क्रायसोपर्ला प्रजाति (*कार्निया*–समूह) की आहार क्षमता एवं कीटनाशी संबंधी सुरक्षा का मूल्यांकन

Feeding potential and insecticidal safety evaluation of *Chrysoperla* sp. (*carnea*-group)

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Feeding potential and insecticidal safety evaluation of *Chrysoperla* sp. (*carnea*-group)

By

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This is to certify that the thesis entitled Feeding potential and insecticidal safety evaluation of *Chrysoperla* sp. (*carnea*-group), submitted to the faculty of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in ENTOMOLOGY embodies the results of bona fide research work carried out by Mr. SHAH VIVEK HANSKUMAR (Roll no. 20053) under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that any help or source of information that has been availed of in this connection has been duly acknowledged by him.

Date: June 30, 2012
Place: New Delhi

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Dedicated

To

My Beloved Parents

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CHAPTER 1 INTRODUCTION

Biological control is one of the oldest, economical, sustainable and environment friendly means of managing the pest. The importance of natural enemies (parasites, predators and pathogens) for combating pests in agro-ecosystems is coming into closer focus based on modern investigations (Bailey, 1991). Presence of predators and parasitoids in field crops, orchards and vegetables has been a subject for many studies for reducing the insecticide usage and thereby environmental pollution (White Comb and Bell, 1964; Dean and Sterling, 1992). Sometimes the role played by the predators itself reduces the need of pesticide application. Among several predators identified as biocontrol agents the Neuropterans (Neuroptera: Chrysopidae) play a potential role in combating the insect pest damage.

Across the Indian subcontinent, the agriculturally important *Chrysoperla carnea* species-group of Chrysopidae is represented by a single common species, *Chrysoperla sillemi* (Esben-Petersen). However, the cryptic species within the *carnea* group can be reliably distinguished from one another only by their substrate borne vibrational songs. Hence the name *Chrysoperla* sp. (*carnea*-group) has been retained in the present thesis (Henry et al., 2010).

The common green lacewing, *Chrysoperla* sp. (*Carnea*-group) also known as golden eyes and aphid lions is an important predator belonging to order ‘Neuroptera’. This order consists of a group of insects with rather soft bodies, biting mouthparts and two pairs of very similar membranous wings which are usually held roof-like along the abdomen at rest. Their agricultural importance lies in their carnivorous habits. The larvae are all predators and some are terrestrial, feeding on jassids, psyllids, aphids, coccids, mites etc., and others are aquatic. It is rare in the tropics to find a large colony of aphids without at least some neuroptern larvae feeding on them. One larva may devour as many as five hundred aphids in its life time and there is no doubt that they play an important part in the natural control of many small homopterous pests (Michaud, 2001, Legaspi *et al*., 1994).

Chrysopid predators are known to feed on more than 80 species of insects and 12 species of mites (Kharizanov and Babrikova, 1978). The larva of *Chrysoperla* sp. has a broad range of prey acceptance including aphids, whiteflies, eggs of moths and other soft-bodied insects. They are widely distributed voracious polyphagous predators (New, 1975) and easy to mass multiply under laboratory conditions (Araujo and Bichao, 1990). In India, 65 species of Chrysopids belonging to 21 genera have been recorded out of these *Chrysoperla* is the dominant genera, containing several species which are widely used in augmentation programme (Gautam, 1994).

Chrysoperla sp. received much attention of farmers as well as researchers as a potential biological pest control agent due to its tolerance to some pesticides as well (Hassan *et al*., 1985). Effectiveness of *Chrysoperla* sp. as biological control agent has been demonstrated in field crops, orchards and in green houses (Hagley and Miles, 1987). Inspite of all these benefits sighted, *Chrysoperla* sp. in field is rare due to frequent use of non-selective agrochemicals (Nasreen *et al*., 2005). Now, the importance of bio-intensive pest management has been recognized as a holistic approach for integrated pest management. This can be achieved only by using an insecticide which is selective enough to kill the insect pest and spare the natural enemies.

As insecticides are unavoidable in insect pest management programs especially when the pest crosses economic threshold level (ETL). Nevertheless, often the plant protection products kill the natural enemy population making the pest to resurge and thus demanding more insecticidal applications. Continuous and indiscriminate use of synthetic chemicals in plant protection resulted in toxicity to non target beneficial organisms. Therefore, Selective insecticides that target pest species could play a role in conserving this wide diversity of natural enemies. Several insecticides that are widely used to suppress various insect pests can disrupt the effectiveness of these beneficial agents. It is still not clear to what degree insecticides are disruptive to other non-target organisms. Improved understanding of pest-natural enemy-insecticide interactions will assist in formulating more effective Integrated Pest Management strategies, keeping in view the harm done to beneficial organisms.

Neonicotinoids are the new group of crop protection products found highly effective against the sucking pests and selective as well. Neonicotinoids act on receptor protein of insect nervous system and thus possess a new mode of action (Leicht, 1996). They are acute, contact and stomach poisons with translaminar and systemic properties. At lower concentrations they act as anti-feedants, a property they share with nicotine. Their selectivity, lower use rate and safety to beneficial insects especially when used as seed dressings make neonicotinoids an ideal component in any IPM programme.

Chrysoperla sp. is important predator, available commercially in many countries of the world for augmentative release in various agro-ecosystems for population management of many insect pests. Mass multiplication of this predator is very important to ensure its timely and adequate supply to farmers. In general, mass multiplication of *Chrysoperla* sp. under laboratory conditions is done on factitious hosts like *Corcyra cephalonica* (Stainton), *Sitotroga cerealella* (Olivirer) and *Anagastra kuehniella* (Zeller) worldwide. But, in India *C. cephalonica* is used for mass multiplication (Sandya *et al*., 2002). Rearing of *C. cephalonica* is tedious, time consuming and also causes respiratory hazards to workers due to inhalation of scales of the moth (Jalali and Singh, 1989; Sreekumar *et al*., 1997). So there is need to find alternate prey insect which can be utilised for mass production of *Chrysoperla* sp. in order to have regular supply and timely availability of predator with sufficient number. So keeping this in view present investigation was carried out with the following objectives:

1. To study feeding potential of *Chrysoperla* sp. (*Carnea*-group) on different host species.
2. To study the effect of biopesticides and synthetic insecticides on *Chrysoperla* sp. (*Carnea*-group).

CHAPTER 2 BACKGROUND

Among predators, lacewings thrive well in a wide range of habitat, about 1200 species have been known worldwide. Some of the known and common species are: *Chrysoperla carnea* (Stephens), *Chrysoperla rufilabris* (Burmeister), *Chrysoperla plorabunda* (Fitch), *Chrysoperla mediterranea* (Hölzel), *Chrysoperla oculata* (Say), *Chrysoperla adamsi* (Henry, Wells and Pupedis), *Chrysoperla johnsoni* (Henry, Wells and Pupedis), *Chrysoperla lucasina* (Lacroix), *Chrysoperla nigricornis*, *Chrysoperla downesi* (Smith), *Chrysoperla mohave* (Banks), *Chrysoperla comanche* (Banks), *Chrysoperla formosa* (Brauer), *Chrysoperla pallens* (Rambur), *Chrysoperla lacciperda* (Kimmins), *Chrysoperla scelestes* (Banks). *Chrysoperla* spp., especially *C. carnea* and *C. rufilabris*, are sold commercially by numerous producers and suppliers (Hunter, 1994; Penny *et al*., 2000; James, 2003 and 2006) to control insect pests.

So a detailed account on previous work done on aspects of predatory potential of *Chrysoperla* on different prey species and also impact of different insecticides on larval mortality and adult development is reviewed in detail in this chapter under following headings.

a. Predatory potential of *Chrysoperla* sp.

b. Effect of different insecticides on *Chrysoperla* sp.

2.1. Predatory potential of *Chrysoperla* sp.

Kharizanov and Dimitrov (1972) reported that a single larva of *C. carnea* feeds on 600-950 nymphs and adults of *Myzus persicae* (Sulzer) under laboratory conditions and larval period ranged from 9-10 days. Afzal and Khan (1978) conducted a laboratory experiment and they found that *C. carnea* consumed mean number of 487.2 aphids, *Aphis gossypii* (Glover) or 510.8 whitefly pupae, *Bemisia tabaci* (Gennadius) from egg emergence till pupation.

Results of laboratory experiments conducted by Balasubramani and Swamiappan (1994) revealed that the total development period (egg to adult emergence) of the common green lacewing, *C. carnea* lasted for 19.15, 19.35, 19.95, 20.15, 20.60 and 22.50 days when the larvae were fed with *Bemisia tabaci*, eggs of

Corcyra cephalonica (Stainton), *Heliothis armigera* (Hubner), *A. gossypii*, *Amrasca biguttula* and (Ishida) neonates of *H. armigera* respectively. Larval development was rapid on eggs of *C. cephalonica* (8.20 days) and prolonged on neonates of *H. armigera* (11.10 days). Pupal development period was quicker on *B. tabaci* and *A. biguttula* (7.40 days) and prolonged on neonates of *H. armigera* (8.40 days). During development each larva of *C. carnea* consumed an average of 732.35 eggs of *C. cephalonica*, 662.53 eggs of *H. armigera*, 419 nymphs of *A. gossypii*, 409.55 neonates of *H. armigera*, 329.70 pupae of *B. tabaci* and 288.45 nymphs of *A. biguttula*. In all the cases, the third instar larvae consumed the major portion of the total number consumed (60–80%). The most suitable preys, resulting in rapid development, for *C. carnea* were pupae of *B. tabaci* and eggs of *C. cephalonica*.

Osman and Selman (1996) showed that *Pieris brassicae* (Linnaeus) eggs serves as an important prey as compared with aphids. Authors also used *Drosophila melanogaster* (Meigen) pupae and adults as prey and found that it is relatively inferior as prey source.

Mannan *et al*. (1997) conducted studies on biology of *C. carnea* on *A. gossypii* and *M. persicae*. The pre-oviposition, oviposition and post oviposition period were found to be 6.55, 21.10 and 7.95 days on *A. gossypii* and 9.25, 21.85 and 11.20 days on *M. persicae* respectively. The mean fecundity of *C. carnea* was about 84.70 and 103 eggs; the incubation periods were 2.25 and 3.68 days. The duration of development of first, second and third instar larvae were 2.60, 2.25, 2.38 and 3.75, 2.78 and 3.35 days when reared on *A. gossypii* and *M. persicae*, respectively. The pupal period was 9.43 and 11.40 days on *A. gossypii* and *M. persicae*, respectively. The females lived longer (35.70 and 38.80 days) than males (32.20 and 35.80 days) on two respective hosts.

Kundu *et al*. (1998) found that average number of *C. cephalonica* eggs consumed by larvae of *C. carnea* was 896±42.11 for complete development while on other hand Thite and Shivpuje (1999) observed that first, second and third instar larvae consumed an average of 36.77, 78.1 and 146.1 *Corcyra* eggs/day respectively.

Saminathan *et al*. (1999) studied the biology and predatory potential of *C. carnea* on eggs of *C. cephalonica*, *Earias vitella* (Fabricius) and *H. armigera*, neonate larvae of *E. vitella* and *H. armigera* and *A. gossypii* lover) collected from cotton

(*Gossypium hirsutum* L.), okra (*Hibiscus esculentus* L.) and guava (*Psidium guajava* L.) and *Aphis craccivora* (Koch.) collected from cowpea [*Vigna unguiculata* (L.) Walp.] and groundnut (*Arachis hypogaea* L.). The egg, grub and pupal period of *C. carnea* were minimum on *A. craccivora* collected from groundnut and maximum on *H. armigera* neonate larvae. The total developmental period of *C. carnea* on different insect hosts ranged from 18.59 days on *A. craccivora* (groundnut) to 22.74 days on *H. armigera* neonate larvae. *C. carnea* adult laid a maximum of 318.40 eggs when reared on *A. craccivora* as compared to any other host.

Geethalakshmi *et al*. (2000) studied the biology and feeding of *C. carnea* on *C. cephalonica* eggs. Total development period from egg to adult emergence was completed in 22.2 days. Larval and pupal period was 10.3 and 8.4 days, respectively. Progeny had a sex ratio of 1: 0.95 (female: male) an average of 640 eggs were laid per female. Males survived for 26.5 days and females for 39.0 days. A single larva fed an average of 30.3 eggs of *C. cephalonica*, 33.4 eggs of *H. armigera*, 0.54 egg masses of *Spodoptera litura* (Fabricius), 5.9 and 7.9 first instar larvae of *H. armigera* and *S. litura* and 33.3 and 24.6 *A. gossypii* and *Planococcus citri* (Rossi) respectively in a single day.

The total number of fourth stadium aphids consumed by *C. carnea* larvae differed significantly among individuals fed different aphid species. *C. carnea* consumed more *A. gossypii* (292.4) and *M. persicae* (272.6) than *L. erysimi* (146.4). Proportions of aphids consumed by each larval stadium to the total number of aphids consumed were similar, 3.9-7.1% by the first stadium, 12.0-16.8% by the second stadium, and 78.1-83.9% by the third stadium (Liu *et al*., 2001).

Larval and cocoon periods were significantly affected due to variations in prey species, while the total developmental period of *C. carnea* (egg to adult) on different insect hosts ranged from 18.40 (*C. cephalonica*) to 21.35 days (*A. craccivora*). The survival of larva feeding on *A. craccivora*, *D. melanogaster* and *C. cephalonica* were 51.85, 80.95 and 86.67%, while cocoon weight as 11, 22 and 8 mg, respectively. *C. carnea* adults laid a maximum of 1079.0 eggs/ female when reared on *C. cephalonica*, followed by *D. melanogaster* (582) and *A. craccivora* (172.8) eggs/ female (Tesfaye and Gautam, 2002).

Studies were carried out to find an alternate host, which was ecofriendly and easy to mass-produce the predator. *Tribolium castaneum* (Herbst) larva and *D. melanogaster* larva were identified as better alternate hosts for mass multiplication of the predator. Even though, *D. melanogaster* larva, proved as an inferior host compared to *C. cephalonica* eggs, it could be recommended as a better alternate host because of its fast multiplication, cheaper production and harmlessness to workers. Larva reared on *T. castaneum* larvae underwent a high incubation period (5.25-6.13 days), high prepupal period (1.13-1.89 days) and pupal period (10.88-13.50 days) compared to those fed with *C. cephalonica* eggs which remained in incubation for 3.79-4.83 days, with prepupal and pupal period of 0.29-0.84 and 7.66-9.13 days, respectively. Highest adult longevity and fecundity was observed when larvae were fed with *T. castaneum* larvae as compaired to eggs of *C. cephalonica* (Viji and Gautam, 2005)

The feeding efficiency of larvae was observed on mustard and wheat aphids by Mari *et al*. (2007). They observed that mean per cent feeding per day by first, second and third instar larvae were 26.92, 49.58 and 85.18 on mustard aphid and 44.6, 62.6 and 94.2 per day on wheat aphid. The feeding rate fitted the logistic model which indicated that the third instar consumed more aphids than formers.

Studies were conducted by Muzammil Sattar *et al*. (2007) on predatory potential of *C. carnea* on the mealy bugs under laboratory conditions. The results revealed that *C. carnea* larvae were voracious feeder of mealy bugs. On an average, a larva consumed 1604.0 nymphs of 1st instar, 689 nymphs of 2nd instar and 144.7 nymphs of 3rd instar of cotton mealy bug in its entire larval period (no choice feeding). First instar nymph of mealy bug was most preferred for feeding (free choice feeding).

