significantly higher when A. gossypii nymphs were provided as prey followed by A. biguttula biguttula and B. tabaci. It was also observed that every successive instar consumed significantly more preys than previous one. The pooled data of these four sets of experiments is given in

Table 6. Feeding capacity of C. carnea larvae on different prey species under laboratory conditions

Set I (13.7.96 to 3.8.96)

Prey species	Number of preys consumed* by larval instars			No. of preys consumed by larva during its life span	Per day consumption	Average temp.(°C)	
	Ist	2nd	3rd			Maximum	Minimum
Aphis gossypii	74.50 (8.69)	140.10 (11.88)	240.40 (15.53)	455.30 (21.36)	45.19 (6.79)	27.15± 1.45	21.7± 1.45
Amarasca biguttula biguttula	40.80 (6.44)	81.70 (9.10)	167.80 (12.99)	290.30 (17.07)	27.25 (5.31)	27.15± 1.45	21.7± 1.45
Bemisia tabaci	35.60 (6.04)	63.40 (8.01)	157.40 (12.58)	257.40 (16.07)	25.31 (5.12)	27.15± 1.45	21.7± 1.45
C.D.(P = 0.05)	(0.34)	(0.24)	(0.15)	(0.19)	(0.19)	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 7 Feeding capacity of C. carnea larvae on different prey species under laboratory conditions

Set II (5.8.96 to 25.8.96)

Prey species	Number of preys consumed* by larval instars			No. of preys consumed by larva during its life span	Per day consumption	Average temp.(°C)	
	Ist	2nd	3rd			Maximum	Minimum
Aphis gossypii	76.80 (8.81)	150.50 (12.30)	251.60 (15.89)	478.90 (21.90)	47.90 (6.99)	28.38± 1.29	22.5± 1.97
Amarasca biguttula biguttula	42.60 (6.60)	80.90 (9.05)	170.70 (13.10)	294.20 (17.18)	26.86 (5.27)	28.38± 1.29	22.5± 1.97
Bemisia tabaci	36.30 (6.10)	65.70 (8.16)	169.20 (13.04)	271.20 (16.49)	25.95 (5.18)	28.38± 1.29	22.5± 1.97
C.D.(P = 0.05)	(0.17)	(0.17)	(0.19)	(0.19)	(0.98)	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 8 Feeding capacity of C. carnea larvae on different prey species under laboratory conditions

Set III (18.8.96 to 10.9.96)

Prey species	Number of preys consumed* by larval instars			No. of preys consumed by larva during its life span	Per day consumption	Average temp.(°C)	
	Ist	2nd	3rd			Maximum	Minimum
Aphis gossypii	71.10 (8.49)	136.70 (11.73)	225.20 (15.03)	433.00 (20.83)	44.69 (6.76)	25.61± 1.53	19.85± 0.98
Amarasca biguttula biguttula	40.90 (6.46)	85.00 (9.27)	166.90 (12.95)	292.80 (17.13)	28.46 (5.43)	25.61± 1.53	19.85± 0.98
Bemisia tabaci	32.40 (5.77)	61.60 (7.91)	149.10 (12.24)	243.10 (15.62)	24.76 (5.07)	25.61± 1.53	19.85± 0.98
C.D.(P = 0.05)	(0.21)	(0.16)	(0.13)	(0.16)	(0.10)	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 9. Feeding capacity of C. carnea larvae on different prey species under laboratory conditions

Set IV (12.9.96 to 1.10.96)

Prey species	Number of preys consumed* by larval instars			No. of preys consumed by larva during its life span	Per day consumption	Average temp.(°C)	
	Ist	2nd	3rd			Maximum	Minimum
Aphis gossypii	69.40 (8.38)	135.40 (11.68)	216.00 (14.72)	420.80 (20.53)	52.37 (7.30)	25.76± 2.06	20.89± 1.29
Amarasca biguttula biguttula	38.30 (6.26)	72.50 (8.57)	147.90 (12.20)	259.70 (16.14)	26.79 (5.27)	25.76± 2.06	20.89± 1.29
Bemisia tabaci	30.50 (5.61)	60.30 (7.83)	139.10 (11.83)	229.90 (15.19)	26.75 (5.26)	25.76± 2.06	20.89± 1.29
C.D.(P = 0.05)	(0.22)	(0.17)	(0.15)	(0.17)	(0.14)	-	-

* Each figure is mean of 10 replications
± indicate standard error
Figures in parentheses indicate square root transformation

Table 10.

The data presented in Table 10 reveal that average number of aphid and jassid nymphs and white fly adults consumed by C. carnea larvae during its development was 447.00, 284.25 and 250.40 at a temperature of 26.72 (maximum) and 21.23°C (minimum). The present findings corroborates the earlier reports where the average total consumption of A. gossypii, A. biguttula biguttula and pupae of B. tabaci by C. carnea has been reported to be 419.18, 288.45 and 329.70 (Balasubramani and Swamiappan, 1994). Mannan (1994) also reported that the number of Aphis gossypii consumed during larval development were 449.43 at a mean minimum and maximum temperature of 27.49 and 32.51°C, respectively. Similarly number of Myzus persicae consumed during larval development were 173.75 at mean minimum and maximum temperature of 22.79 and 28.87°C. Afzal and Khan (1978) also reported that number of A. gossypii consumed by larvae of C. carnea averaged 487.2.

