TRITROPHIC INTERACTION IN THE MANEGEMENT OF *Helicoverpa armigera* (Hubner) ON COTTON AND SUNFLOWER USING *Chrysoperla carnea* (Stephens)

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I. INTRODUCTION

The use of insecticides provided temporary relief from insect pests but disrupted the ecological balance by eliminating natural enemies. In situations, where this ecological balance is disrupted, potential insect pests are relieved from the resistance imposed by their natural enemies and therefore, unhindered- population growth resulted in pest outbreak.

Classical biological control though long lasting, self perpetuating and ecologically sounds but has been successful approximately in one third of all the attempts made (Hall and Ehler, 1979). An attempt of biological control through manipulation of natural enemy density has only limited success due to insufficient knowledge of trophic level interactions between pests and natural enemies in different ecosystems. Apparently, more effective strategies and techniques for the use of entomophages have to be developed for future success in biological control.

Extensive studies have revealed that the bitrophic and tritrophic level interactions involving host plant, pest insect and entomophages are mediated predominantly by chemical cues, through which an organism can detect its environment and effect the organism's behaviour or physiology (Ananthakrishnan *et al*., 1991).

An exhaustive array of chemical substances are produced and released by plants and other organisms, which serve in inter specific communication. This vast network of semiochemicals or more specifically allelochemicals constitute an allelochemicals web, which is most significant and in some ways more extensive than the food web (Whitman, 1988), as they can link organisms that are unconnected nutritionally. These chemical compounds produced either by the plants or insects have been shown to govern the organisms choice for host or prey.

Allelochemicals mediated interactions in insect host-plant interactions and host plant resistances have been recognized as most important in the successful establishment of an insect species on a crop (Beck, 1965; Detheir, 1970). Allelochemicals produced by plants also have considerable influence on the prey / host selection behaviour of entomophagous insects, so that plants, herbivores, and natural enemies are interconnected through the well knit array of chemicals. It is the intimate as well as intricate involvement of plants, herbivores and natural enemies which necessitated the inter -specific communication. A natural enemy initially seeks an environment and it does so regardless of the presence or absence of hosts (Doutt, 1964). The host plant natural enemies utilize host plant chemical cues to find the host habitat initially and then the herbivore on the host plant (Vinson, 1975). The host plant volatile profile play a key role in attracting or repelling or retaining the natural enemies, thereby causing considerable change in pest populations in different varieties (Vinson, 1975). Elzen *et al*. (1983) proved that the parasitoid, *Campoletes* orients itself and searches on host plants more effectively than in laboratory cages possibly because of plant volatile emanating from the plants.

Natural enemies have been utilized to control the pests in different ways *viz*., augmentation, inoculation, attraction and conservation. The potential use of biocontrol agents are yet to be fully explored and evaluated in most pest systems. Classical biological control has been most successful with pests of fruit and forest crops, where the perennial nature of the crop provides a continuous habitat. However, there is an urgent need to develop strategies for effective use of natural enemies on field crops, especially on crops like cotton and sunflower, where cotton alone consume more than 50 per cent of hazardous agrochemicals in India and created turbulence in the ecosystem.

Cotton is an important fibre crop that historically has experienced serious *Helicoverpa armigera* (Hubner) problems (Smith *et al*., 1976). This pest has developed resistance to most of the commonly used insecticides in cotton ecosystem and therefore, it is imperative to take care of cotton and sunflower from this dreaded pest. As a result, there has been much research into methods of insect pest control on cotton, with resistant cultivars as major components of insect pest management programme, but interaction between resistant cultivars and carnivores (Predators and Parasitoids) remain poorly known (Painter, 1951). A number of insect resistant cotton genotypes have been identified, but most have limitations,

which reduce their usefulness in breeding programme because the factors conferring resistance to one insect may increase the susceptibility to another. The negative influence of certain characters of host plant on natural enemies is suspected to be a cause for these contradictory effects (Schuster and Calderon, 1986).

Sunflower (*Helianthus annus* L.) has witnessed considerable growth in terms of area and production in recent years. However, the yield level has been low, due to its cultivation under poor management. Quite often, pests are the limiting factors for high yield. The crop is attacked by a number of lepidopteran insect pests of which the head borer (Capitulum borer), *H. armigera* is the key pest. The capitulum borer is highly polyphagous with about 300 host plants including important crop plants such as pulses, cotton, vegetables, etc. (Manjunath, 1995) and the pest is prevalent throughout Africa, Asia and Australia (Basappa, 1997). It is causing direct damage to receptacle, ovaries, developing seeds and thereby resulting loss in seed yield to the extent of over 50 per cent (Lewin, *et al*., 1973, Rangarajan *et al.,* 1975). There are reports of outbreak of *Helicoverpa* on sunflower in Northern parts of Karnataka during 1997 Kharif season (Anon., 1997a).

Altogether 77 parasitoids and 33 predators have been reported on this insect pest in different crops (Manjunath, 1995). In cotton and sunflower, predators such as *Chrysoperla carnea* (Stephens) and *Menochilus sexmaculatus* (Fab.) have been found to be predominant (Anon., 1992a and 1993).

In the recent past, chrysopids are one among the few insect predators, which attracted the attention of scientific community working in the field of biological control in India and elsewhere. Chrysopids, besides being resistant to many insecticides (Pree *et al*., 1989), devour eggs and neonates of lepidopterous pests, aphids, whiteflies, mealy bugs, mites and other soft bodied insects. This polyphagous nature has made them to emerge as potential and important component of Integrated Pest Management (IPM) strategy against various dreaded crop pests.

Host plant mediated orientation and ovipositional behaviour of three species of adult chrysopids, *viz*., *C. carnea, Mallada boninensis* (Okamoto) and *Mallada astur* (Banks), towards three different host plants *viz*., cotton, sunflower and pigeonpea has been studied. Wind tunnel studies indicated that *C. carnea* males had a significantly higher preference for sunflower and females for both sunflower and cotton, while pigeonpea was least preferred (Ballal and Singh, 1999). The chrysopids, in particular *C. carnea* is known for its wide distribution, but most of the information generated in the past is restricted to temperate regions of the world.

Intercropping of cotton with chilli, groundnut, soybean, and sorghum is an accepted agronomic technology in Karnataka for higher profitability. Cotton based intercrops such as cereals, lucerne and few pulses encouraged the activity of *C. carnea* (Baliddawa, 1985; Anon., 1995a; Hegde, 1997).

Use of botanicals, neem derivatives in particular as a component of IPM strategy is gaining momentum. Further, these insecticides have been reported to be safe to the natural enemies apart from being effective on cotton pests (Joshi *et al.,* 1982 and Salem and Matter, 1991).

A fundamental concept of IPM strategy is conservation, protection and promotion of natural enemies to make them self perpetuating. Keeping the importance of host plant allelochemicals and semiochemicals in view, the present study has been taken up to know the differential influence of various cotton and sunflower cultivars on the behavioural dynamics and performance of *C. carnea* and their further utilization in IPM with the following objectives.

1. To study the ovipositional preference of the pest, *H. armigera* and the predator, *C. carnea* on different genotypes of cotton and sunflower under net house conditions,
2. To study the response of *C. carnea* to different parts of cotton and sunflower genotypes using Wind tunnel olfactometer,
3. To study the electroantennogram (EAG) response of *H. armigera* and *C. carnea* on different genotypes of cotton and sunflower,

4. To study the feeding potential of three species of chrysopids against *H. armigera* eggs on cotton and sunflower genotypes and
5. Use of *C. carnea* in the management of *H. armigera* on selected genotype of cotton and sunflower.

II. REVIEW OF LITERATURE

The role of semiochemicals in mediating insect plant interactions has received increased attention of the biological control workers, since the early seventies. The present review is confined to kairomone mediated bitrophic and tritrophic level interactions involving chrysopid spp.

Kairomone constitute an important group of allelochemicals, which are adaptively favourable to the receiver of the stimuli (Brown *et al*., 1970). Their role in interspecific interactions involving insects has now been recognized, especially in host location by natural enemies. They may be released either by the plant or the host insect and act either as long range guiding systems for the natural enemies or short range contact stimuli eliciting strong host seeking response in the parasitoids upon direct contact (Hendry *et al*., 1976).

The predators (chrysopids) belonging to the family Chrysopidae are widely used in biocontrol of number of insect pests like lepidopterous eggs and neonate larvae, aphids, whiteflies, mealybugs, leafhoppers and other soft bodied insect pests. They are known to make use of wide range of chemical stimuli in host searching, the most important being kairomones mediated by host insects and plants (Nordlund *et al*., 1985).

2.1 Ovipositional preference of the pest, *Helicoverpa armigera* (Hubner) and the predator, *Chrysoperla carnea* (Stephens) on cotton genotypes of

A study on seasonal abundance of *H. armigera* showed that during Kharif season, the pest started its activity in groundnut from the first week of July. Thereafter, the pest moved to cotton from the last week of July and started to build up its population during the month of August to mid September. Simultaneously, the pest infestation was also noticed in sunflower and pearl millet during this period, but the population was very low on sunflower. Navon *et al.* (1991) evaluated three pubescent cultivars of cotton (Texas-172, Pilose hybrid and Texas –100) one glabrous cultivar (Sicot –2) and the commercial variety, Acala SJ-2 were bioassayed in the laboratory and field in Israel against the noctuids, *Spodoptera littoralis* Fab. *H. armigera* and the *Bemisia tabaci* (Gennadius). The weight gain and leaf feeding capacity of the lepidopteran on the pubescent cultivars were less than on the others. However, shaving the trichomes from the leaves of Texas –172 did not increase feeding by *H. armigera* and the larvae on the shaved leaves partly avoided ingesting the pigment glands.

Moths of *H. armigera* preferred to oviposit on genotypes with more leaf trichomes. The degree of hairiness has been associated with resistance to *Heliothis* spp. (Lukefahar *et al*., 1971). Oviposition by *H. armigera* on cotton appears to be reduced when other crops such as sorghum, sunflower and maize become available (Roome and Matthews, 1971). The presence of kairomones in the eggs fo *Heliothis zea* (Boddie) was associated to attraction of *C. carnea* larvae. These kairomones are involved in prey finding or acceptance or both (Nordlund *et al*., 1977).

Chrysopids like *C. carnea* and *Chrysoperla Formosa* Brauer were present on aphid infested plants and laid more number of eggs than on non-infested plants (Varenik and Khavruk, 1977). Both physical factors (leaf pubescense and Plant height) and chemical cues (Volatile / surface chemicals) are known to be involved in the oviposition behaviour of some *Helicoverpa* spp. (Jackson *et al*., 1984; Tingle and Mitchell, 1984; Ramaswamy *et al*., 1987; Firempong and Zalucki, 1990; Navasero and Ramaswamy, 1991; Jallow, 1998).

Jenkins (1989) correlated hairiness of leaves and stem with the leafhopper resistance. However, hairiness led to high trash contents in the lint and high incidence of *Heliothis* and whitefly. Glabrous trait provided significant resistance to bollworms.

Shvetsova *et al.* (1989) reported that, the *H. armigera* showed least preference for oviposition on cotton varieties with few hairs, high gossypol content and no extra floral nectaries. Three groups of varieties were distinguished, with low, moderate and high attractiveness to the pest. The least attractive were S -2210, Mutant – 1, S- 1259, S –26, Aleppo –33, L-342 and B.49. All, except B-49 had no nectaries and the first three were without hairs. Singh and Rembold (1989) reported that the mean preoviposition period of *H. armigera* was 2.9 days. Peak fecundity occurred between 5th and 9th day and the highest

mating frequency was noticed at 4^{th} to 6^{th} day after adult emergence. Firempong and Zalucki(1990) reported the role of some plant properties in host plant selection by adults of the polyphagous noctuid, *H.armigera*. The presence of flowers greatly increased plants attractiveness to oviposition. The presence of *H. armigera* larvae, larval damage and larval frass reduced the oviposition on cotton plant by *H. armigera* (Firempong and Zalucki, 1991).

Among the cultivated species of cotton, *G. arboreum* and *G. herbaceum* are inherently tolerant to insect pests. The dominant mode of resistance is antibiosis wherein, the morphological and biochemical factors tend to act as deterrents for oviposition and feeding (Sundaramurthy and Chitra, 1992). Sundaramurthy and Chitra (1992) recorded cultivated species of cotton, *G. arboreum* and *G. herbaceum* as inherently tolerant to insect pests. Some early maturing varieties such as Abadhita, SH-131 and SV – 213 escape from attack of bollworms.

The effect of food plant on parasitism of second instar *H. armigera* by *Microplitis demolitor* (Wilkinson) was studied under green house condition. Parasitism was nill (0.0%) on chickpea, moderate to high amounts of parasitism (22.4 to 75.4%) was recorded on sorghum, sunflower, maize, cotton and soybean (Murray and Rynne, 1994). Annadurai *et al*. (1995) found that MCU-7 expressed higher concentrations of protein, carbohydrate, phenols, amino acids and gossypol in squares than MCU-11. Higher concentrations of the primary metabolites, secondary products such as phenols and gossypol have also been observed in the bolls of MCU-7 than in other cultivars, which led to increased resistance in *H. armigera*. Selection for resistance to sucking pests with more hairy leaves of cotton brought increased susceptibility to bollworms.

Ramnath and Uthamasamy (1995) found that MCU-9 was most preferred by *H. armigera* for oviposition with a mean of 45.33 eggs per plant. It also had a high number of trichomes i.e., $92/cm^2$. LK-861 was least preferred with a mean of 0.66 eggs per plant, which had the lowest number of trichomes per unit area.

Jallow and Zalucki (1995) studied the oviposition preference of *H. armigera* in free choice experiments with free flying females in cages. Though individual females differed in oviposition preference, but the most preferred ones are maize, sorghum and tobacco followed by cotton. The least preferred plants were cowpea and lucerne. Butter *et al*., (1996) studied the ovipositional response of *H. armigera* to different cotton varieties and species under caged conditions. Maximum oviposition (51.6 eggs / female) was recorded on LH-900, a variety of *G. hirsutum* and minimum oviposition (3.0 eggs/ female) on G-27, a variety of *G. arboreum*. Of the number of factors found to affect the ovipsition of *H. armigera*, trichome length on the upper surface of the leaf, rather than density, showed a positive correlation.

The maximum congregation of *H. armigera* larvae was on flower than other plant parts under multiple choice experiments. The red coloured genotypes (IL-112 and G-27) of *G. hirsutum* and *G. arboretum,* respectively were least preferred by *H. armigera* for feeding purposes. The resistance in these two cotton genotypes could be due to certain chemical deterrents, which may inhibit feeding by *H. armigera*. The most preferred genotypes for feeding were the LH- 886 (*G. hirsutum)* and LD – 230 (*G. arboreum)* (Butter and Singh, 1996a).

Newly developed food product, envirofeast, and three other food sprays *viz*., sugar, envirofeast-2 and petroleum oil plus kelgum mixture on oviposition by *Helicoverpa* spp on cotton crops were evaluated under mesh house choice and no choice tests and large scale field trials at three sites in Australia. Envirofeast treated plant received significantly fewer eggs than any other treatment and control plot, both in the mesh house choice and no choice tests and in field plots exposed to natural population of *Helicoverpa* spp. This effect could modify the predator to prey ratios so as to enhance levels of biological control (Mensah, 1996). Tritrophic interactions among host plant, the aleyrodid, *Bemisia argentifollia* Gennadium and the predatory chrysopids were studied under laboratory conditions. Females of *B.argentifollia* avoided ovipositing on leaves on which larvae of *C. rufilabris* were previously located. This tendency appeared to increase with increasing exposure time of the predators to the leaves. The effect of host plant on body weight, duration of development and survival of predators was also studied. *B. argentifollia* reared on cataloups (melons) and cucumber

appeared to be a better quality prey than those reared on poinsettia or limabean (*Phaseolus lunatus* L.) (Legaspi and Nordlund, 1996).

Genotypes with low density of hairs on the upper surface and high density hair on the lower leaf surface of cotton helps in reduction of pest incidence (Khadi *et al*., 1998). Dale and Pedro (1998) reported reduced parasitoid searching efficiency due to higher trichomes. Asifulla *et al*. (1998) conducted a field experiment under rainfed condition to know the parasitization of *Trichogramma chilonis* Ishii on bollworm eggs in different cotton cultivars. Parasitization was higher in glabrous cultivars DCH –32 (23.80%) and BCS – 23 –48 – 7 (17.8%) compared with Abadhita, (3.5%) NHH-44, (6.3%), AK – 235 (9.8%) and Jayadhar (11.3%).

Vennila (1998) reported that in general, hybrids harboured more number of leafhoppers and aphids than the open pollinated cultivars. Predators like chrysopids and coccinellids were almost four times higher on hybrids than on the open pollinated cultivars. Ballal and Singh (1999) observed that the egg laying by *M. astur* on sunflower, cotton and pigeonpea was much lower compared to *C. carnea* and *M. boninensis.* This could be attributed to its lower fecundity (Bakthavatsalam *et al*., 1994).

Ballal and Singh (1999) studied the oviposition preference of three species of chrysopids on three host plants like cotton, sunflower and pigeonpea. Among the different crops, more eggs were laid on sunflower and cotton and fewer eggs on pigeonpea, when the chrysopid adults were tested under no choice conditions. In free choice tests with all three host plants, *C. carnea* and *M. boninensis* followed the same pattern, while *M. astur* had no marked preference for any of the host plants. On sunflower, the eggs were almost equally distributed over the tender leaves, florets and bracts, with no special preference for any specific site. On cotton, *C. carnea* laid more eggs on the leaves than the buds, while *M. boninensis* and *M. astur* did not exhibit any preference.

Some varieties tolerant to bollworms are G-27, Lohit, LD-327, MCU-7, LH-900, Sharada, Abadhita and LRK–516. Some non preference characters of *H. armigera* in cotton are smooth leaves, nectarilessness, long pedicel, thick boll rind, hard boll rind, and okra type of leaf (Singh, 2000). Anon. (2002) found that among the different entries evaluated for resistance to insect pests in cotton, Sahana a variety of *G. hirsutum* recorded highest number of *H.armigera* eggs (3.12 eggs/ plant) and lowest eggs per plant (0.83/ plant) on the entry KC-2. Bakthavatsalam *et al*. (2002) in their ovipositional response studies reported that, *H. armigera* showed highest ovipositional response on C-256, which was statistically at par with MCU-5, MCU-7 and G-27. Whereas, *C. carnea* showed highest ovipositional response on MCU-7 which was at par with Kanchana and HLS-72. In the second set of experiments, *H. armigera* preferred to lay eggs on MCU-10 and MCU-9 than other cultivars.

Mellet and Schoeman (2004) reported that female moths of *H. armigera* did not discriminate between Bt cotton (N_4DPal) and non-Bt cotton fields for oviposition

2.1.1 Oviposition preference of *H. armigera* and *C. carnea* on sunflower

Shepard and Sterling (1972) reported that hirsute genotypes generally supported fewer beneficial arthropods. The screening of 15 sunflower varieties during the rainy season at Bangalore indicated fewer incidences of *H. armigera* caterpillars on EC 101497, EC-101489 and EC-101495. The less incidence was due to earliness of these genotypes (Panchabhavi *et al*., 1977). Arora *et al.* (1998) evaluated eight sunflower hybrids at different dates of sowing against insect pests and their natural enemies. Early sown crop supported a significantly greater population of predatory insects like *C. carnea* and coccinellids. Cultivar, GKSFH-2002 showed significantly lower population of phytophagous insects and greater populations of predatory insects. It also recorded highest seed yield of 2366 kg/ha.

Kuruppuchamy *et al*. (1993) conducted a field experiment in the rainy season of 1991 to investigate the yield losses of sunflower caused by *H. armigera*. The economic injury level was reported to be 0.92 larvae/ plant.

Sengonca *et al*. (1995) reported that oviposition of *C. carnea* was greatest with 2.1 and 1.3 eggs per plant in May and July, respectively and the mean number of adults reached 28.7 individuals per 300 m^2 area. Arya *et al*. (1995) identified 21 insect pests belonging to eight

orders and 13 families infesting sunflower in Haryana, India. Among 21 insect pests, *H. armigera* to be the major pest of sunflower.

Mannan *et al*., (1995) found that *C. carnea* laid eggs on cotton during the first week of July and eggs were then present throughout the cropping season. In case of sunflower, the first eggs were observed during November and also recorded up to mid March. There was a clear positive correlation between the predator and its prey (*Myzus persicae*) on sunflower.

Colonization by the predators indicated that sunflower cultivars RHA–274 and RHA–421-6 with 4.67 and 4.33 eggs and larvae per plant, respectively were most favoured by *C. carnea.* These entries may prove useful as donors for the development of hybrids suitable for use in integrated pest management programme (Arora *et al*., 1996).

Bhat *et al*. (1996) screened hundreds of germplasm accessions and cultivars against *H. armigera* and found that among them few accessions like KBSH–6,7,8,9, TNSU-3, RHA-263, 291B, EC-109281, EC-107285 and BRS-3 were found superior to the rest in recording lower eggs and larval density per plant. The entries 352 B and RH 272 having 0.17 caterpillars/ plant were least susceptible to the semilooper, *Plusia orichalcea* (Fab.). This was followed by 339 B and 336 A x 336 B both with 0.33 caterpillar / plant as compared to PSFH-67 which harboured 1.33 caterpillars/ plant (Arora *et al*., 1996).

Geetha and Swamiappan (1998) conducted an experiment to know the preference of *C. carnea* on different pollen rich crops like cotton, sunflower, astur and coriander under walk-in cages. During the first week, cotton and sunflower plants significantly favoured the retention of *C. carnea* adults, more *C. carnea* eggs were laid on the cotton plants (94.4 eggs) over the four weeks period, followed by the sunflower plants (88.2 eggs). The larval population of the pest, *H. armigera* was reduced from 3 to 2 per head by green lace wing larvae (*C. carnea*) released twice at weekly intervals, at the rate of two/ head and the yield in the release plot was 940 kg/ ha as reported by Venkatesan *et al*. (1997).

2.2 Wind tunnel olfactometer studies of *C. carnea* on different genotypes of cotton and sunflower

Vet (1983) described olfactometer, which can be used to screen a number of different sources without a detailed knowledge of the insect behaviour. *Campoletis sonorensis* (Cameron) is a larval parasitoid of *H. virescens*. Females are attracted to the flowers of some plants in an olfactometer, and will examine and probe plant parts especially flowers, even in the absence of host (Elzen *et al*., 1983).

Wind tunnel studies indicated that, terpenes did not elicit flight behaviour of *C. sonorensis* but C6 and C7 carbon aldehydes and alcohols from cotton did. Parasitoids were more attracted to damaged than to undamaged plants (Vinson, 1988). Navasero and Elzen (1989) the relative attractiveness of host plants to the braconid, *Microplitis croceipes* (Cresson) a parasitoid of the noctuid *H. virescens* in a wind tunnel. Female parasitoids flew significantly more to glandless than to glanded cotton, but there was no significant difference between the responses to nectaried and nectariless cotton.

Bakthavatsalam and Singh (1996) conducted a laboratory and field cage experiments to select the best kairomone as an ovipositional attractant for *C. carnea*. Acid hydrolysed L-tryptophan (stored for 15 days) was highly attractive to males and females of *C. carnea* in no choice test in a wind tunnel, and in multiple choice tests using Kairomone treated filter paper. Pure commercial honey and 25 and 50 per cent honey solutions were also attractive in no choice tests but not in multiple choice tests.

Extracts of wheat flowers and wheat leaves were used to investigate their efficacy to attract *H. armigera*. Results in a wind tunnel olfactomater showed that volatile secondary metabolites of wheat flowers and leaves attracted *H. armigera*. Orientation rates were 45 to 75 per cent compared to 22.2 per cent in control and orientation rates of females were greater than those of males (Zhang *et al*., 1997). Results of four arm olfactometer test indicated that cotton bollworm moths were strongly attracted by these plant volatiles, resulting in selective indices of 0.78, 0.61, 0.49 and 0.31 for cotton squares, cotton tips, maize silk and groundnuts, respectively (Ding *et al*., 1997b). Hou *et al*. (1997) studied the two odour choice tests that mechanically damaged cotton leaves and the aphid honeydew plant leaf complex were more

attractive to the parasitoids than intact leaves. Wind tunnel studies indicated that males of *C. carnea* showed a significantly higher preference for sunflower and females for both sunflower and cotton, while pigeonpea was least preferred. Males of *M. boninensis* did not show a specific preference for any of these three host plants, while females preferred cotton. Males and females of *M. astur* did not show a specific preference for any of the host plants. (Ballal and Singh, 1999).

Hexane wash of gallery and body of *Opisina arenocella* Walker elicited positive response from the parasitioids namely *Goniozus nephantidis* (Muesebeck), *Brachymeria nephantidis* Gahan and *Elasmus nephantidis* Rohwer, in terms of more number of parasitoids entering the Kairomone arm than hexane arm in 'Y' tube olfactometer as reported by Bakthavatsalam *et al*. (1999).

Bakthavatsalam *et al*. (2000) conducted a wind tunnel olfactometer studies to know the response of *C. carnea* to different plant parts of cotton when infested with *H. armigera* larvae. The adults of *C. carnea* spent distinctively more time in zone–6 with extracts of *H. armigera* infested bolls. In dual choice test, significantly more number of adults reached the synomone arm with extracts of infested cotton bolls than the control arm.

2.3 Feeding potential of Chrysopid spp

Treacy *et al*. (1983) found that predation of *H. zea* eggs by *C. rufilabris* was low in pilose varieties of cotton and high in glabrous ones. Treacy *et al*. (1987) also found that cotton trichomes act as mechanical barriers, which reduce mobility and consequently predating ability of the aphid lion grub. The third instar grubs of aphid lion were less affected by trichomes than first and second instars.

Sengonca *et al*. (1987) conducted a laboratory test to examine the effect of feeding with different prey on the development, mortality and fecundity of *C. carnea*. Aphids, especially, *Aphis pisum* Glover proved most suitable and *Tetranychus urticae* (Koch) the least suitable prey with *Memestra brassicae* (L) eggs only slightly better. Predation of *C. carnea* on *B. tabaci* was investigated in the laboratory by Butler and Henneberry (1988). First instar larvae of *C. carnea* consumed eggs and larvae of *B. tabaci* in about the same time, while second instar predator larvae consumed eggs more rapidly than first instar larvae.

The predation of *Chrysoperla scelestes* (Bank) on eggs and larvae of *H. armigera* was maximum in LK-861, where one predatory grub devoured 18-6 eggs and 8.66 neonate larvae per day. The predatary potential was in the decreasing order for LPS-141, MCU-11, MCU-9, TCH-1002 and JK-276-4. The maximum predation of larvae was on LK – 861 and the lowest TCH –1002. The rate of predation was negatively associated with the trichome density (Ramnath and Uthamasamy, 1995).

The predation rate of *H. armigera* eggs by *C. scelestes* indicated an increase in squares, followed by bolls, flowers and leaves. Among the varieties, the per cent predation by *C. scelestes* was significantly higher (64.9%) on savine and least was reported on MCU-7 (31.7%) (Annadurai *et al*., 1995).

Predation of eggs and neonates of *H. armigera* by *C. scelestes* on different cotton genotypes was studied by Ramnath and Uthamasamy (1995). Genotypes with fewer trichomes recorded increased percentage of predation. Egg and larval predation was maximum on LK-861, which had minimum number of trichomes on the leaves.

2.4 Electroantennogram (EAG) response of *C. carnea* and *H. armigera* to different genotypes of cotton and sunflower

2.4.1 The Predator

Bechrecke *et al*. (1989) found that the combined gas chromatography and electroantennogram studies were used to record the olfactory receptor responses of the ichneumonid parsitioid. *C. sonorensis* to volatile chemicals which had been previously identified in cotton plants. EAG depolarizations to green leaf chemicals were greater than to terpenoids. Li *et al*. (1992) studied the antennal olfactory responses of *M. croceipes* to 29

cotton volatile compounds by electroantennogram (EAG) techniques. No significant sexual differences were found between EAGs of males and females to volatiles emanating from 100 µg stimulus loads of the 29 cotton compounds. Green leaf volatiles, heptanol, benzaldehyde and acetophenone elicited the largest EAG responses. Monoterpenes elicited moderate EAG response with beta – ocimone being the most effective monoterpenes tested.

The highest EAG response was noticed in the mated females and this increased behavioural response was also confirmed in the olfactometer studies (Bakthavatsalam and Singh, 1996). EAG response of female *C.carnea* antenna to extract of corn leaves was greater than that of males (Zhu *et al*., 1999). Chrysopid species like *Chrysoperla pollens* (Rambur) and *C. carnea* were found to show electroantennogram response to kairomones (Boo *et al.,* 1998; Zhu *et al*., 1999; Bakthavatsalam *et al*., 2000).