Studies carried out by Ningxing Huang (2010) on predatory capacity and prey preference of larvae of *C. carnea* on eggs or larvae of *P. brassicae* in the absence and presence of cabbage aphids as an alternative prey were evaluated in laboratory experiments at 25°C. Both instars preyed upon the butterfly eggs and larvae as well as on cabbage aphids with third instar being the most voracious. The lacewings had a strong preference for caterpillars to butterfly eggs. In the presence of the aphids the predation on *P. brassicae* eggs or larvae was either completely abandoned or reduced by about 70 per cent, respectively, by second instar lacewings and either reduced by about 80 per cent or maintained, respectively, by third instar lacewings. Both instars thus had a clear preference for aphids compared to eggs of *P. brassicae*. However, second instar lacewings preferred aphids to caterpillars, whereas the opposite was the case for third instar lacewings. The results indicated that 3rd instar *C.* carnea has a potential as biocontrol agent against *P. brassicae*.

Saminathan *et al* (1999) studied *C. carnea* adult laid highest number of eggs (318.40/ female) when reared on *A. craccivora* on cowpea which was significantly different insect hosts the fecundity was minimum on *C. cephalonica* eggs (189.40 eggs/ female). The hatchability ranged from 74.30 (*Erias vitella* neonate larvae) to 83.88% (*C. cephalonica* eggs).

2.2. Effect of different insecticides on *Chrysoperla* sp.

Studies were carried out by Miszcka (1975) to evaluate toxicity of 13 insecticides, 3 acaricides and 2 fungicides against eggs and larvae of *C. carnea.* Most of these insecticides were highly toxic to eggs, hatching larvae and first instar larvae, but trichlorophon and methyldemeton-O was comparatively harmless to eggs and hatching larva. Methyldemeton-O had no effect on first instar larvae. Of the fungicides, methylthiophanate was toxic to eggs. None of the fungicides was toxic to larvae. The acaricides were slightly toxic to the eggs and did not affect the larvae of *C. carnea*.

Plapp and Bull (1978) reported that most organophosphate insecticides and the carbamate, methomyl were highly toxic to the predator *C. carnea*. Another carbamate, carbaryl, a formamidine chlordimeform, several pyrethroids and several organochlorine were much less toxic to *C. carnea*. In Comparision with *Heliothis virescens* (Fabricius), phosphorothionate (P=S) insecticides were highly selective against *H. virescens.*

Babrikova (1979) determined the effects of some pesticides on the adult and pre-adult stages of *C. carnea.* He found that the eggs, larvae and pupae were for the most part resistant to the compounds, while the adults were the most sensitive. Tetrachlorvinphos, phosalone and ethiofencarb were the least toxic of the contact compounds tested, pirimicarb and menazon of the systemic compounds, and dicofol and dinobuton of the acaricides. The fungicides tested caused higher mortality in the egg stage. The above mentioned chemicals are suitable for use in integrated pest management programmes in orchids, vineyards, tobacco and other crop fields.

Shour and Crowder (1980) reported that third instar larvae showed a marked level of tolerance to all pyrethroids (fenvelerate, permethrin, cis-permethrin and transmethrin) tested over a 72-hour period when treated topically with 250 mg insecticides/ insect. Larval survival, adult emergence and fecundity were unaffected by permethrin but not by fenvelerate at 1000 μ/g through one generation (larvae to larvae); the female life span, however, was reduced by permethrin. The ED_{50} (that causing paralysis, failure to pupate, knockdown and mortality) for fenvelerate was around 1000 μ/g, whereas those for other compounds could not be determined but would be greater than 25,000 μ/g.

Hassan *et al*. (1987) reported the resistance / tolerance of *Chrysopa* against *B. thuringensis,* endosulfan, lindane, primicarb, pyrethrum plus PBO, sulphur, captan, mancozeb, vinczolin, desmetry, propachlor, fenbutatin oxide, thiram, and etc.

Fayad and Ibrahim (1988) indicated that *C. carnea* was highly susceptible to deltamethrin, chlorpyriphos and profenofos. In laboratory studies, triazophos, monocrotophos and fenpropathrin sprayed on cotton leaves had a greater residual toxicity to larvae of the predator *C. carnea* than endosulfan, cypermethrin and fenvalerate (Kapadia and Puri, 1991).

Ferreira *et al*. (1989) evaluated insecticide toxicity on larvae of *Chrysoperla externa* (Hagen) under laboratory conditions. The products evaluated were viz., phosmet, methoxyfenozide, tebufenozide, emamectin benzoate, spinosad, etofenprox and chlorpyrifos, using water as control. Spraying of insecticides was on first-instar larvae using the Potter’s Tower. The toxic effect was estimated according to the IOBC recommendations. Emamectin benzoate was classified as harmless (class-1). Methoxyfenozide, etofenprox, tebufenozide, spinosad and phosmet were classified as slightly harmful (class-2) phososmet was moderately harmful (class-3) and chlorpyrifos was classified as harmful (class-4).

El-Magharby *et al*. (1994) studied toxicity of cypermethrin, deltamethrin, fenpropathrin, fenvalerate, methomyl and kelthane-S against the egg stage and the 1st larval instar of *C. carnea*. The authors found that deltamethrin was most toxic against eggs (LC_{90}= 3.35 ppm) as compared with safest compound kelthane-S (LC_{90} = 144 ppm); the toxicity of other compounds ranged between 17.6 and 109.2 ppm. The larval stages needed higher concentrations to achieve similar mortality percentages.

Vogt (1994) studied the effect of seven insecticides on *C. carnea* by treating young dwarf apple trees on which larvae had been released. The insect growth regulators flufenoxuron, diflubenzuron, teflubenzuron and fenoxycarb were found to be moderately harmful. Cyfluthrin was highly toxic while thiocyclam and phosmet exhibited little effect on the larvae.

Toda and Kashio (1997) investigated toxic effects of 34 insecticides on 1st instar larvae of *C. carnea* in the laboratory, using a direct dipping and a residual contact test. Out of these, ethofenprox, permethrin and cypermethrin showed high toxicity, while five other insecticides showed low toxicity. Three carbamate insecticides showed high toxicity, while primicarb showed no toxicity. All organophosphate insecticides showed high toxicity except trichlorofon. Flufenoxuron, teflubenuron and chlorfluazuron showed no toxicity within 48h, but showed high mortality after 96h. Tebufenozide, buprofezin and pyriproxyfen were not toxic. Nitenpyram, imidachloprid and acetamiprid showed low toxicity in the dipping test, but high toxicity in the residual contact test.

Balasubramani Swamiappan (1997) exposed chrysopids to cotton leaves which has been previously sprayed with chlorpyriphos 20 EC, dicofol 18 EC, endosulfan 35 EC, fenvalerate 20 EC, methyldemeton (demeton-s-methyl) 25 EC, monocrotophos 36 WSC, phosalone 35 EC and quinalphos 25 EC at 3.2, 2.4, 2.8, 0.6, 0.8, 1.0, 4.0 and 3.2 ml/ litre, respectively. Chlorpyriphos was toxic for 8 days, while quinolphos and fenvalerate was toxic for 6 and 4 days respectively. The remaining insecticides were not toxic to *C. carnea.*

Patil, *et al*. (1997) reported that indigenous plants extract of *Stachytarpheta indica* (Linnaeus), *Parthenium hysterophorus* (Linnaeus), *Vitex negundo* Linnaeus were found to be safe to the eggs, larvae and adults of potential predators *C. carnea.*

Duffie *et al*. (1998) evaluated the mortality of predaceous arthropods on cotton. Insecticide classes included representatives from the following: Insect growth regulator (IGR), carbamates, pyrethroid, chloronicotinyl and organophosphate. The IGR had low toxicity while carbamates were moderately toxic to the predaceous arthropods. chloronicotinyl and organophosphate classes were the most toxic causing dramatic reductions in predator numbers.

Elbert *et al*. (1998) indicated that in soil application, the residual toxicity of imidachloprid for controlling whitefly adults was sometime higher than acetamiprid reaching their higher toxicity 7-14 days after application.

Two formulations of azadirachtin, applied in the laboratory at the highest recommended field concentrations (0.3% Neem Azal- T/S and 0.15% Align), were highly toxic to first instar larvae of the predator *C. carnea*. The oily formulation Neem Azal- T/S was more toxic, but in the both cases the pesticide disrupted larval development inducing larval mortality of the different instars preventing pupation and adult emergence. Other effects observed were delayed development, inhibition of weight gain and several moulting deficiencies (distorted mandibles, abnormal melanization, gut extrusion, inability of complete shedding off the old cuticle), disoriented movements and lesser mobility (Vogt *et al*., 1998).

Sarode and Sonalkar (1999) proved that neem seed extract was comparatively safe against eggs of *C. carnea* followed by phosalone. Chlorpyriphos, deltamethrin and cypermethrin were found highly toxic to *C. carnea*.

First, second and third instar larvae of *C. carnea* were evaluated using half of the recommended dose of organophospahate and carbamate insecticides by dry film technique. Third instars were more tolerant than the second and first ones. Organophosphorous insecticides were more toxic than carbamates. Pirimiphosemethyl, malathion and dimethoate had the same LC_{50} (140 ppm) against third instar larvae. Per cent mortalities of third instar larvae; even by using the double of the recommended rate of application were low, viz., 7 and 14% for primicarb and carbosulfan (Badawy and El-Arnaouty, 1999).

Srinivasan and Babu (2000a) also showed the effects of certain insecticides on different life stage of predatory green lacewing, *C. carnea* where in abamectin caused the maximum egg mortality of 25.2% as against 6.3% in control. Carbaryl affected the larvae more and the mortality was 83.3%. endosulfan and abamectin had no adverse influence on the larvae and the larva mortality was only 3.3 and 6.7 per cent, respectively. Adult emergence was highly affected by carbaryl, which recorded only

10.00 per cent against 93.33 per cent adult emergence in control. The fecundity was 0.5 eggs as against 160.4 eggs in control.

Neem seed kernel extract and commercial neem products viz., Neem Azal-T/S, Neem Azal-F, Nimbicidine, neem gold, TNAU neem products 0.03%, TNAU neem product No 60 EC (C) and Indneem were evaluated against eggs, larvae, adults of *C. carnea* by Srinivasan and Babu, (2000b). The products caused 14.66 to 25.33% egg mortality compared with 8.00% in untreated controls and 6.66 to 16.66 larva mortality compared with 3.33% in controls. The longevity of adults ranged between 18.66 and 20.66 days in treatments, while it was 23.66 days in controls. Fecundity was also affected slightly by all neem products (599.66 to 741. 66 eggs) as against 874.66 eggs in controls.

Toxic effects of five commercial insecticides viz., carbosulfan, leufenuron, cyfluthrin, methomyl and fenpropathrin were evaluated on green lacewing under laboratory bioassays. Insect mortality was determined following insecticide exposure by eggs immersion, larval leaf dip bioassay and by direct adult topical application. Larval mortality was observed for the instar treated and for following instars and pupae. Following insecticide exposure, *C. carnea* mortality was greatest for life stages treated directly and decreased during subsequent life stages. Methomyl, cyfluthrin and fenpropathrin caused about 95 per cent mortality when 1st instar larvae were exposed to chemicals. Methomyl and fenpropathrin remained effective and caused 92 per cent mortality when 2nd instar larvae were exposed to chemicals. All chemicals caused about 60-70 per cent mortality, when applied to 3rd instar. Mortality of adults was highest for fenpropathrin (57 per cent). All materials registered significant effect on longevity and fecundity of adults (Abida Nasreen *et al*., 2007).

The effects of imidacloprid, propargite, and pymetrozine on the *C. carnea* were investigated in laboratory, using the IOBC-system and the life table response experiment. Residual glass plate bioassays were carried out using two-day-old larvae at the Iranian maximum field recommended rate of each commonly used pesticide. All three tested pesticides produced significant adverse effects on pre-imaginal survival. Imidacloprid had no significant effect on fecundity, but propargite and pymetrozin caused significant reductions. According to the IOBC classification, imidacloprid was found to be harmless (E = 27.44 per cent); propargite (E = 49.78 per cent) and pymetrozine (E = 66.9 per cent) were slightly harmful. Life table assays revealed that imidacloprid and propargite had no significant effects on the intrinsic rate of natural increase, while pymetrozine caused a 34 per cent reduction in rm value. Propargite was found to be non-toxic to *C. carnea* under the tested conditions. In case of imidacloprid, using a glass plate as test substrate led to underestimation of its effects. The life table assay showed more adverse effects of pymetrozine than the IOBC method (Rezaei, *et al*., 2007).

Preetha *et al*. (2009) conducted laboratory studies to find out the toxicity of imidacloprid and diafenthiuron to the eggs, larvae and adults of *C. carnea* and reported that imidacloprid at the recommended dose of 0.28 ml/l caused 15.38 per cent egg mortality, 26.67 and 33.33 per cent larval mortality by ingestion and contact action, respectively and 50.00 per cent adult mortality. Diafenthiuron recorded 15.38 per cent egg mortality, 23.33 per cent larval mortality and 26.67 per cent adult mortality. Based on the classification given by IOBC/WPRS working group on Pesticides and non-target invertebrates, both the insecticides were classified as harmless to *C. carnea*, since the recommended dose caused less than 50% mortality under the laboratory conditions.

Maroufpoor *et al*. (2010) evaluated the toxicity of spinosad to several stages of *C. carnea* under laboratory conditions and mortalities were recorded 1-3 day post treatment. In contact bioassay tests, a direct relationship was detected between the concentration of spinosad and mortality rate of first instar larvae. Negligible mortality rate was observed on application of 250 ppm of spinosad on second and third instar larvae 3 days after treatment, whereas the first instars larvae suffered 33 per cent mortality. The authors concluded that toxicity of spinosad to *C. carnea* is at par with conventional synthetic insecticides.

CHAPTER 3 MATERIALS AND METHODS

The present investigation was carried out at Division of Entomology, IARI, New Delhi. Laboratory studies were conducted to find out the toxicity of newer group of insecticides on *Chrysoperla* sp. (*carnea*-group) and also to find out feeding potential of predator on different prey species. The study was undertaken during 2011-2012. Nucleus culture for the mass culturing of the predator was obtained from the Biological Control Laboratory, Division of Entomology, IARI, New Delhi. Prey species required for study was either mass reared under laboratory conditions or collected from field and commercial formulations of insecticides used for the study were procured from the market. The details of the rearing equipments and chemicals used, the methodology adopted for recording observations on various aspects under study and statistical analysis used for interpretations of the results are presented in this chapter.

Information related to different materials and methods used for study is as follows:

3.1 Materials

3.1.1. Glasswares

Plastic jars (10 x 7 cm and 22.5 x 15 cm), were used for rearing of *Aphis craccivora* Kotch. and its predator *Chrysoperla* sp. (*carnea*-group). Glass vials of 15 x 2.5 cm size, used for collecting the individual insect of *Chrysoperla* sp. (*carnea*-group) to study the effect of different prey on their survival and predation. Glass Petriplates of 10 cm diameter were used for bioassay and feeding potential studies. Plastic trays of 30 x 10 cm and 15 x 7.5 cm size were used for keeping the Petri plates.