However, the average number of aphids consumed by larvae of C. carnea was 426.6 at 30°C and 40% R.H. and 382.6 at 20°C and 40% R.H (Zaki, 1987). The slight variation in prey consumption by C. carnea may be due to difference in rearing temperature and prey species involved.

The number of aphid and jassid nymphs consumed by 1st, 2nd and 3rd instar larvae of C. carnea were 72.95, 140.67, 233.30 and 40.65, 80.02, 163.32 respectively at a laboratory temperature of 26.72 (maximum) and 21.23°C (minimum) (Fig.3). The corresponding consumption of white fly adults by 3 larval instars of C. carnea

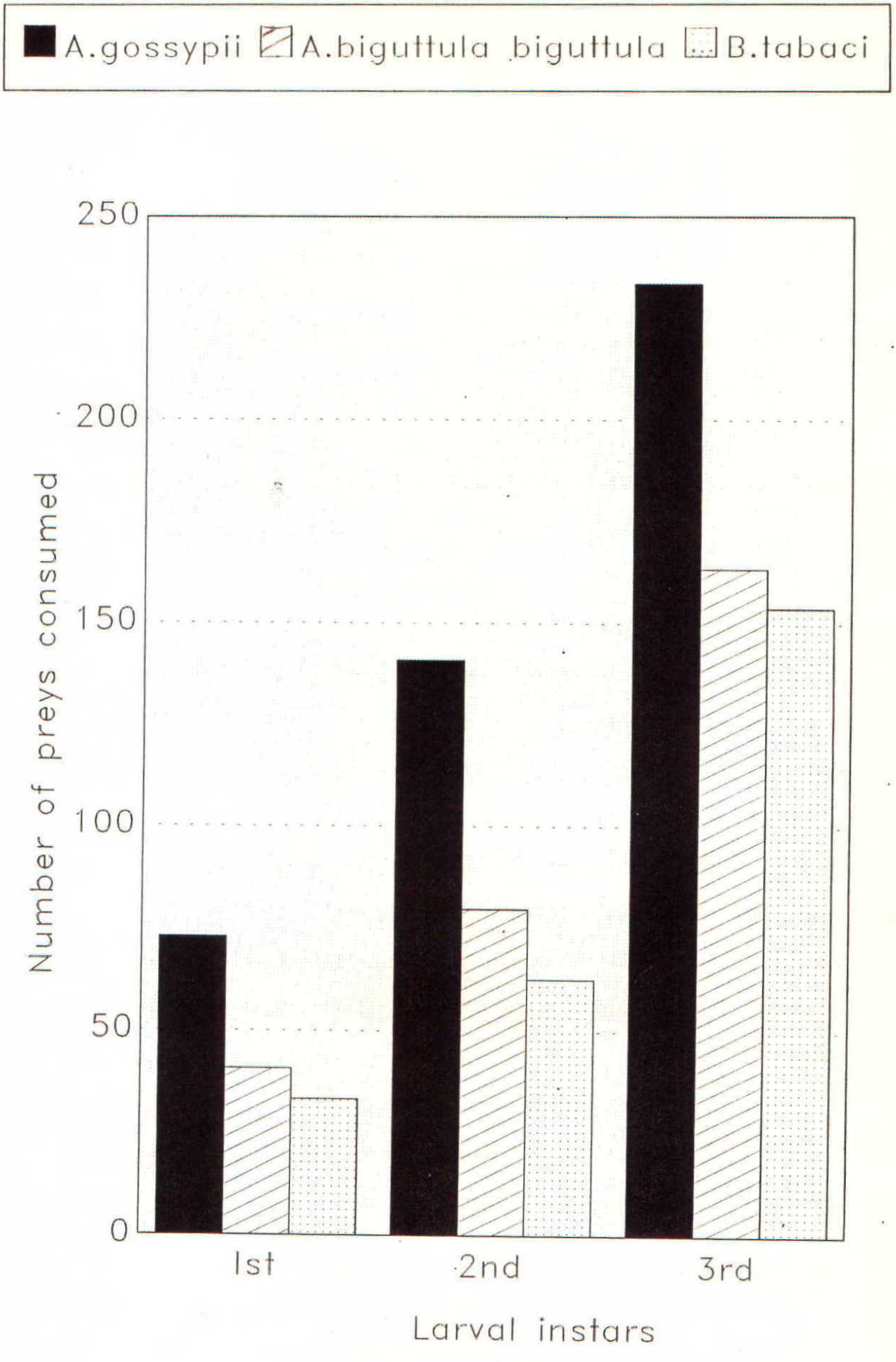

Fig.3 : Feeding capacity of C.carnea larvae on different prey species.