2.4.2 The pest, *Helicoverpa armigera* (Hubner)

Candidate mating inhibitors for three lepidopterous cotton pests were screened out of 90 synthetic pheromone like compounds, using the EAG recording techniques (Gothilf *et al*., 1978). Among the synthetic pheromone like compounds (Z)-9-tetradecenyl formete and (Z)-11-hexadecenal were most stimulatory to *H. armigera* followed by (Z)-9-tetradecenyl acetate but next to the natural pheromone.

Delorme and Payne (1984) studied the EAG of adult males of *H. zea* to the female sex pheromme, (Z)-11-hexadecenal. Pharate adult males were able to respond to the pheromone two days before emergence. Such a response was very high on the day of emergence, with no significant change upto third day of adult life. Hartlieb and Rembold (1996) reported that elctrophysiological recordings form female *H. armigera* antennae showed good responses to each of the compounds of the sesquiterpene mixture. Piccardi *et al*. (1997) reported that a compound from the female *H. armigera* was identified as (Z) –11-hexa decenal. This aldehyde was a potent olfactory stimulant for the male *H. armigera* in laboratory tests and was also attractive to males in the field in the Sudan.

The electroantennogram (EAG) response of antennae of *H. armigera* showed a significant strong response to flower and leaf extracts compared to the control. EAG response to wheat flower extract was slightly greater than that to leaf extract (Zhang *et al*., 1997).

Elechtroantennogram (EAG) responses were recorded from virgin laboratory reared male and female adults of *H. armigera* to sex pheromone components and a range of plant volatile components. Only male responded to sex pheromone component (7)–11-hexdecenal. For plant volatile compounds, a large degree of uniformity of EAG responses was observed between males and females. The greatest EAG responses for plant volatiles were elicited by monoenoic C-6 alcohal and aldehyde constituents of the general green leaf odour that emits from most of the plants (Chen *et al*., 1997). Electroantennography (EAG) was used to explore electro physiological responses of cotton bollworm to volatiles. EAG responses of virgin females to volatiles of squares, flowers and stem tips of cotton and flowers and seedlings of groundnuts increased with age. Mated females had significantly stronger EAG responses than virgin females, suggesting that these plants emitted chemicals capable of promoting oviposition (Ding *et al*., 1997a).

EAG was used to investigate electrophysiological response of cotton bollworm (*H. armigera)* to volatiles of carrot flowers. Results of EAG and Gas Chromatography Mass Spectrum (GCMS) showed the presence fo five active components (including 3 methyl–2-pentanol, myrcene, limonene and ocimone) in volatile oil. Carrot flowers volatiles were only attractive to one to two day old moths, suggested that carrot flower volatiles are semiochemicals solely associated with feeding behaviour of cotton bollworm (Ding *et al*., 1997a). Mated females of *H. armigera* showed significantly stronger EAG response to allelochemicals of host plants like cotton, maize and peanut suggesting that these plant released chemicals are capable of promoting oviposition (Ding *et al*., 1997a). Yan *et al*. (2002) analysed the volatile composition of transgenic cotton, GK-12 and regular cotton, “Simian NO.3” and studied the antennal response of mated female of *H. armigera*. The ratio of alpha pinene and beta-pinene were much higher in Bt cotton than in regular cotton. Overall,

it was concluded that nine volatile compounds of Bt cotton were responsible for EAG peaks in GC-EAD tests.

2.5 Integrated pest management of *H. armigera* in cotton and sunflower ecosystem using *C. carnea*

2.5.1 Seed treatment

Mizell and Sconyer (1992) reported lowest toxicity of imidacloprid to predatory arthropods. Nauen and Elbert (1994), reported that the imidacloprid protected against *A. gossypii* up to seven weeks in cotton when the seeds were treated with imidacloprid @ 5.0 g/ kg of seeds. Mote *et al*. (1995) observed imidacloprid seed treatment @ 10g /kg enhanced growth of cotton plants with the increase in chlorophyll and nitrogen content, which may be the reason for attracting more predators.

Toda and Kashio (1997) reported imidacloprid as the least toxic insecticide to *C.carnea* larvae among the 34 insecticides tested under the laboratory conditions. Mizell and Sconyer (1992) reported lowest toxicity of imidacloprid to predatory arthropods. Seed treatment with imidacloprid @ 5g and 7.5g per kg of sunflower seed gave protection from leafhoppers up to 35 to 40 days after sowing as reported by Basappa and Sriharan (1999).

Seed treatment with imidacloprid (Gauch) 70 WS at 7g per kg or foliar application of imidacloprid (Confidor) 200SL at 100 ml per ha was found to be effective against both aphids and leafhoppers on cotton (Kumar and Santharam, 1999). Satpute *et al*. (2002) found that seed treatment of cotton with imidacloprid and thiamethoxam was not only safe but also attracted the population of *Chilomenes sexmaculata* (Fab) adults and *C.carnea* for egg laying.

Bhat *et al*. (2003) evaluated sunflower seeds (cu. Morden) treated with imidacloprid 70WS at 5, 7.5 and 10g per kg seeds for the management of leafhoppers, whiteflies and thrips at Bangalore. Forty-one days after sowing, all the sucking pests recorded significantly lower population when the seeds were treated with imidacloprid as compared to control. Kannan *et al*. (2004) reported that the seed treatment to transgenic cotton with imidacloprid at 5 g per kg seeds was more effective in keeping pests below ETL upto 40 DAS than other treatments *viz.,* dimethoate and the untreated control. Seed treatment of Bt cotton with imidacloprid also attracted more insect predators and spiders *viz., Coccinella septempunctata* L., *C. sexmaculatus* and *C. carnea* etc.

2.5.2 Effect of intercropping in conservation of natural enemies

Stern *et al*. (1964) demonstrated that strip cropping of alfalfa in cotton in California greatly increased the population of nabids, chrysopids, anthocoreids and coccinellids. The benefits of increased natural enemies in strip cropping and interplanting alfalfa with cotton could be transferred to cotton (Stern, 1969).

Intercropping of cotton with cowpea, sorghum and maize and strip cropping of alfalfa colonized higher levels of natural enemies than in monocropping (Smith, 1967; Smith and Reynolds, 1972; Usembo, 1976 and Baliddawa, 1985). Baruducci (1972) reported that maize interplanted at the rate of one row per twelve rows of cotton increased control of *Helicoverpa* spp. by anthocoreid bugs and other predators.

Diversified cropping system helps in interchange of parasitoids and predators (Stern, 1969 and Fly, 1972) and also the number and / or species of natural enemies may be increased (Prince and Waldbauer, 1975) or decreased (Root, 1973). The reduction in pest incidence in intercropping system may be due to low resource concentration (Root, 1973 and Risch, 1981) or due to abundance of natural enemies (Bach, 1980). Bhatnagar and Davies (1980) concluded that field diversity provided by the intercropping systems may not always contribute to increased predation and parasitism of pest insect on the principal crop. They noticed few hymenopterans egg and larval parasitoids of *H. armigera* on sorghum intercropped in pegeonpea. But the natural enemies failed to transfer to main crop after harvest of the intercrop.

Greater density of natural enemies is caused by improvement in conditions for their survival and reproduction, such as greater temporal and spatial distribution of nectar and

pollen sources, which could increase reproductive potential of natural enemies and abundance of alternative host/ prey when the pest species are scarce or at an inappropriate stage (Risch, 1981). These factors provide more favorable conditions for natural enemies and thereby enhance their numbers and effectiveness as biocontrol agents.

A greater per cent parasitization was found when safflower was intercropped with sorghum, wheat, chickpea, lentil, linseed, sunflower and chilli than in safflower alone (Pawar *et al*., 1985). Intercropping of cotton with cowpea, sorghum and maize and strip cropping of alfalfa colonized higher level of natural enemies than in monocropping (Smith, 1969; Baliddawa, 1985).

Cotton intercropped with cowpea, soybean and onion harboured more number of coccinellids than sole cotton (Natarajan and Sheshadri, 1988). Li (1987) noticed the high build up of *Chrysopa* in safflower + cotton intercropping system. The aphid *M. persicae* which infested safflower naturally served as alternative food for the predator. Intercropping of corn, beans or weeds with cotton reduced the population of *A. gossypii* and predators other than *C. carnea* (Schultz, 1988). Duelli (1980) reported that the *C.carnea* population was maximum in lucerne field, *C. carnea* to thrive in environments where changes in the quality of the habitat are unpredictable and drastic.

Nordlund *et al*. (1984) found that *Trichogramma* parasitization in polyculture plots was much higher than on monoculture corn. Intercropping may increase the effects of natural enemies, because the intercropped plant provides allelochemical attraction or a nectar or pollen source for natural enemies or because the intercrop improves microclimatic conditions (eg. moisture, shelter) for ground dwelling predators (Van Emden, 1989). The advantages of diversification of the crop and neighbouring environments have been extolled by organic farmers and other protagonists of sustainable and alternative agriculture for many years (Anon., 1989b)

Cotton intercropped with barley, ground cover crops and green manure crops protected over wintering predators and increased their numbers (Zhang *et al*., 1990). Singh *et al*. (1991) reported that groundnut intercropped with sorghum reduced the incidence of *Empoasca kerri* Pruthi, due to increased activity of predatory insects. Basappa and Sriharan (1999) reported that mixed cropping of sunflower with cotton resulted in comparatively lower thrips and leafhopper infestation on the former. Venugopal Rao *et al*. (1992) noticed the higher activity of larval parasitoids, which were attracted to the umbelliferae at flowering stage, when chickpea was intercropped with coriander.

Absolute populations of predators were four to ten times higher in the intercropped areas than in the monoculture ones. Based on these observations, Edward *et al*. (1992) concluded that increasing crop diversity favours population of the natural enemies of the pest. Intercropping of groundnut in cotton reduced the pest load by increasing the activity of natural enemies (Venugopal Rao *et al*., 1994). Singh *et al*. (1993), recorded high incidence of eggs of *H. armiger*a on okra and nymphs of the cicadellids on okra and sunflower and more number of *C. carnea* eggs suggested the possibility of exploiting these crops in cultural control of the above pests on cotton. A mixed or intercropping regime will provide a greater total land productivity as well as unstable market value to any single crop. In addition, crops in intercropping systems not only improve soil fertility and availability of alternative sources of nutrient products (Risch *et al*., 1983), but also reduce the insect pest incidence (Smith and Reynolds, 1972 and Robinson *et al*., 1972).

Intercropping of groundnut in cotton reduced the pest load by increasing the activity of natural enemies (Venugopal Rao *et al*., 1994).

Coccinellid population build-up was differentially favoured by different intercrops. While, sole crop of pigeonpea recorded significantly less predatory population, soybean failed to encourage buildup of predatory population of pigeonpea as compared to cowpea, setarea, sorghum and bajra. However, the natural enemies transferred to main crop after harvest of intercrops (Hegde, 1995). Intercropping seteria, cowpea, mungbean and soybean with cotton resulted in conservation of generalist natural enemies viz., *Trichogramma* spp*. Apenteles* spp*., Menochilus* sp*., Neoscona* spp. and *C. carnea* (Anon., 1995b).

Cotton grown with strip crops of rape, wheat and sorghum (over lapping temporally, *ie.* acting as relay intercrops) recorded lowest number of aphids and highest number of predators compared with monoculture cotton (Parajulee *et al*., 1997).

2.5.3 Efficacy of neem products in the management of *H. armigera*

Azardirachtin from neem inhibited the feeding and growth of the last instar larvae of *H. virescens* (Rucose, 1972). Spraying of two rounds of 5.0 per cent aqueous extract of Neem Seed Kernel Extract (NSKE) on chickpea crop was found to minimize the incidence of gram pod borer, *H. armigera* (Kareem, 1978). Rao and Srivastava (1984) reported that the neem oil and NSKE based water dispersible powder at one per cent concentration inhibited the growth of the larvae of *H. armigera* on sorghum ear heads. When *H. armigera* larvae were allowed to feed on chickpea plants treated with 0.1 per cent NSKE, larval pupal intermediates and abnormal adults were observed (Jotwani and Srivastava, 1984). Evaluation of neem extracts and insecticides in the field reveled that eight per cent NSKE significantly reduced the damage due to *H. armigera* and was comparable with 0.05 per cent quinalphos and 0.02 per cent fenvalerate (Srivastava *et al*., 1984).

Siddappaji *et al*. (1986) noticed least per cent of pod damage (52.74 %) when NSKE was applied @ 5 per cent which was on par with insecticides viz., phenthoate and chlorpyriphos and proved its superiority over untreated control. Further, they opined its harmless nature and can be easily be incorporated in the IPM programme. On the contrary, Fagoonee (1987) proved the inefficiency of NSKE @ 5 per cent against *H. armigera* on tomatoes as compared to deltamethrin application, but it has given good control when alternated with the insecticides.

Padke *et al.* (1988) noted that neemark @ 0.4 per cent was superior to fenvalerate in the control of whitefly eggs and recorded less bollworm incidence. Further, the neemark is significantly superior to control and neem water extract (Decoction), in all parameters like incidence of whitefly (eggs and pupae) boll weight and yield.

Results of Thakur *et al*. (1988) proved ineffectiveness of neem kernel and leaf extracts @ 5 per cent. Less larval population was noticed on chickpea one and two weeks after all chemical insecticides, but neem extracts recorded significantly less larval population as compared to control, However, the chemical insecticides were found to be more effective than neem kernel and leaf extracts after one week but these were at par with each other after two weeks. Even then they have suggested using neem extracts as they are cheap and harmless. Methanol fraction of Neem Seed Kernel (NSK) and *Tribulix terrestris* as aqueous suspension at 0.01 per cent, when applied directly to the final instar larvae of *S. litura* predisposed with NPV increased the pupal mortality and abnormality with *T. terrestris* (Deviprasad *et al*., 1990). The oviposition deterrent effect of NSKE has been reported against *H. armigera* on different corps (Saxena and Rembold, 1984; Jhansi and Singh, 1996).

De and Hague (1992) stated that application of four sprays of one per cent Achook, a neem antifeedant at fortnightly interval produced the highest fresh yield of edible bhendi fruits (27.16 tonnes / ha) which was 9.60 tonnes per ha (54.60 %) more than the control. This was superior to routine application of decamethrin 0.05 per cent and need based application of endosulfan 0.05 per cent. The next best treatment was three sprays of one per cent Achook producing 50.80 per cent more yield with 15.01 per cent infested fruits. As compared to control, all the Achook treatments produced more than 12 per cent edible fruit yield.

Neem oil @ 5 per cent sprayed on cotton against *H. armigera* gave poor control of the pest although significantly better than untreated control. But, neem oil alternated with chemical insecticides *viz.,* sevin and decis produced a comparable yield with those sprayed with chemical insecticides. The low rate of efficacy indicates that the presence of more larvae which did not necessarily cause damage on the cotton bolls due to deterred feeding (Solsoloy and Embuido, 1992). Laboratory trails on two neem formulataions, Neemrich 20 EC and 80 EC conducted by Bhatnagar and Kandasamy (1993) against cotton insect pests indicated that Neemrich 20 EC at 0.1 per cent exhibited 51.10 and 50.80 per cent

antifeedant activity against larvae of *Earias vittella* (Fab.) and *Euproctis luneta* (Walk), respectively. Neemrich 80 EC at 0.8 per cent resulted in 84.0 per cent mortality of aphids.

Satpute *et al.* (1993) observed that all the four synthetic pyrethroids tested were significantly superior than endosulfan, chlorpyriphos and herbal product, neemark (0.10 %) in reducing the bollworm incidence, Rajashekhar *et al*., (1994) stated that the plant products like neem oil, replin and some neem oil based formulations were useful as additives to conventional insecticides to manage the insecticides resistant *H. armigera* .

Many neem origin botanicals have been evaluated against *H. armigera* on many crops but on sunflower there is very little information (Basappa, 1996). Sunflower crop was treated with NSKE (5%), *Clerodendron inerme* (L.) dust (25%) and *C. inerme* fresh plant extract (10%) results in larval-pupal intermediates and abnormal adults of *H. armigera.* Sequential application of Nuclear Polyhedrosis Virus (NPV) @ 250 LE per ha followed by NSKE (5%) and *C. inerme* extract (10%) was found promising in reducing *H. armigera* population in the sunflower field (Basappa, 1998). NSKE (2%) was found effective against whitefly with 74 per cent population reduction, which was on par with endosulfan (Anon., 1997a).

Econeem and neemazal (0.1 to 1.0%) were safer to *Trichogramma japonicum* Ashmead compared to insecticides, particularly quinalphos and chlorpyriphos which had adverse effects on parasitization (Jhansi Lakshmi and Singh, 1996). Among several botanicals evaluated, Neem Seed Kernel Extract was found to be most effective against leafhoppers (Anon., 1997a).

Neem Seed Kernel Extract (2%) was found most effective among various neem products tested against leafhoppers at Akola which brought 89 per cent reduction in population with highest yield of 1350 kg per ha which was on par with endosulfan in its performance compared to 771 kg per ha in control (Anon., 1998). *Bacillus thurengiensis* (Dipel) and neem (Godrej Achook) were found to be less toxic to *C. carnea* predator in cotton ecosystem (Kundu *et al.,* 1998).

The effect of palmarosa oil (P.O) 50 EC on the parasitization of egg parasitoid *T. chilonis* and the larvae of *C.carnea* was studied. Palmarosa oil was relatively non toxic to *T. chilonis* and to the larvae of *C. carnea*. However, P.O at higher concentrations of 15 to 20 ml per litre. was found to reduce the parasitization by *T. chilonis,* but, cent per cent survival of larvae, pupation and adult emergence of *C. carnea* larvae was observed. (Thilagavathi and Ali, 1998).

NSKE (5%) proved to be effective in reducing sucking pests and *H. armigera* population in sunflower with highest yield of 987.6 kg per ha. All the botanicals were found to be safer to natural enemies and pollinators (Sridevi, 1998). Application of Neem Seed Kernal Extract (5%) and neem based pesticides will not only reduce the damage due to *H. armigera* but also helps in conserving the activity of natural enemies as well as honeybees (Basappa, 1998). Nuclear Polyhedrosis Virus can also be used in sequence with NSKE (5%) for effective management of these pests (Basappa and Sriharan, 1999). The use of biorationals (NSKE) in cotton ecosystem drastically reduces the egg laying by *H. armigera* and *S. litura* as reported by Bajpai and Sehgal (1998, 1999 and 2003).

2.5.4 Use of sex pheromone traps in IPM

Helicoverpa armigera males can be attracted to sex pheromone traps, the seasonal field incidence studies also showed that the onset of rainfall initiated its occurrence on the crop (Anon., 1988). Much time and effort have been devoted to the development of pheromone traps for *H. armigera* (Pawar *et al*., 1988).

In case of sunflower, little work has been done on utilization of these sex pheromones for the pest management strategies. Monthly pheromone trap catches of *S. litura* and *H. armigera* were recorded since 1991 at Bangalore centre of AICRP net work (Anon., 1995a). Usage of pheromone traps in assessing the level of pest population and their role as an important tool in IPM was studied. The moth catch is affected by temperature, wind speed, direction, moonlight, cloud cover etc. The efficacy of pheromone depends on trap shape, placement, dispenser, quantity of pheromones and weather (Lakshminarayana, 1999).

2.5.5 Role of Green lace wing, *C.carnea* in the suppression of cotton insect pest complex

Two field releases totaling 2,92,000 *C. carnea* larvae per acre reduced the population of *H. virescens* to the extent of 96 per cent and increased the yield three fold. Whereas release of *C. carnea* eggs in field cages at the rate of 50,000 and 1,00,000 per acre also provided effective control of the tobacco budworm (Lingren *et al*., 1968: Ridgway and Jones, 1969). Similarly, Van Emden (1989) studied the impact of naturally occurring predators and deliberately introduced individual predator species of *H. zea* in caged cotton in California. Predator *Geocoris pallens* (Stal) reduced the bollworm at about 50 per cent, whereas, *Nabis americoferus* and *Chrysopa carnea* caused even higher mortality.

Searching ability of *C. carnea* was studied by Butler and May (1971). They stated that the predator, *C. carnea* searched equally well for the eggs of *Heliothis* spp. on both the top and bottom surfaces of glass plates (simple searching arena), but on artificial cotton plants (complex arena) the most effective searching occurred in the top half of the plants. In simple arena, the larvae consumed 6.7 eggs per day, whereas, second and third instars consumed seven times more than this number. The rate of successful search in second and third stage larvae was five times that of first stage in complex topography.

Adults of *C. carnea* were attracted by caryophyllene, a volatile released by actively growing plant tissues of cotton (Flint *et al*., 1979). Application of semio-chemicals to crops has not been universally successful in stimulating increased rates of mortality. The use of a uniform spray of moth scale extracts may increase egg parasitization by *Trichogramma* spp at low host densities (Lewis *et al*., 1979).

Dakruory *et al*. (1979) worked out consumption capacity of *C. carnea* of both eggs and larvae of *H. armigera* in laboratory. Later, Krishnamoorthy and Mani (1982) reported that *C. carnea* and *C. scelestes* are the common predators. The adults are long lived and the grubs have tolerance to pesticide residues. A single *C. scelestes* larva was found to consume 665 eggs or 410 larvae of *H. armigera*.

Chrysopids have been recorded as important natural enemies in suppressing several pests, especially soft bodied insects and lepidopterous pests (Canard *et al*., 1994 and Anon., 1992b). Odours from the larvae of *H. virescens* on cotton leaves attract more female *C. sonorensis* than cotton leaves alone, suggesting that host volatiles serve as Kairomones for host location (Elzen *et al*., 1983).

Effectiveness of the Chrysopid, *C. carnea* and *Brinckochrysa scelestis* (Banks) against *H. armigera* eggs and larvae on cotton has been reported by Morrison (1985) and Yadav and Patel (1987a). Patel and Vyas (1985) recorded site for oviposition preference of females of *C. carnea*, which is an important predator of cotton pests. Of 126 eggs laid on cotton plants, 38.9 per cent were laid on the lower surface of leaf, followed by 21.43 per cent on branches, 19.05 per cent on upper leaf surface, 6.35 per cent on petioles, 6.35 per cent on flowers and / or squares, 5.56 per cent on stem and 2.38 per cent on bolls. Yadav and Patel (1987b) opined that in the crops like pigeonpea and chickpea where use of *Trichogramma* is limited due to host plant mediated chemicals, the use of *Chrysopa* spp. offers as best alternative choice for biosuppresion of *Heliothis.*

Dhandapani *et al*. (1987) used a combination of *T.chilonis (*one lakh/ ha) and *C. carnea* 50,000 per ha per release (three times) for effective control of *H. armigera* and whitefly, *B. tabaci* on cotton.

Sunflower crop is a reservoir of several species of coccinellids, lygaeids and chrysopids. These predators play vital role in suppression of lepidopterous eggs and neonate larvae and sucking pests like, thrips, leafhoppers and aphids (Goel and Kumar, 1990).

Anon. (1992a) reported predators such as *C.carnea, Menochilus sexmaculatus* (Fab.) and parasitoids such as *Bracon* spp., *Campoletis* spp and *Trichogramma* spp., as most predominant in sunflower. Occurrence of several predators of *H. armigera* has been reported by various workers. *C. carnea* in Karnataka and coccinellid beetle complex in North India were predominant key mortality factors of this pest (Anon., 1993).

Bhat *et al.* (1993) noticed marginal reduction in egg and larvae of capitulum borer by releasing *C. carnea* @ one larva per head in Bangalore. Field trials conducted to determine the monocrotophos resistant strain of *C. carnea* revealed that it could survive the field recommended doses and exert the control of sucking pests *viz.,* leafhoppers and aphids as compared to susceptible strain (Patel and Yadav, 1993). On the other hand, the laboratory experiments 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 and 22.50 days when larvae were fed with *B. tabaci*, eggs of *Corcyra cephalonica* (Staiston), *H. armigera, A. gossypii, Amrasca biguttula biguttula* Ishida and neonates of *H. armigera,* respectively (Balasubramani and Swamiappan, 1994).

At Coimbatore, three releases of *C.carnea* @ 1 per head against head borer recorded maximum reduction of pest population (2.5 larvae/ 20 plants) and highest yield (959 kg/ha) followed by two releases of *C.carnea* @ 1 per head (Anon., 1994a).

Altogether 77 parasitoids and 33 predators have been reported on *H. armigera* in different crops (Manjunath, 1995). The larval population of *H. armigera* was reduced from three to one per head in sunflower by green lacewing larvae (*C. carnea*) released twice at weekly intervals at the rate of 2 per head and the yield in the release plot was 940 kgs per ha compared to 776 kg in the untreated control plot (Venkatesan *et al*., 1997).

Field studies conducted during 1995 and 1997 at IARI revealed that natural population of *C.carnea* (immature stages) in cotton was maximum (13.5/plant) in unsprayed plot, whereas in insecticide treated plots, its population was adversely affected (Kundu *et al*., 1998).

Hegde (1995) studied the impact of artificial release of *C. carnea* at different dosages (0.50, 0.75, 1.00 and 1.25 lakh per ha) against the pod borer, *H. armigera* on pigeonpea. Release of *C.carnea* @ 1.25 lakh per ha reduced the pod borer egg (30.08%) and larval population (24.41%). Grain yield was at par or higher with @ 1.0 lakh and 1.25 lakh per ha.

Chrysoperla carnea was the most prevalent natural enemy in sunflower ecosystem. The mean number of eggs, larvae and pupae recorded were 9,1 and 1 per head, respectively during April-June. These bio-agents played a major role in the population regulation of other pests too in sunflower ecosystem (Ballal and Singh, 1999). Among several chrysopids which migrate to sunflower and Egyptian clover, *C. carnea* dominated followed by two species of *Mallada* at Faridkot, Punjab (Narasimhan, 1992 personal communication). In sunflower crop grown in spring in Punjab, the population of biotic agents remained quite high because of migration of predatory chrysopids and coccinellids from the maturing *rabi* crops to sunflower crop. Thus, spring sown crop can be raised without any insecticidal spray or any other pest management action (Ballal and Singh, 1999).

Helicoverpa armigera moth laid significantly more eggs on pentane extracts of MHR-II and DP-90 compared to their respective controls, indicating that chemical constituents in the cotton genotypes function as kairomone in mediating oviposition behaviour (Jallow *et al*., 1999).

The predatory green lacewing, *C. carnea* and the microbial pesticide, *Bacillus thuringiensis* var. *galleriae* emerged as the important components of IPM for lepidopteran pests *viz*., *H. armigera* and *S. litura* (Longanathan *et al*., 2000). Singh and Kumar (2000) reported *C. carnea* as a potential predator and can be utilized in mustard aphid, *Lipaphis erysimi* (Kalt.) management programme. Bharpoda *et al*. (2000) reported that, *H. armigera* can be managed effectively on cotton by releasing at the rate of one grub of *C. carnea* per plant with marigold as a trap crop. Bharpoda *et al*. (2000) who reported that three releases of *C. carnea* @ one larva per plant in IPM block of cotton revealed the establishment of the predator for the management of *H. armigera*. Inundative release of *C. carnea* has been found to bring immediate and direct reduction in target pest population (Kumar *et al*., 2001).

Praveen and Dhandapani (2001) evaluated effectiveness of different biological control agents against the major pests of okra i.e. leafhopper, whitefly, cotton aphid and the fruit borers. The results revealed that release of the predator, *C. carnea* (25,000 grubs /ha) + econeem 0.3 per cent for three times at 15 days interval starting from 45 days after sowing was found to be effective in reducing the population of sucking pests as well as the fruit

borers. The fruit yield (10,326 kg/ha) and cost benefit ratio (1 : 2.6) were also higher when *C. carnea* and econeem 0.3 per cent were combined, compared with either, *C. carnea* (9643 kg fruits/ha and 1:2.39) or econeem 0.3 per cent (9533 kg fruits / ha and 1: 2.44) alone.

Balakrishnan *et al*. (2004) reported the efficacy of *C. carnea* in combination with biopesticides against *H. armigera* infesting cotton cv. MCU-10. The lowest mean larval population of *H. armigera,* minimum damage on shed squares, bolls and loculi and higher yields were recorded in two releases of *C. carnea* and two sprays of *B. thuringiensis* var. *kurstaki* (Btk) treated plots followed by *C. carnea* in conjunction with HaNPV and Btk alone treated plots.