3.1.2. Equipments

Table lamp is used while collections of adults from jar and small hand atomizer (Vintage Atlas Hand Atomizer) is used to apply different concentrations of insecticides.

3.1.3. Miscellaneous

Black, white muslin cloth, rubber bands to cover the rearing jars, cotton plugs, tissue papers and blotting papers etc. were used to cover the glass vials and to line the Petri plates, respectively. Needles, forceps and camel hairbrush were used for handling the grubs of predator.

3.2 Mass culturing of the predator *Chrysoperla* sp (*carnea*-group):

Nucleus culture was obtained from the Biological Control Laboratory was maintained using standard set of procedure as given by Gautam (1994). Adults were transferred to jar and fed with 50 per cent honey solution and castor pollen apart from this mixture of Proteinex® + yeast (8:2 ratio) were mixed with honey solution to make paste this was applied on walls of jar acting as food supplement for adult. The jar was covered with black markin cloth. Females laid stocked eggs on the cloth. For initial 3 weeks the cloth was changed every alternate day and later cloth was changed once in three days. The stalked eggs laid by the females on roof board were destalked after 24 hours by gently brushing with a piece of sponge and kept in plastic jar (15 × 8 cm) covered with muslin cloth.

For larval rearing cloths containing eggs of predator were transferred to jars for hatching and *Corcyra cephalonica* Stainton eggs were provided as larval food after 2-3 days after emergence of larvae. Second instar larvae were transferred to plastic jar (15 × 8 cm) @ 25-30 larvae/jar and provided with fresh eggs of *C. cephalonica* as food. Fresh eggs of *C. cephalonica* were provided daily in each jar until cocoon formation. Few paper pieces were provided inside the jar and their by reducing cannibalism and also acting as substrate for pupation. Pupae were collected and kept in separate jar for emergence. The adults emerged out from the cocoons were collected individually in plastic tube (5 × 2 cm) and transferred again in the oviposition cage. The oviposition cages were covered with black muslin cloth as *Chrysoperla* prefers to lay eggs on black surface Wet cotton plug is provided inside the jar to maintain high humidity for better emergence. Culture was maintained at temperature 27 ± 1º C and 65 ± 5% RH.

3.2 Mass rearing of different prey species under field and semi field conditions.

3.2.1 Rearing of *Aphis craccivora* Kotch.

Cowpea seeds were cleaned and soaked in water overnight slightly sprouted seeds were spread evenly over sterilized absorbent cotton wetted with water placed inside the jar. Once seeds germinated, fully grown aphids were collected from field and released gently on the sprouted seeds. Sufficient amount of water was added time to time to ensure healthy growth of cowpea plants. Jar was covered with muslin cloth. The aphids obtained from this can further be used for increasing prey number.

3.2.2 Rearing of *Corcyra cephalonica* Stainton.

Eggs of the *Corcyra cephalonica* were used for mass culturing of the predator. In the laboratory the larvae of *C. cephalonica* were reared on broken sorghum or maize placed in a jar containing 2.5 kg of food material. Nearly, 0.25cc (5000) eggs of rice meal moth were sprinkled in a jar and kept for development at 30 ± 2ºc and 60 ± 5% RH. The larvae fed on the grain and pupated in the silken cacoons. Jar containing full grown larvae or nearing to pupation are transferred to wooden trays (45cm× 30cm× 10cm) for smooth pupation and adult emergence. Moths started emerging 30th day onwards were collected daily either manually or with aspirator. These adults were caged in a oviposition cage fitted with 40 mash size wire mesh. Eggs fall at bottom of the oviposition cage through the wire mesh. Eggs were collected; scales are blown off and cleaned, used for mass rearing of predator (Gautam, 2008). Regular supply of *Corcyra* eggs was obtained from Biological Control Laboratory, Division of Entomology, IARI, New Delhi.

3.2.2 Rearing of mustard aphid under semi field conditions

Mustard seedlings were raised by sowing seeds in plastic pots of size (15cms×12.5cms) covered with wire mesh cage. seedlings were watered on daily basis. 3-4days old seedlings were inoculated with apterous females of mustard aphid. Aphids were removed from plants and used for experiments to study predatory potential and also utilised for mass rearing of the predator.

3.3 Feeding potential of *Chrysoperla* sp. on different preys under laboratory

The predatory efficiency of *Chrysoperla* sp. (*Carnea*-group) on four different aphid species *viz*., *Aphis craccivora* Kotch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kaltenbach) and *Rhophalosiphum maidis* Fitch. The effects of four aphid species on development and predation of common green lacewing, Chrysoperla sp. (carnea-group) were determined in the laboratory. The individual grub would be reared in

Petri dish right from hatching of the eggs till cocoon formation. The grub would be fed individually using different prey species. Prey individuals would be provided daily in the morning hours. Predatory efficiency would be determined by counting the number of prey consumed.

Per day consumption:

Feeding potential of different larval instars was studied in the laboratory. Per day and total consumption rate of the predator on different prey species was studied by providing known number of prey species to larvae from hatching till cocoon formation. The per cent prey consumption by different instars of predator is determined. The experiment was replicated five times and per day consumption was recorded.

Fecundity of *Chrysoperla* sp. (*carnea*-group) on different aphid species

Newly emerged adults were kept in rearing jar (12cm×9cm) and provided with adult food supplements. The period of survival of each male and female was recorded regularly in order to record longevity (days). Observations were recorded by counting total number of eggs laid at four day intervals. Total number of eggs laid by each female during their oviposition period was recorded. These experiments had five replications.

The data collected on the feeding potential, egg, larval, pupal period and fecundity were analysed by suitable statistical methods.

3.3 Effect of insecticides on *Chrysoperla* sp.

Newer groups of insecticides such as acetamiprid, thiamethoxam, imidacloprid and buprofezin were tested under laboratory conditions against second instar larvae of *Chysoperla* sp. and compared with untreated control.

For testing the effect of insecticides first step done was screening of the insecticides to find the approximate LC_{50} value. Taking 50 per cent mortality as base concentration of the insecticide bioassay experiment is designed in such a way that few concentration were taken above 50 per cent mortality value and few concentration were taken below it.

3.3.1 Screening of insecticide

Eggs of *C. cephalonica* were exposed to UV radiation of 15 W for 15 min to kill the embryo. The UV killed *Corcyra* eggs were taken on a filter paper and insecticide solutions of wider concentrations are was sprayed on it using a hand atomizer. The treated eggs were air dried for 15 min and then transferred to Petri plates at the rate of 1 cm^3 per Petri plate. The untreated check was maintained by spraying the eggs with distilled water. Second instar larvae of *Chrysoperla* sp. were transferred to Petri plates containing *Corcyra* eggs. The larvae were allowed to feed the treated eggs. Each treatment was replicated five times. Response of the insect towards different doses was ascertained by recording mortality 24 hrs after application. Further bioassays were conducted again considering the 50 per cent mortality concentrations with little variations taking 2-3 concentrations above and 2-3 concentrations below it so as to fine-tune the LC_{50} value.

3.3.2 Evaluation of toxicity of insecticide on *Chrysoperla* sp.

Eggs of *C. cephalonica* were exposed to UV radiation of 15 W for 15 min to kill the embryo. The UV killed *Corcyra* eggs would be taken on a filter paper and insecticide solutions of pre decided concentrations were sprayed on it using a hand atomizer. The treated eggs were air dried for 15 min and then transferred to Petri plates at the rate of 1 cm^3 per Petri plate. The untreated check was maintained by spraying the eggs with distilled water. Second instar larvae of *Chrysoperla* sp. were transferred to Petri plates containing *Corcyra* eggs. The larvae were allowed to feed the treated eggs and once they complete feeding, untreated *Corcyra* eggs were provided after 24 hrs until pupation. The treatments were replicated five times. Observations would be made on the larval mortality (24, 48 and 72hr after treatment).

CHAPTER 4 RESEARCH PAPER-I

Biology and predatory potential of green lacewing, *Chrysoperla* sp. (*carnea*-group) (Neuroptera: Chrysopidae) on different aphid species

4.1 Abstract

Laboratory experiments were conducted during 2011 to study the biology and predatory potential of green lacewing *Chrysoperla* sp. (*carnea*-group) on four aphid species viz. *Aphis craccivora* Kotch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kaltenbach) and *Rhophalosiphum maidis* Fitch. The effects of four aphid species on development and predation of common green lacewing, *Chrysoperla* sp. (*carnea*-group) were determined in the laboratory. Mean number of aphids consumed throughout the grub period were *Aphis craccivora* (394.8±4.472), *A. gossypii* (332.6±3.689), *Lipaphis erysimi* (132.4±6.074) and *Rhophalosiphum maidis* (260.4±4.092). The total developmental period was least in case of *A. craccivora* (21.1 days) and it is on par with general laboratory host i.e., *Corcyra cephalonica* (20.5 days). Whereas, highest developemental period was recorded on *L. erysimi* (24.2 days). Feeding potential of the predator was in the order of *A. craccivora*> *A. gossypii* >*R. maidis*> *L. erysimi*. Although total numbers of aphids consumed by the three larval stadia differed significantly, the proportions of aphids consumed by each larval stadium to the total number of aphids consumed were 3.72-8.45% by the first stadium, 15.99-26.13% by the second stadium, and 68.89-80.25% by the third stadium. Fecundity was found to be significantly higher in case of *C. cephalonica* (789.6±9.883 eggs), while in case of *A crassivora* value was recorded to be 250.8±7.703 eggs. Present study concluded that though all the parameters with respect to developmental period of *Chrysoperla* sp. (*carnea*-group) reared on *A. craccivora* were on par with *C. cephalonica* but fecundity was found to be lower on *A. craccivora*.

4.2 ***Key words:*** aphids, biological control, lacewings, predation.

4.3 Introduction

The genus *Chrysoperla* contains several important species of predatory insects. Green lacewing *Chrysoperla* sp. (*carnea*-group) is an important generalist predator used in biological control of insect pests in various cropping systems. It is mass reared in laboratory on the eggs of the rice moth *Corcyra cephalonica* Stainton. (Patel *et al*., 1988). The common green lacewing, *Chrysoperla*, has been recorded as an effective predator of aphids, including *A. craccivora, A. gossypii*, *Lipaphis erysimi* and *Rhophalosiphum maidis*. It has significant potential for commercialization and use against a variety of crop pests in combination with other insect pest management tactics.

Kharizanov and Dimitrov (1972) reported that a single larva of *Chrysoperla carnea* feeds on 600-950 nymphs and adults of *Myzus persicae* (Sulzer). Similarly, Afzal and Khan (1978) found that *C. carnea* can consume mean number of 487.2 aphids, *Aphis gossypii* or 510.8 whitefly pupae, *Bemisia tabaci* (Gennadius). Osman and Selman (1996) showed that *Pieris brassicae* (Linnaeus) eggs serves as an important prey as compaired with aphids. Geethalakshmi *et al*. (2000) studied the biology and feeding of *C. carnea* on *C. cephalonica* eggs. Total development period from egg to adult emergence was completed in 22.2 days. Larval and pupal period was 10.3 and 8.4 days, respectively. Progeny had a sex ratio of 1: 0.95 (female: male) an average of 640 eggs were laid per female. Males survived for 26.5 days and females for 39.0 days. The feeding efficiency of larvae was observed on mustard and wheat aphids they found that third instar consumed more aphids than formers (Mari *et al*., 2007).

The knowledge of biology plays an important role in mass production of the predator and its utilization in pest management programme. Larval prey quality has considerable influence on the biology and behaviour of chrysopids (Canard and Principi, 1984). To insight the information on biology and feeding potential of *Chrysoperla* sp. (*carnea*-group) on different prey species, the present investigation was carried out in Biological Control Laboratory, Division of Entomology, IARI, New Delhi.

4.4 Materials and Methods

The experiment was conducted at the Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi. The cultures were maintained at 27± 1^0C temperature and 65±5% of relative humidity (RH).

4.4.1 Mass culturing of host insect

4.4.1.1 Rearing of *Aphis craccivora* Kotch.

The cowpea aphid was reared based on the standard procedure given by Gautam, (2008). Cowpea seeds were cleaned and soaked in water overnight freshly sprouted seeds were spread evenly over sterilized absorbent cotton wet with water placed inside the jar. Once seeds germinated, fully grown aphids were collected from field and released gently on the sprouted seeds. Sufficient amount of water was added time to time to ensure healthy growth of cowpea plants. Jars (10 X 6 inches) were covered with muslin cloth. The aphids obtained from rearing were used for increasing prey number.

4.4.1.2 Rearing of *Corcyra cephalonica* Stainton.

Eggs of the *C. cephalonica* were used for mass culturing of the predator. In the laboratory, the larvae of *C. cephalonica* were reared on broken sorghum or maize placed in a jar containing 2.5 kg of food material. Nearly, 0.25cc (approximately 5000) eggs of rice meal moth were sprinkled in the jar and kept for development at 30±1ºC and 60±5% RH. The larvae fed on the grain and pupated in the silken cacoons. Jars containing full grown larvae or nearing to pupation were transferred to wooden trays (45cm × 30cm × 10cm) for smooth pupation and adult emergence. The moths started emerging on 30th day onwards and were collected daily either manually or with aspirator. These adults were caged in oviposition cage fitted with 40 mesh size wire mesh. Eggs fell at bottom of the oviposition cage through the wire mesh were collected and sterilized under UV for half an hour to kill the embryo. Scales were blown off and eggs were cleaned and used for mass rearing of predator (Gautam, 2008). Regular supply of *Corcyra* eggs was obtained from Biological Control Laboratory, Division of Entomology, IARI, New Delhi.

4.4.1.3 Rearing of mustard aphid under semi field conditions

Mustard seedlings were raised by sowing seeds in plastic pots of size (15cms×12.5cms) covered with wire mesh cage. Seedlings were watered on daily basis. Three to Four days old seedlings were inoculated with apterous females of mustard aphid. Aphids were removed from plants and used for experiments to study predatory potential and also utilised for mass rearing of the predator.

4.4.1.4 Rearing of cotton and maize aphid under field conditions

Cotton and maize plants are raised on small plots and inoculated with aphids. Plants were watered regularly. Once aphids got established, they used for the experiments.

4.4.2 Mass culturing of predator, *Chrysoperla* sp. (*carnea*-group)

Nucleus culture was obtained from the Biological Control Laboratory was maintained using standard procedure by Gautam (1994). For larval rearing, cloths containing eggs of predator were transferred to jars (10x 6 inches) for hatching and *Corcyra* eggs were provided as larval food up to 2-3 days after emergence of larvae. Second instar larvae were transferred to plastic jar (15 × 8 cm) @ 25-30 larvae/jar. Fresh eggs of *C. cephalonica* were provided daily in each jar until cocoon formation. Few paper pieces were also provided inside the jar in order to reduce cannibalism and also acting as substrate for pupation. Pupae were collected and kept in separate jar for emergence. The adults emerged out from the cocoons were collected individually in plastic tubes (5 × 2 cm) and transferred again to the oviposition cage which was covered with black muslin cloth as *Chrysoperla* prefers to lay eggs on black surface. Wet cotton plug was provided to maintain high humidity for better emergence; culture was maintained at temperature 27±1° C and 65±5% relative humidity (RH).

4.4.2 Studies on Biology of *Chrysoperla* sp.

Ten eggs of *Chrysoperla* sp. reared on respective hosts were kept individually in glass vials and open end was plugged with cotton. After hatching, grubs were fed with various hosts insects separately till completion of the larval period. Development period of each instar of *Chrysoperla* were recorded during egg, larval and pupal period and adult survival.