was 33.15, 62.75 and 153.70 (Table 10). The studies on the consumption of different prey species by three larval instars of C. carnea showed that 3rd instar larvae consumed maximum number of preys. It was also observed that every successive instar consumed more preys than previous one. The number of preys consumed by 3rd instar larvae was more than the combined consumption of first, two larval instars in all the prey species. This may be attributed to the fact that 3rd instar larva was more voracious feeder than first two larval instars.The present findings are similar to the earlier reports where the three instars of C. carnea consumed 85.30, 120.85, 243.40 A. gossypii at a mean minimum and maximum temperature of 27.49 and 32.51°C. Similarly, 3 instars of C. carnea consumed 30.65, 49.33, 93.75 Myzus persicae at mean minimum and maximum temperature of 22.79 and 28.67°C, respectively (Mannan, 1994). Yuksel and Gocman (1992) also reported that Aphis gossypii consumption by three instars of C. carnea was 53.6, 174.4, 724.4 and 60.3, 88.6, 506.7 at 25 and 30°C, respectively. The low Myzus persicae consumption may be due to low rearing temperature and difference in species involved.

The number of aphid and jassid nymphs and white fly adults consumed by 1st instar larvae of C. carnea were 72.95, 40.65 and 33.15, respectively. Similarly, number of preys consumed by 2nd instar larvae of C. carnea were 140.67, 80.02 and 62.75 and by 3rd instar larvae of C. carnea were 233.30, 163.32 and 153.70, respectively.

In all the 3 instars, larvae consumed significantly more number of A. gossypii followed A. biguttula biguttula and B. tabaci.

A single larva of C. carnea consumed 47.Ø3, 27.34 and 25.69 nymphs of aphid and jassid and white fly adults respectively (Table 1Ø). It was observed that per day consumption was significantly higher in case of A. gossypii. However, it was at par in A. biguttula biguttula and B. tabaci. El-Daksoury (1977) reported that the average daily consumption by a single larva of C. carnea was 9.8, 14.3 and 26.2 on eggs of Heliothis armigera in the three instars, respectively and that of larvae of H. armigera was 11.8, 24.Ø and 9Ø.3, respectively.

4.3 Preference of C. carnea larvae for different prey species

To study the preference of 2nd instar larvae of C. carnea, 3Ø nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci each and 1Ø larvae of C. carnea were released on potted plants of cotton. The data presented in the Table 11 revealed that nymphs of aphids were significantly more preferred by C. carnea larvae followed by jassid nymphs and white fly adults as prey species. C. carnea larvae consumed significantly more number of aphid (27.9, 26.3Ø) followed by jassid nymphs (12.3, 13.2) and whitefly adults (8.1Ø, 7.2Ø) after 6 hours in experiment I and II.

The preference for A. gossypii may be attributed to the fact that nymphs of aphids were more succulent and less mobile as compared to other two prey species.

Table 10. Feeding capacity of Chrysoperla carnea larvae on different prey species under laboratory conditions

Pooled data (Set I to IV)

Prey species	Number of preys consumed* by larval instars			No. of preys consumed by larva during its life span	Per day consumption	Average temp.(°C)	
	Ist	2nd	3rd			Maximum	Minimum
Aphis gossypii	72.95 (8.60)	140.67 (11.90)	233.30 (15.30)	447.00 (21.36)	47.03 (6.93)	26.72	21.23
Amarasca biguttula biguttula	40.65 (6.45)	80.02 (8.99)	163.32 (12.81)	284.25 (16.88)	27.34 (5.32)	26.72	21.23
Bemisia tabaci	33.15 (6.40)	62.75 (7.98)	153.70 (12.42)	250.40 (15.85)	25.69 (5.16)	26.72	21.23
C.D.(P = 0.05)	(1.06)	(0.33)	(0.28)	(0.40)	(0.27)	-	-

* Each figure is mean of 40 replications
Figures in parentheses indicate square root transformation

Table 11. Preference of C. carnea for different prey species

Prey species	Mean number of preys consumed* out of 30 by 10 larvae of C. carnea after 6 hours	
	Experiment I	Experiment II
Aphis gossypii	27.90 (5.37)	26.30 (5.22)
Amrasca biguttula biguttula	12.30 (3.64)	13.20 (3.76)
Bemisia tabaci	8.10 (3.01)	7.20 (2.86)
CD (p = 0.05)	(0.16)	(0.20)

* Each figure is a mean of 10 replications

Figures in parenthesis indicate square root transformation

4.4. Toxicity of insecticides to different larval instars of C. carnea when exposed to treated food (eggs of Corcyra cephalonica

Ten insecticides viz. carbaryl 50WP, chlorphyriphos 20EC, cypermethin 10EC, dimethoate 30EC, endosulfan 35EC, ethion 50EC, fenitrothion 50EC, imidacloprid 200SL, monocrotophos 36SL and phosphamidon 85SL recommended for the control of cotton pests were tested against different larval instars of C. carnea for their effect on larval mortality under laboratory conditions. The insecticidal concentrations equivalent to those prescribed for field application for the control of cotton pests were used to treat the food (eggs of Corcyra cephalonica) of C. carnea larvae.