An experiment was conducted by Panchabhavi *et al*. (2004) to study the efficacy of *T. chilonis* (1.5 lakh/ ha) and *C. carnea* (2 second instar larvae/plant or 4 eggs/plant) at different rates of releases independently and together in comparison to NSKE (5%) and endosulfan (0.07%) against bollworm of cotton at College of Agriculture, Nagpur during kharif 1999-2000. Combined releases of *T. chilonis* @ 1.5 lakh parasitized eggs/ha with different rates of *C. carnea* were comparable for their efficacy with recommended insecticides endosulfan 0.07 per cent and proved to be effective in reducing the infestation on squares, flowers, green bolls and open bolls due to bollworm complex, loculi damage by pink bollworm and per cent bad seed cotton, thus contributing to a higher yield of seed cotton.

2.5.6 Biochemical properties in insect pest management

Flint *et al*. (1979) found that caryophyellene and ß-caryophyllene a closely related compound was equally attractive to green lacewings under field conditions. Chemicals produced by the hosts normal food plants that help to attract the parasitoids to the host habitat and to find the host have been identified in some cases and were termed as synomones (Nordlund *et al*., 1981).

Plant chemicals appear to be involved in habitat location, since certain plant extracts can stimulate increased rates of parasitization (Altieri *et al*., 1981; Nordlund *et al*., 1984).

The chemical constituents of cotton and sunflower showed that some plant chemicals were responsible for reducing damage by insects by inhibiting their growth. Two cyclopropenoid acids were important in the protection of developing seeds and monomeric flavenoids known to be present in cotton had significantly different levels of effectiveness against the various species of cotton pests (Sneft and Waiss, 1982).

The chemoreceptors in adults of *H. armigera* were studied using scanning and transmission electronmicroscopy. The olfactory reaction to 21 volatile oils known to occur in cotton and other host plants and the response to sugars, acids, hydroxides and salts were observed by Salama *et al*. (1987). Vinson (1988) studied the role of plants in interaction between cotton, *H. virescens* and *C. sonorensis*. Three groups of compounds, which influence the orientation of *C. sonorensis,* were isolated from cotton. There were low molecular weight alcohols and aldehydes, monoterpenes and sesquiterpenes.

Plants are known to produce a wide variety of allelochemicals which include attractants and repellents leading to the differential behaviour of natural enemies on different host plants. Ovipositional excitants and feeding stimulants are known to be released from plants (Ananthakrishnan, 1992).

III. MATERIAL AND METHODS

Studies on tritrophic interactions were carried out at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka) and Project Directorate of Biological Control (PDBC), Bangalore (Karnataka). Dharwad is located at an altitude of 678 m above mean sea level and lies between 17° N latitude and 76° 46' E longitude. It lies in the northern transitional zone of Karnataka, with a mean annual rainfall of 725 mm, well distributed during the cropping season. Temperature and relative humidity recorded during the study period ranged from 12 to 40°C and 44 to 85 per cent, respectively. Meteorological data recorded during the experimental period are presented in Appendix–I. The field experiments were carried out in deep black soils under rainfed conditions.

Appendix I: Weekly Weather data at Main Agricultural Research Station, University of Agricultural Science, Dharwad

The details of materials used and methodology followed during the course of investigations are described here under.

3.1. Ovipositional preference of *Helicoverpa armigera* (Hubner) and *Chrysoperla carnea* (Stephens) on different genotypes of cotton and sunflower

3.1.1 Maintenance of host insect culture

The culture of the factitious host, *Corcyra cephalonica* Stainston was maintained at 24±2°C and 60 ± 5 per cent relative humidity. The larvae were reared on broken sorghum grains, which were heat sterilized in an oven at 100°C for 30 minutes. Later broken grains were sprayed with 0.1 per cent formalin (to prevent the growth of molds and increase the grain humidity), which was lost due to heat sterilization and mixed with two per cent yeast. The adults were collected daily and transferred into oviposition cages. The eggs were collected 24 hr later, cleaned through sieves and used for continuous maintenance of the host culture as well as predators. The eggs to be used for mass rearing of the predators were exposed to the ultra violet radiation in a closed wooden chamber for 60 minutes in order to kill the host embryo. These eggs were then used for further studies.

3.1.2 Mass rearing of *C. carnea*

The nucleus culture of the predators *viz*., *C. carnea*, *Mallada astur* (Bank) and *Mallada boninensis* (Okamoto) were obtained from Project Directorate of Biological Control (PDBC), Bangalore. They were mass multiplied on *C. cephalonica* eggs under laboratory conditions. Eggs collected from PDBC were mixed with *C. cephalonica* eggs and these mixtures poured into a plastic tub containing corrugated paper strips. A day after hatching, chrysopid species started feeding on *Corcyra* eggs (each species maintained separately). On third day after hatching, larvae were transferred to small injection vials containing *Corcyra* eggs to avoid cannibalism. After pupation, pupae were collected with camel hairbrush and kept for adult emergence in oviposition cage measuring 75 x 30 cm. The sides of the cage were lined with smooth nylon wire mesh (not preferred for egg laying) but, the sliding top cover was fitted with black cloth for obtaining eggs. To prevent damage to the eggs the top was slided over a comb fitted on both the sides of the cage. The sliding top cover was replaced every day starting from fourth day onwards. The adults in oviposition cage were fed daily using cotton swabs containing drinking water, 50 per cent honey solution, equal quantity of proteinex + fructose + honey + powdered yeast (dissolved in small quantity of water) and castor pollen.

One day old eggs were dislodged from the black cloth top cover of oviposition cage by gently working with a piece of sponge. Eggs collected were used for further multiplication, tritrophic studies and field release.

3.1.3 Mass rearing of *H. armigera*

Second and third instar *H. armigera* larvae were collected from the cotton field and reared under laboratory in separate glass vials by providing soaked bengalgram seeds till pupation. After discarding the feeble and diseased pupae, the healthy ones were subjected to sterilization by dipping in 0.25 per cent sodium hypochlorite solution. The sterilized pupae were taken in petriplate (10 cm diameter) containing fine sawdust and were kept in earthen pots. After a week, pupae were taken outside and transferred to rearing cage (30 cm x 30 cm x 30 cm) for eclosion. The freshly emerged male and female moths were released into earthen pots (45 x 30 cm) in 13 : 10 ratio (Gopali, 1998). The earthen pots were placed in plastic basins surrounded by moist sand to half of the height of the basin. The sand bed was moistened daily with one per cent sodium hypochlorite solution to avoid fungal growth. The top portion of pot was covered with black muslin cloth fastened by rubber band for oviposition. Fresh honey solution (10.0%) enriched with vitamins in cotton wad was provided as adult food daily till the death of moths. Eggs were collected daily at morning (10 am) by changing the black cloth. The eggs of 24 hr old were surface sterilized with one per cent sodium hypochlorite solution. Immediately after hatching of eggs, the neonate larvae were reared for four days on chickpea seedlings. Then, the larvae were shifted to individual glass vials (5 x 2 cm). The larvae were reared on overnight soaked and washed bengalgram seeds which were reported to be highly protinacious diet for oviposition (Butter and Singh, 1996b). The larvae were provided with bengalgram seeds daily till pupation. The feeble and diseased pupae were discarded and healthy pupae were used for further tritrophic studies.

3.1.4 Cotton and sunflower genotypes

Twelve cotton genotypes representing *Gossypium hirsutum, G. herbaceum, G. arboreum* and intra hirusutum and ten genotypes of sunflower representing varieties and hybrids were selected for the study (Table 1). The genotypes were grown in 25 cm x 30 cm size earthen pots filled with soil, compost and vermicompost. Two to three seeds of each genotype were sown and only one plant was retained at the later stage of the growth.

Table 1: Genotypes of cotton and sunflower selected for the study

3.1.5 Experimental set up

The study was conducted during *kharif* 2002 at Main Agricultural Research station, UAS, Dharwad in net house conditions. The experiment was conducted with 12 treatments replicated thrice in Completely Randomized Design (CRD). The treatments consisted of both varieties and hybrids.

The investigations made in two separate sets are as follows.

a. *H. armiger*a + *C. carnea* release set

b. Only *C. carnea* release set

Treatments were imposed thrice as follows

a. At vegetative stage

b. At square formation/flowering stage

c. At boll formation stage of the crop

3.1.6 Raising potted plants

Seeds were treated with imidacloprid 70 WS @ 10 g per kg seeds. Three seeds of each cotton hybrids and variety per pot were sown with proper labeling, later one plant per pot was maintained. Potted plants were raised as per recommended package of practices except pesticide treatments. Potted plants were maintained in good condition (pest free) in open field until flowering. Early formed flowers in some of the genotypes were removed to synchronize the flowering in all the plants and care was taken to maintain uniform number of fruiting bodies in all the plants prior to the imposition of treatments.

Table 1. Genotypes of cotton and sunflower selected for the study

Sl. No.	Cotton genotypes	Sl.No.	sunflower Genotypes
1.	LRA-5166	1	DSH –1
2.	DB-3-12	2.	KBSH-1
3	Jayadhar	3	PCSH-243
4	DHH-543	4	MSFH –17
5	DHH-11	5	Morden
6	Abadhita	6	RSFH-1
7	Sahana	7	SFL-107
8	MCU-5	8	Jwalamukhi
9	NHH-44	9	DSF-2
10	AK-235	10	VRF-21
11	DLSA-17		
12	PA-255		

3.1.7 Net house

Net house was constructed with nylon net of 3x10 m with 2.5 m height and 3x10 m with 2.5 m height partitioned into two with a barrier at the centre to accommodate two sets of treatments. The net house was kept free from weeds and grasses to prevent *Helicoverpa* from egg laying on them. The potted plants were arranged replicationwise and separated by one meter apart inside the net house in a linear fashion. All the treatments within the replication were randomized. Identical randomization pattern was followed for *H. armigera* + *C. carnea* release set and only *C. carnea* release set.

3.1.8 Ovipositional preference among cotton genotypes

a) *Helicoverpa armigera* + *C. carnea* release set

Healthy pupae of *H. armigera* were selected and sexed into male and female at pupal stage and were kept in separate cages until adult emergence. Pupae were surface sterilized by dipping in 0.25 per cent sodium hypochlorite solution. Pupae were taken in Petriplates of 10 cm diameter and kept in an earthen pot. After a week they were transferred to rearing cages (30 cm x 30 cm x 30 cm) separately for adult emergence. Freshly emerged 20 pairs of healthy male and female moths of one to two days old *H. armigera* were shifted to rearing cages for mating by providing with 10 per cent honey solution (Butter and Singh 1996b). The next day, 20 pairs of pre-mated *H.armigera* moths were released into the net house (Plate 1)

for oviposition. The cotton swabs containing 10 per cent honey solution were hung inside the net house to facilitate adult feeding. After two days all the moths inside the net house were removed.

Plate 1: Net house used for *H. armigera* and *C. carnea* oviposition studies on cotton genotypes

Six days old *C. carnea* adults were allowed to mate inside the rearing cage in 1:1ratio and provided with 50 per cent honey solution and proteinex mixture diet as descried by Singh *et al*. (1994). One day after the release of *H. armigera*, 20 pairs of pre mated six days old *C. carnea* were released into the net house for oviposition. Inside the net house, *H. armigera* and *C. carnea* adults were provided with hanging cotton swabs containing foodstuff (50% honey + water + proteinex)

b) *C. carnea* release set

Twenty pairs of pre-mated six days old *C. carnea* were released inside the net house and provided with hanging cotton swabs containing foodstuff as explained in 3.1.8a. Except the *H. armigera* release other things were kept constant as explained in 3.1.8a.

3.1.9 Observation

Observations on number of *H. armigera* and *C. carnea* eggs per plant in *H. armigera + C. carnea* release set and number of *C. carnea* eggs per plant in only *C. carnea* release set were recorded on two and three days after *C. carnea* release. After recording the observations on eggs in both the sets, the eggs were dislodged from the plant by water spraying and camel hair brush.

The treatment imposition was repeated again at flowering and boll formation stage by following the methodology as explained above, and the observations were recorded accordingly.

3.1.10 Ovipositional preference among sunflower genotypes

The ovipositional preference of *H. armigera* and the predator, *C. carnea* to the sunflower genotypes was carried out as explained in experiment 3.1.8a but only the crop stage and genotypes were changed. The number of *H. armigera* adults released was ten pairs and number of *C. carnea* released was 15 pairs in each net house (Plate 2). In sunflower, ovipositional preference was studied thrice *viz*., at late vegetative stage, capitulam formation stage and at flowering stage.

Plate 2: Net house used for *H. armigera* and *C. carnea* oviposition studies on sunflower genotypes

3.1.11 Observations

Observations on number of *H. armigera* and *C. carnea* eggs per plant in *H. armigera + C. carnea* release set and number of *C. carnea* eggs per plant in only *C. carnea* release set were recorded on two and three days after *C. carnea* release. After recording the observations on eggs in both the sets, the eggs were dislodged from the plant by water spraying and camel hairbrush.

The treatment imposition was repeated again at capitulam formation and flowering stage by following the methodology as explained above, and the observations were recorded accordingly.

3.1.12 Trichome density

The number of trichomes per 0.25 sq.cm. area of leaf was recorded at flower initiation stage under the stereobinocular microscope at a magnification of 20x. The trichomes of different cultivars of cotton and sunflower were counted on abaxial surfaces of the leaf. The observations were replicated thrice and later the data were analysed using ANOVA and then subjected to DMRT.

Plate 1. Net house used for *H. armigera* and *C. carnea* oviposition studies on cotton genotypes

Plate 1. Net house used for H. armigera and C. Carnea oviposition studies on cotton genotypes

Plate 2. Net house used for *H. armigera* and *C. carnea* oviposition studies on sunflower genotypes

Plate 2. Net house used for H. armigera and C. carnea oviposition studies on sunflower genotypes

3.2 Response of *C. carnea* to different parts of cotton and sunflower genotypes under wind tunnel olfactometer

Hexane was used as a laboratory solvent to extract volatile chemicals from different parts of cotton and sunflower. The different parts like leaf, flower, bolls of cotton and leaf, capitulam and flower of sunflower were used for the extraction (one gram of plant parts in 10 ml of hexane boiled for 30 minutes at 60 ºC). The cotton swabs containing 0.5 ml of hexane extract of different cultivars were taken and these were kept outside for 30 minutes for evaporation of hexane. Later these cotton swabs containing kairomone were kept in different arms of the olfactometer (Eight arm olfactometer was used for the experiment) (Plate 3). Twenty mated adults of *C. carnea* were released in the test chamber and the observations were recorded at 12 hr interval for number of adults entering the treated (Kairomone) arm.

Plate 3: A view of Wind tunnel olfactometer used for behaviour studies of *Chrysoperla carnea*

3.2.1 Effect of Kairomone to *C. carnea* grub

3.2.1.1 Kairomone extraction from wing scales of *H. armigera*

The known quantities of wing scales (0.1 to 0.6 per cent of scales) from *H. armigera* were blended separately with known quantity of hexane solvent (10 ml) in a pestle and macerated with the help of mortar. After maceration, the extract was filtered through Whattman filter paper then labeled and utilized for the experiment within four days after extraction. The filtrate was always kept under freezed condition and used within four days in wind tunnel olfactometer studies.

3.2.1.2 Kairomone from eggs of *H. armigera*

Known number of eggs (20, 40, 60, 80, 100 and 120 eggs) were blended with known quantity of hexane solvent (10 ml) and stirred for 30 minutes with the help of fine glass rod at room temperature. The rest of the procedure was same as in 3.2.1.1 and the extract was used for wind tunnel olfactometer studies as given under experiment 3.2.

3.3 Feeding potential of chrysopid species against *H. armigera* eggs on cotton and sunflower genotypes

The feeding potential of three species of chrysopids *viz., C. carnea, M. astur* and *M. boninensis* was studied using *H. armigera* eggs on different genotypes of cotton and sunflower under net house condition.

The potted plants were raised in net house which were replicated thrice. The *H. armigera* eggs collected from insect rearing laboratory were loaded / glued @ twenty eggs/ leaf (Plate 4) and two leaves per plant were selected at flower bud initiation and capitulam formation stage of the cotton and sun flower genotypes, respectively and three species of chrysopids were released @ one 2nd instar grub per plant separately (Plate 5). Twenty four hours after release of *C. carnea* grub, number of *H. armigera* eggs consumed was recorded. The predation was recorded with the help of 10 x lens. After completion of experiment all the eggs and larvae were dislodged and subsequent replication was taken on same plants.

Plate 4: Tritrophic relation among cotton plant, *H. armigera* eggs and *C. carnea*

Plate 5: Chrysopid spp. used for the feeding potential studies

3.4. Electroantennogram response of *H. armigera* and *C. carnea* on different cotton and sunflower genotypes

The kairomones prepared from cotton and sunflower genotypes (extraction procedure as given in experiment 3.2) were given through pasture pipettes to antennae of *H. armigera* and the predator, *C. carnea*. The pasture pipettes used for each genotype were separate and each pasture pipette contained an equal length of whatman number 77 filter paper containing kairomone compounds (Kairomone used was extracted from cotton and sunflower genotypes).

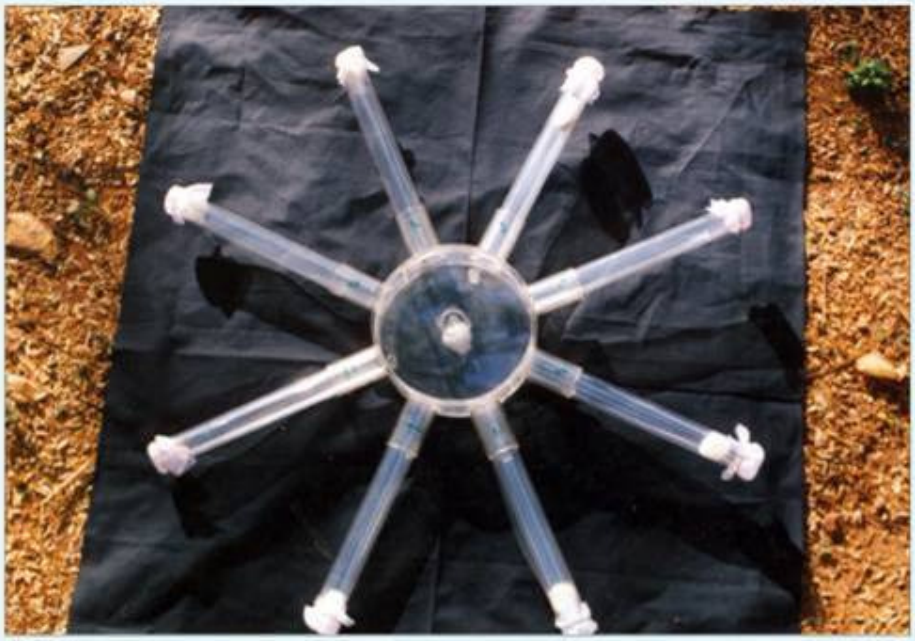

Plate 3. A view of Wind tunnel olfactometer used for behaviour studies of *Chrysoperla carnea*

Plate 3. A view of wind tunnel olfactometer used of behavior studies of Chrysoperla carnea

Electroantennogram (EAG) response of adults of *H. armigera* and *C. carnea* (both mated male and female) were studied using the Syntech® electroantennogram. The antenna of insect which was starved for a day was dissected along with the basal segments (scape and pedicel region) and fixed in the glass electrodes of electroantennogram (M/s. Syntech®, Netherlands) using electro conductivity gel (to keep the antenna live for longer time). The airflow @ 0.5 m / sec and pulse time @ 0.5 sec were maintained. Stimulus source of various test compounds (Kairomone extracted from cotton and sunflower) were given through pasteur pipette of 0.5 x 4 cm size (Plate 7) (Baktavatsalam *et al*., 2002). Fifty per cent honey solution given through pasteur pipette acted as a standard check for each of the antennae.

Plate 7: Pasture pipettes used for EAG experiments

Each antenna was exposed to cotton and sunflower leaf, flower bud, boll and capitulam extract from all the cultivars and five antennae (as a replication) were used for each set of experiments. The data obtained were subjected to logerithemic transformation and analysed using ANOVA using MSTATC software and treatments were compared by following DMRT.

3.4.1 Gas Chromatography Mass Spectrum studies

The chemical characterization was done using Gas Chromatography Mass Spectrum (GCMS) (Plate 8). The hexane extract of different varieties and hybrids of cotton / sunflower was collected (same as the procedure followed in 3.2). The extract obtained was concentrated using a vacuum concentrator and injected into the column and analyzed using GCMS. Analysis was performed on a Hewlett Packard 6890 GC equipped with 5973 mass spectrum detector using HP–MS (Hewlett Packard) cross linked 5 per cent phenyl methyl siloxane column (30 m x 0.25 mm ID x 0.25 µm film thickness). The temperature programme of the oven was 90° C, rising to 160°C @ 2°C/ min. Mass Spectrum conditions (EI mode) were ionized with voltage 70 eV, mass range m/z 999, ion source temperature 230°C. The mass spectra of unknown compounds were compared with those in the Wiley Spectral Data Base (Anon., 2000). Standards of compounds were obtained from Sigma Aldrich and the retention time and mass spectra were compared with the peaks for confirmation. Helium (99.999% purity) was used as the carrier gas with a flow rate of one ml per min.

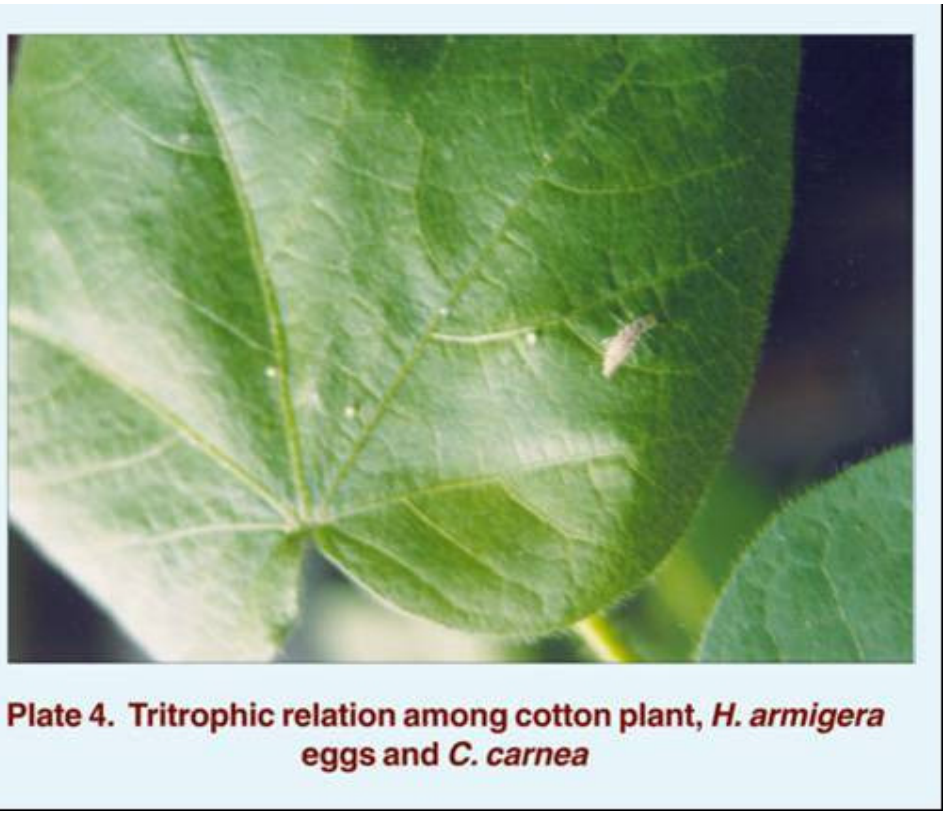

Plate 4. Tritrophic relation among cotton plant, *H. armigera* eggs and *C. carnea*

Plate 4. Tritrophic relation among cotton plant H. armigera eggs and C. carnea

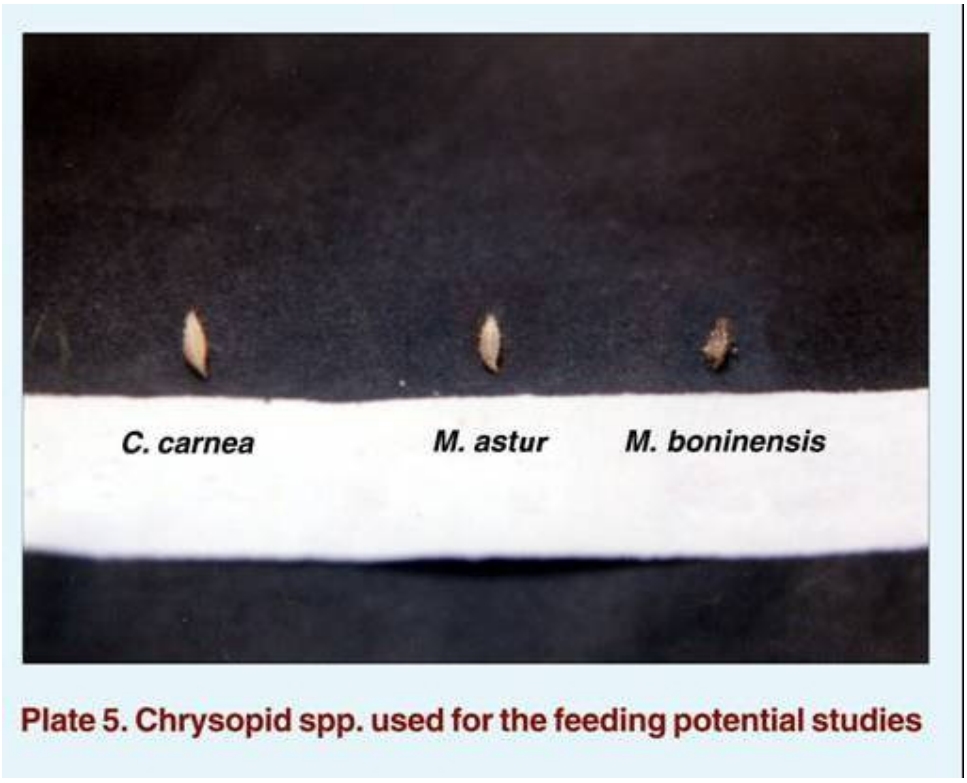

Plate 5. Chrysopid spp. used for the feeding potential studies

Plate 5. Chryspohid spp. used for the feeding potential studies

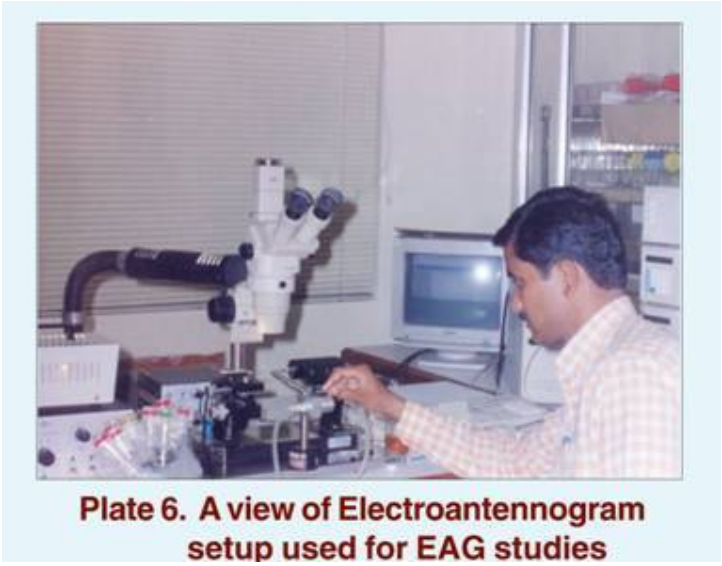

Plate 6. A view of Electroantennogram setup used for EAG studies

Plate 6. A view of Electroantennogram setup used for EAG studies

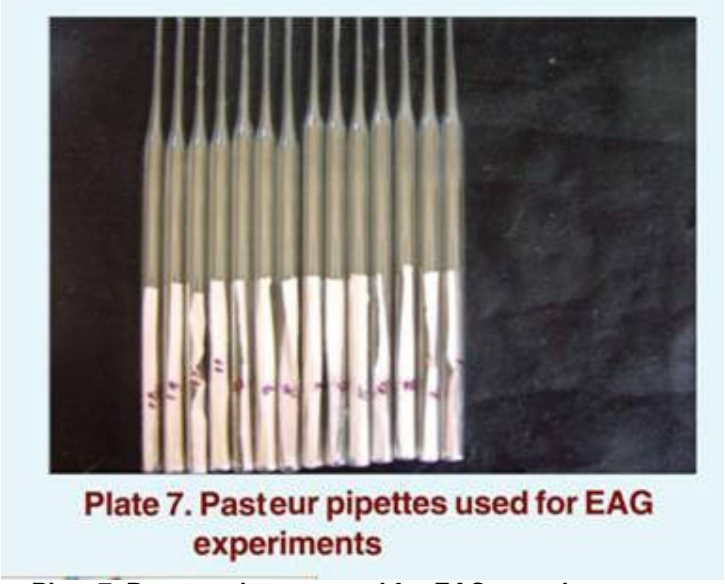

Plate 7. Pasteur pipettes used for EAG experiments

Plate 7. Pasteur pipettes used for EAG experiments

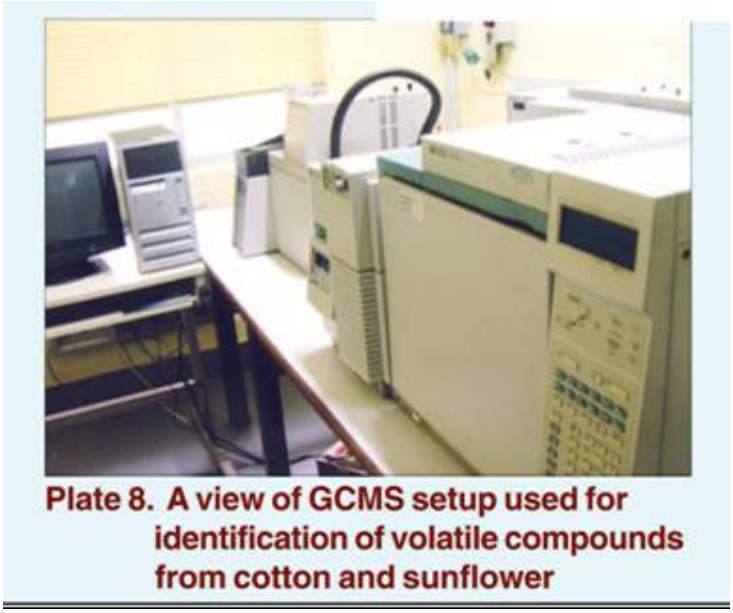

Plate 8. A view of GCMS setup used for identification of volatile compounds from cotton and sunflower