Plate 1.Stalked eggs of *Chrysoperla* sp. (*carnea*-group)

Plates 2.Third instar larvae of *Chrysoperla* sp. (*carnea*-group) feeding on *Corcyra* eggs

Plates 3.Pupae of *Chrysoperla* sp. (*carnea*-group)

Plates 4. Adults of *Chrysoperla* sp. (*carnea*-group)

Plates 5. Adult emergence jar of *Chrysoperla* sp. (*carnea*-group)

4.4.3 Predatory potential of *Chrysoperla* sp. (*carnea*-group)

A single predatory larva was confined to glass vial (5cm×2.5cm) which was provided with 100 aphids on daily basis till the completion of larval period. Observations were made on number of prey consumed at interval of 24 hrs, and total numbers of prey consumed per instar wise as well as throughout life period were calculated.

4.4.4 Fecundity of *Chrysoperla* sp. (*carnea*-group)

Newly emerged adults were kept in rearing jar (4 cmX7.5 cm) and provided with adult food supplements. The period of survival of each male and female was recorded regularly in order to record longevity (days). Observations were recorded by counting total number of eggs laid at four day intervals. Total number of eggs laid by each female during their oviposition period was recorded. These experiments had five replications.

4.4.5 Statistical analysis

Rate of the predation efficiency of larval instars and adult beetles were analysed using OP STAT, HAU, Hisar, Haryana.

4.5 Results

Predatory potential of grubs of *Chrysoperla* sp. (*carnea*-group) were studied on different prey species *viz*., *A. craccivora*, *A. gossypii*, *L. erysimi* and *R. maidis* by providing counted number of prey (aphids) to grubs of predator. Results showed that among four different species of aphids, grubs of *Chrysoperla* had fed more on *A. craccivora* whereas *L. erysimi* was least preyed. Mean number of aphids consumed throughout the grub period were *A. craccivora* (394.8 ± 4.472), *A. gossypii* (332.6 ± 3.689), *L. erysimi* (132.4 ± 6.074) and *R. maidis* (260.4 ± 4.092) (Table 4.1 and Fig. 4.1). Feeding potential of the predator is in order of *A. craccivora*> *A. gossypii* > *R. maidis*> *L. erysimi*. Although total numbers of aphids consumed by the three larval stadia differed significantly, the proportions of aphids consumed by each larval stadium to the total number of aphids consumed were 3.72-8.45%, 15.99-26.13%, 68.89-80.25% by first, second and third stadium respectively.

The per day consumption rate of the *Chrysoperla* on different prey species revealed that the consumption rate increased significantly from 7th day onwards (Table 4.2 and Fig. 4.2) that coincides with third instar of the grub, indicating that 3rd instar was the main predatory stage contributing upto 68.89-80.25% of total prey consumed.

The incubation period of *Chrysoperla* reared on different insect hosts ranged from 3 days on *A. craccivora* (which is on par with *C. cephalonica* 2.7 days) incubation to 4.1 days on *L. erysimi*. The total grub period was longest on *L. erysimi* (10.7 days) followed by *R. maidis* (10.4 days), *A. gossypii* (9.7 days), whereas total grub period in case of *A. craccivora* and *C. cephalonica* were 9.5 and 9 days respectively (Table 4.3 and Fig. 4.3). The pupal period on different hosts recorded was 8.6 days on *A. craccivora*, 9 days on *A. gossypii*, 9.3 days on *R. maidis*, 9.4 days on *L. erysimi* and 8.8 days on *C. cephalonica*. The total life cycle of *Chrysoperla* ranged from 21.1 days to 24.2 days.

Longevity in case of adult female survived more number of days than their counterpart irrespective of prey species consumed. Among four species of aphids, longevity of male (32.8 ± 1.463) as well as female (38.6±0.927) was highest when reared on *A. craccivora*, whereas female longevity was found to be more when reared on eggs of factitious host *i.e.*, *C. cephalonica* (Table 4.4 and Fig. 4.4).

The average pre-oviposition period of *Chrysoperla* sp. (*carnea*-group) was found to be least when reared on *A. gossypii* (4.8±0.374 days), whereas highest period was recorded in case of *R. maidis* (7.2±0.583 days). The average post oviposition period was recorded and range from 4.8±0.374 to 8.2±0.374 days. Average fecundity was found to be significantly higher in case of *C. cephalonica* (789.6±9.883 eggs), while in case of *A crassivora* value was recorded to be 250.8±7.703 eggs. Although all the biological parameters of *A crassivora* were on par with that of *C. cephalonica* eggs, but as far as fecundity was concerned *C. cephalonica* eggs were found to be better host for mass rearing under laboratory conditions (Table 4.5 and Fig. 4.5).

4.6 Discussion

This study revealed that the four aphid species significantly affected the grub development, adult longevity of *Chrysoperla* sp., as well as the number of aphids consumed. The development time of *Chrysoperla* larvae was shortest when fed with *A. craccivora*, intermediate on *A. gossypii* and *R. maidis,* whereas longest on *L. erysimi*. Results of laboratory experiments conducted by Balasubramani (1994) also revealed that the total development period (egg to adult emergence) of the common green lacewing, *C. carnea* lasted for 19.15, 19.35, 19.95, 20.15, 20.60 and 22.50 days when the larvae were fed with *Bemisia tabaci*, eggs of *C. cephalonica*, *H. armigera* (Hubner), *A. gossypii*, *Amrasca biguttula* (Ishida)) and neonates of *Heliothis armigera* respectively. Saminathan *et al*. (1999) found that the egg, grub and pupal period of *C. carnea* were minimum on *A. craccivora* collected from groundnut and maximum on

Table 4.1 Predation potential of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids (Mean±SE)

(Mean of five observations)

Prey Species/ Instar	I	II	III
A. craccivora	33.400 ±0.245	89.200± 1.356	272.200±2.871
A. gossypii	12.400 ±0.400	53.200 ±1.772	267.000 ±1.517
R. maidis	10.800 ±0.800	45.800 ± 0.583	203.800±2.709
L. erysimi	5.800 ±0.860	34.600 ± 2.421	92.000± 2.793
CD	1.912	5.055	7.662
SE(m) ±	0.632	1.672	2.534

Table 4.2 Per day consumption of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids (Mean±SE)

(Mean of five observations)

Prey Species/ Days	1	2	3	4	5	6	7	8	9
A. craccivora	3.8±0.58	13.4±0.74	16.2±0.86	20.4± 1.20	24.4±1.2	44.4± 2.15	85.4±2.29	93 ±1.14	93.8±1.65
A. gossypii	2.4±0.51	4±0.70	6±0.70	15±1.09	15.2±1.15	23±2.04	89.6±2.87	90.4±2.50	87±1.70
R. maidis	2.6±0.51	3±0.70	5.2±0.37	12±0.83	14.6±1.07	19.2±1.06	73.6±3.04	66.6±2.42	63.6±2.04
L. erysimi	1.6±0.51	2±0.31	2.2±0.37	9±1.30	11.4±1.50	14.2±1.46	26.6±1.4	32.6±2.04	32.8±1.82
CD	NS	1.948	1.864	3.401	3.771	5.268	7.520	6.339	5.481
SE(m) ±	0.529	0.644	0.616	1.125	1.247	1.742	2.487	2.096	1.812

Table 4.3 Developmental period of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids (Mean±SE)

(Mean of five observations)

Prey Species/ Stage	Egg	I	II	III	Pupal
A. craccivora	3± 0.158	3 ±0.158	3.3±0.200	3.2±0.122	8.6 ±0.187
A. gossypii	3.3±0.200	3.3±0.200	3.1±0.100	3.3±0.200	9±0.274
R. maidis	3.8±0.122	3.5±0.224	3.4±0.187	3.2±0.122	9.3±0.200
L. erysimi	4.1±0.187	3.8±0.200	3.4±0.187	3.5±0.224	9.4±0.367
C. cephlonica	2.7±0.122	2.8±2.800	3±0.158	3.2±0.122	8.8±0.255
CD	0.479	0.548	N.S.	N.S.	N.S.
SE (m) ±	0.161	0.184	0.170	0.164	0.265

Table 4.4 Longevity of adults of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids (Mean±SE)

(Mean of five observations)

Prey Species	Male	Female
A. craccivora	32.8 ± 1.463	38.6± 0.927
A. gossypii	28± 1.414	36.2± 1.594
R. maidis	23.8± 1.594	33.6±0.927
L. erysimi	23.4± 1.364	23.9± 3.906
C. cephlonica	30.2± 1.855	44.2± 1.463
CD	4.598	6.183
SE (m) ±	1.548	2.081

Table 4.5 Oviposition period and fecundity of adults of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids (Mean±SE)

(Mean of five observations)

Prey species	Pre-oviposition	Oviposition	Post- oviposition	Fecundity
A. craccivora	6.2±0.583	22.8±0.663	7.8±0.583	250.8±7.703
A. gossypii	4.8±0.374	23.6±0.872	6.2±0.374	512±8.456
R. maidis	7.2±0.583	19±0.707	8.2±0.374	320.8±9.927
L. erysimi	5.4±0.51	14.800±0.735	4.8±0.374	101.2±5.435
C. cephlonica	6.4±0.51	31.8±0.860	8.2±0.374	789.6±9.883
CD	1.538	2.293	1.260	25.088
SE (m) ±	0.518	0.772	0.424	8.445

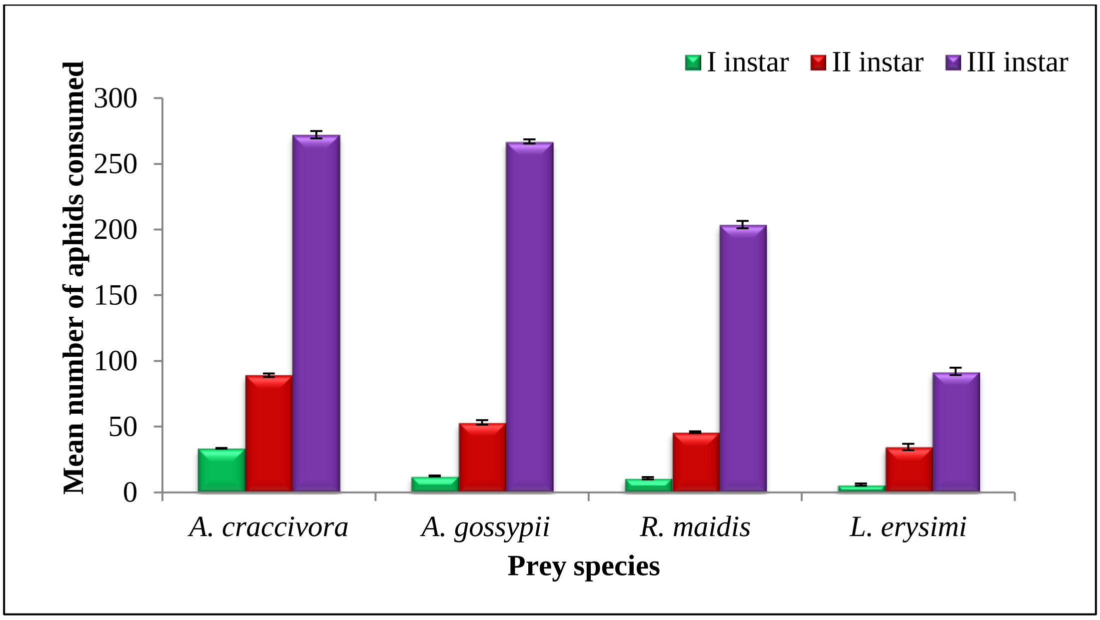

Fig. 4.1 Predation potential of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids

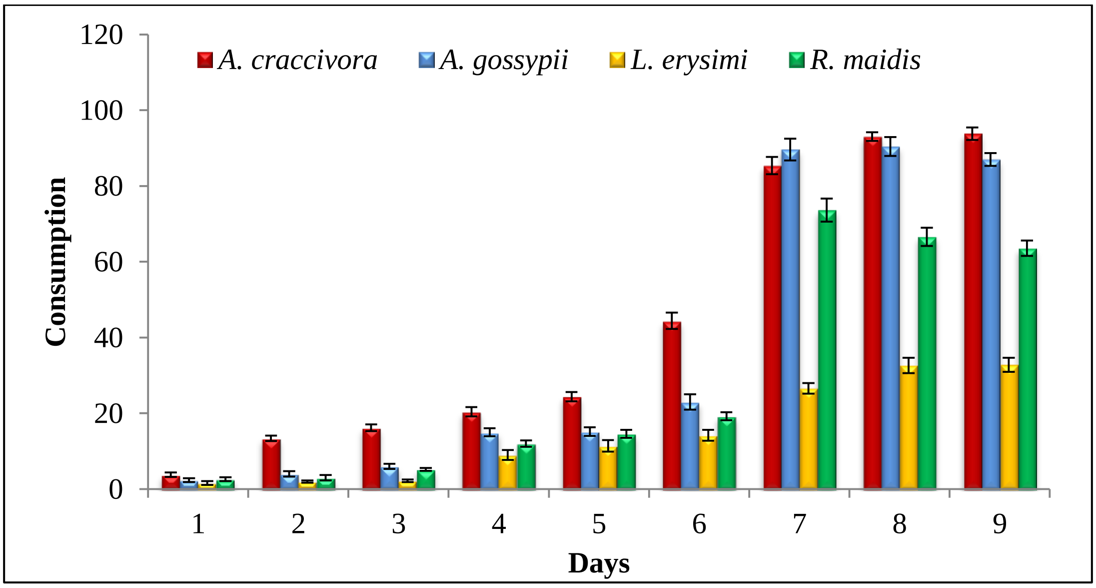

Fig. 4.2 Per day consumption of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids

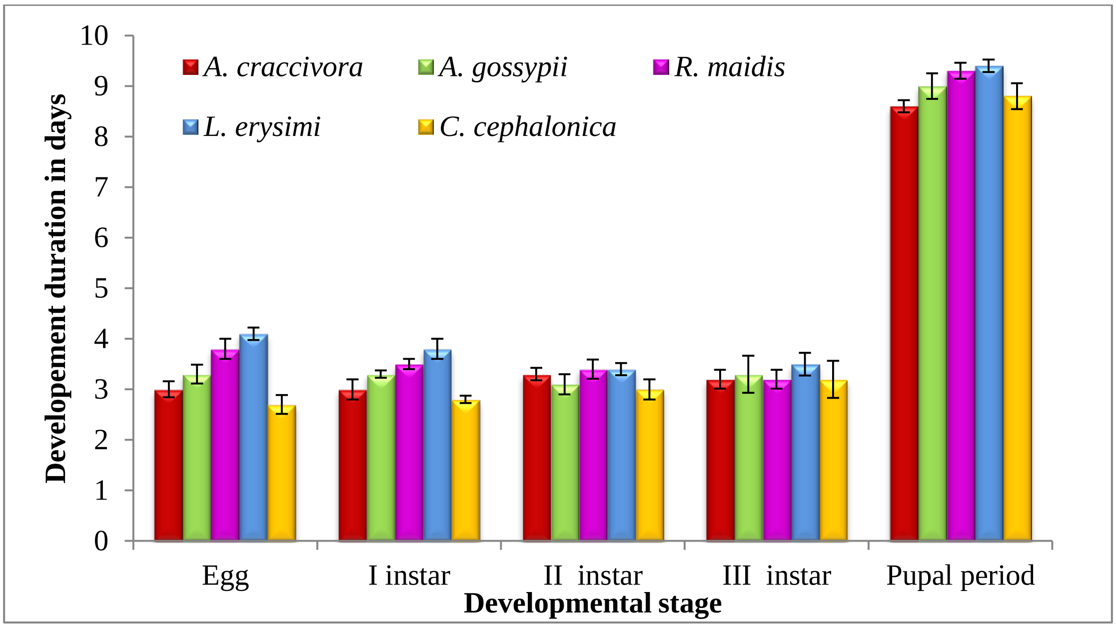

Fig. 4.3 Developmental period of *Chrysoperla* sp. (*carnea*-group) grub on four different species of aphids