4.4.1 Toxicity to 1st instar larvae

The data presented in Table 12 reveal that insecticides showed a wide range of toxicity to larvae of C. carnea. Larval mortality increased with each time intervals in all the insecticides tested. After 48 hour of exposure, significantly low mortality was observed in case of imidacloprid and carbaryl (56.66 and 63.33%) followed by cypermethrin and dimethoate (70%) which was at par with carbaryl. Five insecticides namely ehtion, phosphamidon, monocrotophos, endosulfan and chlorpyriphos recorded significantly higher mortality (83.33 to 100%) and proved to be highly toxic. Almost similar trend was observed in earlier observations recorded at time interval of 12, 24 and 36 hours. The 1st instar larvae surviving exposure to insecticides were found to successfully complete metamorphosis.

Table 12. Toxicity of insecticides to first instar larvae of C. carnea when exposed to treated food (eggs of Corcyra cephalonica)

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC (0.075%)	10.00 (18.43)	40.00 (39.13)	40.00 (39.13)	53.33 (46.90)	70.00 (56.97)	70.00 (56.97)
Endosulfan 35EC (0.28%)	36.66 (37.21)	43.33 (41.14)	60.00 (50.83)	83.33 (66.12)	83.33 (66.12)	100.00 (89.96)
Chlorpyriphos 20EC (0.32%)	36.66 (37.21)	46.66 (43.06)	73.33 (58.98)	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)
Carbaryl 50WP (0.40%)	20.00 (26.06)	20.00 (26.06)	46.66 (43.06)	46.66 (43.06)	63.33 (52.84)	63.33 (52.84)
Cypermethrin 10EC (0.016%)	10.00 (18.43)	13.33 (21.14)	36.66 (37.21)	36.66 (37.21)	53.33 (46.90)	70.00 (56.97)
Imidacloprid 200SL (0.008%)	10.00 (18.43)	10.00 (18.43)	23.33 (28.77)	40.00 (39.13)	56.66 (48.82)	56.66 (48.82)
Fenitrothion 50EC (0.34%)	30.00 (32.99)	40.00 (39.21)	53.33 (46.90)	80.00 (63.90)	80.00 (63.90)	100.00 (89.96)
Ethion 50EC (0.32%)	13.33 (21.14)	30.00 (32.99)	40.00 (39.21)	60.00 (50.83)	73.33 (58.98)	83.33 (66.12)
Monocrotophos 36SL (0.14%)	26.66 (30.98)	50.00 (44.98)	66.66 (54.96)	83.33 (66.12)	100.00 (89.96)	100.00 (89.96)
Phosphamidon 85SL (0.064%)	20.00 (26.06)	36.66 (37.21)	60.00 (50.83)	73.33 (58.98)	96.66 (83.82)	96.66 (83.82)
C.D.(p = 0.05)	(8.08)	(8.17)	(8.05)	(8.08)	(8.37)	(7.14)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

4.4.2. **Toxicity to 2nd instar larvae**

The data presented in Table 13 reveals that larval mortality increased with each time interval in all the insecticides tested against C. carnea. After 48 hour of exposure, significantly low mortality was observed in case of imidacloprid and cypermethrin (50.00 and 53.33%) followed by phosphamidon, carbaryl, dimethoate, endosulfan (56.66 to 63.33%) which are at par with imidacloprid. Fenitrothion and ethion recorded significantly higher mortality (73.33 to 80.00%) and proved to be highly toxic. However, chlorpyriphos and monocrotophos proved to be moderately toxic resulting in 66.66% larval mortality. Almost similar trend was observed in earlier observations recorded at time interval of 12, 24 and 36 hours. The 2nd instar larvae surviving exposure to insecticides were found to successfully complete metamorphosis.

4.4.3. **Toxicity to 3rd instar larvae**

The data presented in Table 14 reveals that there was successive increase in mortality with each time interval in all the insecticides tested against C. carnea. After 48 hours of exposure, significantly low mortality was observed in case of dimethoate (36.66%), cypermethrin (40%), carbaryl and imidacloprid (46.66%) followed by chlorpyriphos and phosphamidon (53.33%) which were at par with cypermethrin. Endosulfan, fenitrothion, ethion and monocrotophos recorded significantly higher mortality (56.66 to 66.66%) and proved to be highly toxic. Almost similar trend was observed in earlier observations recorded at time intervals of 12, 24 and 36 hours. Third instar larvae were comparatively more

Table 13. Toxicity of insecticides to second instar larvae of C. carnea when exposed to treated food (eggs of Corcyra cephalonica)