Plate 8: A view of GCMS setup used for identification of volatile compounds from cotton and sunflower

Table 2. Details of treatments imposed in cotton and sunflower

Treatments in cotton	Treatments in sunflower
T1. 1. Seed treatment with imidacloprid 70 WS @ 10 g/ kg of seeds	**T1**. 1. Seed treatment with imidacloprid 70 WS @ 10 g/ kg of seeds
2. Intercropping of lucerne (1:1 ratio)	2. Application of 5% NSKE
3. Application of 5% NSKE	3. Monitoring of *H. armigera* through sex pheromone traps @ 2 traps/ ac
4. Monitoring of *H.armigera* through sex pheromone traps @ 2 traps/ ac	4. Release of *C. carnea* @ 20,000/ ha
5. Release of *C.carnea* @ 50,000/ ha	
T2. T1 (1-4)+ 75,000 *C.carnea/* ha	**T2**. T1(1-3) + 40,000 *C.carnea* / ha
T3. T1 (1-4)+ 1,00,000 *C.carnea/* ha	**T3**. T1(1-3) + 60,000 *C.carnea* / ha
T4. Recommended package of practices (RPP)	**T4**. Recommended package of practices (RPP)
T5. Untreated check	**T5**. Untreated check

3.5 Use of *C. carnea* in Integrated Pest Management on selected genotypes of cotton and sunflower

3.5.1 Cotton

A field experiment was conducted during *kharif* 2002 at Main Agricultural Research Station (MARS), Dharwad. Three IPM module were developed with *C. carnea* as a component in the management of cotton pests along with seed treatment using imidacloprid, intercropping with lucerne, monitoring the bollworm population through sex pheromone trap and application of neem based pesticide, (Table 3) were evaluated in comparison with chemical control. The IPM modules consisted different sequences of use of predator, *C. carnea* and botanicals (5% NSKE). *H. armigera* sex pheromone traps were installed 45 days after sowing @ 2 traps / ac for monitoring the activity of old world bollworm. Randomized block design was followed with five treatments replicated five times with a plot size of 10 x 11m. DHH-543 an interspecific hybrid was sown on July 12th with a spacing of 90 cms between rows and 60 cms between plants. The crop was raised following recommended agronomic practices (Anon., 1997b).

Table 3: Details of treatment imposition in cotton during 2002 *kharif* season

IPM treatments were intercropped with lucerne (*Medicago sativa* L.) variety "Sirsa–9". One row of lucerne was grown between cotton rows with 10 cm spacing from plant to plant (Plate 9). Care was taken to maintain uniform plant population in all the plots.

Plate 9: A field view of cotton IPM experiment

The second instar, *C. carnea* grubs were released on the plants during cool hours (4-6 pm of a day) with the help of camel hairbrush. Observation on the incidence of pests and *C. carnea* was recorded at 15 days interval starting from 30 DAS.

Incidence of sucking pests *viz*., leafhoppers, whiteflies, thrips and aphids, was recorded per three leaves on five randomly selected plants from each replication. Eggs and larvae of *H.* armigera and eggs and grubs of *C. carnea* were recorded as number per plant. Population of *C. carnea* on intercrop was also recorded as number of eggs and grubs per meter row. Further at each picking, observations were also recorded on good opened bolls and bad opened bolls per plant on five randomly selected and tagged plants in each plot. Later, the yield was recorded and was extrapolated on ha. basis.

Bollworm damage per plant was recorded and converted to per cent and then subjected to arc sin transformations prior to statistical analysis. Data on good opened bolls, bad opened bolls and yield were analysed with one way ANOVA and then subjected to DMRT as suggested by Gomez and Gomez (1984).

3.5.2 Sunflower

Another field experiment was carried out during *rabi* 2002-03 at MARS, Dharwad. Five treatments were replicated four times in a randomized block design with a plot size of 9.2 × 11 m (Plate 10). Sunflower hybrid (KBSH-1) was sown with a spacing of 60 × 30 cm and the crop was raised following recommended agronomic practices (Anon., 1997b).

Plate 10: A field view of sunflower experiment

Three IPM modules consisting of seed treatment with imidacloprid, different sequences of *C. carnea* and NSKE application were evaluated in comparison with recommended package of practices (Table 4). *Helicoverpa* sex pheromone traps were installed @ 2 traps per acre 45 days after sowing for monitoring purpose. Observations were recorded at 10 days interval from five randomly selected and tagged plants in each plot starting from 30 DAS.

Table 4: Details of treatment imposition in sunflower during 2002 *rabi* season

The predator, *C. carnea* grubs (2^{nd} instar) were released at cool hours of the day (4-6 PM) with the help of camel hairbrush.

The population of sucking pests *viz*., leafhopper, whiteflies, and thrips was taken on top three leaves and the population of *H. armigera* eggs and larvae and *C. carnea* eggs and grubs were recorded per plant basis on five randomly selected plants. Later, the seed yield per plot was recorded at harvest and then extrapolated to ha. basis.

All data were transferred suitably and were analysed with one way ANOVA and treatment means were superscripted by DMRT as suggested by Gomez and Gomez (1984).

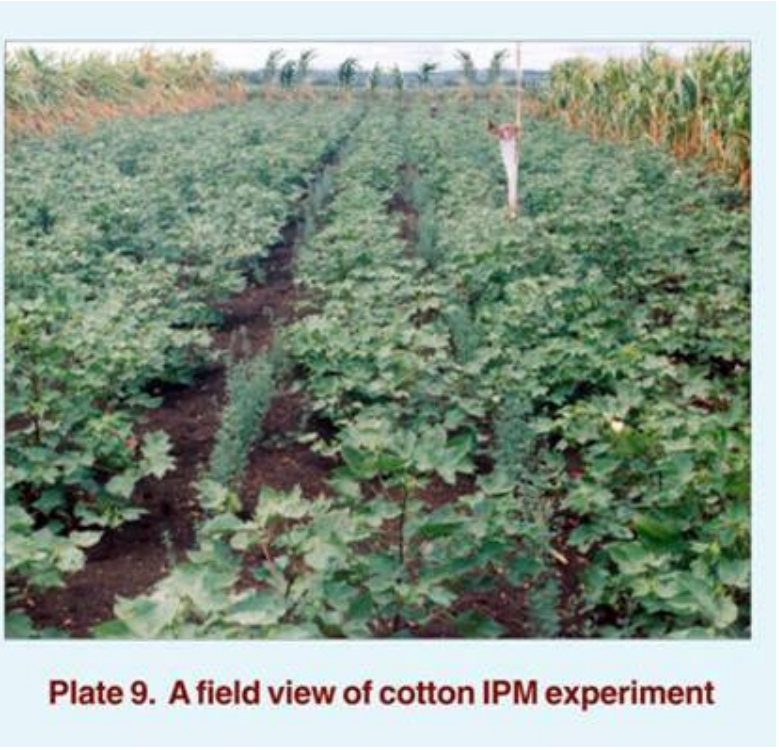

Plate 9. A field view of cotton IPM experiment

Plate 9. A field view of cotton IPM experiment

Plate 10. A field view of sunflower experiment

Plate 10. A field view of sunflower experiment

Table 3. Details of treatment imposition in cotton during 2002 *kharif* season

Date of treatment imposition	T1	T2	T3	T4	T5
At sowing	Seed treatment with imidachloprid 70WS @ 10g /kg of seeds	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	No seed treatment (control plot)
38 DAS	NSKE 5% spray	NSKE 5% spray	NSKE 5% spray	Oxydemeton methyl 25 EC at 1.5 ml/ l	No spray
43 DAS	Release of *C.carnea* at 50.000/ ha (1/2 dose) + Ha pheromone trap @ 5/ha	Release of *C.carnea* at 75.000/ ha (1/2 dose) + Ha pheromone trap @ 5/ha	Release of *C.carnea* at 1,00,000/ ha (1/2 dose) + Ha pheromone trap @ 5/ha	No spray	No spray
60 DAS	NSKE 5%spray	NSKE 5% spray	NSKE 5% spray	Thiodicarb 75 WP at 1.0 g/ l	No spray
70 DAS	*C.carnea* @ 50,000/ha (remaining (1/2 dose)	*C.carnea* @ 75,000/ha (remaining (1/2 dose)	*C.carnea* @ 1,00,000/ha (remaining (1/2 dose)	-	No spray
90 DAS	-	-	-	Cypermethrin 10 EC at 0.5 ml/ l	No spray
105 DAS	-	-	-	Monocrotophos 36 SL at 1.5 ml/ l	

Table 4. Details of treatment imposition in sunflower during 2002 *rabi* season

Date of treatment imposition	T1	T2	T3	T4	T5
At sowing	Seed treatment with imidachloprid 70WS @ 10g /kg of seed	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	Seed treatment with imidachloprid 70WS@ 10g/kg of seeds	No seed treatment
37 DAS	NSKE 5% spray	NSKE 5% spray	NSKE 5% spray	-	No spray
39 DAS	Release of *C.carnea* at 20.000/ ha (1/2 dose) + Ha pheromone trap @ 5/ ha	Release of *C.carnea* at 40.000/ ha (1/2 dose) + Ha pheromone trap @ 5/ ha	Release of *C.carnea* at 60,000/ ha (1/2 dose) + Ha pheromone trap @ 5/ ha	Oxydemeton methyl 25 EC at 1.5 ml/ l	No spray
58 DAS	NSKE 5 % spray	NSKE 5% spray	NSKE 5% spray	Phosolone 35 EC at 2.0 ml/ l	No spray
70 DAS	Releaseof *C.carnea* at 20,000/ha (remaining (1/2 dose) + Pheromone trap @ 5/ha	Release of *C.carnea* at 40,000/ha (remaining (1/2 dose) + Pheromone trap @ 5/ha	Releaseof *C.carnea* at 60,000/ha (remaining (1/2 dose) + Pheromone trap @ 5/ha	Endosulfan 35 EC at 2.0 ml/ l	No spray

IV. EXPERIMENTAL RESULTS

Results of the investigations carried out on ovipositional preference of the pest, *Helicoverpa armigera* (Hubner) and the predator, *Chrysoperla carnea* (Stephens), behavioural response of *C. carnea* to cotton leaf, flowers and boll wash and sunflower leaf, capitulam and flower wash using wind tunnel olfactometer, electroantennogram (EAG) response of *H. armigera* and *C. carnea* and feeding potential of three species of chrysopids against *H. armigera* eggs on different genotypes of cotton and sunflower and use of *C. carnea* in the management of *H. armigera* on selected genotypes of cotton and sunflower are presented below.

4.1 Ovipositional preference of the pest, *H. armigera* and the predator, *C. carnea* on different genotypes of cotton and sunflower under net house condition.

In order to assess the ovipositional preference of *C.carnea* on different genotypes of cotton and sunflower, an attempt was made to identify suitable genotype of cotton and sunflower for *C. carnea* under net house condition. The results obtained from the study are presented below.

4.1.1 Ovipositional preference of *C. carnea* and *H. armigera* at vegetative stage of cotton genotypes

In the absence of *H. armigera* eggs, *C. carnea* laid significantly more number of eggs on DHH-543 (9.33/ plant), DLSA-17 (8.80 / plant), DHH-11 (7.66 / plant), LRA-5166 (7.33/ plant) and Jayadhar (7.33/ plant) which were at par with each other and superior from rest of the hybrids and varieties of cotton (Table 5). The next best genotypes which received more number of *C. carnea* eggs were Sahana (7.00/ plant), NHH-44 (6.99/ plant), MCU-5 (6.66/ plant) and DB-3-12 (5.99/ plant) which were at par with each other. Least oviposition by *C. carnea* was observed on PA-255 (4.00/ plant), Abadhita (4.66/ plant) and AK – 235 (4.99/ plant) which were at par with each other (Table – 5). Whereas, in the presence of *H. armigera* eggs, it laid the highest number of eggs on DHH-543 (12.66/ plant) which was significantly superior over rest of the genotypes. This was followed by DHH-11 (9.99/ plant), Jayadhar (9.99/plant) DLSA-17 (9.99/ plant), LRA-5166 (9.66/ plant), DB-3-12 (9.66/plant), Sahana (9.66/ plant) NHH-44 (9.33/plant) and MCU-5 (8.00 / plant) which were statistically at par with each other and superior over rest of the genotypes. Least ovipositional preference by *C. carnea* was observed on PA-255 (5.33 / plant) which was on par with Abadhita (6.33 / plant) and AK-235 (6.66/ plant).

Helicoverpa armigera showed a non significant difference in egg laying pattern between hybrids and varieties of cotton. However, among the hybrids and varieties it laid more number of eggs on Sahana (30.33/plant), AK-235 (26.33/ plant), LRA-5166 (26.33/ plant), DHH-11 (24.33 / plant),NHH-44 (24.00/ plant) MCU-5 (21.66/ plant) and DHH-543 (21.00/ plant) which were statistically on par with each other. The next genotypes which received higher number of *H. armigera* eggs were on DLSA-17 (16.66/ plant), Jayadhar (16.66 / plant) which were at par with each other. The genotypes which received lower number of *H. armigera* eggs were DB-3-12 (13.99 / plant), Abadhita (15.00/ plant), and PA-255 (15.66/ plant) which were at par with each other.

Trichome density at vegetative stage of crop growth was significantly highest in AK-235 (32.66/ 0.25 cm^2) and NHH- 44 (32. 33/ 0.25 cm^2) both being statistically on par with each other and significantly superior to rest. These were followed by DHH 543 (28.33/ 0.25 cm^2). The next highest trichome density was recorded on MCU-5 (24.66/ 0.25 cm^2) followed by LRA-5166 (22.33/ 0.25 cm^2) and DHH-11 (21.66/ 0.25 cm^2) and were statistically at par with each other. Significantly least number of trichomes was recorded on PA-255 (14.33/ 0.25 cm^2) and DLSA-17 (14.99/ 0.25 cm^2) being statistically at par with each other, followed by Abadhita (17.00/ 0.25 cm^2) and Jayadhar (17.99/ 0.25 cm^2) (Table 5).In general, irrespective of the genotypes, *C.carnea* laid more number of eggs per plant (8.99) in the presence of *H. armigera* eggs compared to the situation without it (6.66/ plant).

Table 5. Ovipositional preference of *Chrysoperla carnea* (Stephens) and *Helicoverpa armigera* (Hubner) on cotton genotypes at vegetative stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	LRA – 5166	7.33 (2.71)^{ab}	9.66 (3.11)^{b}	26.33 (5.14)^{ab}	22.33^{d}
2	DB – 3 – 12	5.99 (2.44)^{bcd}	9.66 (3.11)^{b}	13.99 (3.73)^{d}	19.66^{f}
3	Jayadhar	7.33 (2.71)^{ab}	9.99 (3.16)^{b}	16.66 (4.08)^{bcd}	17.99^{g}
4	DHH – 543	9.33 (3.05)^{a}	12.66 (3.54)^{a}	21.00 (4.59)^{abcd}	28.33^{b}
5	DHH – 11	7.66 (2.76)^{ab}	9.99 (3.16)^{b}	24.33 (4.94)^{abc}	21.66^{de}
6	Abadhita	4.66 (2.10)^{de}	6.33 (2.50)^{cd}	15.00 (3.88)^{cd}	17.00^{g}
7	Sahana	7.00 (2.64)^{b}	9.66 (3.11)^{b}	30.33 (5.48)^{a}	20.33^{ef}
8	MCU – 5	6.66 (2.58)^{bc}	8.00 (2.83)^{bc}	21.66 (4.65)^{abcd}	24.66^{c}
9	NHH – 44	6.99 (2.63)^{b}	9.33 (3.05)^{b}	24.00 (4.9)^{abc}	32.33^{a}
10	AK – 235	4.99 (2.23)^{cde}	6.66 (2.58)^{cd}	26.33 (5.14)^{ab}	32.66^{a}
11	DLSA – 17	8.80 (2.80)^{ab}	9.99 (3.16)^{b}	16.66 (4.09)^{bcd}	14.99^{h}
12	PA – 255	4.00 (1.99)^{e}	5.33 (2.31)^{d}	15.66 (3.96)^{cd}	14.33^{h}
Mean		6.66 (2.51)	8.99 (2.97)	21.46 (4.62)	
S.Em±		0.13	0.12	0.36	0.523
C.D. @ 5%		0.37	0.36	1.10	1.533
CV (%)		8.65	7.10	14.80	5.82

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are Square root transformed values

4.1.2 Ovipositional preference of *C. carnea* and *H. armigera* at flowering stage on cotton genotypes

Chrysoperla carnea laid higher number of eggs on DHH-543 (13.33/ plant), DLSA-17 (12.99/ plant) and LRA-5166 (11.66/ plant) being statistically at par with each other. This was followed by Jayadhar (10.33/ plant), Sahana (9.99/ plant) and DHH-11 (9.66/ plant). The next genotypes which received more number of *C. carnea* eggs were DB-3-12 (9.00 / plant), MCU-5 (9.00 / plant), AK –235 (8.99 / plant) and NHH-44 (8.66 / plant) and were statistically on par with each other. It laid least number of eggs on PA-255 (6.33 / plant) and Abadhita (6.99 / plant). While, in the presence of *H. armigera* eggs, it laid highest number of *C. carnea* eggs

on DHH-543 (15.99 / plant), Jayadhar (13.99 / plant), Sahana (13.66 / plant), LRA-5166 (13.33/ plant), DLSA-17 (13.00/ plant), DHH-11 (12.66 / plant) and NHH-44 (12.33 / plant) which were statistically on par with each other. The genotypes which received more number of *C.carnea* eggs next in the order were MCU-5 (11.33 / plant), AK –235 (11.33 / plant) and DB-3-12 (10.33 / plant) which were on par with each other. Least oviposition by *C.carnea* was recorded on PA-255 (6.33 / plant) and Abadhita (6.66 / plant) which were at par with each other (Table 6). In general, irrespective of the genotypes, *C.carnea* laid more number of eggs per plant in presence of *H. armigera* eggs.

Table 6: Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on cotton genotypes at flowering stage

Under net house conditions, *H. armigera* showed a non significant difference in egg laying pattern between hybrids and varieties of cotton. However, among the genotypes it laid significantly more number of eggs on Sahana (33.99 / plant), NHH-44 (30.66 / plant), AK –235 (28.33 / plant), DHH-11 (28.33/ plant), LRA-5166 (28.33/plant) and MCU-5 (28.33/ plant) which were on par with each other. DB-3-12 (18 / plant), Abadhita (20.33/plant), PA-255 (21.66/ plant), DLSA-17 (22.33 / plant), Jayadhar (22.99 / plant) and DHH-543 (26.00 / plant) recorded lower egg load of *H. armigera* at flowering stage of the cotton genotypes under net house condition.

At flowering stage of the crop growth, significantly highest trichome density was recorded on AK-235 (44.33 / 0.25 cm^2) followed by NHH-44 (36.00 / 0.25 cm^2) and DHH-543 (32.66 / 0.25 cm^2). The trichome density on LRA-5166 (28.66 / 0.25 cm^2) and MCU-5 (27.99 / 0.25 cm^2) was statistically on par with each other and was significantly least on PA- 255 (14.00 / 0.25 cm^2) followed by DLSA -17 (16.00 / 0.25 cm^2) (Table 6).

4.1.3 Ovipositional preference of *C. carnea* and *H. armigera* at boll formation stage on cotton genotypes

It is evident from the data presented in table 7 that, *C. carnea* in the absence of *H.armigera* eggs laid higher number of eggs on the genotypes *viz*., DHH-543 (12.99 / plant) and DLSA- 17 (10.99 / plant) and were statistically on par with each other. Sahana (9.66 / plant), Jayadhar (9.66 / plant), DB-3-12 (8.99 / plant) and DHH–11 (8.99 / plant) being on par with each other were next to LRA-5166 (9.99 / plant). Significantly least number of eggs were recorded on Abadhita (5.66 / plant) and PA–255 (6.00 / plant) which were statistically on par with each other. Whereas in the presence of *H. armigera* eggs, *C. carnea* laid significantly higher number of eggs on DHH- 543 (15.66 / plant), DHH-11 (14.33 / plant), Sahana (13.66 / plant), LRA-5166 (13.33 / plant) and MCU-5 (12.66 / plant) which were on par with each other and superior to rest of the genotypes. The next best genotypes which performed significantly superior in recording higher number of *C.carnea* eggs were Jayadhar (12. 33 / plant), NHH-44 (12.00/ plant), DLSA-17 (11.66 / plant), DB-3-12 (11.66 / plant) and AK –235 (10.99 / plant) were statistically on par with each other. The genotypes which recorded significantly lower egg load of *C. carnea* were PA–255 (5.00 / plant) and Abadhita (7.00 / plant) (Table 7). In general, irrespective of the genotypes, *C.carnea* laid more number of eggs per plant (11.69) in the presence of *H. armigera* eggs compared to that in the absence of if (8.91 / plant).

Table 7: Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on cotton genotypes at boll formation stage

The pest, *H. armigera* showed non significant difference in egg laying pattern between hybrids and varieties of cotton. However, among the genotypes it laid significantly more number of eggs on Sahana (28.99/ plant), NHH-44 (28.66/ plant), AK – 235 (27.33 / plant), LRA-5166 (27.33 / plant), DHH-11 (26.33 / plant) followed by MCU-5 (25.99 / plant). Significantly least number of eggs were laid by *H. armigera* on DB-3-12 (16.99 / plant), Jayadhar (17.99 / plant) and Abadhita (19.00 / plant) at boll formation stage of the cotton under net house condition.

At boll formation stage significantly higher trichome density was recorded on NHH 44 (37.33 / 0.25 cm^2) and AK-235 (36.99 / 0.25 cm^2) both being statistically at par with each other. These were followed by DHH-543 (30.66 / 0.25 cm^2), MCU-5 (28.99 / cm^2) and LRA-5166 (28.00 / 0.25 cm^2). Significantly least trichome density was recorded on PA -255 (16.66

Table 6. Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on cotton genotypes at flowering stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	LRA – 5166	11.66 (3.41)^{ab}	13.33 (3.65)^{ab}	28.33 (5.32)^{abc}	28.66^{d}
2	DB – 3 – 12	9.00 (3.00)^{c}	10.33 (3.21)^{b}	18.00 (4.25)^{d}	23.33^{e}
3	Jayadhar	10.33 (3.21)^{bc}	13.99 (3.72)^{a}	22.99 (4.79)^{cd}	18.66^{g}
4	DHH – 543	13.33 (3.64)^{a}	15.99 (3.92)^{a}	26.00 (5.10)^{bcd}	32.66^{c}
5	DHH – 11	9.66 (3.11)^{bc}	12.66 (3.56)^{ab}	28.33 (5.32)^{abc}	20.66^{f}
6	Abadhita	6.99 (2.64)^{de}	6.66 (2.55)^{c}	20.33 (4.51)^{d}	18.00^{g}
7	Sahana	9.99 (3.16)^{bc}	13.66 (3.69)^{ab}	33.99 (5.83)^{a}	22.33^{e}
8	MCU – 5	9.00 (3.00)^{c}	11.33 (3.36)^{b}	28.33 (5.32)^{abc}	27.99^{d}
9	NHH – 44	8.66 (2.94)^{cd}	12.33 (3.51)^{ab}	30.66 (5.54)^{ab}	36.00^{b}
10	AK – 235	8.99 (2.99)^{c}	11.33 (3.36)^{b}	28.33 (5.32)^{abc}	44.33^{a}
11	DLSA – 17	12.99 (3.59)^{a}	13.00 (3.61)^{ab}	22.33 (4.73)^{cd}	16.00^{h}
12	PA – 255	6.33 (2.51)^{e}	6.33 (2.52)^{c}	21.66 (4.65)^{cd}	14.00^{i}
Mean		9.74 (3.1)	11.74 (3.41)	26.13 (5.09)	
S.Em±		0.11	0.16	0.23	0.342
C.D. @ 5%		0.32	0.48	0.68	1.002
CV (%)		5.99	8.29	14.82	5.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

/ 0.25 cm^2) followed by Jayadhar (18.00 / 0.25 cm^2), DLSA-17 (18.33 / 0.25 cm^2) and Abadhita (18.33 / 0.25 cm^2) (Table 7).