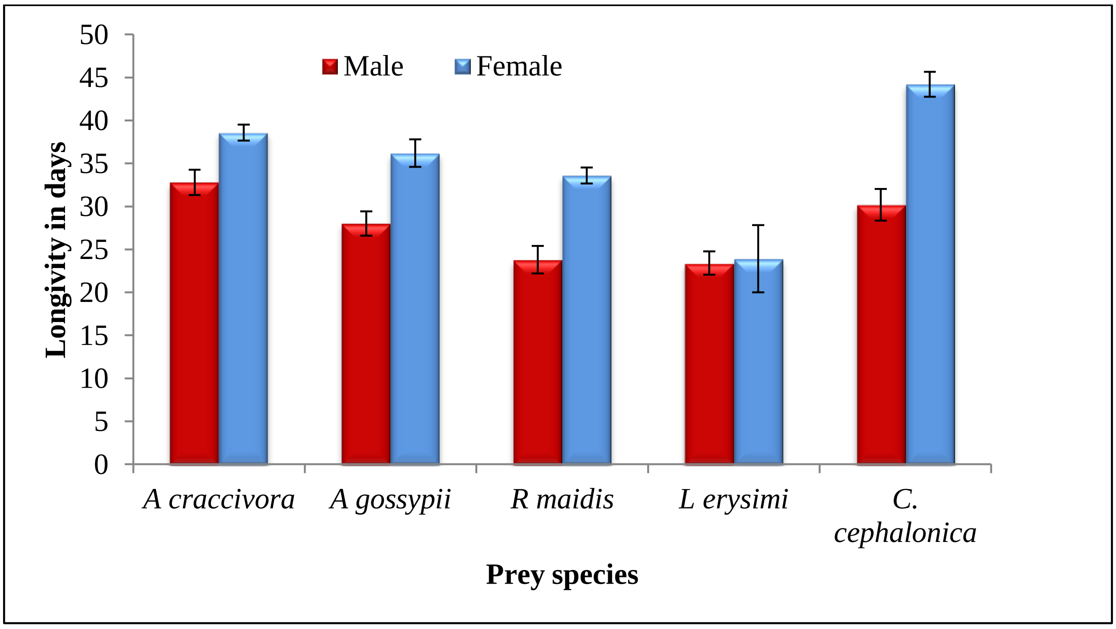

Fig. 4.4 Longevity of adults of *Chrysoperla* sp. (*carnea*-group) on four different species of aphids

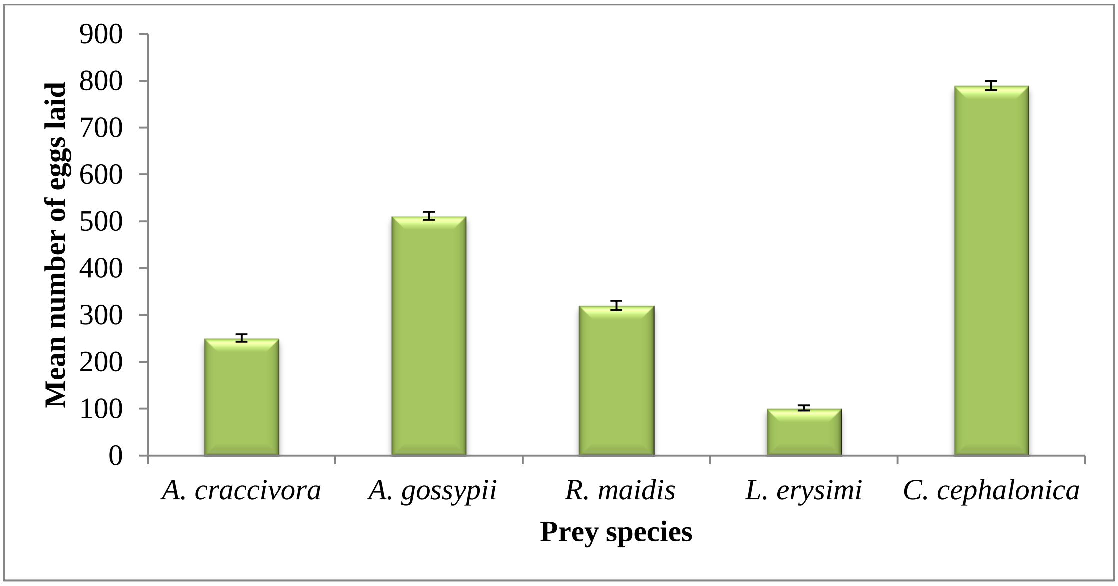

Fig. 4.5 Fecundity of adults of *Chrysoperla* sp. (*carnea*-group) on four different species of aphids

H. armigera neonate larvae. The total developmental period of *C. carnea* on different insect hosts ranged from 18.59 days on *A. craccivora* (groundnut) to 22.74 days on *H. armigera* neonate larvae. *C. carnea* adult laid a maximum of 318.40 eggs when reared on *A. craccivora* as compared to any other host. Tesfaye and Gautam (2002) found that larval and cocoon periods were significantly affected due to variations in prey species, while the total developmental period of *C. carnea* (egg to adult) on different insect hosts ranged from 18.40 (*C. cephalonica*) to 21.35 days (*A. craccivora*).

Per day consumption rate of the *Chrysoperla* sp. on different prey species revealed that the consumption rate increased significantly from 7th day onwards indicated that 3rd instar was the main predatory stage contributing upto 68.89-80.25% of total prey consumed. Whereas, prey consumption was 3.72-8.45% by the first stadium, 15.99-26.13% by the second stadium of the predator. Similar studies carried out by Liu *et al*. (2001) found that proportions of aphids consumed by each larval stadium to the total number of aphids consumed were similar *i.e.*, 3.9-7.1% by the first stadium, 12.0-16.8% by the second stadium, and 78.1-83.9% by the third stadium.

The incubation period of *Chrysoperla* reared on different insect hosts ranged from 3 days on *A. craccivora*, 2.7 days on *C. cephalonica*, whereas incubation period was highest on *Lipaphis erysimi* (4.1 days). The total grub period was longest on *L. erysimi* (10.7 days), whereas 9.5 days on *A. craccivora*. The pupal period was lowest on *A. craccivora* (8.6 days) and highest on *L. erysimi* (9.4 days). Similar studies conducted on biology of *C. carnea* by Liu *et al*. (2001) indicated that the developmental durations of *C. carnea* larvae were significantly different among larvae fed on three aphid species. The developmental duration from first stadium to adult emergence was shortest when larvae were fed with *A. gossypii*, followed by *M. persicae*, and then *L. erysimi*. The total number of fourth stadium aphids consumed by *C. carnea* larvae differed significantly among individuals fed with different aphid species. *C. carnea* consumed more *A. gossypii* (292.4) and *M. persicae* (272.6) than *L. erysimi* (146.4).

The fecundity was found to be significantly higher in case of *C. cephalonica* (789.6±9.883 eggs), while in case of *A crassivora* value was recorded to be

250.8±7.703 eggs. Similar studies carried out by El-Serafi *et al*. (2000) found that average number of eggs laid per female was 480.2±14.2 eggs when larvae were reared on *A. gossypii*, 320.26±10.90 eggs on *Sitobian avenae*, 336.44±12.5 eggs on *R. maidis* and 215.70±9.6 eggs on *A. neri*. Adane Tesfaye and Gautam (2002) reported that mean fecundity of *C. carnea* was higher (1079) on *C. cephalonica* eggs as compared with *Drosophila melanogaster* (582) and *A. craccivora* (173). The average oviposition per day per female of the progeny was 9.12, 18.30 and 26.16 eggs when reared from *A. craccivora*, *D. melanogaster*, *C. cephalonica* eggs respectively. Mannan *et al*. (1987) reported the mean fecundity of *C. carnea* about 84.70 and 103 when larvae reared on *A. gossypii* and *Myzus persicae* respectively.

4.7 Conclusion

In the present investigation it was concluded that although all the biological parameters such as egg, grub, pupal period as well as adult longevity were at par with that of *C. cephalonica* eggs. The fecundity was found to be significantly lower on *A. craccivora* as compared to eggs of *C. cephalonica* indicating it to be better host for mass rearing of *Chrysoperla* under laboratory conditions.

Evaluation of toxicity of neonicotinoides and Neem product on larval stages of *Chrysoperla* sp. (*carnea*-group)

5.1 Abstract

Insecticides are unavoidable in pest management programs. Nevertheless, often the plant protection products kill the natural enemy population making the pest to resurge and thus demanding more sprays. The use of selective insecticides could improve conservation of natural enemies and therefore contribute to the success of Integrated Pest Management (IPM) programs. Keeping this in view laboratory studies were conducted to find out the toxicity of Neembaan® imidacloprid, acetamiprid, thiamethoxam and buprofezin on larvae of *Chrysoperla* sp. (*carnea*-group). Among five insecticides tested Neembaan® proved to be safest causing less than 50% mortality even at higher doses, whereas acetamiprid and thiamethoxam proved to be highly toxic to predator and buprofezin was relatively least toxic. Relative toxicity of different insecticides indicated that imidacloprid 18.54, thiamethoxam 40.17 and acetamiprid 48.2 times more toxic to the predator when buprofezin was taken as unity. The descending order of safety of chemicals to predator was in order of Neembaan® > buprofezin > imidacloprid > thiamethoxam > acetamiprid. So from the present study it was very clear that Neem, buprofezin are relatively safe and exhibited slight harmful effect at higher doses than other synthetic insecticides, whereas imidacloprid having low mortality rates at field recommended dose under laboratory conditions can be used in IPM programme. Insecticides are inevitable to be used in pest management so dose and selectivity of chemicals are two important criteria that must be considered in selecting insecticide in IPM.

5.2 *Key words:* *Chrysoperla* sp. (*carnea*-group), insecticides, toxicity.

5.3 Introduction

Chemical and biological control measures are often considered incompatible. However, latest research indicates that the integration of chemical, cultural and biological control measures are getting popular among farmers as integrated pest management components, throughout the world. In this regard, biological control occupies a central position in integrated pest management programmes. Because biological control of invertebrate pest and weeds has enormous and unique advantages, it is safe, permanent, economical and socially acceptable. In any integrated control programme, it is necessary to utilize some insecticides with minimal toxicity to natural enemies of insect pests.

The adverse impact of insecticides on natural enemies can be mitigated through choice of insecticide, dosage, or timing of insecticide application. Biological control and selective insecticides proved to be compatible tactics in Integrated Pest Management (IPM) programs (Galvan *et al*., 2005). So combining biological control with pesticide use is the cornerstone on which the concept of integrated control was founded (Perkins and Garcia, 1999). Integrating biological control with selective insecticides can also minimize the likelihood of pest resurgence and possibly reduce the number of insecticide applications (Hutchison *et al*., 2004). The role of generalist predators as effective control agents is being supported by both biocontrol theory and practice (Symondson *et al*., 2002). Insecticides such as organophosphates, carbamates, and synthetic pyrethroids are generally highly toxic to biological control agents, due to their broad spectrum of activity (Croft, 1990). The impact of synthetic pesticides on beneficial arthropods and the human health risks posed by exposure to these chemicals are issues of growing concern (Cisneros *et al*., 2002).

Croft and Brown (1975) reported that indiscriminate use of pesticides not only results in the development of insecticide resistance but also eliminates the natural enemies of insect pests. Therefore, it is important to examine the possible disruptive effects of candidate insecticides on beneficial insects, so as to determine the insecticide compatiblity with key biological control agents (Stapel *et al*., 2000).

The increase in knowledge is the basis for reducing the undesirable effects of pesticides applications, which among others, is an important principle of integrated production (Cross and Dickler, 1994). Many workers have reported the importance of *Chrysoperla* sp. (*carnea*-group) in biological control and the inevitability of chemicals to be applied in synchronization as a prerequisite of IPM. The purpose of work reported here was to evaluate effects of the insecticides on larvae of *Chrysoperla* sp. (*carnea*-group) under laboratory conditions.

5.4 Materials and Methods

The present experiment on the comparative toxicity of insecticides to 2nd instar (5 day) larvae of *Chrysoperla* sp. (*carnea*-group) was carried out at the Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi. Commercial formulations of insecticides used for the study were viz., imidacloprid 17.8 SL (Confidor®, Bayer Crop Science), acetamiprid 20 SP (Baadshah®, Hindustan Petroliun Marketting Ltd), thiamethoxam 25 WG (Actara®, Syngenta India Ltd), buprofezin 25 SC (Appalaud®, Rallis India Ltd), Azadirachtin 1500 ppm. (Neembaan®, Pest control India private Ltd).

5.4.1 Mass culturing of host insect

Eggs of the *C. cephalonica* were used for mass culturing of the predator. The larvae of *C. cephalonica* were reared on broken sorghum grains placed in a jar containing 2.5 kg of food material. Nearly, 0.25cc (approximately 5000) eggs of rice meal moth were sprinkled in a jar and kept for development at 30±1ºc and 60±5% RH. The larvae fed on the grain and pupated in the silken cacoons. Jars containing full grown larvae or nearing to pupation were transferred to wooden trays (45cm× 30cm× 10cm) for smooth pupation and adult emergence. The moths started emerging 30th day onwards and collected daily either manually or with aspirator. These adults were caged in a oviposition cage fitted with 40 mesh size wire mesh. Eggs fell at bottom of the oviposition cage through the wire mesh. The eggs were collected; scales are blown off, cleaned and used for mass rearing of the predator (Gautam, 2008)

Bioassay experiment

Toxicity to the larvae was estimated using diet contamination method. Eggs of *C. cephalonica* were exposed to UV radiation of 15 W for 15 min to kill the embryo. The UV killed *Corcyra* eggs were taken on blotting paper (1 cc) and sprayed with desired concentrations of insecticides with hand atomiser. The treated eggs were shade dried for 15 min and then transferred to Petri dish. The untreated check was maintained as control by spraying the eggs with distilled water. Second instar larvae

(5 day old) of *Chrysoperla* sp. (*carnea*-group) (10 nos) were transferred into the Petri dish containing pre-treated *Corcyra* eggs. The larvae were allowed to feed the treated eggs and once they complete feeding, untreated *Corcyra* eggs were provided until pupation. The treatments were replicated five times. Observations were made on the per cent larval mortality at different time intervals as 24, 48, and 72 hrs, after treatment. Five treatments and a control were used. Treatments includes imidacloprid (Confidor®), acetamiprid (Baadshah®), thiamethoxam (Actara®), buprofezin (Applaud®) and Azadirachtin (Neembaan®). Different concentrations of each of these insecticides were taken and mortality data was recorded. From this the LC_{50} value and fudicial limits were calculated.