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC	0.0	10.00	26.66	50.00	60.00	60.00
(0.075%)	(0.0)	(18.43)	(30.98)	(44.98)	(51.12)	(51.12)
Endosulfan 35EC	0.0	10.00	30.00	46.66	53.33	63.33
(0.28%)	(0.0)	(18.43)	(32.99)	(43.06)	(46.90)	(52.84)
Chlorpyriphos 20EC	13.33	20.00	43.33	56.66	60.00	66.66
(0.32%)	(21.14)	(26.55)	(41.14)	(48.83)	(50.75)	(54.97)
Carbaryl 50WP	0.0	10.00	23.33	36.66	56.66	56.66
(0.40%)	(0.0)	(18.43)	(28.77)	(37.21)	(48.83)	(48.83)
Cypermethrin 10EC	16.66	23.33	23.33	30.00	43.33	53.33
(0.016%)	(23.84)	(28.77)	(28.77)	(32.99)	(41.14)	(46.90)
Imidacloprid 200SL	0.0	10.00	13.33	36.66	46.66	50.00
(0.008%)	(0.0)	(18.43)	(21.14)	(37.21)	(43.06)	(44.98)
Fenitrothion 50EC	10.00	13.33	40.00	53.33	63.33	73.33
(0.34%)	(18.43)	(21.14)	(39.13)	(46.90)	(53.05)	(58.98)
Ethion 50EC	13.33	26.66	50.00	60.00	73.33	80.00
(0.32%)	(21.14)	(30.98)	(44.98)	(50.75)	(58.98)	(63.90)
Monocrotophos 36SL	10.00	13.33	30.00	46.66	63.33	66.66
(0.14%)	(18.43)	(21.14)	(32.99)	(43.06)	(52.75)	(54.76)
Phosphamidon 85SL	0.0	10.00	26.66	43.33	50.00	56.66
(0.064%)	(0.0)	(18.43)	(30.98)	(41.14)	(44.98)	(48.83)
C.D.(p = 0.05)	(4.56)	(4.59)	(8.59)	(7.30)	(9.85)	(10.92)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

Table 14. Toxicity of insecticides to third instar larvae of C. carnea when exposed to treated food (eggs of Corcyra cephalonica)

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC	0.0	0.0	10.00	26.66	30.00	36.66
(0.075%)	(0.0)	(0.0)	(18.43)	(30.98)	(32.98)	(37.20)
Endosulfan 35EC	0.0	0.0	13.33	36.66	36.66	56.66
(0.28%)	(0.0)	(0.0)	(21.14)	(37.21)	(37.21)	(48.82)
Chlorpyriphos 20EC	6.66	13.33	20.00	36.66	40.00	53.33
(0.32%)	(12.28)	(21.14)	(26.55)	(37.21)	(39.13)	(46.90)
Carbaryl 50WP	0.0	0.0	13.33	23.33	36.66	46.66
(0.40%)	(0.0)	(0.0)	(21.14)	(28.77)	(37.21)	(43.06)
Cypermethrin 10EC	6.66	13.33	13.33	23.33	33.33	40.00
(0.016%)	(12.28)	(21.14)	(21.14)	(28.77)	(34.99)	(39.13)
Imidacloprid 200SL	0.0	10.00	13.33	26.66	33.33	46.66
(0.008%)	(0.0)	(18.43)	(21.14)	(30.98)	(34.99)	(43.06)
Fenitrothion 50EC	6.16	10.00	13.33	33.33	46.66	66.66
(0.34%)	(12.28)	(18.43)	(21.14)	(34.99)	(43.06)	(54.97)
Ethion 50EC	10.00	13.33	36.66	43.33	63.33	63.33
(0.32%)	(18.43)	(21.14)	(37.21)	(41.14)	(52.84)	(52.84)
Monocrotophos 36SL	6.66	20.00	20.00	36.66	46.66	63.33
(0.14%)	(12.28)	(26.55)	(26.06)	(37.21)	(43.06)	(52.84)
Phosphamidon 85SL	10.00	13.33	20.00	33.33	46.66	53.33
(0.064)	(18.43)	(21.14)	(26.55)	(34.99)	(43.06)	(46.90)
C.D.(p = 0.05)	(12.00)	(4.87)	(7.31)	(N.S.)	(8.98)	(9.34)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

tolerant to insecticides as compared to 1st and 2nd instar. The 3rd instar larvae surviving exposure to insecticides were also found to successfully complete metamorphosis.

4.5. Toxicity of insecticide to different larval instars of C. carnea by direct spray on cotton plants

The same insecticides were tested against different instars of C. carnea larvae for their effect on larval mortality under laboratory conditions. The insecticides concentrations equivalent to those prescribed for field application for the control of pests were sprayed directly on cotton plants on which C. carnea larvae were released and observations on larval mortality were recorded at different time intervals.