It is clear from the table 8 that , across the different stages of crop growth in absence of *H. armigera* eggs, *C. carnea* laid significantly highest number of eggs on DHH-543 (11.88 / plant) compared to rest of the genotypes. The next best genotypes which recorded higher number of eggs by *C. carnea* were DLSA-17 (10.66 / plant) and LRA-5166 (9.66 / plant) which were at par with each other. These were followed by Jayadhar (9.10 / plant), Sahana (8.88 / plant) and DHH-11 (8.77 / plant). Least oviposition by *C.carnea* in absence of *H.*

Table 7. Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on cotton genotypes at boll formation stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	LRA – 5166	9.99 (3.16)^{bc}	13.33 (3.63)^{ab}	27.33 (5.22)^{ab}	28.00^{c}
2	DB – 3 – 12	8.99 (2.99)^{cde}	11.66 (3.41)^{b}	16.99 (4.12)^{e}	24.66^{d}
3	Jayadhar	9.66 (3.11)^{cde}	12.33 (3.50)^{b}	17.99 (4.24)^{e}	18.00^{fg}
4	DHH – 543	12.99 (3.60)^{a}	15.66 (3.96)^{a}	24.00 (4.90)^{cd}	30.66^{b}
5	DHH – 11	8.99 (2.99)^{cde}	14.33 (3.76)^{a}	26.33 (5.13)^{abc}	22.99^{e}
6	Abadhita	5.66 (2.33)^{f}	7.00 (2.64)^{c}	19.00 (4.35)^{e}	18.33^{f}
7	Sahana	9.66 (3.11)^{cde}	13.66 (3.69)^{ab}	28.99 (5.38)^{a}	33.00^{e}
8	MCU – 5	7.66 (2.77)^{e}	12.66 (3.56)^{ab}	25.99 (5.09)^{bc}	28.99^{c}
9	NHH – 44	8.33 (2.88)^{de}	12.00 (3.47)^{b}	28.66 (5.35)^{ab}	37.33^{a}
10	AK – 235	7.99 (2.83)^{de}	10.99 (3.32)^{b}	27.33 (5.22)^{ab}	36.99^{a}
11	DLSA – 17	10.99 (3.30)^{ab}	11.66 (3.41)^{b}	23.33 (4.83)^{cd}	18.33^{f}
12	PA – 255	6.00 (2.45)^{f}	5.00 (2.24)^{c}	23.02 (4.80)^{d}	16.66^{g}
Mean		8.91 (2.96)	11.69 (3.38)	24.94 (5.00)	
S.Em±		0.12	0.14	0.09	0.468
C.D. @ 5%		0.36	0.40	0.27	1.371
CV (%)		7.09	6.90	9.66	5.90

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

Table 8. Ovipositional preference of *Chrysoperla carnea* on cotton genotypes across the different stages without *H. armigera* eggs

Sl. No.	Genotypes	No. of eggs laid by *C. carnea* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Flowering	Boll formation	Mean	
1	LRA – 5166	7.33 (2.71)^{ab}	11.66 (3.41)^{ab}	9.99 (3.16)^{bc}	9.66 (3.10)^{bc}	26.33^{c}
2	DB – 3 – 12	5.99 (2.44)^{cde}	9.00 (3.)^{c}	8.99 (2.99)^{cde}	7.99 (2.82)^{def}	22.55^{d}
3	Jayadhar	7.33 (2.71)^{ab}	10.33 (3.21)^{bc}	9.66 (3.11)^{cde}	9.10 (3.01)^{c}	18.21^{e}
4	DHH – 543	9.33 (3.05)^{a}	13.33 (3.64)^{a}	12.99 (3.60)^{a}	11.88 (3.44)^{a}	30.55^{b}
5	DHH – 11	7.66 (2.76)^{ab}	9.66 (3.11)^{bc}	8.99 (2.99)^{cde}	8.77 (2.96)^{cde}	21.77^{d}
6	Abadhita	4.66 (2.10)^{ef}	6.99 (2.64)^{de}	5.66 (2.33)^{f}	5.77 (2.40)^{g}	17.77^{e}
7	Sahana	7.00 (2.64)^{c}	9.99 (3.16)^{bc}	9.66 (3.11)^{cde}	8.88 (2.97)^{cd}	21.88^{d}
8	MCU – 5	6.66 (2.58)^{cd}	9.00 (3.)^{c}	7.66 (2.77)^{e}	7.77 (2.78)^{ef}	27.21^{c}
9	NHH – 44	6.69 (2.63)^{c}	8.66 (2.94)^{cd}	8.33 (2.88)^{de}	7.99 (2.82)^{def}	35.33^{a}
10	AK – 235	4.99 (2.23)^{def}	8.99 (2.99)^{c}	7.99 (2.83)^{de}	7.32 (2.70)^{f}	34.66^{a}
11	DLSA – 17	8.00 (2.80)^{ab}	12.99 (3.59)^{a}	10.99 (3.30)^{ab}	10.66 (3.26)^{b}	16.44^{f}
12	PA – 255	4.00 (1.99)^{f}	6.33 (2.51)^{e}	6.00 (2.45)^{f}	5.44 (2.33)^{g}	14.99^{g}
	Mean	6.66 (2.51)	9.74 (3.10)	8.91 (2.96)		
	S.Em±	0.13	0.11	0.12	0.057	0.449
	C.D. @ 5%	0.37	0.32	0.36	0.167	1.318
	CV (%)	8.65	5.99	7.09	8.20	5.68

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

armigera eggs was observed on PA-255 (5.44 / plant) and Abadhita (5.77 / plant) and were at par with each other (Table 8).

Table 8: Ovipositional preference of *Chrysoperla carnea* on cotton genotypes across the different stages without *H. armigera* eggs

In presence of *H. armigera* eggs across the three different stages of crop growth, significantly higher mean number of *C. carnea* egg density was noticed on DHH-543 (14.77 / plant). This was followed by Sahana (12.3 / plant), DHH –11 (12.32 / plant), Jayadhar (12.10 / plant), LRA-5166 (12.10 / plant), DLSA-17 (11.55 / plant) and NHH-44 (11.22 / plant) which were at par with each other. The genotypes next in the order which recorded higher number

of eggs were MCU–5 (10.66 / plant) and DB-3-12 (10.55 / plant) which were at par with each other. Genotype PA- 255 (5.55 / plant) recorded significantly lower number of *C. carnea* eggs even in the presence of *H. armigera* eggs followed by Abadhita (6.66 / plant) (Table 9).

Table 9: Ovipositional preference of *Chrysoperla carnea* on cotton genotypes across the different stages with *H. armigera* eggs

Comparative ovipositional preference by *H. armigera* across the three different stages of crop growth revealed that significantly higher mean number of egg load was recorded on Sahana (31.10 / plant). This was followed by NHH-44 (27.77 / plant), AK-235 (27.33 / plant) LRA-5166 (27.33 / plant) and DHH-11 (26.33 / plant) and were at par with each other. Significantly least oviposition by *H. armigera* was recorded on DB-3-12 (16.33 / plant), followed by Abadhita (18.11 / plant) (Table 10).

Table 10: Ovipositional preference of *H. armigera* on cotton genotypes across the different stages of the crop growth

The trichome density across all the stages of the crop growth was significantly higher on NHH-44 (35.33 / 0.25 cm^2) and AK-235 (34.66 / 0.25 cm^2) both being statistically at par with each other. These were followed by DHH-543 (30.55 / 0.25 cm^2). Least trichome density was recorded on PA-255 (14.99 / 0.25 cm^2) followed by DLSA-17 (16.44 / 0.25cm^2) (Table 10).

4.1.4 Ovipositional preference of *C. carnea* and *H. armigera* on sunflower genotypes at vegetative stage of the crop growth

It is evident from the data presented in table 11 that, in the absence of *H. armigera* eggs, *C. carnea* laid significantly higher number of eggs on Morden (8.33 / plant), KBSH-1 (8.00 / plant), MSFH-17 (7.99 / plant), DSH-1 (6.66 / plant), PCSH-243 (6.33 / plant) and RSFH-1 (6.00 / plant) which were statistically on par with each other. The least oviposition by *C. carnea* in absence of *H. armigera* eggs was on DSF-2 (2.99 / plant), VRF-21 (3.33 / plant), SFL-107 (4.33 / plant) and Jwalamukhi (5.00 / plant) which were statistically on par with each other (Table 11). Whereas in presence of *H. armigera* eggs, *C. carnea* egg laying pattern was similar to that observed in the absence of *H. armigera* eggs but, comparatively more number of eggs were laid. Significantly higher number of eggs laid by *C. carnea* were on KBSH-1 (11.00 / plant), Morden (10.00 / plant), RSFH-1 (9.00 / plant) and SFL-107 (8.33 / plant) which were statistically on par with each other. These were followed by MSFH-17 (8.00/ plant), PCSH-243 (7.99/ plant) DSH-1 (7.99 / plant) and Jwalamukhi (5.99 / plant) which were statistically on par with each other. The genotypes which received least number of *C. carnea* eggs in presence of *H. armigera* eggs were VRF-21 (4.00/ plant) and DSF-2 (4.33 / plant). In general, irrespective of the genotypes, *C. carnea* laid more number of eggs per plant in presence of *H. armigera* eggs.

Table 11: Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at vegetative stage

At vegetative stage of the various sunflower genotypes, *H. armigera* laid significantly higher number of eggs on DSF-2 (31.00 / plant), SFL-107 (28.99 / plant), PCSH-243 (28.00 / plant), MSFH-17 (21.99 / plant), RSFH-1 (21.99 / plant), DSH-1 (20.66 / plant), Jwalamukhi (20.33 / plant) and Morden (19.00/ plant) which were statistically on par with each other. The genotype which received lower number of *H. armigera* eggs among the genotypes tested under tritrophic interaction studies was VRF-21 (13.66 / plant) (Table 11).

Trichome density was significantly highest in SFL 107 (23.66 / 0.25 cm^2), PCSH-243 (20.33 / 0.25 cm^2) and DSF-2 (19.33 / 0.25 cm^2) at vegetative stage. The genotypes next in the order which recorded significantly highest trichome density were MSFH-17 (18.33 / 0.25 cm^2) and RSFH-1 (17.33 / 0.25 cm^2). Significantly least trichome density was recorded on Morden (12.00 / 0.25 cm^2). This was followed by Jwalamukhi (15.66 / 0.25 cm2), VRF-21 (16.00 / 0.25 cm^2), KBSH-1 (16.00 / 0.25cm^2) and DSH-1 (16.66 / 0.25 cm2) all being on par with each other (Table 11).

Table 9. Ovipositional preference of *Chrysoperla carnea* on cotton genotypes across the different stages with *H. armigera* eggs

Sl. No.	Genotypes	No. of eggs laid by *C. carnea* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Flowering	Boll formation	Mean	
1	LRA – 5166	9.66 (3.11)^{b}	13.33 (3.65)^{ab}	13.33 (3.63)^{ab}	12.10 (3.47)^{b}	26.33^{c}
2	DB – 3 – 12	9.66 (3.11)^{b}	10.33 (3.21)^{b}	11.66 (3.41)^{b}	10.55 (3.24)^{cd}	22.55^{d}
3	Jayadhar	9.99 (3.16)^{b}	13.99 (3.72)^{a}	12.33 (3.50)^{b}	12.10 (3.47)^{b}	18.21^{e}
4	DHH – 543	12.66 (3.54)^{a}	15.99 (3.92)^{a}	15.66 (3.96)^{a}	14.77 (3.84)^{a}	30.55^{b}
5	DHH – 11	9.99 (3.16)^{b}	12.66 (3.56)^{ab}	14.33 (3.76)^{a}	12.32 (3.51)^{b}	21.77^{d}
6	Abadhita	6.33 (2.50)^{cd}	6.66 (2.55)^{c}	7.00 (2.64)^{c}	6.66 (2.57)^{e}	17.77^{e}
7	Sahana	9.66 (3.11)^{b}	13.66 (3.69)^{ab}	13.66 (3.69)^{ab}	12.32 (3.50)^{b}	21.88^{d}
8	MCU – 5	8.00 (2.83)^{bc}	11.33 (3.36)^{b}	12.66 (3.56)^{ab}	10.66 (3.26)^{cd}	27.21^{c}
9	NHH – 44	9.33 (3.05)^{b}	12.33 (3.51)^{ab}	12.00 (3.47)^{b}	11.22 (3.34)^{bc}	35.33^{a}
10	AK – 235	6.66 (2.58)^{cd}	11.33 (3.36)^{b}	10.99 (3.32)^{b}	9.66 (3.10)^{d}	34.66^{a}
11	DLSA – 17	9.99 (3.16)^{b}	13.00 (3.61)^{ab}	11.66 (3.41)^{b}	11.55 (3.39)^{bc}	16.44^{f}
12	PA – 255	5.33 (2.31)^{d}	6.33 (2.52)^{c}	5.00 (2.24)^{c}	5.55 (2.35)^{f}	14.99^{g}
	Mean	8.99 (2.97)	11.74 (3.41)	11.69 (3.38)		
	S.Em±	0.12	0.14	0.14	0.060	0.449
	C.D. @ 5%	0.39	0.48	0.40	0.177	1.318
	CV (%)	7.10	8.29	6.90	6.20	5.68

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

Table 10. Ovipositional preference of *H. armigera* on cotton genotypes across the different stages of the crop growth

Sl. No.	Genotypes	No. of eggs laid by *H. armigera* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Flowering	Boll formation	Mean	
1	LRA – 5166	26.33 (5.14)^{ab}	28.33 (5.32)^{abc}	27.33 (5.22)^{cd}	27.33 (5.22)^{b}	26.33^{c}
2	DB – 3 – 12	13.99 (3.73)^{d}	18.00 (4.25)^{d}	16.99 (4.12)^{g}	16.33 (4.03)^{h}	22.55^{d}
3	Jayadhar	16.66 (4.08)^{bcd}	22.99 (4.79)^{cd}	17.99 (4.24)^{g}	19.21 (4.38)^{fg}	18.21^{e}
4	DHH – 543	21.00 (4.59)^{abcd}	26.00 (5.10)^{bcd}	24.00 (4.90)^{de}	23.66 (4.86)^{d}	30.55^{b}
5	DHH – 11	24.33 (4.94)^{abc}	28.33 (5.34)^{a}	26.33 (5.13)^{b}	26.33 (5.13)^{bc}	21.77^{d}
6	Abadhita	15.00 (3.88)^{cd}	20.33 (4.51)^{d}	19.00 (4.35)^{g}	18.11 (4.25)^{g}	17.77^{e}
7	Sahana	30.33 (5.48)^{a}	33.99 (5.83)^{a}	28.99 (5.38)^{bc}	31.10 (5.57)^{a}	21.88^{d}
8	MCU – 5	21.66 (4.65)^{abcd}	28.33 (5.32)^{abc}	25.99 (5.09)^{de}	25.33 (5.03)^{cd}	27.21^{c}
9	NHH – 44	24.00 (4.90)^{abc}	30.66 (5.54)^{ab}	28.66 (5.35)^{bcd}	27.77 (5.26)^{b}	35.33^{a}
10	AK – 235	26.33 (5.14)^{ab}	28.33 (5.32)^{abc}	27.33 (5.22)^{ab}	27.33 (5.23)^{b}	34.66^{a}
11	DLSA – 17	16.60 (4.09)^{bcd}	22.33 (4.76)^{cd}	23.33 (4.83)^{ef}	20.88 (4.56)^{e}	16.44^{f}
12	PA – 255	15.66 (3.96)cd	21.66 (4.65)^{cd}	23.02 (4.80)^{f}	20.11 (4.48)^{ef}	14.99^{g}
	Mean	21.46 (4.62)	26.13 (5.09)	24.94 (5.)		
	S.Em±	0.36	0.23	0.09	0.051	0.449
	C.D. @ 5%	1.10	0.68	0.27	0.151	1.318
	CV (%)	14.80	14.82	9.66	4.80	5.68

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

Table 11. Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at vegetative stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	DSH – 1	6.66 (2.58)^{ab}	7.99 (2.83)^{bc}	20.66 (4.54)^{ab}	16.66^{ef}
2	KBSH – 1	8.00 (2.83)^{a}	11.00 (3.31)^{a}	18.66 (4.31)^{b}	16.00^{ef}
3	PCSH – 243	6.33 (2.52)^{abc}	7.99 (2.81)^{bc}	28.00 (5.29)^{a}	20.33^{b}
4	MSFH – 17	7.99 (2.83)^{a}	8.00 (2.83)^{bc}	21.99 (4.69)^{ab}	18.33^{cd}
5	Morden	8.33 (2.89)^{a}	10.00 (3.14)^{ab}	19.00 (4.36)^{ab}	12.00^{g}
6	RSFH – 1	6.00 (2.44)^{abc}	9.00 (3.00)^{ab}	21.99 (4.68)^{ab}	17.33^{de}
7	SFL – 107	4.33 (2.03)^{bcd}	8.33 (2.89)^{ab}	28.99 (5.37)^{a}	23.66^{a}
8	Jwalamukhi	5.00 (2.24)^{bcd}	5.99 (2.45)^{cd}	20.33 (4.51)^{ab}	15.66^{f}
9	DSF – 2	2.99 (1.73)^{d}	4.33 (2.08)^{de}	31.00 (5.57)^{a}	19.33^{bc}
10	VRF - 21	3.33 (1.77)^{cd}	4.00 (1.99)^{e}	13.66 (3.69)^{c}	16.00^{ef}
Mean		5.89 (2.39)	7.66 (2.73)	22.43 (4.70)	
S.Em±		0.16	0.14	0.14	0.473
C.D. @ 5%		0.49	0.42	0.41	1.406
CV (%)		11.91	8.96	5.08	5.10

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

4.1.5 Ovipositional preference of *C. carnea* and *H. armigera* on sunflower genotypes at capitulam formation stage

It is clear from the table 12 that, in absence of *H. armigera* eggs, *C.carnea* laid significantly highest number of eggs on KBSH-1 (10.66/ plant), Morden (10.00 / plant), MSFH-17 (10.00 / plant), PCSH-243 (8.33/ plant), DSH-1 (8.33 / plant) and RSFH-1 (8.33 / plant) which were statistically at par with each other. Significantly least number of the predatory

Table 12. Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at capitulam formation stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	DSH – 1	8.33 (2.88)^{ab}	9.99 (3.15)^{bc}	27.66 (5.26)^{cd}	18.66^{cd}
2	KBSH – 1	10.66 (3.24)^{a}	14.00 (3.74)^{a}	23.33 (4.82)^{de}	18.99^{bcd}
3	PCSH – 243	8.33 (2.88)^{ab}	10.00 (3.15)^{bc}	33.33 (5.76)^{b}	26.33^{a}
4	MSFH – 17	10.00 (3.15)^{a}	11.99 (3.46)^{ab}	30.99 (5.57)^{b}	20.00^{bc}
5	Morden	10.00 (3.16)^{a}	13.00 (3.61)^{ab}	22.33 (4.73)^{e}	12.99^{d}
6	RSFH – 1	8.33 (2.87)^{ab}	11.66 (3.41)^{ab}	24.66 (4.95)^{cde}	19.00^{bcd}
7	SFL – 107	6.00 (2.45)^{cd}	11.33 (3.37)^{ab}	40.33 (6.45)^{a}	25.33^{a}
8	Jwalamukhi	7.00 (2.65)^{bc}	7.99 (2.83)^{cde}	29.66 (5.44)^{b}	17.33^{c}
9	DSF – 2	4.99 (2.23)^{d}	6.33 (2.52)^{de}	33.66 (5.79)^{b}	20.66^{b}
10	VRF - 21	5.33 (2.31)^{cd}	6.00 (2.45)^{e}	16.33 (4.04)^{f}	18.99^{bcd}
Mean		7.90 (2.78)	10.23 (3.17)	28.73 (5.34)	
S.Em±		0.13	0.13	0.16	0.574
C.D. @ 5%		0.38	0.38	0.47	1.708
CV (%)		8.00	6.98	5.15	5.02

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

eggs were laid on DSF-2 (4.99 / plant), VRF-21 (5.33 / plant) and SFL-103 (6.00 / plant) which were statistically on par with each other. Whereas in presence of *H. armigera* eggs, significantly higher number of eggs were laid by *C.carnea* on KBSH-1 (14.00 / plant), Morden (13.00 / plant), MSFH-17 (11.99 / plant), RSFH-1 (11.66 / plant) and SFL-107 (11.33 / plant) which were statistically on par with each other. Least number of *C. carnea* eggs was observed on VRF-21 (6.00/ plant), DSF-2 (6.33 / plant) and Jwalamukhi (7.99 / plant) which were statistically at par with each other.

At capitulam formation stage *H. armigera* laid significantly higher number of eggs on SFL-107 (40.33 / plant). This was followed by DSF-2 (33.66 / plant), PCSH-243 (33.33/ plant), MSFH-17 (30.99 / plant) and Jwalamukhi (29.66 / plant) which were statistically on par with each other. The genotypes which received significantly lower number of *H. armigera* eggs were VRF-21 (16.33 / plant).This was followed by Morden (22.33 / plant), KBSH-1 (23.33 / plant) and RSFH-1 (24.66 / plant) all being statistically at par with each other (Table 12).

Table 12: Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at capitulam formation stage

Significantly higher number of trichome density was recorded on PCSH-243 (26.33 / 0.25 cm^2), SFL 107 (25.33 / 0.25 cm^2) both being statistically at par with each other at capitulam formation stage of the crop growth. This was followed by DSF-2 (20.66 / 0.25 cm^2), MSFH-17 (20.00 / 0.25 cm^2), RSFH –1 (19.00 / 0.25 cm^2), VRF-21 (18.99 / 0.25 cm^2) and KBSH-1 (18.99 / 0.25 cm^2). Least trichome density was recorded on Morden (12.99 / 0.25 cm^2) (Table 12).

4.1.6 Ovipositional preference of *C. carnea* and *H. armigera on* sunflower genotypes at flowering stage

In absence of *H. armigera* eggs, number of eggs laid by *C. carnea* at flowering stage of sunflower genotypes is presented in table 13. It is clear that significantly higher number of eggs were laid by *C. carnea* on KBSH-1 (15.66 / plant) and Morden (14.99 / plant) compared to rest of the genotypes. This was followed by MSFH-17 (12.00/ plant) RSFH-1 (11.33 / plant), PCSH- 243 (11.00 / plant) and DSH-1(10.33 / plant) all being at par with each other. Significantly least number of eggs was laid by *C. carnea* on DSF-2 (6.00/ plant). This was followed by VRF-21 (6.33 / plant) and SFL-107 (7.00/ plant) which were statistically on par with each other.

While in the presence of *H. armigera* eggs, *C .carnea* laid comparatively higher number of eggs than in their absence. Among the genotypes studied under tritrophic interaction in presence of *H. armigera* eggs, *C. carnea* laid significantly highest number of eggs on Morden (16.99 / plant), KBSH-1 (16.66 / plant) and RSFH-1 (15.66 / plant). The next best genotypes which received more number of *C. carnea* eggs were PCSH-243 (14.00 / plant), MSFH-17 (13.33 / plant), DSH-1 (13.00 / plant), Jwalamukhi (12.99 / plant) and SFL-107 (11.99 / plant). On the other hand it laid significantly lower number of eggs on VRF–21 (7.66 / plant) and DSF-2 (9.33 / plant) (Table 13).

Table 13: Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at flowering stage

Helicoverpa armigera showed significant difference in the egg laying pattern between the genotypes under tritrophic interaction studies. It laid significantly more number of eggs on SFL-107 (48.66 / plant) (Table 13).This was followed by PCSH-243 (38.66 / plant), DSF-2 (36.99 / plant) and MSFH-17 (35.99/ plant). Significantly least oviposition by *H. armigera* was recorded on VRF-21 (18.00 / plant).

At flowering stage of the crop growth, significantly highest trichome number was recorded on PCSH-243 (27.33 / 0.25 cm^2) followed by SFL-107 (25.00 / 0.25 cm^2). The next genotypes which recorded significantly higher trichome density were on DSF-2 (22.00 / 0.25 cm^2) and MSFH-17 (22.00 / 0.25 cm^2) both being statistically at par with each other. Least trichome density was recorded on Morden (11.33 / 0.25cm^2) followed by Jwalamukhi (16.66 / 0.25 cm^2) and DSH–1 (18.00 / 0.25 cm^2) both being statistically on par with each other.

4.1.7 Comparative ovipositional preference of *C. carnea* and *H. armigera* on sunflower genotypes

It is evident from the data presented in table 14 that, across the crop stages in absence of *H. armigera* eggs, significantly higher number of eggs were laid by *C.carnea* on KBSH-1 (11.44 / plant) and Morden (11.10 / plant) which were statistically on par with each other. The next best genotypes which received more number of *C.carnea* eggs were MSFH-17 (10.00 / plant), followed by PCSH-243 (8.55 / plant), RSFH-1 (8.55 / plant) and DSH-1 (8.44 / plant) which were statistically on par with each other. Significantly lower number of

Table 13. Ovipositional preference of *Chrysoperla carnea* and *Helicoverpa armigera* on sunflower genotypes at flowering stage

Sl. No.	Genotypes	No. of eggs laid / plant by			Trichome density/ 0.25 cm^2
		C. carnea		*H. armigera*	
		Without *H. armigera* eggs	With *H. armigera* eggs		
1	DSH – 1	10.33 (3.22)^{cd}	13.00 (3.60)^{cd}	32.66 (5.71)^{c}	18.00^{ef}
2	KBSH – 1	15.66 (3.94)^{a}	16.66 (4.07)^{ab}	28.00 (5.29)^{de}	19.66^{d}
3	PCSH – 243	11.00 (3.29)^{cd}	14.00 (3.73)^{bcd}	38.66 (6.21)^{b}	27.33^{a}
4	MSFH – 17	12.00 (3.46)^{bc}	13.33 (3.65)^{cd}	35.99 (5.99)^{bc}	22.00^{c}
5	Morden	14.99 (3.87)^{ab}	16.99 (4.12)^{a}	24.66 (4.96)^{e}	11.33^{g}
6	RSFH – 1	11.33 (3.37)^{cd}	15.66 (3.96)^{abc}	26.99 (5.20)^{e}	18.33^{de}
7	SFL – 107	7.00 (2.65)^{ef}	11.99 (3.46)^{d}	48.66 (6.97)^{a}	25.00^{b}
8	Jwalamukhi	8.66 (2.94)^{de}	12.99 (3.60)^{cd}	31.99 (5.65)^{cd}	16.66^{f}
9	DSF – 2	6.00 (2.45)^{g}	9.33 (3.05)^{e}	36.99 (6.08)^{b}	22.00^{c}
10	VRF - 21	6.33 (2.52)^{ef}	7.66 (2.77)^{e}	18.00 (4.24)^{f}	18.66^{de}
Mean		10.33 (3.17)	13.16 (3.60)	33.50 (5.76)	
S.Em±		0.14	0.13	0.12	0.513
C.D. @ 5%		0.46	0.37	0.36	1.524
CV (%)		7.78	5.97	5.10	4.58

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

eggs were noticed on DSF–2 (4.66 / plant) and VR –21 (4. 99 / plant) and were at par with each other followed by SFL-107 (5. 78 / plant) (Table 14).

The number of eggs laid by *C.carnea* across the crop stages in the presence of *H. armigera* eggs was significantly higher on KBSH-1 (13.88 / plant) and Morden (13.33 / plant) and were at par with each other. These were followed by RSFH -1 (11.88 / plant), MSFH-17 (11.10 / plant), SFL-107, PCSH-243 (10.66 / plant), (10.77 / plant) and DSH-1 (10.33 / plant). On the other hand it laid significantly least number of eggs on VRF 21 (5.88 / plant) and DSF-2 (6.66 / plant) followed by Jwalamukhi (8.99 / plant) (Table 15).

Table 14. Ovipositional preference of *C. carnea* across the crop stages on sunflower genotypes without *H. armigera*

Sl. No.	Genotypes	No. of eggs laid by *C. carnea* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Capitulam formation	Flowering	Mean	
1	DSH – 1	6.66 (2.58)^{ab}	8.33 (2.88)^{ab}	10.33 (3.22)^{cd}	8.44 (2.98)^{c}	17.77^{c}
2	KBSH – 1	8.00 (2.83)^{a}	10.66 (3.24)^{a}	15.66 (3.94)^{a}	11.44 (3.38)^{a}	18.21^{c}
3	PCSH – 243	6.33 (2.52)^{abc}	8.33 (2.88)^{ab}	11.00 (3.29)^{cd}	8.55 (2.92)^{c}	24.66^{a}
4	MSFH – 17	7.99 (2.83)^{a}	10.00 (3.15)^{a}	12.00 (3.46)^{bc}	10.00 (3.16)^{b}	20.11^{b}
5	Morden	8.33 (2.89)^{a}	10.00 (3.16)^{a}	14.99 (3.87)^{ab}	11.10 (3.33)^{ab}	12.10^{d}
6	RSFH – 1	6.00 (2.44)^{abc}	8.33 (2.87)^{ab}	11.33 (3.37)^{cd}	8.55 (2.91)^{c}	18.22^{c}
7	SFL – 107	4.33 (2.03)^{bcd}	6.00 (2.45)^{cd}	7.00 (2.65)^{ef}	5.78 (2.40)^{e}	24.66^{a}
8	Jwalamukhi	5.00 (2.24)^{bcd}	7.00 (2.65)^{bc}	8.66 (2.94)^{de}	6.88 (2.60)^{d}	16.55^{c}
9	DSF – 2	2.99 (1.73)^{d}	4.99 (2.23)^{d}	6.00 (2.45)^{g}	4.66 (2.15)^{f}	20.66^{b}
10	VRF - 21	3.33 (1.77)^{cd}	5.33 (2.31)^{cd}	6.33 (2.52)^{ef}	4.99 (2.23)^{ef}	17.88^{c}
	Mean	5.89 (2.39)	7.90 (2.78)	10.33 (3.17)		
	S.Em±	0.16	0.13	0.14	0.068	0.608
	C.D. @ 5%	0.49	0.38	0.43	0.203	1.807
	CV (%)	11.91	8.00	7.78	8.94	5.52

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

The comparative ovipositional preference of *H. armigera* across the three different stages of crop growth indicated that significantly higher number of eggs were laid on SFL-107 (39.32 / plant). This was followed by DSF-2 (33. 88 / plant) and PCSH-243 (33.33 / plant) being statistically at par with each other. The next genotype which recorded higher number of eggs was on MSFH-17 (29.65 / plant). This was followed by Jwalamukhi and DSH-1 (27.32 and 26.99 / plant, respectively) being on par with each other. Significantly least number of eggs were laid by *H.armigera* on VRF-21 (15.99 / plant) followed by Morden and KBSH-1 (21.99 and 23.33 / plant, respectively) (Table 16).