Statistical analysis

The per cent mortality in laboratory studies was corrected using Abbot's formula (Abbot 1925). The mortalities (number) were transformed using square root transformation and subjected to statistical analysis adopting completely randomized design. Probit analysis was done using EPA software.

5.5 Results

All insecticidal treatments significantly affect the larval mortality at different concentrations. Among five insecticides tested, Neembaan® proved to be safest showing less than 50% mortality even at higher doses. Among the other four chemicals tested acetamiprid was proved to be highly toxic whereas, buprofezin was found to be least toxic. The LC_{50} values of these insecticides were 0.013%, 0.005%, 0.006% and 0.241% for imidacloprid, acetamiprid, thiamethoxam and buprofezin respectively (Table 5.1 and Fig. 5.1). The relative toxicity of different insecticides was imidacloprid 18.54, thiamethoxam 40.17 and acetamiprid 48.2 times more toxic to the predator when buprofezin was taken as unity (Table.5.1 and Fig. 5.1).

The maximum larval mortality was recorded in the higher dose of acetamiprid (0.02%) with mean mortality recorded was 74%, 76% and 78% mortality at 24, 48 and 72 hours after treatment (HAT), which was on par with mortality records of thiamethoxam registering mortality of 70%, 78% and 82% 24, 48 and 72 HAT. acetamiprid and thiamethoxam were found to be highly toxic to grubs of *Chrysoperla* sp. (*carnea*-group) (Table 5.3, 5.4 and Fig. 5.4, 5.5).

Table 5.1 Comparative toxicity (LC_{50}) of various insecticides on grubs of *Chrysoperla* sp. (*carnea*-group) by diet contamination method

(Mean of five observations)

Insecticides	Heterogeneity $\chi 2$	Regression equation Y= a+bx	LC_{50} (%)	Fiducial limits (%)		0RE
				MAX	MIN	
Imidacloprid	2.057	1.3753X+7.6148	0.013	0.019	0.01	18.54
Acetamiprid	1.761	1.0772 X+7.5267	0.005	0.006	0.003	48.2
Thiamethoxam	1.639	1.0065X+7.2062	0.006	0.01	0.004	40.17
Buprofezin	2.73	1.6799X+6.0374	0.241	0.31	0.189	01.00
Neembaan®	<50% IGR activity at highest dose					

Table 5.2 Toxicity of imidacloprid to larva of *Chrysoperla* sp. (*carnea*-group) by diet contamination method.

(Mean of five observations)

Concentration/ hrs	24 hrs	48 hrs	72 hrs
0.02%	58 (49.688) ^{a}	68 (55.738) ^{a}	76 (60.810) ^{a}
0.015%	54 (47.328) ^{a}	60 (50.842) ^{ab}	66 (54.408) ^{b}
0.01%	52 (46.226) ^{ab}	58 (49.688) ^{bc}	60 (50.842) ^{b}
0.007%	42 (40.354) ^{b}	50 (45.020) ^{c}	50 (45.020) ^{c}
0.005%	26 (30.570) ^{c}	32 (34.434) ^{d}	36 (36.842) ^{d}
0.003%	20 (26.282) ^{c}	24 (29.240) ^{d}	26 (30.570) ^{e}
Control (water)	2 (3.688) ^{d}	2 (3.688) ^{e}	4 (7.376) ^{f}
CD	(7.385)	(6.503)	(6.683)
SE (m) ±	(2.536)	(2.233)	(2.295)

Means followed by a common letter are not significantly different at $p = 0.05$ by DMRT
Figures in parentheses are arcsine transformed values

Table 5.3 Toxicity of acetamiprid to larva of *Chrysoperla* sp. (*carnea*-group) by diet contamination method.

(Mean of five observations)

Concentration/ hrs	24 hrs	48 hrs	72 hrs
0.02%	74 (59.480) ^{a}	76 (60.810) ^{a}	78 (62.140) ^{a}
0.01%	70 (56.944) ^{a}	74 (59.480) ^{a}	76 (60.810) ^{a}
0.007%	54 (47.328) ^{b}	64 (53.202) ^{b}	68 (55.738) ^{b}
0.005%	48 (43.866) ^{bc}	56 (48.482) ^{c}	62 (51.996) ^{bc}
0.003%	44 (41.558) ^{c}	52 (46.174) ^{c}	56 (48.482) ^{c}
0.001%	28 (31.476) ^{d}	36 (36.842) ^{d}	38 (38.046) ^{d}
Control	2 (3.688) ^{e}	2 (3.688) ^{e}	4 (7.376) ^{e}
CD	(6.747)	(6.020)	(6.537)
SE (m) ±	(2.317)	(2.068)	(2.245)

Means followed by a common letter are not significantly different at $p = 0.05$ by DMRT
Figures in parentheses are arcsine transformed values

Table 5.4 Toxicity of thiamethoxam to larva of *Chrysoperla* sp. (*carnea*-group) by diet contamination method.

(Mean of five observations)

Concentration/ hrs	24 hrs	48 hrs	72 hrs
0.02%	70 (57.364) ^{a}	78 (62.436) ^{a}	82 (65.392) ^{a}
0.01%	60 (51.018) ^{ab}	68 (55.738) ^{ab}	72 (58.150) ^{b}
0.007%	54 (47.380) ^{ab}	58 (49.688) ^{bc}	62 (52.048) ^{c}
0.005%	44 (41.458) ^{bc}	48 (43.816) ^{cd}	52 (46.174) ^{d}
0.003%	32 (34.132) ^{cd}	36 (36.666) ^{de}	38 (37.996) ^{e}
0.001%	26 (30.146) ^{d}	28 (31.774) ^{e}	30 (33.104) ^{e}
Control	2 (3.688) ^{e}	4 (7.376) ^{f}	4 (7.376) ^{f}
CD	(10.419)	(8.899)	(7.668)
SE (m) ±	(3.578)	(3.056)	(2.634)

Means followed by a common letter are not significantly different at p = 0.05 by DMRT
Figures in parentheses are arcsine transformed values

Table 5.5 Toxicity of buprofezin to larva of *Chrysoperla* sp. (*carnea*-group) by diet contamination method.

(Mean of five observations)

Concentration/ hrs	24 hrs	48 hrs	72 hrs
0.7%	78 (62.436) ^{a}	80 (64.062) ^{a}	88 (72.038) ^{a}
0.5%	70 (56.944) ^{a}	72 (58.150) ^{a}	76 (60.810) ^{b}
0.3%	56 (48.534) ^{b}	62 (52.048) ^{b}	66 (54.408) ^{c}
0.1%	36 (36.666) ^{c}	46 (42.712) ^{c}	50 (45.020) ^{d}
0.07%	18 (24.654) ^{d}	24 (28.942) ^{d}	28 (31.774) ^{e}
0.05%	10 (16.380) ^{de}	16 (23.324) ^{d}	22 (27.612) ^{e}
Control	2 (3.688) ^{e}	2 (3.688) ^{e}	4 (7.376) ^{f}
CD	(9.270)	(7.710)	(8.895)
SE (m) ±	(3.184)	(2.648)	(3.055)

Means followed by a common letter are not significantly different at $p = 0.05$ by DMRT
Figures in parentheses are arcsine transformed values

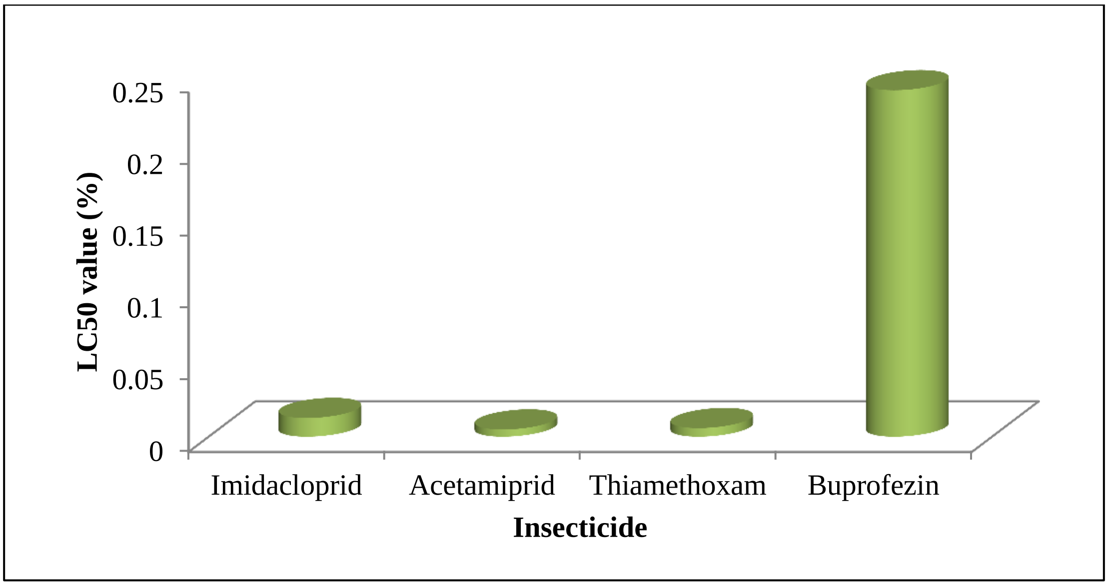

Fig. 5.1 Comparative toxicity (LC_{50}) value of various insecticides against grubs of *Chrysoperla* sp. (*carnea*-group)

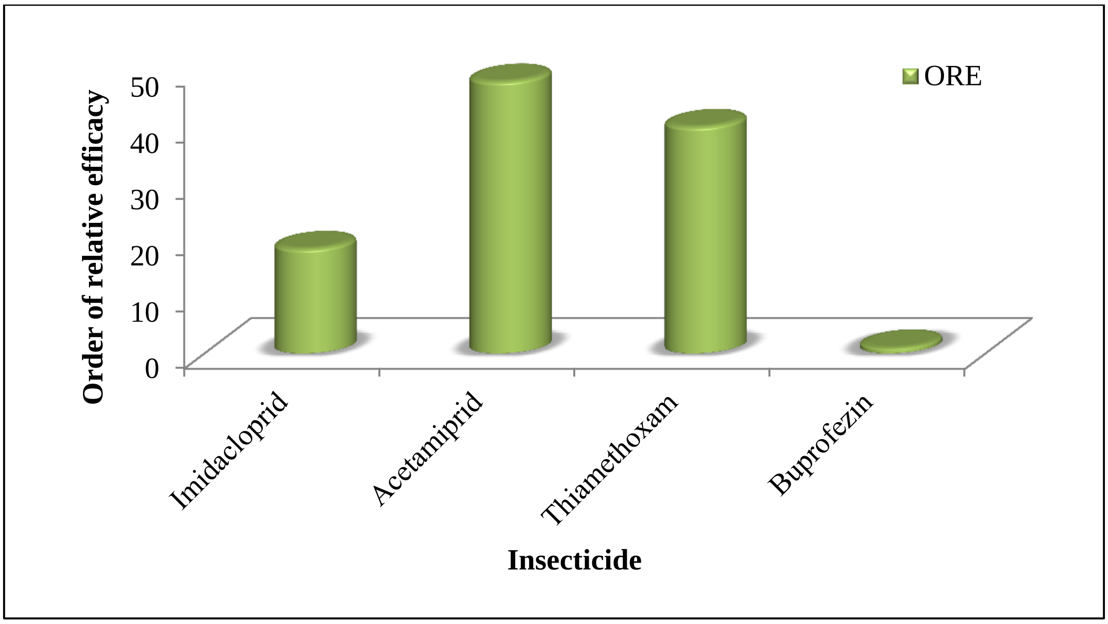

Fig. 5.2 Order of relative efficacy of various insecticides against grubs of *Chrysoperla* sp. (*carnea*-group)

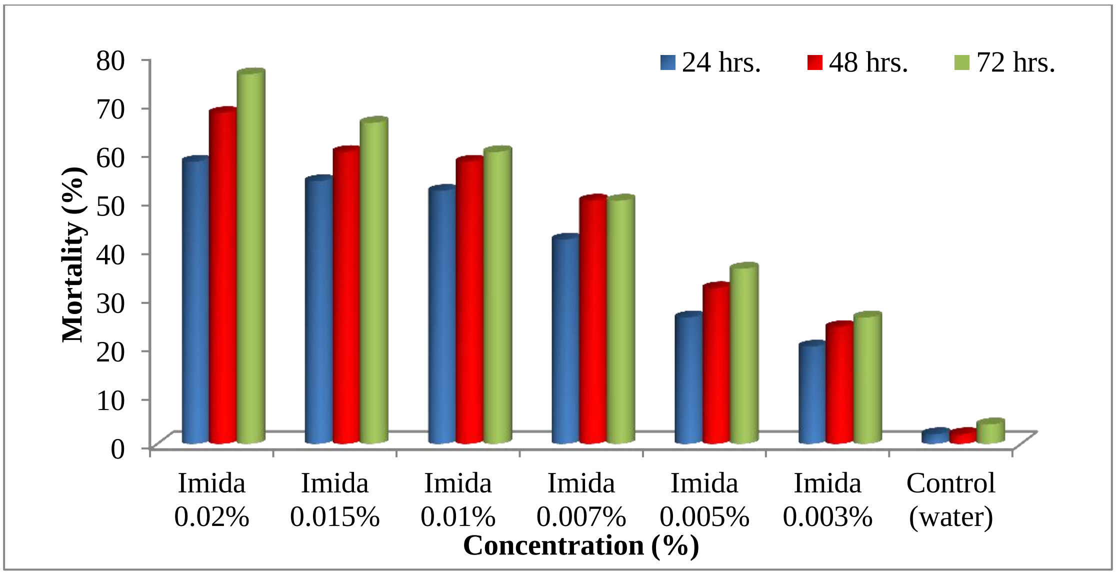

Fig. 5.3 Toxicity of imidacloprid to larva of *Chrysoperla* sp. (*carnea*-group)

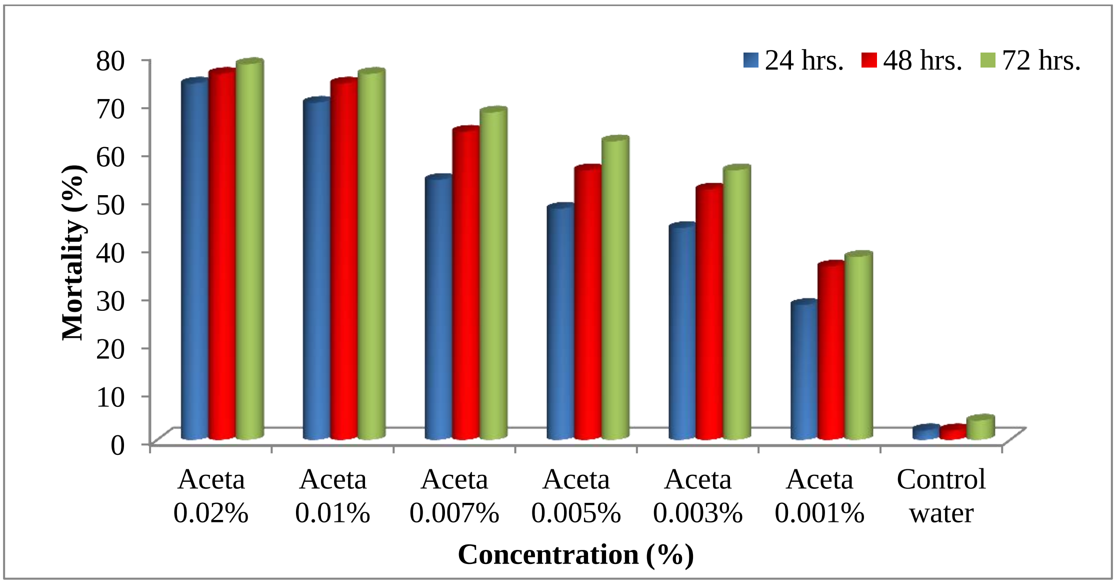

Fig. 5.4 Toxicity of acetamiprid to larva of *Chrysoperla* sp. (*carnea*-group)