4.5.1. Toxicity to 1st instar larvae

The insecticide tested showed a wide range of toxicity to C. carnea larvae. The data presented in Table 15 reveal that larval mortality increased with each time intervals in all the insecticides tested against C. carnea. After 48 hour of exposure, significantly low mortality was observed in case of cypermethrin and carbaryl (56.66 and 63.33%) followed by imidacloprid and dimethoate (70.00 and 73.33%) which was at par with carbaryl. However, fenitrothion, ethion, monocrotophos, phosphamidon, endosulfan and chlorpyriphos proved to be highly toxic resulting in 80.00 to 100.00% mortality. Almost similar trend was observed in earlier observation recorded after 36 hour of exposure. Cypermethrin proved significantly least toxic to C. carnea larvae at all the time intervals. However, it was at par with dimethoate,

Table 15. Toxicity of insecticides to first instar larvae of C. carnea by direct spray on cotton plants

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC	10.00	30.00	46.66	60.00	73.33	73.33
(0.075%)	(18.43)	(32.99)	(43.06)	(50.83)	(58.98)	(58.98)
Endosulfan 35EC	26.66	43.33	70.00	83.33	100.00	100.00
(0.28%)	(30.98)	(41.14)	(56.97)	(66.12)	(89.96)	(89.96)
Chlorpyriphos 20EC	40.00	53.33	73.33	80.00	100.00	100.00
(0.32%)	(39.13)	(46.90)	(58.98)	(63.90)	(89.96)	(89.96)
Carbaryl 50WP	20.00	30.00	36.66	56.66	63.33	76.66
(0.40%)	(26.55)	(32.99)	(37.21)	(48.83)	(52.84)	(61.19)
Cypermethrin 10EC	10.00	26.66	36.66	46.66	56.66	66.66
(0.016%)	(18.43)	(30.98)	(37.21)	(43.06)	(48.83)	(54.96)
Imidacloprid 200SL	20.00	23.33	40.00	56.66	70.00	80.00
(0.008%)	(26.05)	(28.77)	(39.13)	(48.83)	(56.97)	(63.41)
Fenitrothion 50EC	20.00	33.33	46.66	60.00	83.33	100.00
(0.34%)	(26.55)	(34.99)	(43.06)	(50.83)	(66.12)	(89.96)
Ethion 50EC	13.33	36.66	40.00	56.66	83.33	83.33
(0.32%)	(21.14)	(37.21)	(39.13)	(48.83)	(66.12)	(66.12)
Monocrotophos 36SL	20.00	36.66	50.00	63.33	80.00	80.00
(0.14%)	(26.55)	(37.21)	(44.98)	(52.84)	(63.90)	(63.90)
Phosphamidon 85SL	20.00	33.33	50.00	70.00	83.33	83.33
(0.064%)	(26.05)	(35.20)	(44.98)	(56.97)	(66.12)	(66.12)
C.D.(p = 0.05)	(7.08)	(7.92)	(8.42)	(8.71)	(7.69)	(7.52)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

carbaryl, fenitrothion and ethion after 12 and 24 hours of exposure. The 1st instar larvae surviving exposure to insecticides were found to successfully complete metamorphosis.

4.5.2. **Toxicity to 2nd instar larvae**

The data presented in Table 16 reveal that larval mortality increased with each time interval in all the insecticides tested against C. carnea. Significantly low mortality was observed after 48 hour of exposure in case of dimethoate and cypermethrin (46.66 and 56.66%) followed by carbaryl (66.66%) which was at par with cypermethrin. Chlorpyriphos, endosulfan, fenitrothion, ethion, monocrotophos and phosphamidon recorded significantly higher mortality (73.33 to 83.33%). Dimethoate showed significantly low mortality at all the time intervals which was followed by carbaryl and cypermethrin. The 2nd instar larvae surviving exposure to insecticides were found to successfully complete metamorphosis. The larval mortality was comparatively low in case of 2nd instar larvae as compared to 1st instar.

4.5.3. **Toxicity to 3rd instar larvae**

The different insecticides tested showed a wide range of toxicity to C. carnea larvae. The larval mortality increased with each time interval in all the insecticides tested against C. carnea. After 48 hour of exposure, significantly low mortality was observed in case of dimethoate, imidacloprid and cypermethrin (33.33 to 43.33%) followed by carbaryl (46.66%) which was at par with imidacloprid and cypermethrin (Table 17). Endosulfan, fenitrothion, ethion recorded significantly higher mortality

Table 16. Toxicity of insecticides to second instar larvae of C. carnea by direct spray on cotton plants