Table 15. Ovipositional preference of *C. carnea* across the stages on sunflower genotypes with *H. armigera*

Sl. No.	Genotypes	No. of eggs laid by *C. carnea* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Capitulam formation	Flowering	Mean	
1	DSH – 1	7.99 (2.83)^{bc}	9.99 (3.15)^{bc}	13.00 (3.60)^{cd}	10.33 (3.21)^{c}	17.77^{c}
2	KBSH – 1	11.00 (3.31)^{a}	14.00 (3.74)^{a}	16.66 (4.07)^{ab}	13.88 (3.72)^{a}	18.21^{c}
3	PCSH – 243	7.99 (2.81)^{bc}	10.00 (3.14)^{bc}	14.00 (3.73)^{bcd}	10.66 (3.26)^{c}	24.66^{a}
4	MSFH – 17	8.00 (2.83)^{bc}	11.99 (3.46)^{ab}	13.33 (3.65)^{cd}	11.10 (3.33)^{c}	20.11^{b}
5	Morden	10.00 (3.14)^{ab}	13.00 (3.61)^{ab}	16.99 (4.12)^{a}	13.33 (3.65)^{ab}	12.10^{d}
6	RSFH – 1	8.33 (2.89)^{ab}	11.66 (3.41)^{ab}	15.66 (3.96)^{abc}	11.88 (3.44)^{bc}	18.22^{c}
7	SFL – 107	9.00 (3.00)^{ab}	11.33 (3.37)^{ab}	11.99 (3.46)^{d}	10.77 (3.27)^{c}	24.66^{a}
8	Jwalamukhi	5.99 (2.45)^{cd}	7.99 (2.83)^{cde}	12.99 (3.6)^{cd}	8.99 (2.99)^{d}	16.55^{c}
9	DSF – 2	4.33 (2.08)^{de}	6.33 (2.52)^{de}	9.33 (3.05)^{e}	6.66 (2.58)^{e}	20.66^{b}
10	VRF - 21	4.00 (1.99)^{e}	6.00 (2.45)^{e}	7.66 (2.77)^{e}	5.88 (2.42)^{e}	17.88^{c}
	Mean	7.66 (2.73)	10.23 (3.17)	13.16 (3.60)		
	S.Em±	0.14	0.13	0.13	0.073	0.608
	C.D. @ 5%	0.42	0.38	0.37	0.220	1.807
	CV (%)	8.96	6.98	5.97	8.01	5.52

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

The trichome density across the stages of the crop growth was significantly higher on PCSH-243 (24.66 / 0.25 cm^2) and SFL-107 (24.66 / 0.25 cm^2) both being statistically at par with each other. These were followed by DSF-2 (20.66 / 0.25 cm^2) and MSFH-17 (20.11 / 0.25 cm^2) and they were at par with each other. Significantly least trichome density was recorded on Morden (12.10 / 0.25 cm^2) followed by RSFH-1 (18.22 / 0.25 cm^2), KBSH -1 (18.21 / 0.25 cm^2), VRF-21 (17.88 / 0.25 cm^2), DSH-1 (17.77 / 0.25 cm^2) and Jwalamukhi (16.55 / 0.25 cm^2) all being statistically at par with each other (Table 16).

Table 16: Ovipositional preference of *H. armigera* across the stages on sunflower genotypes

4.2 Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different genotypes of cotton

The results on orientation of *C. carnea* adults to extracts of different genotypes of cotton leaf, flower and boll under wind tunnel olfactometer are presented below.

4.2.1 Behavioural response of *C. carnea* to cotton leaf extract

The orientation of *C. carnea* towards the extract of different genotypes of cotton leaf was studied under laboratory condition using eight arm olfactometer. The results showed that significantly highest number of *C. carnea* adults reached the arm containing honey solution. Among the genotypes, significantly highest number of *C. carnea* adults oriented towards the extract of DHH 543 (3.33 / arm), followed by DHH-11 (2.66/arm) and DLSA-17 (2.66 / arm). The next highest number of *C. carnea* adults oriented towards the kairomone source were AK-235 (2.33/ arm) and LRA-5166 (2.33/ arm) which were statistically on par with each other. Abhadita, MCU-5 and PA-255 received moderate number of adult *C. carnea* (2.00 / arm). Significantly least number of *C. carnea* adults reached towards the extract of DB-3-12 (1.00/ arm), Jayadhar (1.66/arm) followed by Sahana (1.66 / arm) and NHH-44 (1.66 / arm). However, control arm containing only hexane attracted significantly lowest *C. carnea* adults (0.66/ arm) than extract of cotton genotypes and honey solution (Table 17).

Table 17: Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different genotypes of cotton

4.2.2 Behavioural response of *C. carnea* to flower extract of cotton genotypes

In general, irrespective of the genotypes, the mean number of *C. carnea* adults moved towards the kairomone source of various genotypes of flower extract was higher than the leaf extract. But, the trend is similar to that of leaf extract. Of the total number of *C. carnea* adults released in to the test chamber, significantly higher number moved towards the extract of DHH-543 (3.99 / arm) and honey solution (3.66 / arm) being statistically on par with each other. This was followed by DHH-11, NHH-44 and AK-235 which received 3.00 / arm and were statistically on par with each other. LRA-5166, Jayadhar, MCU-5, DLSA-17 and PA-255 received equal number (2.66 / arm) of *C. carnea* adults being statistically on par with each other. Significantly least number of adult *C. carnea* was observed in the arm of DB-3-12 (1.66 / arm). However, least number (0.33/arm) of *C. carnea* moved towards the control arm (Table 17).

4.2.3 Behavioural response of *C. carnea* towards different genotypes of cotton boll extract

Of the total number of *C. carnea* adults released into the test chamber, significantly highest number of adults moved towards the extract of DHH-543 (3.66 / arm) being statistically on par with honey solution. This was followed by DHH-11 (3.00/arm), Jayadhar (2.66 / arm), NHH-44 (2.66 / arm) and AK–235 (2.66 / arm) being statistically on par with each other. Moderate number of *C. carnea* adults (2.33 / arm) oriented towards the boll extracts of LRA-5166, Sahana, MCU-5, DLSA-17 and PA-255 being statistically on par with each other. DB-3-12 recorded significantly lowest number (1.33 / arm) of *C. carnea* adults in its arm. However, significantly least number of *C. carnea* adults oriented towards control chamber (0.66/arm) of wind tunnel alfactometer (Table 17).

The pooled data analysis of cotton leaf, flower and boll extract once again proved the superiority of DHH-543 (3.66 / arm) and DHH-11 (2.89 / arm) being on par with honey solution (3.77 / arm) as a standard check. While AK-235 (2.66 / arm), DLSA – 17 (2.55 / arm), NHH–44 (2.44 / arm), LRA- 5166 (2.44 / arm), PA-255 (2.33 / arm), Jayadhar (2.33 / arm), Sahana (2.11 / arm) and Abadhita (1.99 / arm) also found higher number of *C. carnea* adults oriented towards these extracts. On the other hand, significantly least number of *C. carnea* adults oriented towards DB-3-12 (1.33 / plant) but was superior to control (Table 17).

4.2.4 Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of sunflower genotypes

Table 16. Comparative ovipositional preference of *H. armigera* across the stages on sunflower genotypes

Sl. No.	Genotypes	No. of eggs laid by *H. armigera* / plant at				Trichome density / 0.25 cm^2
		Vegetative	Capitulam formation	Flowering	Mean	
1	DSH – 1	20.66 (4.54)^{ab}	27.66 (5.26)^{cd}	32.66 (5.71)^{c}	26.99 (5.19)^{d}	17.77^{c}
2	KBSH – 1	18.66 (4.31)^{b}	23.33 (4.82)^{de}	28.00 (5.29)^{de}	23.33 (4.83)^{f}	18.21^{c}
3	PCSH – 243	28.00 (5.29)^{a}	33.33 (5.76)^{b}	38.66 (6.21)^{b}	33.33 (5.77)^{b}	24.66^{a}
4	MSFH – 17	21.99 (4.69)^{ab}	30.99 (5.57)^{b}	35.99 (5.99)^{bc}	29.65 (5.44)^{c}	20.11^{b}
5	Morden	19.00 (4.36)^{ab}	22.33 (4.73)^{e}	24.66 (4.96)^{e}	21.99 (4.68)^{g}	12.10^{d}
6	RSFH – 1	21.99 (4.68)^{ab}	24.66 (4.95)^{cde}	26.99 (5.20)^{e}	24.54 (4.95)^{e}	18.22^{c}
7	SFL – 107	28.99 (5.37)^{a}	40.33 (6.45)^{a}	48.66 (6.97)^{a}	39.32 (6.27)^{a}	24.66^{a}
8	Jwalamukhi	20.33 (4.51)^{ab}	29.66 (5.44)^{b}	31.99 (5.65)^{cd}	27.32 (5.22)^{d}	16.55^{c}
9	DSF – 2	31.00 (5.57)^{a}	33.66 (5.79)^{b}	36.99 (6.08)^{b}	33.88 (5.82)^{b}	20.66^{b}
10	VRF - 21	13.66 (3.69)^{c}	16.33 (4.04)^{f}	18.00 (4.24)^{f}	15.99 (3.99)^{h}	17.88^{c}
	Mean	22.43 (4.70)	28.73 (5.34)	33.50 (5.76)		
	S.Em±	0.14	0.16	0.12	0.031	0.608
	C.D. @ 5%	0.41	0.47	0.36	0.093	1.807
	CV (%)	5.08	5.15	5.10	5.03	5.52

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

4.2.4.1 Orientation response of *C. carnea* towards the leaf extract of sunflower genotypes

The orientation of *C. carnea* towards the extract of different genotypes of sunflower leaf extract using eight arm olfactometer revealed that, significantly highest number of *C. carnea* adults moved towards the arm containing the leaf extract of KBSH-1 (3.66 / arm) and Morden (3.66/arm) both being on par with each other. This was followed by RSFH-1 (3.33/arm). The next highest number of *C. carnea* adults oriented towards the kairomone source were Jwalamukhi (2.66 / arm) and MSFH-17 (2.66/arm). SFL-107 (2.00 / arm), DSF-2 (2.00 / arm) and VRF-21 (1.99/arm) which received significantly lower number of adult *C.*

Table 17. Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different genotypes of cotton

Sl. No.	Genotypes	No. of *C. carnea* adults reached the kairomone source of			
		Leaf	Flower	Boll	Mean
1	LRA – 5166	2.33 (1.53)^{d}	2.66 (1.63)^{c}	2.33 (1.53)^{c}	2.44 (1.56)^{bc}
2	DB – 3 – 12	1.00 (1.02)^{g}	1.66 (1.29)^{e}	1.33 (1.15)^{e}	1.33 (1.14)^{d}
3	Jayadhar	1.66 (1.29)^{f}	2.66 (1.63)^{c}	2.66 (1.63)^{bc}	2.33 (1.52)^{bc}
4	DHH – 543	3.33 (1.83)^{b}	3.99 (1.19)^{a}	3.66 (1.91)^{a}	3.66 (1.91)^{a}
5	DHH – 11	2.66 (1.63)^{c}	3.00 (1.73)^{b}	3.00 (1.73)^{b}	2.89 (1.70)^{ab}
6	Abadhita	2.00 (1.42)^{e}	2.33 (1.53)^{d}	1.66 (1.29)^{d}	1.99 (1.41)^{c}
7	Sahana	1.66 (1.29)^{f}	2.33 (1.53)^{d}	2.33 (1.53)^{c}	2.11 (1.45)^{bc}
8	MCU – 5	2.00 (1.43)^{e}	2.66 (1.63)^{c}	2.33 (1.53)^{c}	2.33 (1.52)^{bc}
9	NHH – 44	1.66 (1.29)^{f}	3.00 (1.73)^{b}	2.66 (1.63)^{bc}	2.44 (1.55)^{bc}
10	AK – 235	2.33 (1.53)^{d}	3.00 (1.73)^{b}	2.66 (1.63)^{bc}	2.66 (1.62)^{bc}
11	DLSA – 17	2.66 (1.63)^{c}	2.66 (1.63)^{c}	2.33 (1.53)^{c}	2.55 (1.59)^{bc}
12	PA – 255	2.00 (1.42)^{e}	2.66 (1.63)^{c}	2.33 (1.53)^{c}	2.33 (1.52)^{bc}
13	Honey	3.99 (1.99)^{a}	3.66 (1.91)^{a}	3.66 (1.91)^{a}	3.77 (1.94)^{a}
14	Control	0.66 (0.81)^{h}	0.33 (0.57)^{f}	0.66 (0.81)^{f}	0.55 (0.74)^{e}
	Mean	2.14 (1.43)	2.61 (2.22)	2.40 (1.52)	
	S.Em±	0.02	0.03	0.04	0.060
	C.D. @ 5%	0.05	0.09	0.10	0.238
	CV (%)	2.20	3.33	3.86	13.13

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

carnea were found statistically on par with each other. However, control arm (without any kairomone source) received significantly lower *C. carnea* adults (0.33/arm) (Table 18).

Table 18: Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different genotypes of sunflower

4.2.4.2 Orientation behaviour of *C. carnea* towards capitulam extract of different genotypes of sunflower

When compared to leaf extract, the number of *C. carnea* adults towards the kairomone source of various genotypes of capitulam extract was higher than the leaf extract. Of the total number of *C. carnea* adults released under free choice test into the test chamber, the greatest number moved towards the extract of honey solution (5.00 / arm). This was followed by KBSH-1 (4.00 / arm), Morden (3.99/arm) and RSFH-1(3.99/arm) which were statistically on par with each other.

The capitulam extract of MSFH-17 (2.99/arm) and Jwalamukhi (2.66/arm) received more number of *C. carnea* adults than DSH-1, PCSH-234, SFL-107 and DSF-2 (2.33 / arm). Significantly least number of *C. carnea* adults moved towards the capitulam extract of VRF-21 (2.00 / arm), DSF-2 (2.33 / arm), SFL-107 (2.33 / arm), PCSH-243 (2.33 / arm) and DSH-1 (2.33 / arm), which were on par with each other but significantly higher than control (0.33 / arm) (Table 18).

4.2.4.3 Orientation behaviour of *C. carnea* adults towards the flower extract of different genotypes of sunflower

Significantly highest number of *C. carnea* adults oriented towards the honey solution (5.00 / arm) which was on par with flower extract of KBSH-1 (4.99/arm), Morden and RSFH-1 (4.66/arm). The next best flower extract of sunflower genotypes which received significantly higher number of *C. carnea* adults were PCSH-243 (3.00/arm), Jwalamukhi (2.99/arm), DSF-2, DSH-1 and VRF-21 (2.66/arm) and were statistically on par with each other. However, significantly least number of *C. carnea* adults (0.33 / arm) oriented towards the control chamber of wind tunnel olfameter (Table 18).

The pooled data analysis of leaf, capitulam and flower extract of sunflower once again signified the superiority of KBSH–1 (4.22 / arm), Morden (4.10 / arm) and RSFH-1 (3.99 / arm) in recording higher number of *C. carnea* adults oriented towards these extracts and all these three treatments were on par with each other but inferior to honey solution (5.22 / arm) as standard check. Least number of *C. carnea* adults oriented towards the extract of DSH–1 (2.44 / arm) PCSH-243 (2.55 / arm), SFL-107 (2.66 / arm), Jwalamukhi (2.77 / arm), DSF-2 (2.33 / arm) and VRF-21 (2.22 / arm) but significantly higher than the control chamber (0.33 / arm)
(Table 18).

4.2.5 Kairomone source of *C. carnea* adult

A detailed observation was made on the source of kairomone for *C. carnea* adults. Different concentrations of *H. armigera* scale extract were tried in wind tunnel olfactometer under laboratory condition. The response in terms of *C. carnea* adults reached the Kairomone source in wind tunnel olfactometer was increased from 1.62 ± 0.16 to 4.52 ± 0.32 as concentration of extract increased from 0.1 to 0.6 per cent, respectively. Further increase in concentration of scale extract did not result into increased response from *C. carnea* adults. Least number of *C. carnea* adults oriented towards only hexane swab and water swab (Table 19).

Table 18. Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different genotypes of sunflower

Sl. No.	Genotypes	No. of *C. carnea* adults reached the kairomone source of			
		Leaf	Capitulam	Flower	Mean
1	DSH – 1	2.33 (1.53)^{e}	2.33 (1.53)^{de}	2.66 (1.63)^{c}	2.44 (1.56)^{e}
2	KBSH – 1	3.66 (1.92)^{b}	4.00 (2.00)^{b}	4.99 (2.23)^{a}	4.22 (2.05)^{b}
3	PCSH – 243	2.33 (1.53)^{e}	2.33 (1.53)^{de}	3.00 (1.73)^{c}	2.55 (1.59)^{de}
4	MSFH – 17	2.66 (1.63)^{d}	2.99 (1.73)^{c}	3.99 (1.99)^{b}	3.21 (1.79)^{cd}
5	Morden	3.66 (1.92)^{b}	3.99 (1.99)^{b}	4.66 (2.16)^{a}	4.10 (2.02)^{b}
6	RSFH – 1	3.33 (1.83)^{c}	3.99 (1.99)^{b}	4.66 (2.15)^{a}	3.99 (1.99)^{bc}
7	SFL – 107	2.00 (1.43)^{f}	2.33 (1.53)^{de}	3.66 (1.91)^{b}	2.66 (1.63)^{de}
8	Jwalamukhi	2.66 (1.63)^{d}	2.66 (1.63)^{cd}	2.99 (1.73)^{c}	2.77 (1.66)^{de}
9	DSF – 2	2.00 (1.42)^{f}	2.33 (1.53)^{de}	2.66 (1.63)^{c}	2.33 (1.52)^{e}
10	VRF - 21	1.99 (1.41)^{f}	2.00 (1.41)^{e}	2.66 (1.63)^{c}	2.22 (1.48)^{e}
11	Honey	5.66 (2.40)^{a}	5.00 (2.24)^{a}	5.00 (2.24)^{a}	5.22 (2.28)^{a}
12	Control	0.33 (0.57)^{g}	0.33 (0.57)^{f}	0.33 (0.57)^{d}	0.33 (0.57)^{f}
	Mean	2.70 (1.60)	2.86 (1.64)	3.44 (1.80)	
	S.Em±	0.03	0.04	0.05	0.051
	C.D. @ 5%	0.08	0.13	0.15	0.206
	CV (%)	3.11	8.20	4.91	5.28

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

Table 19. Response of *C. carnea* adult to Kairomone of *H. armigera* scale extract

Sl. No.	***H. armigera* scale extract**	No. of adults reached the Kairomone source
1.	0.1 Per cent	1.62 ± 0.16
2	0.2 per cent	2.18 ± 0.19
3	0.3 per cent	3.10 ± 0.20
4	0.4 per cent	3.84 ± 0.20
5	0.5 per cent	4.52 ± 0.32
6	0.6 per cent	4.00 ± 0.30
7	Only hexane	0.68 ± 0.08
8	Swab with water	0.94 ± 0.10

Table 20. Response of *C. carnea* adults to Kairomone of *H. armigera* egg extract

Sl. No.	*H. armigera* egg extract (No. of eggs / 10 ml of hexane)	No. of adults reached the Kairomone source
1.	20	1.08 ± 0.12
2	40	1.64 ±0.14
3	60	2.60 ± 0.19
4	80	2.80 ± 0.20
5	100	3.10 ± 0.24
6	120	3.00 ± 0.24
7	Only hexane	0.60 ± 0.09
8	Swab with water	0.96 ± 0.11

Further, in the second set of experiment, different concentrations of *H. armigera* egg extract was tried. The response in terms of number of *C. carnea* adults oriented towards the different concentrations of kairomone source was studied under wind tunnel olfactometer. The response in terms of number of *C. carnea* adults reached the kairomone source increased from 1.08 ± 0.12 to 3.10 ± 0.24 as the concentration of extract increased from 20 eggs / 10 ml of hexane to 100 eggs / 10 ml of hexane, respectively. Further, increase in concentration of egg extract did not result in increase response of *C. carnea* adults. Least number of *C. carnea* adults oriented towards only hexane swab (0.60 + 0.09) and water swab (0.90 + 0.11) (Table 20).

Table 20: Response of *C. carnea* adults to Kairomone of *H. armigera* egg extract

4.3 Feeding potential of chrysopids on *H. armigera* eggs on different genotypes of cotton and sunflower

4.3.1 Feeding potential of chrysopids on *H. armigera* eggs on different genotypes of cotton

The feeding potential of three species of chrysopids *viz*., *Chrysoperla carnea, Mallada astur* (Bank) and *Mallada boninesnsis* (Okamoto) on *H. armigera* eggs was tried on different genotypes of cotton under net house condition. The results obtained are described here under.

4.3.1.1 Feeding potential of *C. carnea* on *H. armigera* eggs on genotypes of cotton

It is evident from the data presented in table 21 that, significantly higher number of *H. armigera* eggs were consumed by grubs of *C. carnea* on DLSA-17 and DHH-543 (13.33 / grub), Abadhita (13.00 / grub), DHH-11, MCU-5 and PA-255 (12.33 / grub) and they were statistically on par with each other. The next genotypes on which the *C. carnea* consumed more number of eggs of *H. armigera* were Jayadhar (11.66 / grub), NHH-44 (10.99/grub) and LRA-5166 (10.66/grub) and they were statistically on par with each other. However, the genotypes on which *C. carnea* consumed significantly lower number of *H. armigera* eggs were AK-235 (8.66 / grub), Sahana (8.00/grub), DB-3-12 (7.99/grub) and they were statistically on par with each other.

Table 21: Feeding potential of three species of Chrysopids on *H. armigera* eggs on different genotypes of cotton

4.3.1.2 Feeding potential of *Mallada astur* on *H. armigera* eggs on genotypes of cotton

The results indicated that, the feeding potential of *M. astur* remained statistically same on *H. armigera* eggs present on different genotypes of cotton (Table 21).

4.3.1.3 Feeding potential of *M. boninensis* on *H. armigera* eggs on genotypes of cotton

Data presented in table 21 clearly indicates that, significantly highest number of *H. armigera* eggs was consumed by *M. boninensis* on cotton genotypes DHH-543 (11.66/ grub), DLSA-17 (11.33/ grub), PA-255 and Abadhita (11.00/ grub) and they were statistically on par with each other. The next genotypes on which *M. boninensis* consumed significantly more number of eggs of *H. armigera* were MCU-5, Jayadhar (10.0/ gurb), DHH-11 (9.99/ grub) and NHH-44 (8.99/grub) being statistically on par with each other. However, the predator consumed significantly lower number of eggs of *H. armigera* on DB-3-12(6.33/ grub) and Sahana (7.33/ grub) both being on par with each other.

The pooled analysis of data on feeding potential of *C. carnea*, *M. astur* and *M. boninensis* once again signified the superiority of DHH-543 (10.11 / grub), Abadhita (9.88 / grub) , DLSA-17 (9.88 / grub), PA-255 (9.33 / grub) , MCU-5 (9.11 / grub) and DHH-11 (9.10 / grub) all being on par with each other. These were followed by Jayadhar (8.55 / grub), NHH-44 (8.33 / grub) and LRA–5166 (7.88 / grub) being at par with each other in recording significantly highest number of eggs consumed by these predatory grubs. Significantly least predation was observed on DB-3-12 (6.44 / grub), Sahana (6.77 / grub) and AK-235 (6.88 / grub) and were at par with each other (Table 21).

In general, irrespective of the cotton genotypes the feeding potential of *C. carnea* on *H. armigera* eggs was highest (11.22 / grubs) followed by *M. boninensis* (9.52 / grub) and *M. astur* (4.82 / grub) (Table 21).

Table 21. Feeding potential of three species of Chrysopids on *H. armigera* eggs on different genotypes of cotton

Sl. No.	Genotypes	No. of *H. armigera* eggs consumed by (24 hr after release)			
		C. carnea	***M. astur***	***M. boninensis***	**Mean**
1	LRA – 5166	10.66 (3.26)^{d}	4.33 (2.05)^{a}	8.66 (2.94)^{d}	7.88 (2.80)^{c}
2	DB – 3 – 12	7.99 (2.82)^{e}	4.99 (2.23)^{a}	6.33 (2.52)^{f}	6.44 (2.53)^{d}
3	Jayadhar	11.66 (3.41)^{bcd}	4.00 (2.10)^{a}	10.00 (3.16)^{bc}	8.55 (2.92)^{bc}
4	DHH – 543	13.33 (3.65)^{a}	5.33 (2.30)^{a}	11.66 (3.41)^{a}	10.11 (3.17)^{a}
5	DHH – 11	12.33 (3.51)^{abc}	5.00 (2.23)^{a}	9.99 (3.16)^{bc}	9.10 (3.01)^{ab}
6	Abadhita	13.00 (3.60)^{ab}	5.66 (2.37)^{a}	11.00 (3.31)^{ab}	9.88 (3.14)^{a}
7	Sahana	8.00 (2.82)^{e}	4.99 (2.23)^{a}	7.33 (2.70)^{ef}	6.77 (2.60)^{d}
8	MCU – 5	12.33 (3.51)^{abc}	4.99 (2.23)^{a}	10.00 (3.16)^{bc}	9.11 (3.01)^{ab}
9	NHH – 44	10.99 (3.31)^{cd}	5.00 (2.23)^{a}	8.99 (2.99)^{cd}	8.33 (2.88)^{bc}
10	AK – 235	8.66 (2.94)^{e}	4.00 (2.10)^{a}	7.99 (2.83)^{de}	6.88 (2.62)^{d}
11	DLSA – 17	13.33 (3.65)^{a}	5.00 (2.23)^{a}	11.33 (3.36)^{ab}	9.88 (3.14)^{a}
12	PA – 255	12.33 (3.51)^{abc}	4.66 (2.15)^{a}	11.00 (3.31)^{ab}	9.33 (3.05)^{ab}
	Mean	11.22 (3.33)	4.82 (2.20)	9.52 (3.07)	
	S.Em±	0.07	---	0.06	0.055
	C.D. @ 5%	0.22	NS	0.20	0.160
	CV (%)	5.29	---	5.87	6.51

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

4.3.2 Feeding potential of chrysopids on *H. armigera* eggs on different genotypes of sunflower

4.3.2.1 Feeding potential of *C. carnea* on *H. armigera* eggs on genotypes of sunflower

It is clear from the table 22 that *C. carnea* consumed significantly higher number of *H. armigera* eggs on KBSH-1 (14.33/grub), Morden (14.00/grub), RSFH-1 (13.99/ grub) and VRF-21 (12.66/ grub) which were statistically at par with each other. The next genotypes of sunflower on which *C. carnea* consumed more number of *H. armigera* eggs were DSH-1 (10.33/ grub), SFL-107 (9.33/ grub) and MSFH-17 (8.99/ grub) and were statistically on par with each other. However, significantly lower number of *H. armigera* eggs were consumed by *C. carnea* on PCSH-243 (6.00 / grub), Jwalamukhi (7.33 / grub) and DSF-2 (7.33 / grub) being statistically on par with each other.

4.3.2.2 Feeding potential of *M. astur* on *H. armigera* eggs on genotypes of sunflower

Significantly highest number of *H. armigera* eggs were consumed by *M. astur* on Morden (8.99/grub), RSFH-1 (8.33/ grub), KBSH-1 (7.66/ grub) and SFL-107 (7.00 / grub) and these were statistically on par with each other. The next genotypes on which the *M. astur* consumed significantly higher number of *H. armigera* eggs were VRF-21 (6.0/ grub), DSH-1 (5.66/grub), MSFH-17 (5.33/ grub), DSF-2 (5.00/grub) and Jwalamukhi (4.66/ grub) which were on par with each other. Significantly least number of *H. armigera* eggs were consumed by *M. astur* on PCSH-243 (4.00/ grub) as compared to rest of the genotypes tried except MSFH-17, Jwalamukhi and DSF-2 (Table 22).

Table 22: Feeding potential of three species of Chrysopids on *H. armigera* eggs on different genotypes of sunflower

4.3.2.3 Feeding potential of *M. boninensis on H. armigera* eggs on sunflower genotypes

It is clear from the table 22 that, significantly higher number of *H. armigera* eggs were consumed by *M. boninensis* on KBSH-1 (13.33/ grub), Morden (12.99/ grub) and RSFH-1 (12.00/grub) and these were statistically on par with each other. The next genotypes on which *M. boninensis consumed* significantly higher number of *H. armigera* eggs were VRF-21 (9.99/ grub), SFL-107 (8.99/ grub) and DSH-1(8.66/grub). Whereas, *M. boninensis* consumed significantly lower number of eggs of *H. armigera* on PCSH-243 (4.33/ grub) being on par with DSF-2 (5.33 / grub).