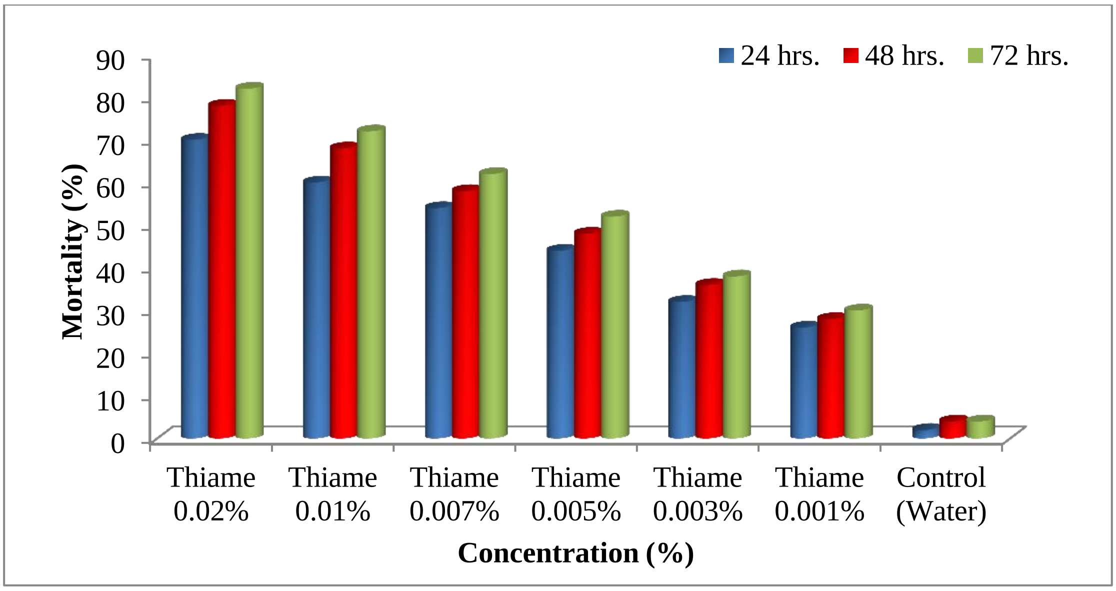

Fig. 5.5 Toxicity of thiamethoxam to larva of *Chrysoperla* sp. (*carnea*-group)

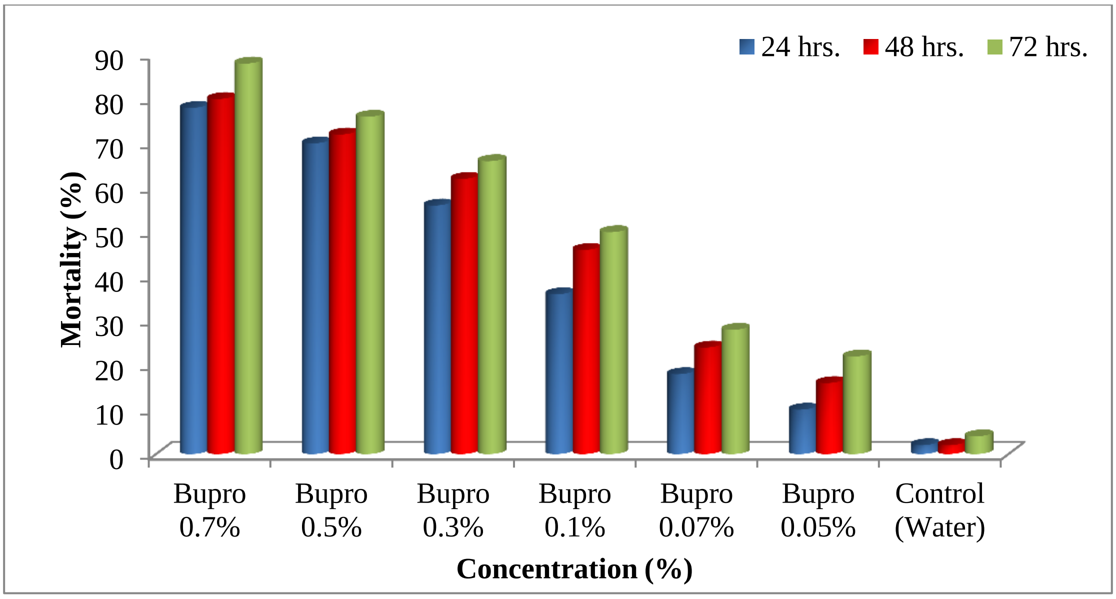

Fig. 5.6 Toxicity of buprofezin to larva of *Chrysoperla* sp. (*carnea*-group)

The field recommended dose of imidacloprid (@ 0.28 ml/l (0.005%) recorded the mortality of 26% and 32% at 24 and 48 HAT respectively (Table 5.2), whereas, acetamiprid (@ 0.3gms/lit (0.006%) and thiamethoxam (@ 0.2gms/lit (0.005%) caused 50% mortality (Table 5.4, 5.5 and Fig. 5.5, 5.6). Buprofezin at recommended dose i.e., 0.5 ml/lit (0.013%) was considered to be safer and at 0.05% produced mortality of 10% and 16% at 24 and 48 HAT respectively (Table 5.5 and Fig. 5.6). From the present study it was very clear that relative order of safety among the five insecicides tested was Neembaan® > buprofezin > imidacloprid > thiamethoxam > acetamiprid.

5.6 Discussion

Among the five insecticides tested Neembaan® proved to be safest showing less than 50% mortality even at higher doses this finding was in accordance with studies carried out by Medina *et al*. (2001) they found that spinosad, tebufenozide and azadirachtin were not toxic to the eggs and pupae of *C. carnea.* Similarly Sorade and Sonalkar (1999) observed that chloropyriphos, deltamethrin and cypermethrin were highly toxic to *C. carnea*. They also reported that neem seed extract was comparatively safe against eggs of *C. carnea*. El-Wakeil *et al*. (2006) concluded that neem products did not exhibit any serious side effects on parasitism and emergence rates of *Trichogramma* spp.and on efficiency of *Chrysoperla* and achieved a good control of *H. armigera* in laboratory and greenhouse.

In the present study, buprofezin was proved to be least toxic to grubs of *Chrysoperla* sp. (*carnea*-group). Similar observations were made by Nasreen (2005) where diafenthiuron and buprofezin were found harmless at low and recommended concentrations while high concentration of both insecticides was found slightly harmful after 24 hours exposure.

Imidacloprid (0.005%) recorded the mortality of 26% and 32% at 24 and 48 HAT and was considered to be relatively safe to the predator. Similar trend was observed in a study conducted by Preetha *et al*. (2009) under laboratory conditions. They classified imidacloprid and diafenthiuron as harmless to the eggs, larvae and adults of *C. carnea* since the recommended dose caused less than 50% mortality.

Among the five insecticides maximum larval mortality was recorded in acetamiprid and thiamethoxam as toxicity level of both the insecticides were found to be on par with that of conventional insecticides. Field recommended dosage of acetamiprid is (0.006%); thiamethoxam (0.005%) caused almost 50% mortality. Similar studies conducted by Maroufpoor *et al*. (2010) indicated that the toxicity of spinosad to *C. carnea* is at par with conventional synthetic insecticides.

5.7 Conclusion

Selection of a suitable insecticide in an IPM program not only depends on its efficacy against the target pest but also on its toxicity to beneficial insects. Among all the insecticides tested Neemban®, buprofezin were proved to be relatively safe and showed slight harmful activity at higher doses. Thus neem formulations with optimum dose could be considered as a promising active ingredient to be used in IPM programmes, and are more compatible with natural enemies like *Chrysoperla* sp. (*carnea*-group) than any other synthetic insecticides. Whereas imidacloprid having low mortality rates at field recommended dose was less toxic to the predator, thus it can be incorporated in IPM programs. However other two insecticides i.e., acetamiprid and thiamethoxam proved to be highly toxic to the predator should be used with at most care so as to conserve natural enemies under field conditions.

CHAPTER 6 GENERAL DISCUSSION

Biological control agents can cause substantial decrease in pest population numbers. Predators are the most widely exploited and employed biocontrol agents in the insect pest management from centuries. Among various predators green lacewings *Chrysoperla* sp. (*carnea*-group) proves to be an efficient biocontrol agent in many crop ecosystems. Green lacewing is a generalist and widely distributed predator of many soft bodies insect pests, *Chrysoperla* sp. (*carnea*-group) has been reported from India and many other countries in the world. It has very wide host range like aphids, jassids, mealy bugs, eggs of lepidopteran pests. However in general, mass multiplication of *Chrysoperla* sp. under laboratory conditions is done on factitious hosts like *Corcyra cephalonica* (Stainton), *Sitotroga cerealella* (Olivirer) and *Anagastra kuehniella* (Zeller) worldwide. Present investigation was carried out to find out impact of different aphid species on biology and feeding potential of *Chrysoperla* sp. (*carnea*-group).

Studies on feeding potential of *Chrysoperla* sp. (*carnea*-group) on different aphid species revealed that among four aphid species tested *Aphis craccivora* was most preferred and can also be utilized for restoring the fecundity and predatory activity of *Chrysoperla* that is lost if reared for several generations on the eggs of *Corcyra cephalonica* under laboratory conditions. At the same time *Lipaphis erysimi* had potential as prey. Predatory efficiency of *Chrysoperla* sp. (*carnea*-group) increased with the development of grub. As the grub grew from first instar to third instar, the consumption rate increased in all the species of aphids used as prey. The per day prey consumption of the larvae were significantly higher 7th day onwards this coincides with the third instar of the larvae. This study was in accordance with Krishnamoorthy and Mani (1982), Megahed *et al*., (1984), Sharma *et al*. (1991), Saminathan *et al*. (2003) and Jagadish and Jayaramaiah (2004).

Mari *et al*. (2007) studied the feeding efficiency of larvae of *C. carnea* on mustard and wheat aphids. They observed that mean per cent feeding per day by first, second and third instar larvae were 26.92, 49.58 and 85.18 on mustard aphid and 44.6, 62.6 and 94.2 per day on wheat aphid. The feeding rate fitted the logistic model which indicated that the third instar consumed more aphids than formers. Studies conducted by Chakraborty *et al*. (2010) on feeding efficiency of green lacewing on six different species of aphids indicated that the predatory efficiency of *C. carnea* increased with the development of grub. As the grub grew from first instar to third instar, the consumption rate increased in all the species of aphids.

Results of our present investigations on the biology of *Chrysoperla* sp. (*carnea*-group) indicated that the total developmental period of *Chrysoperla* sp. ranged from 21.1 days to 24.2 days on different aphid species. Total life cycle of *Chrysoperla* sp. on general laboratory host, *C. cephalonica* was found to be 20.5 days. Among four aphid species tested *A. craccivora* having shortest developmental period of 21.1 days which is on par with that of *Corcyra* eggs. So, *A. craccivora* serves to be potential alternative for mass rearing of *Chrysoperla* under laboratory conditions. As far as longevity of the adult is concerned it was found that female survived more number of days then their counterpart irrespective of prey species consumed.

Similar studies carried out by Liu *et al*. (2001) against three aphid species (fourth instars only), *Aphis gossypii* Glover; *Myzus persicae* (Sulzer) and *Lipaphis erysimi* (Kaltenbach), on immature development, survival and predation of the common green lacewing, *C. carnea*, showed that the developmental duration from first stadium to adult emergence was shortest when larvae were fed with *A. gossypii* (19.8± 0.4 d), followed by *M. persicae* (22.8± 0.2 d), and then *L. erysimi* (25.5± 0.4 d). The total number of fourth stadium aphids consumed by *C. carnea* larvae differed significantly among individuals fed different aphid species.

Sattar *et al*. (2007) observed that only larval period was extended upto 22.3 days when *Chrysoperla* was reared on cotton mealy bugs. With the duration of first, second and third instar extended upto 9.3 days, 8 days and 5 days respectively. From this wide variability that is the total developmental period of predator was found to be 21.1 days when reared on *A. craccivora.* Whereas, only larval period extended upto 22.3 days when reared on cotton mealy bugs. So it is very clear that the total developmental period of the predator purely depends on type of prey species available although it is also governed by extent of predation.

Balasubramani and Swamiappan (1994) studied development of *C. carnea* on different hosts in laboratory and found that larval development was rapid on eggs of

C. cephalonica (8.20 days) and longest on neonates of *H. armigera* (11.10 days). Mannan *et al*. (1997) studied biology of *C. carnea* on *A. gossypii* and *M. persicae* and observed that larval duration was long when fed on *M. persicae*.

Saminathan *et al*. (1999) and Bansod and Sarode (2000) studied the biology and feeding potential of *C. carnea* on different hosts and noted that developmental period of *C. carnea* ranged from 18.6 days on *A. craccivora* to 22.7 days on *H. armigera* neonate larvae. Giles *et al*, (2000) studied nutritional interactions among alfalfa, *Medicago sativa* L. and faba bean, *Vicia faba* L., as host plants, pea aphid, *Acyrthosipnon pisum* (Harris) an herbivore and *C. carnea* a predator. *C. carnea* larvae developed faster on pea aphid reared on alfalfa than on pea aphid raised on faba bean. Chemical analysis showed that aphids reared on faba bean had 6.3 times more levels of myristic acid.

Osman and Selman (1993) investigated the influence of different aphid species on larval development and fecundity of *C. carnea*. *M. persicae* and *A. pisum* were suitable, while *A. fabae* was most unsuitable prey causing high juvenile mortality. *C. carnea* larvae fed on this aphid and *Macrosiphum albifrons* had reduced fecundity. Obrycki *et al*. (1989) observed that 26-40% of the *C. carnea* larvae died where reared on *Agrotis ipsilon* neonateson the other hand 100% larval mortality was recorded when larvae were reared on *Ostrinia nubilalis* due to entanglement of silk produced by these larvae.

The fecundity was found to be significantly higher in case of *C. cephalonica* (789.6±9.883 eggs), while *A. crassivora* recorded 250.8±7.703 eggs. Similar results were also observed by Adane Tesfaye and Gautam (2002) wherein they reported that mean fecundity of *C. carnea* was higher (1079) on *C. cephalonica* as compaired with *D. melanogaster* (582) and *A. craccivora* (173). The average oviposition per day per female of the progeny was 9.12, 18.30 and 26.16 eggs when reared from *A. craccivora, D. melanogaster, C. cephalonica* respectively. Mannan *et al*. (1987) reported the mean fecundity of *C. carnea* about 84.70 and 103 when larvae reared on *A. gossypii* and *M. persicae* respectively.