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC	0.0	10.00	10.00	23.33	46.66	46.66
(0.075%)	(0.0)	(18.43)	(18.43)	(28.77)	(43.06)	(43.06)
Endosulfan 35EC	13.33	26.66	26.66	66.66	83.33	83.33
(0.28%)	(21.14)	(30.77)	(30.77)	(54.97)	(66.12)	(66.12)
Chlorpyriphos 20EC	0.0	10.00	23.33	53.33	56.66	73.33
(0.32%)	(0.0)	(18.43)	(28.77)	(46.90)	(48.83)	(58.98)
Carbaryl 50WP	13.33	20.00	20.00	36.66	53.33	66.66
(0.40%)	(21.14)	(26.55)	(26.55)	(37.21)	(46.90)	(54.97)
Cypermethrin 10EC	13.33	13.33	36.66	46.66	56.66	56.66
(0.016%)	(21.14)	(21.14)	(37.21)	(43.06)	(48.83)	(48.83)
Imidacloprid 200SL	13.33	36.66	46.66	50.00	73.33	73.33
(0.008%)	(21.14)	(37.21)	(43.06)	(44.98)	(58.98)	(58.98)
Fenitrothion 50EC	10.00	20.00	33.33	56.66	66.66	83.33
(0.34%)	(18.43)	(26.06)	(34.99)	(48.83)	(54.96)	(66.12)
Ethion 50EC	20.00	26.66	40.00	50.66	73.33	83.33
(0.32%)	(26.06)	(30.98)	(39.13)	(44.98)	(58.98)	(66.12)
Monocrotophos 36SL	13.33	20.00	36.66	53.33	76.66	76.66
(0.14%)	(21.14)	(26.55)	(37.20)	(46.90)	(61.19)	(61.19)
Phosphamidon 85SL	23.33	33.33	46.66	70.00	73.33	73.33
(0.064%)	(28.77)	(34.99)	(43.06)	(56.97)	(58.98)	(58.98)
C.D.(p = 0.05)	(7.27)	(8.09)	(7.61)	(6.84)	(6.79)	(7.67)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

(70.00 to 73.33%) and prove to be highly toxic. However, phosphamidon, monocrotophos and chlorpyriphos proved to be moderately toxic resulting in 53.33 to 63.33% larval mortality. Similar trend in larval mortality was observed after 12, 24 and 36 hour of exposure. The 3rd instar larvae were comparatively more tolerant to insecticides as compared to previous two instars as the larval mortality was considerably low in this case. The 3rd instar larvae surviving exposure to insecticides were found to successfully complete metamorphosis.

Cypermethrin 10EC, dimethoate 30EC, carbaryl 50WP and imidacloprid 200SL were found to be least toxic to different instars of C. carnea larvae, in both experiments i.e. exposure to treated food and by direct spray on cotton plants. Endosulfan, chlorpyriphos, monocrotophos, fenitrothion and phosphamidon proved highly toxic to different instars of C. carnea larvae. However, the 3rd instar larvae were comparatively more tolerant to insecticides as compared to previous two instars of C. carnea.

The present findings are similar to the earlier reports where residues of dimethoate after 24 hours of exposure were not appreciably toxic to the larvae of C. carnea but phosphamidon and endosulfan were highly toxic to the larvae of C. carnea (Bartlett, 1964). Plapp and Bull (1978) have also reported that carbaryl have a low toxicity to larvae of C. carnea. The present studies also corroborates the earlier findings of Singh and Varma (1984) who reported that endosulfan, monocrotophos and fenitrothion were highly toxic to larvae of C. carnea. Kismir and Sengonca (1980) also reported that monocrotophos caused heavy larval mortality

Table 17. Toxicity of insecticides to third instar larvae of C. carnea by direct spray on cotton plants

Insecticide (conc. %)	Percentage mortality* (Hours after exposure)					
	3 hr	6 hr	12 hr	24 hr	36 hr	48 hr
Dimethoate 30EC	0.0	0.0	10.00	26.66	26.66	33.33
(0.075%)	(0.0)	(0.0)	(18.43)	(30.98)	(30.98)	(35.20)
Endosulfan 35EC	20.00	33.33	46.66	53.33	66.66	70.00
(0.28%)	(26.55)	(35.20)	(43.06)	(46.90)	(54.96)	(56.97)
Chlorpyriphos 20EC	10.00	26.66	30.00	46.66	56.66	56.66
(0.32%)	(18.43)	(30.98)	(32.99)	(43.06)	(48.83)	(48.83)
Carbaryl 50WP	0.0	13.33	23.33	36.66	46.66	46.66
(0.40%)	(0.0)	(21.14)	(28.77)	(37.21)	(43.06)	(43.06)
Cypermethrin 10EC	0.0	0.0	10.00	23.33	43.33	43.33
(0.016%)	(0.0)	(0.0)	(18.43)	(28.77)	(41.14)	(41.14)
Imidacloprid 200SL	0.0	10.00	20.00	26.66	40.00	40.00
(0.008%)	(0.0)	(18.43)	(26.06)	(30.98)	(39.13)	(39.13)
Fenitrothion 50EC	10.00	23.33	40.00	53.33	73.33	73.33
(0.34%)	(18.43)	(28.77)	(39.21)	(46.90)	(58.98)	(58.98)
Ethion 50EC	10.00	13.33	30.00	43.33	70.00	70.00
(0.32%)	(18.43)	(21.14)	(32.99)	(41.14)	(56.97)	(56.97)
Monocrotophos 36SL	10.00	20.00	26.66	46.66	63.33	63.33
(0.14%)	(18.43)	(26.06)	(30.98)	(43.06)	(52.84)	(52.84)
Phosphamidon 85SL	23.33	40.00	40.00	46.66	53.33	53.33
(0.064%)	(28.77)	(39.21)	(39.21)	(43.06)	(46.90)	(46.90)
C.D.(p = 0.05)	(2.07)	(6.15)	(5.68)	(5.05)	(7.02)	(6.61)