The pooled data analysis on feeding potential of *c.carnea, M. astur and M. boninensis* on *H. armigera* eggs on different sunflower genotypes once again signified the superiority of Morden (11.99 / grub), KBSH-1 (11.77 / grub) and RSFH-1 (11.44 / grub) which were statistically on par with each other. These were followed by VRF-21 (9.55 / grub). SFL-107 (8.55 / grub) and DSH-1 (8.22 / grub). However, least number of *H. armigera* eggs consumed by these three species of chrysopids was recorded on PCSH -243 (4.78 / grub) followed by Jwalamukhi (6.11 / grub) and DSF-2 (6.44 / grub) (Table 22).

4.4 Electroantennogram (EAG) response of *C. carnea* and *H. armigera* on different genotypes of cotton and sunflower

The study was undertaken at Project Directorate of Biological Control (PDBC), Bangalore to know the response of mated male and female of both predator, *C. carnea* and the pest *H. armigera* against genotypes of cotton and sunflower. The results obtained from the study are presented below.

4.4.1 Electroantennogram response of *C. carnea* and *H. armigera* to cotton leaf extract

The adults of both male and female of *C. carnea* and *H. armigera* showed typical electrophysiological response to kairomonal substance of cotton leaf and boll extract.

It is clear from the table 23 that, the EAG response of mated female of *C. carnea* showed highest response to the kairomones than mated male. The mated male of *C. carnea* did not show any significant response to kairomones of any of the cotton genotypes including the standard check (50 per cent honey solution) as a reference. However, male *C. carnea*

Table 22. Feeding potential of three species of Chrysopids on *H. armigera* eggs on different genotypes of sunflower

Sl. No.	Genotypes	No. of *H. armigera* eggs consumed by (24 hr after release)			
		C. carnea	***M. astur***	***M. boninensis***	**Mean**
1	DSH – 1	10.33 (3.21)^{bc}	5.66 (2.38)^{bc}	8.66 (2.94)^{cd}	8.22 (2.86)^{c}
2	KBSH – 1	14.33 (3.78)^{a}	7.66 (2.75)^{ab}	13.33 (3.65)^{a}	11.77 (3.43)^{a}
3	PCSH – 243	6.00 (2.42)^{e}	4.00 (1.99)^{d}	4.33 (2.06)^{f}	4.78 (2.18)^{f}
4	MSFH – 17	8.99 (2.99)^{cd}	5.33 (2.27)^{cd}	7.00 (2.65)^{de}	7.11 (2.66)^{d}
5	Morden	14.00 (3.74)^{a}	8.99 (2.99)^{a}	12.99 (3.59)^{a}	11.99 (3.44)^{a}
6	RSFH – 1	13.99 (3.73)^{a}	8.33 (2.88)^{a}	12.00 (3.45)^{ab}	11.44 (3.38)^{a}
7	SFL – 107	9.33 (3.11)^{cd}	7.00 (2.65)^{ab}	8.99 (2.99)^{cd}	8.55 (2.92)^{c}
8	Jwalamukhi	7.33 (2.71)^{de}	4.66 (2.16)^{cd}	6.33 (2.51)^{e}	6.11 (2.47)^{e}
9	DSF – 2	7.33 (2.71)^{de}	5.00 (2.24)^{cd}	5.33 (2.31)^{ef}	6.44 (2.53)^{de}
10	VRF – 21	12.66 (3.55)^{ab}	6.00 (2.44)^{bc}	9.99 (3.16)^{bc}	9.55 (3.09)^{b}
	Mean	10.46 (3.19)	6.26 (2.47)	8.89 (2.93)	
	S.Em±	0.13	0.12	0.13	0.054
	C.D. @ 5%	0.39	0.37	0.38	0.163
	CV (%)	7.33	8.74	7.84	6.17

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values

gave significantly higher response to the cotton genotypes and honey solution compared to air as a control (without any kairomone) (Table 23).

Table 23: Electroantennogram response of *C. carnea* to cotton leaf extract

Mated female of *C. carnea* showed significantly higher response than mated male. Among the genotypes tested under EAG, DHH-543 (1.924 mv), DHH-11 (1.552 mv),

Table 23. Electroantennogram response of *C. carnea* to cotton leaf extract

Sl. No.	Genotypes	Response (mv) of *C. carnea* adult	
		Male	Female
1	LRA – 5166	1.201 (0.183)[a]	1.454 (0.374)[abc]
2	DB – 3 – 12	1.162 (0.150) [a]	1.292 (0.256)[bcd]
3	Jayadhar	1.160 (0.148) [a]	1.551 (0.439)[ab]
4	DHH – 543	1.130 (0.122) [a]	1.924 (0.654)[a]
5	DHH – 11	1.102 (0.097) [a]	1.552 (0.439)[ab]
6	Abadhita	0.972 (0.03) [a]	1.201 (0.183)[bcd]
7	Sahana	0.910 (-0.094) [a]	1.346 (0.297)[bc]
8	MCU – 5	0.912 (-0.092) [a]	1.296 (0.259)[bcd]
9	NHH – 44	1.000 (-0.001) [a]	1.302 (0.263)[bcd]
10	AK – 235	1.202 (0.182) [a]	1.082 (0.079)[cd]
11	DLSA – 17	1.102 (0.096) [a]	1.541 (0.432)[ab]
12	PA – 255	0.914 (-0.09) [a]	1.102 (0.096)[cd]
13	Honey	1.102 (0.096) [a]	1.621 (0.483)[ab]
14	Air	0.020 (-4.088) [b]	0.020 -(4.008)[e]
	S.Em±	0.091	0.091
	C.D. @ 5%	0.265	0.265
	CV (%)	3.790	6.640

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

Jayadhar (1.551mv), DLSA-17 (1.541 mv), and LRA-5166 (1.454 mv) evoked significantly better response and they were on par with honey solution (1.621 mv). The genotype, Sahana (1.346 mv), NHH-44 (1.302 mv), MCU-5 (1.296 mv) DB –3-12 (1.292 mv) and Abhadita (1.201) also evoked higher response but lower than DHH-543, DHH-11, DLSA-17, Jayadhar and LRA-5166. Significantly lower EAG response of female *C. carnea* was recorded towards the extract of AK-235 (1.082 mv) being on par with PA-255 (1.102 mv), Abadhita (1.201 mv), DB-3-12 (1.292 mv), MCU-5 (1.296 mv) and NHH-44 (1.302 mv) but significantly higher than the air (0.020mv) as a control (Table 23).

Mated female of *H. armigera* has stronger EAG responses to allelochemicals of cotton genotypes than mated male (Table 24). The response of males to the kairomones of any of the cotton genotypes remained same as there was no significant difference. However, significantly higher electrophysiological responses of male *H. armigera* were recorded to honey solution (0.182 mv) compared to cotton genotypes. However, the EAG response of male *H. armigera* to the kairomones of different cotton genotypes was significantly higher than air (0.020 mv) as a control (Table 24).

Table 24: Electroantennogram response of *H. armigera* to cotton leaf extract

In the other experiment, mated female of *H. armigera* recorded significantly higher electrophysiological response to the leaf extract of Sahana (1.336 mv), DHH-11 (1.332 mv) and LRA-5166 (1.112mv) and they were on par with each other and also honey solution (1.131mv) as a reference. Significantly lower EAG response of female *H. armigera* was recorded against all other remaining genotypes and they were statistically on par with each other (Table 24) but significantly higher than air (0.020 mv) as a control.

4.4.2 Electrophysiological response of *C. carnea* and *H. armigera* to cotton boll extract

The mated adults of both male and female *C. carnea* showed typical electroantennogram response to kairmonal substance of boll extract of cotton genotypes. Among the sexes, mated female of *C. carnea* showed highest response to boll extract of cotton genotypes than male (Table 25).

Table 25: Electroantennogram response of *C. carnea* to cotton boll extract

Mated male of *C. carnea* showed significantly higher response to 50 per cent honey solution as compared to boll extract of cotton genotypes and air as a control. The response of male *C. carnea* towards the electroantennogram response to kairomonal substances to boll extract of cotton genotypes remained same as they were statistically on par with each other (Table 25).

Among the boll extracts of cotton genotypes, mated female of *C. carnea* showed similar EAG response to DHH-543 (2.071mv), DLSA-17 (1.938mv), DHH-11(1.912 mv), LRA-5166 (1.860 mv), NHH-44 (1.824 mv), Sahana (1.812 mv), Abadhita (1.714 mv), DB-3-12 (1.670 mv), MCU-5 (1.660 mv) and Jayadhar (1.612 mv) as they were statistically on par with each other. Fifty per cent honey solution (1.480 mv) also gave significantly better response than PA –255 and air as a control. Least EAG response of mated female of *C. carnea* was recorded to the boll extract of PA 255 (1.114 mv) but, significantly higher than the air (0.020 mv) as a control (Table 25).

From the table 26, it is clear that, mated female of *H. armigera* has evoked significantly stronger EAG response to allelochemicals of boll extract of cotton genotypes than mated male. There was no significant difference in EAG response observed between the boll extract of cotton genotypes to mated male of *H. armigera*. However, significantly higher EAG response of male *H. armigera* to 50 per cent honey solution (0.189 mv) as a reference and significantly lower EAG response to air (0.020 mv) as a control (Table 26) was observed.

Table 26: Electroantennogram response of *H. armigera* to cotton boll extract

Mated female of *H. armigera* showed significantly stronger EAG response to the allelochemicals of cotton boll extract of Sahana (1.340mv), DHH-11 (1.107 mv) and LRA-5166 (1.107 mv) and they are comparable to honey solution as a reference (1.102 mv). The EAG response of female *H. armigera* to the allelochemicals of boll extract of remaining genotypes of cotton remained same as they were statistically on par with each other.

Table 24. Electroantennogram response of *H. armigera* to cotton leaf extract

Sl. No.	Genotypes	Response (mv) of *H. armigera* adult	
		Male	Female
1	LRA – 5166	0.108 -(2.227)^{b}	1.112 (0.106)^{abc}
2	DB – 3 – 12	0.107 -(2.227) ^{b}	0.834 -(0.182)^{cd}
3	Jayadhar	0.109 -(2.227) ^{b}	0.742 -(0.299)^{d}
4	DHH – 543	0.107 -(2.223) ^{b}	0.874 -(0.136)^{bcd}
5	DHH – 11	0.107 -(2.223) ^{b}	1.332 (0.286)^{a}
6	Abadhita	0.108 -(2.226) ^{b}	0.821 -(0.197)^{d}
7	Sahana	0.107 -(2.233) ^{b}	1.336 (0.29)^{a}
8	MCU – 5	0.108 -(2.226) ^{b}	0.819 -(0.199d)
9	NHH – 44	0.108 -(2.226) ^{b}	0.912 -(0.092)^{bcd}
10	AK – 235	0.107 -(2.236) ^{b}	0.972 -(0.029)^{bcd}
11	DLSA – 17	0.106 -(2.245) ^{b}	0.934 -(0.069)^{bcd}
12	PA – 255	0.107 -(2.236) ^{b}	0.752 -(0.286)^{d}
13	Honey	0.182 -(1.72) ^{a}	1.131 (0.123)^{ab}
14	Air	0.020 -(4.008) ^{c}	0.020 -(4.008)^{e}
	S.Em±	0.100	0.089
	C.D. @ 5%	0.290	0.260
	CV (%)	5.220	4.500

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

Table 25. Electroantennogram response of *C. carnea* to cotton boll extract

Sl. No.	Genotypes	Response (mv) of *C. carnea* adults	
		Male	Female
1	LRA – 5166	0.734 -(0.310)^{bc}	1.860 (0.62)^{ab}
2	DB – 3 – 12	0.702 -(0.356)^{bc}	1.670 (0.513)^{abc}
3	Jayadhar	0.703 -(0.352)^{bc}	1.612 (0.477)^{abc}
4	DHH – 543	0.836 -(0.180)^{b}	2.071 (0.728)^{a}
5	DHH – 11	0.802 -(0.222)^{bc}	1.912 (0.648)^{ab}
6	Abadhita	0.621 -(0.476)^{bc}	1.714 (0.539)^{abc}
7	Sahana	0.832 -(0.184)^{b}	1.812 (0.594)^{ab}
8	MCU – 5	0.634 -(0.456)^{bc}	1.660 (0.507)^{abc}
9	NHH – 44	0.823 -(0.195)^{b}	1.824 (0.601)^{ab}
10	AK – 235	0.714 -(0.337)^{bc}	1.315 (0.274)^{cd}
11	DLSA – 17	0.603 -(0.508)^{c}	1.938 (0.662)^{ab}
12	PA – 255	0.692 -(0.369)^{bc}	1.114 (0.108)^{d}
13	Honey	1.171 (0.158)^{a}	1.480 (0.392)^{bc}
14	Air	0.020 -(4.008)^{d}	0.020 -(4.008)^{e}
	S.Em±	0.091	0.087
	C.D. @ 5%	0.265	0.254
	CV (%)	4.290	6.480

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

Table 26. Electroantennogram response of *H. armigera* to cotton boll extract

Sl. No.	Genotypes	Response (mv) of *H. armigera* adult	
		Male	Female
1	LRA – 5166	0.108 -(2.227)[b]	1.107 (0.102)[ab]
2	DB – 3 – 12	0.107 -(2.236)[b]	0.922 -(0.081)[bcd]
3	Jayadhar	0.109 -(2.219)[b]	0.842 -(0.172)[cd]
4	DHH – 543	0.106 -(2.245)[b]	0.858 -(0.140)[bc]
5	DHH – 11	0.107 -(2.236)[b]	1.107 (0.102)[ab]
6	Abadhita	0.108 -(2.227)[b]	0.842 -(0.172)[cd]
7	Sahana	0.107 -(2.236)[b]	1.340 (0.293)a
8	MCU – 5	0.108 -(2.227)[b]	0.800 -(0.224)[d]
9	NHH – 44	0.111 -(2.202)[b]	0.810 -(0.211)[d]
10	AK – 235	0.107 -(2.236)[b]	0.862 -(0.149)[bcd]
11	DLSA – 17	0.106 -(2.245)[b]	0.924 -(0.079)[bcd]
12	PA – 255	0.107 -(2.236)[b]	0.816 -(0.203)[d]
13	Honey	0.189 -(1.676)[a]	1.102 (0.096)[ab]
14	Air	0.020 -(4.008)[c]	0.020 -(4.008)[e]
	S.Em± C.D. @ 5% CV (%)	0.097 0.281 7.200	0.084 0.243 4.200

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

However, the EAG responses to air (0.020 mv) as a control was significantly lower than the remaining treatments (Table 26).

4.4.3 Electroantennogram response of *C. carnea* and *H. armigera* to sunflower leaf extract

4.4.3.1 EAG response of *C.carnea* to sunflower leaf extract

The mated adults of both male and female *C.carnea* resulted in typical electroantennogram response to kairomonal substances of leaf extract of sunflower genotypes. Among the sexes, mated female of *C.carnea* evoked greater response to leaf extract of sunflower genotypes than male. Mated male of *C. carnea* gave significantly higher response to 50 per cent honey solution (4.204 mv) as compared to leaf extract of sunflower genotypes. Among the genotypes, significantly higher EAG response by male *C. carnea* was recorded to the leaf extract of Morden (3.806 mv) and RSFH-1 (3.606 mv) and they were statistically on par with each other, followed by KBSH-1 (3.20 mv). Significantly lower EAG response was recorded to the leaf extract of SFL-107, VRF-21, Jwalamukhi, DFS-2, DSH-1 and PCSH-243 (2.720, 2.800, 2.802, 2.860, 2.882 and 2.908 mv, respectively) and they were statistically on par with each other. Air as a control recorded significantly lower EAG response than the honey solution and leaf extract of sunflower genotypes (Table 27).

Table 27: Electroantennogram response of *C. carnea* to sunflower leaf extract

It is evident from the table 27 that, mated female of *C. carnea* exhibited significantly higher EAG response to the leaf extract of KBSH-1 (4.942 mv), Morden (4.928 mv) and RSFH-1 (4.284 mv) which were statistically on par with each other. These were followed by PCSH-243 (3.982 mv), MSFH-17 (3.326 mv) and Jwalamukhi (3.121 mv). While, VRF-21 (2.506 mv) DSF-2 (2.642 mv) and SFL-107 (2.811 mv) recorded significantly lower EAG response to female *C. carnea* being statistically on par with each other. However significantly least EAG response was recorded to air (0.070 mv) as a control and which differed statistically with leaf extract of sunflower genotypes and 50 per cent honey solution as a reference (Table 27).

4.4.3.2 EAG response of *H. armigera* to sunflower leaf extract

It is clear from the table 28 that, mated female of *H. armigera* evoked stronger EAG response to the allelochemicals of sunflower genotypes than mated male. Mated male of *H. armigera* showed similar EAG response to all the sunflower genotypes and honey solution as a reference. Significantly lower EAG response of mated male of *H. armigera* to the air (0.020 mv) as a control was observed and differed statistically with 50 per cent honey solution and genotypes of sunflower.

In case of female *H. armigera* also, no significant difference in EAG response was observed between the leaf extract of sunflower genotypes and 50 per cent honey solution. However, the EAG response of air was significantly lower (0.20 mv) compared to the sunflower genotypes and honey solution (Table 28).

Table 28: Electroantennogram response of *H. armigera* to sunflower leaf extract

4.4.4 Electroantennogram response of *C. carnea* and *H. armigera* to sunflower capitulam extract

4.4.4.1 EAG response of *C. carnea* to sunflower capitulam extract

The mated adult of both male and female *C. carnea* showed typical electroantennogram response to kairomonal substance of capitulam extract of sunflower genotypes. Among the sexes, mated female of *C.carnea* showed higher response to capitulam extract than male (Table 29).

Table 29: Electroantennogram response of *C. carnea* to sunflower capitulam extract

Among the sunflower genotypes mated male of *C. carnea* recorded significantly higher EAG response to KBSH-1 (3.282 mv), RSFH-1 (3.007 mv) and PCSH-243 (3.002 mv). This was followed by the remaining sunflower genotypes where *H. armigera* evoked similar response. However, mated male of *C. carnea* evoked significantly higher EAG response to 50

Table 27. Electroantennogram response of *C. carnea* to sunflower leaf extract

Sl. No.	Genotypes	Response (mv) of *C. carnea* adult	
		Male	Female
1	DSH – 1	2.882 (1.058)^{d}	3.249 (1.178)^{de}
2	KBSH – 1	3.200 (1.163)^{c}	4.942 (1.598)^{ab}
3	PCSH – 243	2.908 (1.067)^{d}	3.982 (1.382)^{c}
4	MSFH – 17	2.820 (1.037)^{d}	3.326 (1.202)^{d}
5	Morden	3.806 (1.337)^{b}	4.928 (1.595)^{ab}
6	RSFH – 1	3.606 (1.283)^{b}	4.284 (1.455)^{bc}
7	SFL – 107	2.720 (1.001)^{d}	2.811 (1.034)^{ef}
8	Jwalamukhi	2.802 (1.030)^{d}	3.121 (1.138)^{de}
9	DSF – 2	2.860 (1.051)^{d}	2.642 (0.971)^{f}
10	VRF - 21	2.800 (1.030)^{d}	2.506 (0.919)^{f}
11	Honey	4.204 (1.436)^{a}	5.002 (1.610)^{a}
12	Air	0.070 -(2.666)^{e}	0.070 -(2.688)^{g}
	S.Em±	0.026	0.048
	C.D. @ 5%	0.075	0.142
	CV (%)	4.980	8.870

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

per cent honey solution and it was statistically different from sunflower genotypes and air as a control (Table 29).

It is also evident from the table 29 that, significantly higher EAG response was recorded by mated female of *C. carnea* to capitulam extract of KBSH-1 (6.228mvv), Morden (6.006 mv) and 50 per cent honey solution (6.002 mv) as a reference and these were statistically on par with each other. The next best genotypes which recorded significantly higher EAG response of female *C. carnea* were RSFH-1, PCSH-243, MSFH-17 and DSH-1

Table 28. Electroantennogram response of *H. armigera* to sunflower leaf extract

Sl. No.	Genotypes	Response (mv) of *H. armigera* adult	
		Male	Female
1	DSH – 1	0.200 -(1.631)[a]	2.119 (0.751) [a]
2	KBSH – 1	0.182 -(1.704) [a]	1.802 (0.589) [a]
3	PCSH – 243	1.192 -(1.650) [a]	1.891 (0.637) [a]
4	MSFH – 17	0.180 -(1.715) [a]	1.821 (0.599) [a]
5	Morden	0.200 -(1.631) [a]	1.820 (0.599) [a]
6	RSFH – 1	0.211 -(1.557) [a]	1.802 (0.589) [a]
7	SFL – 107	0.181 -(1.709) [a]	2.008 (0.697) [a]
8	Jwalamukhi	0.191 -(1.655) [a]	1.942 (0.664) [a]
9	DSF – 2	0.206 -(1.580) [a]	1.942 (0.664) [a]
10	VRF - 21	0.202 -(1.600) [a]	1.924 (0.654) [a]
11	Honey	0.204 -(1.590) [a]	1.982 (0.684) [a]
12	Air	0.020 -(4.008) [b]	0.020 -(4.008) [b]
	S.Em±	0.113	0.095
	C.D. @ 5%	0.330	0.278
	CV (%)	-8.640	10.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

(5.122, 5.002, 4.864 and 4.859, respectively. Significantly lower EAG response was recorded to VRF-21 (3.900 mv) and DSF-2 (3.891 mv) but higher than air (0.100 mv) as a control.

4.4.4.2 EAG response of *H. armigera* to genotypes of sunflower capitulam extract

From the table 30, it is clear that mated female of *H. armigera* has evoked significantly stronger EAG response to the capitulam extract of sunflower genotypes than mated male. Significantly stronger EAG response of male *H. armigera* was recorded to SFL –

Table 29. Electroantennogram response of *C. carnea* to sunflower capitulam extract

Sl. No.	Genotypes	Response (mv) of *C. carnea* adult	
		Male	Female
1	DSH – 1	2.604 (0.957)^{d}	4.859 (1.581)^{b}
2	KBSH – 1	3.282 (1.188)^{b}	6.228 (1.829)^{a}
3	PCSH – 243	3.002 (1.099)^{bc}	5.002 (1.609)^{b}
4	MSFH – 17	2.808 (1.032)^{cd}	4.864 (1.582)^{b}
5	Morden	2.930 (1.062)^{cd}	6.006 (1.792)^{a}
6	RSFH – 1	3.007 (1.101)^{bc}	5.122 (1.634)^{b}
7	SFL – 107	2.602 (0.956)^{d}	4.220 (1.440)^{c}
8	Jwalamukhi	2.624 (0.965)^{d}	4.320 (1.463)^{c}
9	DSF – 2	2.606 (0.958)^{d}	3.891 (1.359)^{d}
10	VRF - 21	2.862 (1.052)^{cd}	3.900 (1.361)^{d}
11	Honey	3.804 (1.336)^{a}	6.002 (1.792)^{a}
12	Air	0.100 -(2.303)^{e}	0.100 -(2.303)^{e}
	S.Em±	0.037	0.018
	C.D. @ 5%	0.107	0.054
	CV (%)	7.980	1.770

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

107, PCSH-243, DSF-2, RSFH-1 and 50 per cent honey solution (0.680, 0.662, 0.642, 0.635and 0.642 mv, respectively) and were statistically on par with each other. The next genotype of sunflower which evoked stronger EAG response to male *H. armigera* was DSH-1 (0.622 mv). This was followed by MSFH-17 (0.602 mv) and Jwalamukhi (0.560 mv) and they were statistically on par with each other. The EAG response by male *H. armigera* recorded to the capitulam extract of VRF-21 (0.547 mv) and Jwalamukhi (0.560 mv) remained

same. KBSH-1 (0.506 mv) and Morden (0.482 mv) exhibited significantly lower EAG response but comparatively higher than air (0.090mv) as a control.

On the other hand, mated female of *H. armigera* evoked significantly higher EAG response to capitulam extract of SFL-107 (3.826 mv), followed by DSF-2 (3.402mv). Honey solution, PCSH-243, DSH-1 and VRF-21 (3.203, 3.200, 3.120 mv and 3.101 mv, respectively) also recorded significantly higher EAG response but lower than SFL-107 and DSF-2. However, Morden (2.800 mv) and KBSH-1 (2.902 mv) evoked significantly lower EAG response to female *H. armigera* and found inferior than rest of the genotypes tested but significantly higher than the control (0.090) (Table 30).

Table 30: Electroantennogram response of *H. armigera* to sunflower capitulam extract

4.4.5 Head space volatile compounds from cotton and sunflower genotypes

In the present study, various volatile compounds were identified through Gas Chromatography Mass Spectrum (GCMS). Only two genotypes each from cotton and sunflower which performed highest and lowest oviposition by *C. carnea* and also evoked highest and lowest EAG response by *C. carnea* were tried under this study.

In the present study, the gas chromatogram of the plant samples (cotton and sunflower) indicated wide variation in the hydrocarbon profile of individual plants.

4.4.5.1 Head space volatile compounds from cotton genotypes

During the study, the volatile compounds identified from DHH-543 having only >87 per cent purity was taken in to consideration (Table 31).

Gas Chromatography of cotton leaf extract of DHH-543 indicated the presence of caryophyllene oxide at very high concentration (18.68%) followed by 1-Hexanol (12.78%) and 1-Pentanol (11.38%). Compounds which were present at very low concentration are Beta myresane, L–carvone, Decanol and pentadecane (0.01%). The other volatile compounds identified from DHH-543 under GCMS were octane, Linalool oxide (cis and trans) trans-geraniol and l – butanol (Table 31).

The volatile compounds identified from PA-255 during the study having >90% purity only were taken in to consideration (Table 32). This indicated the presence of higher quantity of Linalool (34.36%), Heptadecane (9.51%), 1-Pentanol (9.03%) and 1-Hexanol (5.58%). The other volatile compounds which were present at very low quantity are para cymene (0.04%), gerraniol (0.14%) octane (0.16%) and caryophylla (0.19%). The other volatile compounds which were identified from PA–255 under GCMS were alfa–pinine, Sabanine, Linalool oxide, pentadcane, caryophyllene oxide, hexadecane and octadecane (Table 32).

4.4.5.2 Head space volatile compounds identified from sunflower genotypes

It is evident from the table 33 that Gas chromatography of sunflower genotype (KBSH-1) leaf extract indicated the presence of heptadecane (38.28%), linalool (21.80%), caryophyllene oxide (9.74%) and hexadecane (7.24%) at very high quantity followed by 1-pentanol (3.56%), 1-hexanol (2.64%) and limonene (2.31%). The volatile compounds which were identified from KBSH-1 in very small quantity are tridecane, cyclopentane, 1-butanol, pentadecane and dodecane (0.01, 0.08, 0.01, 0.09 and 0.13%, respectively). The other kairomone identified from KBSH-1 through GCMS are cyclohexane, heptane, octane, alpa-pinene, sabinene, cis and trans linalool oxide, dodecane. From KBSH-1 hybrid of sunflower, 25 volatile compounds are identified under GCMS.

From the table 34, it clearly shows that the presence of only ten volatile compounds from VRF-221 as compared to KBSH-1 which is having >25 volatile compounds. Among the compounds identified through GCMS, presence of heptadecane (20.97%) and 1-pentanol (11%) followed by hexadecane (7.83%) and 1-hexanol (6.42%) at very high quantity was noticed. The other volatile compounds which were identified through GCMS from VRF-21 were octane, alpa – pinene, sabinene, limonene and linalool oxide (Table 34).