Intensive use of pesticides is common and increasing despite a growing and historically well documented awareness of the costs and hazards. The benefits from pesticides of increased yields from sufficient pest control may be outweighed by developed resistance in pests and killing of beneficial natural enemies. One of the major goals of integrated pest management (IPM) is to obtain economic pest control with the judicious use of selective pesticides in concert with biological control agents. Often, biological control agents alone cannot provide economic control of a pest species; thus, supplemental use of a pesticide may be necessary to provide adequate control. However, how we determine compatibility of pesticides with, biological control agents is a contentious issue (Stark and Banks 2003). Pesticide compatibility with biological control agents is a major concern to practitioners of IPM and knowledge about the activity of insecticides toward the pests, the non-target insects, and the environment is a necessity (Stark et al., 2004). The compatibility of an insecticide with biological control agents is often examined by tests screening for mortality of natural enemies.

The importance of predators, *Chrysoperla* sp. (*carnea*-group) in biological control and the inevitability of chemicals to be applied in synchronization as a prerequisite of integrated pest management. The purpose of work reported here was to evaluate the effects of the pesticide on larvae of *Chrysoperla* sp. (*carnea*-group) that could help to find compatible insecticide comparatively less toxic to the predator and which can be used safely in combination with augmentative releases of biocontrol agents.

In the present study It was found that neem proved to be safe among all the five insecticides. Field recommended dose of imidacloprid and buprofezin were found to be relatively safe. Similarly imidacloprid was found relatively safe when used at field recommended dose. Toda *et al*. (1997) found that imidachloprid showed low toxicity in the dipping test, but high toxicity in the residual contact test on grubs of *C. carnea*. Similarly, Elbert *et al*. (1998) reported that imidacloprid is poor in penetration through cuticle so having low insecticidal activity by topical application method then injection which causes less activity to biting type of insects and more activity to sucking Hemipteran insects.

Rezaei *et al*. (2007) reported that imidacloprid caused 36.83% larval mortality on two day old larvae of *C. carnea* with no significant effect on fecundity . Sarode and Sonalkar (1999) proved that neem seed extract was comparatively safe against eggs of *C. carnea.* Srinivasan and Babu, (2000) noticed that all the neem formulations have slight deleterious effect on egg hatching as well as adult longevity. Liu *et al*. (2000) studied the effect of buprofezin, at three tested concentration 100, 500 and 1000 mg (ai)/lit and reported that treatments did not affect viability of eggs and development of instars and pupae of *Chrysoperla rufilabris*.

Among all five insecticides tested the maximum larval mortality was recorded in the acetamiprid and thiamethoxam as toxicity level of both were found to be on par with that of conventional insecticides. Nasreen *et al*. (2003) tested several insecticides against first instar *C. carnea* larvae and found that indoxacarb and profenofos caused 100% mortality after 48 hrs of exposure. Singh and Verma (1986) tested relative toxicity of insecticides against neonate larvae of *C. carnra* under laboratory for 24hrs. at recommended dose level and revealed that endosalfan, quinalphos, monocrotophos, phenthoate and fenitrothion caused 74-89% larval mortality over a 72-h period. They further reported that phosalone, carbaryl and cypermethrin were moderately toxic (34.1-38.1% mortality), while fenvalerate was the least toxic (19.2% mortality). Rajeswaran *et al*. (2004) evaluated toxicity of carbosulfan to eggs, larvae and adults of *C. carnea* and reported that all the concentrations caused significant grub mortality when grubs were subjected to treatment by oral feeding and film method. Carbosulfan was also found to be harmful to adult. Plapp and Bull (1978) reported that most organophosphate insecticides and the methomyl (carbamate) were highly toxic to the predator *C. carnea*.

In study conducted by Maroufpoor *et al*. (2010) observed, in contact bioassay tests, a direct relationship between the concentration of spinosad and mortality rate of first instar larvae of *C. carnea* and concluded that toxicity of spinosad to *C. carnea* is at par with conventional synthetic insecticides.

CHAPTER 7 SUMMARY AND CONCLUSION

The salient findings of the research are summarized under the following headings.

Objective 1: Biology and predatory potential of green lacewing, *Chrysoperla* sp. (*carnea*-group) (Neuroptera: Chrysopidae) on different aphid species.

Biology and predatory potential of green lacewing *Chrysoperla* sp. (*carnea*-group) was evaluated on four aphid species viz. *Aphis craccivora* Kotch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kaltenbach) and *Rhophalosiphum maidis* Fitch. Feeding preference in terms of mean number of aphids consumed throughout the grub period were *A. craccivora* (394.8±4.472), *A. gossypii* (332.6±3.689), *L. erysimi* (132.4±6.074) and *R. maidis* (260.4±4.092). The total developmental period was least in case of *A. craccivora* (21.1 days) and it is on par with general laboratory host, *Corcyra cephalonica* (Stainton) (20.5 days). Whereas, highest developmental period was recorded on *L. erysimi* (24.2 days). Feeding preference of the predator is in the order of *A. craccivora*> *A. gossypii* >*R. maidis*> *L. erysimi*. The proportion of aphids consumed by different larval stadia were 3.72-8.45% by the first stadium, 15.99-26.13% by the second stadium, and 68.89-80.25% by the third stadium, data indicated that third instar contributed significantly to total predation. The per day consumption rate of the *Chrysoperla* increased significantly from 7th day onwards that coincides with third instar of the grub, showing that 3rd instar was the main predatory stage contributing upto 68.89-80.25% of total prey consumed. The egg period of *Chrysoperla* reared on different hosts varied significantly with 3 days on *A. craccivora*, 2.7 days on *C. cephalonica* and 4.1 days on *Lipaphis erysimi*. Grub period was longest when reared on *L. erysimi* (10.7 days), whereas total grub period in case of *A. craccivora* and *C. cephalonica* were 9.5 and 9 days respectively. The pupal period on different host species does not vary significantly with mean values ranging from 8.6 to 9.4 days. The total life cycle of *Chrysoperla* ranged from 21.1 days to 24.2 days. Considering longevity of the adult female survived more number of days then their counterpart irrespective of prey species consumed during larval stages. Taking into account four aphid species, longevity of male (32.8 ±1.463) as well as female (38.6±0.927) was highest when reared on *A. craccivora*, whereas female longevity was found to be more when reared on eggs of *C. cephalonica*. Results clearly indicated that the four aphid species significantly affected the grub development, adult longevity and number of aphids consumed by grubs of *Chrysoperla* sp. The present study indicated that though all the parameters with respect to developmental period of *Chrysoperla* sp. (*carnea*-group) reared on *A. craccivora* were on par with *C. cephalonica* but fecundity was found to be lower on *A. craccivora*.

Objective 2: To evaluate toxicity of neonicotinoides and neem product on larval stages of *Chrysoperla* sp. (*carnea*-group).

In the present study five insecticides were tested, among these Neembaan® was proved to be safest causing less than 50% mortality even at higher doses. Acetamiprid and thiamethoxam were found to be highly toxic to predator. Among four synthetic insecticides tested buprofezin was least toxic, whereas imidacloprid was found to be safe at field recommended dose. Relative toxicity calculated considering buprofezin as unity revealed that imidacloprid, thiamethoxam and acetamiprid were 18.54, 40.17 and 48.2 times more toxic to larvae of *Chrysperla* sp. (*carnea*-group). Descending order of safety of insecticides to predator was in order of Neembaan® > buprofezin > imidacloprid > thiamethoxam > acetamiprid. The LC_{50} values of these insecticides were 0.013%, 0.005%, 0.006% and 0.241% for imidacloprid, acetamiprid, thiamethoxam and buprofezin respectively. In all the treatments maximum larval mortality was recorded in the higher dose. Toxicity of acetamiprid was found to be on par with that of thiamethoxam. The recommended dose of imidacloprid @ 0.28 ml/l (0.005%) recorded the mortality of 26% and 32% at 24 and 48 HAT respectively. Field recommended dosage of acetamiprid @ 0.3gms/lit (0.006%), thiamethoxam @ 0.2gms/lit (0.005%) caused almost 50% mortality. Buprofezin at recommended dose i.e., 0.5ml/lit (0.013%) was considered to be safer 0.05% produced mortality of 10% and 16% mortality 24 and 48 HAT. It was concluded that neem formulations, buprofezin and imidacloprid at optimum field dose could be considered to be more compatible with natural enemies like *Chrysoperla* sp. (*carnea*-group) than other synthetic insecticides.

ABSTRACT

Feeding potential and insecticidal safety evaluation of *Chrysoperla* sp. (*carnea*-group)

Biological control by the use of predators such as, *Chrysoperla* sp. (*carnea*-group) has gained importance in pest management. The larvae have a voracious appetite for aphids, mealy bugs, immature scales, whiteflies, thrips, spider mites and other plant pests. Keeping this in view biology and predatory potential of green lacewing *Chrysoperla* sp. (*carnea*-group) was studied on four aphid species *viz*., *Aphis craccivora* Kotch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kaltenbach) and *Rhophalosiphum maidis* Fitch. Mean number of aphids consumed throughout the grub period were *A. craccivora* (394.8±4.472), *A. gossypii* (332.6±3.689), *L. erysimi* (132.4±6.074) and *R. maidis* (260.4±4.092). The total developmental period was least in case of *A. craccivora* (21.1 days) and it is on par with general laboratory host i.e., *Corcyra cephalonica* (Stainton) (20.5 days), Whereas longest developmental period was recorded on *L. erysimi* (24.2 days). Feeding preference of the predator was in the order of *A. craccivora*> *A. gossypii* > *R. maidis*> *L. erysimi*. Proportions of aphids consumed by each larval stadium were 3.72-8.45% by the first stadium, 15.99-26.13% by the second stadium, and 68.89-80.25% by the third stadium. *C. cephalonica* eggs were found to improve fecundity and longevity of *Chrysoperla* sp. (*carnea*-group). Toxicity of Neembaan®, imidacloprid, acetamiprid, thiamethoxam and buprofezin on larvae of *Chrysoperla* sp. (*carnea*-group) was studied under laboratory conditions. Among five insecticides tested Neembaan® proved to be safest whereas acetamiprid and thiamethoxam proved to be highly toxic to predator and buprofezin was least toxic among the synthetic insecticide. Relative toxicity of different insecticides indicates that imidacloprid 18.54, thiamethoxam 40.17 and acetamiprid 48.2 times more toxic to the predator when buprofezin was taken as unity. The descending order of safety of chemicals to predator was in order of neembaan > buprofezin > imidacloprid > thiamethoxam > acetamiprid. So from this study it was very clear that Neem and buprofezin are relatively safe and showing slight harmful effect at higher doses than other synthetic insecticides whereas Imidacloprid having low mortality rates at field recommended dose under laboratory conditions.

क्रायसोपर्ला प्रजाति (*कार्नियां*–समूह) की आहार क्षमता एवं कीटनाशी संबंधी सुरक्षा का मूल्यांकन

सार

पीड़क–प्रबंधन में, परभक्षियों जैसे कि *क्रायसोपर्ला* प्रजाति (*कार्नियां*–समूह) का उपयोग कर, जैविक नियंत्रण महत्वपूर्ण होता जा रहा है। एफ़्डिस, मीली बग्स, अवयस्क स्केल्स, श्वेत मक्षिकाएं, थ्रिप्स, स्पाइडर माइट्स तथा अन्य पादप–पीडकों हेतु लार्वों में प्रबल भूख होती है। इस बात को ध्यान में रखते हुए चार एफिड प्रजातियों यथा *एफिस क्रैसीवोरा* कोच, *एफिस गौसीपियाई* गलोवर, *लायपाफिस इरीसायमाई* (काल्टेनबैच) एवं *रोपलोसायफम मेडिस* फिच. पर ग्रीन लेसविंग *क्रायसोपर्ला* प्रजाति (*कार्नियां*–समूह) के जीवविज्ञान एवं भक्षण संबंधी क्षमता का अध्ययन किया गया। सम्पूर्ण ग्रब अवधि के दौरान खाए गए एफिडस की औसत संख्याएँ इस प्रकार से थीं, *ए. क्रैसीवोरा* (394.8±4.472) *ए. गौसीपियाई* (332.6±3.689) *ला. इरीसायमी* (132.4±6.074) तथा *रो. मेडिस* (260.4±4.092) विकास संबंधी कुल अवधि *ए. क्रैसीवोरा* में सबसे कम (21.1 दिन) थी और यह सामान्य प्रयोगशाला अतिथेय अर्थात *कोर्सायरा सिफेलोनिका* (21.1 दिन) के समकक्ष थी जबकि सबसे लम्बी विकास–अवधि *ला. इरीसायमी* (24.2 दिन) मे रिकार्ड की गई। परभक्षी की आहार–वरीयता इस क्रम में थी, *ए. क्रैसीवोरा* >*ए. गौसीपियाई* >*रो. मेडिस* >*ला. इरीसायमी*। प्रत्येक लार्वा–स्टेडियम द्वारा भक्षण किये गये एफिड्स के तुलनात्मक भाग इस प्रकार से थे प्रथम स्टेडियम द्वारा 3.72 – 8.45ः, द्वितीय स्टेडियम द्वारा 15.99–26.13ः तथा तीसरे स्टेडियम द्वारा 68.89–80.25ः। *को. सिफेलोनिका* के अण्डों से *क्रायसापर्ला* प्रजाति (*कार्नियां*–समूह) की अण्डोत्पत्ति एवं आयुकाल मे सुधार हुआ। प्रयोगशाला परिस्थितियों में *क्रायसापर्ला* प्रजाति (*कार्नियां*–समूह) के लार्वों पर नीमबाण®, इमिडाक्लोप्रिड, एसिटामाइप्रिड, थायामीथॉकसम एवं ब्यूप्रोफेज़ीन की विषाक्तता का अध्ययन किया गया। परीक्षण किए गए पॉच कीटनाशियों में से नीमबाण सबसे अधिक सुरक्षित सिद्व हुआ जबकि एसिटामाइप्रिड एवं थायमीथॉक्सम, परभक्षी के प्रति अत्यधिक विषाक्त थे तथा संश्लेषित कीटनाशियों में ब्यूप्रोफेज़ीन सबसे कम विषाक्त था। विभिन्न कीटनाशियों की आपेक्षिक विषाक्ता ने दर्शाया कि जब ब्यूप्रोफेज़ीन को एक इकाई के रूप में किया गया तो प्रति इमिडाक्लोप्रिड 18.54 थायमीथाक्सम 40.17 और एसिटामाइप्रिड 48.2 गुना अधिक विषाक्त पाया गया। परभक्षी के प्रति सुरक्षा का घटता अनुक्रम इस क्रम में था, नीमबाण> ब्यूप्रोफेज़ीनझ> इमिडाक्लोप्रिडझ> थायामीथॉकसम> झएसिटामाइप्रिड। इस प्रकार प्रस्तुत अध्ययन से यह स्पष्ट है कि अन्य संश्लेषित कीटनाशियों की तुलना में नीम एवं ब्यूप्रोफेज़ीन, अपेक्षाकृत सुरक्षित हैं और केवल अधिक खुराकों पर हल्का नुकसानदायक प्रभाव दर्शातें हैं जबकि इमिडाक्लोप्रिडझ प्रयोगशाला परिस्थितियों में, खेत में संस्तुत खुराक पर न्यून मर्त्यता रखता है।

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Note- * originals not seen