* Each figure is a mean of 3 replications
Figures in parentheses indicate arc sine angular transformations

(upto 84%) of C. carnea. The present findings are also in line with earlier workers who reported that pyrethroids have marked low toxicity against C. carnea larvae (Plapp and Bull, 1978; Niemczyk et al., 1979 and Rajakulendran and Plapp, 1982). The high tolerance to pyrethroids may be attributed to the higher hydrolysing activity of estrases (enzyme) present in the larvae of C. carnea. This enzyme has unique specificity for hydrolysing cis-permethrin and cypermethrin 2-3 times as fast as the corresponding trans-isomers (Ishaaya and Casida, 1981).

CHAPTER V

SUMMARY AND CONCLUSIONS

The studies on development and predation efficacy of Chrysoperla carnea (Stephens) and effect of insecticidal application on larval mortality were carried out in the biological control laboratory of the Department of Entomology as well as at the Entomological Research Farm, PAU, Ludhiana during 1995-96.

The development of C. carnea larvae was studied on nymphs of Aphis gossypii (Glover), Amrasca biguttula biguttula (Ishida) and adults of Bemisia tabaci (Gennadius) under laboratory conditions at mean minimum and maximum temperature of 21.23 and 26.72°C, respectively.. The mean larval period of C. carnea on nymphs of aphid, jassid and white fly adults was 9.47, 10.40 and 9.77 days, respectively. The duration of 1st, 2nd and 3rd larval instars of C. carnea were found to be 3.46, 2.68, 3.30 and 3.70, 2.80, 3.90 days on nymphs of A. gossypii and A. biguttula biguttula, whereas it was 3.42, 2.70 and 3.65 days, respectively, when adults of B. tabaci were provided as host.

The mean pupal period was 8.67, 7.62 and 7.67 days, when C. carnea was reared on nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci. The pupal development was significantly faster on jassid and white fly as compared to aphid.

The total larval and pupal period was 18.13, 18.03 and 17.45 days when nymphs of A. gossypii, A. biguttula biguttula and adults of B. tabaci were provided as prey species. The larval

development was comparatively faster on A. gossypii followed by B. tabaci and A. biguttula biguttula. However, total larval plus pupal period was shorter on B. tabaci followed by A. biguttula biguttula and A. gossypii.

The average number of aphid and jassid nymphs and white fly adults consumed by C. carnea larvae during its development were 447.00, 284.25 and 250.40. The number of aphid and jassid nymphs consumed by 1st, 2nd and 3rd instar larvae of C. carnea were 72.95, 140.67, 233.30 and 40.65, 80.02, 163.32, respectively. The corresponding consumption of white fly adults by 3 larval instars of C. carnea was 33.15, 62.75 and 153.70. The studies on the consumption of different prey species by three larval instars of C. carnea showed that 3rd instar larvae consumed maximum number of preys. It was also observed that every successive instar consumed more preys than previous one. The number of preys consumed by 3rd instar larvae was more than the combined consumption of first two larval instars in all the prey species.

In all the three instars, the larvae consumed significantly more number of aphid nymphs followed by jassid nymphs and significantly lower number of white fly adults. The 3rd instar larvae consumed maximum number of A. gossypii (233.30) followed by A. biguttula biguttula (163.32) and B. tabaci (153.70).

Per day consumption of aphid and jassid nymphs and white fly adults by C. carnea larvae were 47.03, 27.34 and 25.69, respectively. Per day consumption was significantly higher in

case of aphid followed by jassid and white fly.

The 2nd instar larvae of C. carnea preferred cotton aphid followed by jassid and white fly adults as it consumed significantly more number of aphid nymphs as compared to other two prey species.

Cypermethrin, dimethoate, carbaryl and imidacloprid were found to be comparatively less toxic to all instars of C. carnea when exposed to treated host i.e. eggs of Corcyra cephalonica as well as by direct spray on cotton plants. Endosulfan, chlorpyriphos, monocrotophos, phosphamidon, ethion and fenitrothion were highly toxic to different instars of C. carnea. The 3rd instar larvae were comparatively more tolerant to insecticides as compared to 1st and 2nd instar larvae of C. carnea.

C. carnea could be reared successfully on A. gossypii, A. biguttula biguttula and B. tabaci but A. gossypii was more suitable prey species. C. carnea has higher feeding potential on A. gossypii followed by A. biguttula biguttula and B. tabaci. A. gossypii was most preferred among the three prey species. Cypermethrin 10EC, imidacloprid 200SL, carbaryl 50WP and dimethoate 30EC were found less toxic to all instars of C. carnea.

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