Table 34: Head space volatiles identified from sunflower cultivar, VRF-21 using Gass Chromatography Mass Spectrum (GCMS)

Table 30. Electroantennogram response of *H. armigera* to sunflower capitulam extract

Sl. No.	Genotypes	Response (mv) of *H. armigera* adult	
		Male	Female
1	DSH – 1	0.622 -(0.475)^{bc}	3.120 (1.138)^{cd}
2	KBSH – 1	0.506 -(0.681)^{f}	2.902 (1.065)^{ef}
3	PCSH – 243	0.662 -(0.413)^{ab}	3.200 (1.163)^{c}
4	MSFH – 17	0.602 -(0.508)^{cd}	3.002 (1.099)^{de}
5	Mordrn	0.482 -(0.730)^{f}	2.800 (1.03)^{f}
6	RSFH – 1	0.635 -(0.454)^{abc}	3.002 (1.099)^{de}
7	SFL – 107	0.680 -(0.386)^{a}	3.826 (1.342)^{a}
8	Jwalamukhi	0.560 -(0.581)^{de}	2.984 (1.093)^{de}
9	DSF – 2	0.642 -(0.443)^{abc}	3.402 (1.224)^{b}
10	VRF - 21	0.547 -(0.604)^{e}	3.101 (1.132)^{cd}
11	Honey	0.642 -(0.444)^{abc}	3.203 (1.164)^{c}
12	Air	0.090 (2.412)^{g}	0.090 -(2.408)^{g}
	S.Em±	0.026	0.018
	C.D. @ 5%	0.076	0.053
	CV (%)	-6.270	3.200

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are logarithmic transformed values

4.5 Use of *C. carnea* in the IPM of *H. armigera* on cotton genotype, DHH-543

4.5.1 Incidence of sucking pests as influenced by different treatments

The incidence of leafhopper, *Amrasca biguttella biguttella* Ishida at early stage of the crop growth (30 DAS) remained same except untreated control, which recorded significantly lower

Table 31. Head space volatiles identified from cotton cultivar, DHH – 543, using Gass Chromatography Mass Spectrum (GCMS)

Sl. No.	RT (minutes)	Compounds	% purity	% area
1	4.43	1 – Butanol	90	0.06
2	5.68	1 – Pentanol	90	11.38
3	6.23	Octane	91	2.68
4	10.43	1 – Hexanol	87	12.78
5	26.77	Cis – Linalool oxide	91	0.16
6	28.20	Trans – Linalool oxide	91	0.03
7	29.01	B – Myrcene	91	0.01
8	40.53	L – Carvone	91	0.01
9	41.63	Trans – Geraniol	94	0.02
10	42.92	Decanol	87	0.01
11	43.08	3, 7 – Dimethyl – Octadiene	87	0.03
12	57.50	Pentadecane	98	0.01
13	59.82	Phenol, 2, 4 – bis dimethyle	91	0.02
14	62.74	Caryophyllene oxide	94	18.68

RT = Retention time

population. At 45 DAS, the leafhopper population was uniform in T1, T2 and T3 but

significantly higher than T4 (1.20 / 3 leaves). However, in untreated check, the leafhopper population was significantly higher (5.88 / 3 leaves).

During peak infestation period (60 DAS), exactly similar trend in leafhopper population was noticed as that of 45 DAS but with higher leafhopper population. Untreated control (T5) recorded significantly highest leafhopper population (10.62 / 3 leaves) than rest of the treatments. At 75 DAS similar trend was observed as that of 60 DAS as for as leafhopper population is concerned. The activity of leafhopper was in decreasing trend from 90 DAS onwards. The population of leafhopper was very low at 135 DAS and followed the similar trend as that of 120 DAS. The treatment average indicated that T3 (2.72 / 3 leaves) and T2 (2.79 / 3 leaves) recorded significantly lower leafhopper incidence, which were on par with each other. RPP (1.64 / 3 leaves) recorded significantly lowest leafhopper population. On the other hand, significantly higher population of leafhopper was recorded in T1 (3.11 / 3 leaves). However, the untreated check (T5) recorded significantly highest population of leafhopper (5.46 /3 leaves) (Table 35).

The population of aphid, *Aphis gossypii* Glover in different treatments was uniform (2.86 to 3.44 / 3 leaves) except in untreated check (15.48/ 3 leaves) where it was significantly

Table 32. Head space volatiles identified from cotton cultivar, PA – 255, using Gass Chromatography Mass Spectrum (GCMS)

Sl. No.	RT (minutes)	Compounds	% purity	% area
1	5.23	1 – Pentanol	90	9.03
2	6.12	Octane	93	0.16
3	9.67	1 – Hexanol	90	5.58
4	13.57	α – Pinene	96	1.62
5	16.98	Sabinee	97	0.29
6	21.93	Para – cymene	95	0.04
7	26.69	Linalool oxide	91	0.86
8	28.13	Cis – Linalol oxide	90	0.89
9	29.72	Linalool	94	34.36
10	41.57	Geraniol	89	0.14
11	57.14	Pentadecane	94	0.65
12	60.40	Caryophyllene oxide	94	2.31
13	62.71	Hexadecane	98	0.66
14	64.17	Caryophylla	98	0.19
15	67.73	Heptadecane	96	9.51
16	68.39	Tetradecanoic acid	97	0.13
17	69.90	Octadecane	93	0.08

RT = Retention time

lower at 30 DAS (Table 36). At 45 DAS, the aphid population in T1, T2 and T3 remained same but in RPP the population was significantly lower compared to T1, T2 and T3. However in untreated check it was significantly highest (19.96 / 3 leaves). At 60 DAS, the trend in the efficacy of different treatments remained exactly similar to that of 45 DAS. At 75 DAS, the aphid population in T3 (4.46 / 3 leaves) was significantly lower, being on par with T2 (5.62 / 3 leaves). The efficacy of T1 (5.92 / 3 leaves) and T2 (5.62 / 3 leaves) remained same. However, RPP (2.20/ 3 leaves) recorded significantly lowest aphid population compared to all other treatments. At 90 DAS, T3 (1.20 / 3 leaves) recorded significantly lowest aphid population being on par with T2 (1.42 / 3 leaves). Whereas the efficacy of T1 (2.55 / 3 leaves) and T4 (2.22 / 3 leaves) remained same. At 105 DAS, the efficacy of T1 (1.42 / 3 leaves) T2 (1.00 / 3 leaves) and T3 (0.90 / 3 leaves) remained same. However among the treatments, RPP (2.92 / 3 leaves) recorded significantly highest aphid population. At 120 DAS, T3 (0.40 / 3 leaves) recorded significantly lowest population but on par with T2 (0.46 / 3 leaves). The efficacy of T1 (0.80 / 3 leaves) and T2 (0.46 / 3 leaves) was same. Significantly higher population was observed in RPP (6.0 / 3 leaves). At 135 DAS, the efficacy of T1 (1.48 / 3 leaves), T2 (1.24 / 3 leaves) and T3 (1.20 / 3 leaves) remained same as they were statistically on par with each other. The average population of aphids was significantly lower in T3 (2.63 / 3 leaves) and T2 (2.90 / 3 leaves) which were statistically at par with RPP (2.80 / 3 leaves). Significantly higher aphid population was recorded in T1 (3.33 / 3 leaves) compared to T3 but significantly superior to untreated check (T5) (15.26 / 3 leaves) (Table 36).

At 30 DAS, the population of thrips, *Thrips tabacii* Lind remained same in T1, T2 and T3 which ranged from 2.00 to 2.20 / 3 leaves and these treatments were significantly inferior

Table 33. Head space volatiles identified from sunflower cultivar, KBSH-1, using Gass Chromatography Mass Spectrum (GCMS)

Sl. No.	RT (minutes)	Compounds	% purity	% area
1	2.24	Pentane, 3 – methyl	91	0.33
2	2.58	Cyclopentane, methyl	90	0.08
3	2.69	1, 3 – Pentadiene, 2 – methyl	93	0.01
4	2.93	Cyclohexane	94	0.06
5	3.41	Heptane	93	0.02
6	4.26	1 – Butanol	86	0.01
7	5.07	1 – Pentanol	90	3.56
8	5.95	Octane	95	0.31
9	9.51	1 – Hexanol	90	2.64
10	13.42	α - Pinene	96	0.61
11	16.84	Sabinene	96	0.11
12	21.84	Para – cymene	94	0.03
13	22.27	Limonene	98	2.31
14	26.61	Cis – Linalool oxide	91	0.42
15	28.06	Linalool oxide	91	0.45
16	29.85	Linalool	94	21.80
17	37.38	Dodecane	96	0.13
18	44.64	Tridecane	96	0.01
19	51.31	Tetradecane	96	0.07
20	57.52	Pentadecane	97	0.09
21	58.48	Phenol	93	0.06
22	62.26	Caryophyllene Oxide	94	9.74
23	63.49	Hexadecane	98	7.24
24	68.19	Heptadecane	96	38.28
25	70.04	Octadecane	98	0.41

RT = Retention time

to RPP (0.86 / 3 leaves). However in untreated control (T5), the population was significantly higher (9.20 / 3 leaves). At 45 DAS, similar trend in the thrips population was recorded as that of 30 DAS, except T3 (3.68 / 3 leaves) which was on par with T4 (2.64 / 3 leaves). At 60 DAS, T3 recorded lower thrips population (3.60 / 3 leaves) being on par with T4 (2.84 / 3 leaves) and T2 (4.86 / 3 leaves). Untreated check recorded significantly highest thrips population of 12.22 / 3 leaves. At 75 DAS, T3 (2.84 / 3 leaves) recorded lowest population

Table 34. Head space volatiles identified from sunflower cultivar, VRF-21 using Gass Chromatography Mass Spectrum (GCMS)

Sl. No.	RT (minutes)	Compounds	% purity	% area
1	5.18	1 – Pentanol	90	11.00
2	6.13	Octane	91	0.14
3	9.61	1 – Hexanol	90	6.42
4	13.58	α - Pinene	96	1.72
5	17.00	Sabinene	97	0.30
6	22.30	Limonene	98	0.99
7	26.70	Linalool oxide	90	0.99
8	28.13	Cis – Linalool oxide	90	1.02
9	63.38	Hexadecane	98	7.83
10	67.73	Heptadecane	98	20.97

RT = Retention time

being on par with RPP (T4) (2.62 / 3 leaves). At 90 DAS, T3 (1.40 / 3 leaves) recorded lowest population being on par with T2 (2.00 / 3 leaves) and T4 (2.12 / 3 leaves). Similar trend in the efficacy of treatments was observed at 105 DAS and 120 DAS. At 135 DAS, lowest population was observed in T3 (0.18/ 3 leaves) which was on par with T2 (0.20 / 3 leaves). T1 (1.12 / 3 leaves) was inferior to T4 (0.64 / 3 leaves). Irrespective of the treatments, the population of thrips increased slowly from 30 DAS reaching peak at 60 DAS (6.01 / 3 leaves) and later there was gradual decline reaching minimum at 135 DAS (0.83 / 3 leaves). The average population of thrips indicated significantly lower incidence in T3 (1.91 / 3 leaves). The next best treatment was T2 (2.41 / 3 leaves) followed by T1 (3.11 / 3 leaves). RPP (T4) recorded significantly lowest thrips population (1.71 / 3 leaves). However untreated check (7.60 / 3 leaves) recorded highest population (Table 37).

Whitefly, *Bemisia tabaci* Gennadium population was negligible during the experimental period, which ranged from 0.12 to 6.22 / 3 leaves in the untreated check. There was gradual increase in the whitefly population from 60 DAS reaching peak at 105 DAS (2.05 / 3 leaves). Later there was decline in the whitefly population. At 60 DAS, the whitefly population was uniform in all the treatments as indicated by non significant differences. At 75 DAS, the treatments T2 (0.24 / 3 leaves) and T3 (0.22 / 3 leaves) were as effective as T4 (RPP) (0.18 / 3 leaves) in reducing the whitefly population, while T1 (0.76 / 3 leaves) was inferior to other treatments. At 90 DAS, all the four treatments were equally effective in reducing the whitefly population. However, untreated check recorded significantly higher population (3.66 / 3 leaves). At 105 DAS T1 (1.84 / 3 leaves) and T2 (1.82 / 3 leaves) were ineffective as they were statistically on par with untreated check (3.90 / 3 leaves). Whereas, RPP (0.92 / 3 leaves) recorded significantly lowest population. At 120 DAS T3 (0.44/ 3 leaves), T2 (0.68 / 3 leaves) and T4 (0.62/ 3 leaves) were similar in their effectiveness in

Table 35. Influence of treatments on the population of leafhopper on cotton

Treatments	Average population of leafhopper / three leaves at								
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**105 DAS**	**120 DAS**	**135 DAS**	**Mean**
T1	1.12 (1.05)[a]	3.20 (1.79)[b]	6.32 (2.50)[b]	6.00 (2.44)[b]	3.82 (1.95)[a]	2.82 (1.68)[b]	1.40 (1.18)[b]	0.62 (0.79)[a]	3.11 (1.76)[c]
T2	1.00 (1.02)[a]	3.20 (1.79)[b]	5.40 (2.30)[b]	5.82 (2.39)[b]	3.28 (1.80)[a]	2.20 (1.48)[a]	0.96 (0.98)[a]	0.56 (0.74)[a]	2.79 (1.67)[bc]
T3	1.12 (1.05)[a]	3.00 (1.76)[b]	5.22 (2.28)[b]	5.68 (2.38)[b]	3.20 (1.74)[a]	2.20 (1.48)[a]	0.88 (0.94)[a]	0.52 (0.72)[a]	2.72 (1.65)[b]
T4	1.00 (1.02)[a]	1.20 (1.09)[a]	2.12 (1.45)[a]	1.22 (1.11)[a]	2.55 (1.67)[a]	2.42 (1.55)[a]	1.42 (1.19)[b]	1.22 (1.10)[b]	1.64 (1.28)[a]
T5	4.42 (2.09)[b]	5.88 (2.31)[c]	10.62 (3.24)[c]	10.20 (3.18)[c]	5.22 (2.28)[b]	4.20 (2.05)[b]	2.00 (1.41)[c]	1.14 (1.07)[c]	5.46 (2.33)[d]
Mean	1.73 (1.24)	3.30 (1.75)	5.94 (2.35)	5.78 (2.30)	3.61 (1.90)	2.77 (1.65)	1.33 (1.15)	0.81 (0.88)	
S.Em±	0.05	0.05	0.14	0.13	0.13	0.04	0.03	0.03	0.032
CD @ 5%	0.14	0.15	0.44	0.39	0.41	0.12	0.09	0.10	0.097
CV (%)	7.39	5.57	12.23	11.04	14.11	11.82	5.23	7.48	8.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT
Figures in the parentheses are square root transformed values.
DAS: Days after sowing

T1: 1. Seed treatment with imidacloprid (70 WS) (10 g / kg), 2. Intercropping of lucern, 3. Application of neem based pesticide (5% NSKE)
4. monitoring of *H.armigera* through sex pheromone traps (2 traps/ac), 5. Release of *C.carnea* thrice starting from early reproductive phase at 15 days interval (50,000/ha), **T2 = T1** (1-4) + 75,000 *c.carnea*/ha**,** **T3=T1 (1-4)** + 1,00,000 *C. carnea*/ha**, T4** RPP, **T5** Untreated control

Table 36. Influence of treatments on the population of aphids on cotton

Treatments	Average population of aphids / three leaves at								
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean
T1	3.44 (1.85)[a]	4.82 (2.19)[b]	6.24 (2.50)[b]	5.92 (2.43)[c]	2.55 (1.59)[c]	1.42 (1.19)[a]	0.80 (0.89)[b]	1.48 (1.22)[a]	3.33 (1.81)[b]
T2	3.42 (1.84)[a]	4.62 (2.14)[b]	5.44 (2.33)[b]	5.62 (2.36)[bc]	1.42 (1.19)[ab]	1.00 (1.02)[a]	0.46 (0.67)[ab]	1.24 (1.12)[a]	2.90 (1.70)[ab]
T3	3.40 (1.83)[a]	4.22 (2.05)[b]	5.24 (2.28)[b]	4.46 (2.11)[b]	1.20 (1.09)[a]	0.90 (0.94)[a]	0.40 (0.61)[a]	1.20 (1.10)[a]	2.63 (1.62)[a]
T4	2.86 (1.70)[a]	1.68 (1.30)[a]	0.82 (0.90)[a]	2.20 (1.50)[a]	2.22 (1.50)[bc]	2.92 (1.69)[b]	6.00 (2.45)[c]	4.40 (2.11)[b]	2.80 (1.67)[a]
T5	15.48 (4.01)[b]	19.96 (4.47)[c]	30.22 (5.49)[c]	20.22 (4.50)[d]	12.62 (3.55)[d]	4.24 (2.06)[c]	11.24 (3.35)[d]	9.52 (3.10)[c]	15.26 (3.90)[c]
Mean	5.72 (2.25)	7.06 (2.47)	9.59 (3.0	7.68 (2.76)	4.04 (2.17)	2.09 (1.44)	3.78 (1.94)	3.56 (1.88)	
S.Em±	0.11	0.09	0.09	0.09	0.12	0.09	0.08	0.10	0.038
CD @ 5%	0.33	0.26	0.28	0.27	0.36	0.27	0.25	0.30	0.119
CV (%)	9.46	6.61	6.35	6.44	12.30	13.65	11.59	18.20	7.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 37. Influence of treatments on the population of thrips on cotton

Treatments	Average population of thrips / three leaves at								
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean
T1	2.10 (1.45)^{b}	4.12 (2.02)^{b}	5.48 (2.34)^{c}	4.98 (2.23)^{c}	3.24 (1.79)^{b}	2.12 (1.46)^{b}	1.68 (1.30)^{b}	1.12 (1.06)^{c}	3.11 (1.76)^{d}
T2	2.20 (1.48)^{b}	4.10 (2.01)^{b}	4.86 (2.18)^{bc}	4.00 (2.04)^{bc}	2.00 (1.41)^{ab}	1.42 (1.19)^{ab}	0.48 (0.69)^{a}	0.20 (0.45)^{a}	2.41 (1.55)^{c}
T3	2.00 (1.42)^{b}	3.68 (1.91)^{ab}	3.60 (4.89)^{ab}	2.84 (1.68)^{ab}	1.40 (1.18)^{a}	1.20 (1.09)^{a}	0.40 (0.65)^{a}	0.18 (0.42)^{a}	1.91 (1.38)^{b}
T4	0.86 (0.93)^{a}	2.64 (1.63)^{a}	2.84 (1.67)^{a}	2.62 (1.61)^{a}	2.12 (1.43)^{ab}	1.32 (1.15)^{a}	0.64 (0.79)^{a}	0.64 (0.08)^{b}	1.71 (1.30)^{a}
T5	9.20 (3.03)^{c}	10.42 (3.22)^{c}	12.22 (3.49)^{d}	10.22 (3.19)^{d}	8.61 (2.93)^{c}	5.21 (2.28)^{c}	2.86 (1.68)^{c}	2.00 (1.41)^{d}	7.60 (2.75)^{e}
Mean	3.27 (1.66)	5.00 (2.16)	5.80 (2.40)	4.90 (2.21)	3.47 (1.80)	2.25 (1.50)	1.21 (1.10)	0.83 (0.55)	
S.Em±	0.08	0.09	0.13	0.14	0.13	0.09	0.07	0.06	0.005
CD @ 5%	0.24	0.28	0.39	0.42	0.38	0.27	0.22	0.11	0.016
CV (%)	10.22	8.27	10.67	12.32	14.07	11.97	13.91	8.35	5.77

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 38. Influence of treatments on the population of whiteflies on cotton

Treatments	Average population of whiteflies / three leaves at						
	60 DAS	**75 DAS**	**90 DAS**	**105 DAS**	**120 DAS**	**135 DAS**	**Mean**
T1	0.12 (0.35)^{a}	0.76 (0.87)^{b}	1.42 (1.19)^{a}	1.84 (1.36)^{bc}	0.74 (0.86)^{b}	0.36 (0.59)^{a}	0.87 (0.93)^{c}
T2	0.10 (0.31)^{a}	0.24 (0.49)^{a}	1.40 (1.18)^{a}	1.82 (1.35)^{bc}	0.68 (0.82)^{ab}	0.30 (0.53)^{a}	0.75 (0.86)^{b}
T3	0.12 (0.35)^{a}	0.22 (0.47)^{a}	1.12 (1.05)^{a}	1.40 (1.18)^{b}	0.44 (0.66)^{a}	0.30 (0.54)^{a}	0.60 (0.77)^{a}
T4	0.10 (0.32)^{a}	0.18 (0.42)^{a}	1.10 (1.05)^{a}	0.92 (0.96)^{a}	0.62 (0.78)^{ab}	0.60 (0.77)^{b}	0.58 (0.76)^{a}
T5	0.12 (0.34)^{a}	1.06 (1.03)^{c}	3.66 (1.90)^{b}	3.90 (1.97)^{c}	4.62 (2.14)^{c}	6.22 (2.50)^{c}	3.26 (1.80)^{d}
Mean	0.11 (0.34)	0.49 (0.65)	1.74 (1.31)	1.97 (1.41)	1.42 (1.20)	1.55 (1.24)	
S.Em±	-	0.02	0. 06	0.08	0.06	0.05	0.005
CD @ 5%	NS	0.07	0.19	0.23	0.19	0.14	0.015
CV (%)	-	7.37	9.52	10.39	11.00	10.68	5.88

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

reducing the pest population. However, as expected T5 (4.62 / 3 leaves) recorded significantly highest population. At 135 DAS, T1 (0.36 / 3 leaves), T2 (0.30 / 3 leaves) and T3 (0.30 / 3 leaves) were similar in their effectiveness in recording whitefly population. RPP (T4) recorded significantly higher population of whitefly (0.60 / 3 leaves). However, untreated check (6.22 / 3 leaves) recorded significantly highest population of whitefly. The mean population of whitefly irrespective of the days of observation in different treatments indicated that significantly lowest population was recorded in T3 (0.60 / 3 leaves) and was statistically at par with RPP (0.58 / 3 leaves). This was followed by T2 (0.75 / 3 leaves), which recorded significantly lower population than T1 (0.87 / 3 leaves). However untreated control (T5) recorded significantly higher whitefly population (3.26 / 3 leaves) (Table 38).

4.5.2 *Helicoverpa armigera* population in different treatments

Helicoverpa armigera egg load was negligible but uniform at 30 DAS on cotton and found non significant among the different treatments (Table 39). At 45 DAS, the egg load was uniform in all the treatments except T4, which recorded significantly lowest egg population of 0.18/plant. At 60 DAS, the different treatments did not have any influence in reducing the egg population as they were statistically on par with each other. However, untreated control (T5) recorded significantly highest of 1.68 eggs / plant. At 75 DAS, significantly lowest egg population (0.58 to 0.80 / plant) was recorded in T1, T2 and T3. RPP (T4) recorded significantly highest of 1.10 eggs / plant being on par with T1 (0.80 eggs / plant). However, as expected, untreated check recorded significantly highest of 1.70 eggs / plant. At 90 DAS, the trend in the efficacy of different treatments remained exactly similar to that of 75 DAS. At 120 DAS, significantly lowest egg population was recorded in T3 (0.12 / plant) and T2 (0.16 / plant) being statistically on par with each other, while T1 was inferior (0.42/plant) to T2 and T3. Significantly highest egg population was recorded in T4 (0.80 / plant) and T5 (1.00 / plant), which were significantly inferior to all other treatments. The average egg load of *H. armigera* was significantly lowest on T3 (0.39 / plant) followed by T2 (0.41 / plant). The next best treatment which received significantly lower egg load was T1 (0.59 / plant). Significantly highest egg load was recorded in RPP (0.76 / plant) but lower than the untreated control (1.14 / plant) (Table 39).

Helicoverpa armigera larval population was nil at 30 DAS. At 45 DAS, none of the treatments except RPP (0.16 / plant) were effective in reducing the larval population as they were statistically on par with untreated check (0.28 larvae / plant). At 60 DAS, significantly lower larval population was recoded in T1, T2 and T3 compared to untreated control (0.82 larvae / plant). However, RPP (T4) recorded significantly lowest larval population of 0.20 larvae / plant. At 75 DAS, T3 (0.30 larvae / plant) recorded significantly lowest population being statistically on par with RPP (0.18 larvae / plant) while T1 (0.62 larvae / plant) and T2 (0.48 larvae / plant) were on par with each other. Significantly highest larval population of 1.36 / plant was noticed in untreated control. At 90 DAS, the efficacy of T2 (0.22 larvae / plant), T3 (0.16 larvae / plant) and T4 (0.20 larvae / plant) remained same, whereas T1 (0.30 larvae / plant) was on par with T2 and T4 in recording the larval population. Significantly highest larval population of 1.12 larvae / plant was recorded in untreated control. At 105 DAS, the efficacy of T1, T2 and T3 remained same, whereas RPP was significantly superior over all other treatments except T3 (0.63 larvae / plant). At 120 DAS, T2 and T3 were significantly superior over rest of the treatments, whereas T1 and T2 were on par with each other. At 135 DAS, significantly lower population of *H. armigera* larvae was recorded in T3 (0.16 larvae / plant) being on par with T1 and T2. However untreated check (0.52 larvae / plant) recorded highest larval population. The pooled analysis of *H. armigera* larval population indicated significantly lowest population in T3 (0.23 larvae / plant) being statistically on par with RPP (0.22 larvae / plant) followed by T2 (0.29 larvae / plant) and T1 (0.35 larvae / plant). Untreated check recorded highest larval population of 0.79 larvae / plant (Table 40).

4.5.3 *Chrysoperla carnea* population in different treatments on cotton

Initially (30 DAS) *C. carnea* population was uniform in different treatments which ranged from 0.38 to 0.52 / plant. At 45 DAS, the efficacy of T1, T2 and T3 remained same in recording *C. carnea* population but significantly superior to RPP (0.62 / plant) and untreated check (1.10 / plant). The trend in the efficacy of different treatments at 60 DAS was exactly similar to that of 45 DAS. At 75 DAS, significantly highest population of *C. carnea* was

Table 39. Influence of treatments on the population of *H. armigera* eggs on cotton

Treatments	Average density of *H. armigera* eggs / plant at								
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean
T1	0.20 (0.45)^{a}	0.32 (0.56)^{b}	1.20 (1.09)^{ab}	0.80 (0.89)^{ab}	0.74 (0.87)^{b}	0.80 (0.89)^{b}	0.42 (0.64)^{b}	0.24 (0.48)^{a}	0.59 (0.76)^{c}
T2	0.20 (0.45)^{a}	0.30 (0.54)^{b}	1.00 (1.02)^{a}	0.60 (0.76)^{a}	0.38 (0.63)^{a}	0.46 (0.68)^{a}	0.16 (0.39)^{a}	0.16 (0.40)^{a}	0.41 (0.64)^{b}
T3	0.20 (0.45)^{a}	0.32 (0.56)^{b}	0.92 (0.96)^{a}	0.58 (0.76)^{a}	0.36 (0.60)^{a}	0.44 (0.66)^{a}	0.12 (0.35)^{a}	0.16 (0.39)^{a}	0.39 (0.62)^{a}
T4	0.24 (0.49)^{a}	0.18 (0.42)^{a}	1.10 (1.04)^{a}	1.10 (1.04)^{b}	0.98 (0.98)^{b}	1.12 (1.18)^{c}	0.80 (0.89)^{c}	0.62 (0.77)^{b}	0.76 (0.87)^{d}
T5	0.24 (0.49)^{a}	0.34 (0.58)^{b}	1.68 (1.27)^{b}	1.70 (1.30)^{c}	1.62 (1.27)^{c}	1.72 (1.34)^{d}	1.00 (1.02)^{c}	0.68 (0.82)^{b}	1.14 (1.06)^{e}
Mean	0.22 (0.47)	0.29 (0.53)	1.18 (1.07)	0.95 (0.95)	0.82 (0.90)	0.91 (0.95)	0.50 (0.70)	0.37 (0.60)	
S.Em±		0.03	0.06	0.05	0.04	0.04	0.05	0.40	0.005
CD @ 5%	NS	0.10	0.18	0.16	0.12	0.11	0.14	0.12	0.016
CV (%)		12.25	11.38	12.06	9.94	8.40	14.90	13.79	4.60

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 40. Influence of treatments on the population of *H. armigera* larvae on cotton

Treatments	Average population of *H. armigera* larvae / plant at							
	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean
T1	0.26 (0.50)^{b}	0.48 (0.69)^{b}	0.62 (0.77)^{c}	0.30 (0.55)^{b}	0.62 (0.78)^{b}	0.32 (0.56)^{b}	0.24 (0.49)^{ab}	0.35 (0.59)^{c}
T2	0.28 (0.52)^{b}	0.42 (0.64)^{b}	0.48 (0.69)^{bc}	0.22 (0.47)^{ab}	0.50 (0.70)^{b}	0.26 (0.50)^{ab}	0.20 (0.45)^{ab}	0.29 (0.53)^{b}
T3	0.24 (0.5)^{b}	0.40 (0.63)^{b}	0.30 (0.54)^{ab}	0.16 (0.40)^{a}	0.40 (0.63)^{ab}	0.20 (0.44)^{a}	0.16 (0.38)^{a}	0.23 (0.47)^{a}
T4	0.16 (0.40)^{a}	0.20 (0.44)^{a}	0.18 (0.42)^{a}	0.20 (0.45)^{ab}	0.20 (0.45)^{a}	0.48 (0.69)^{c}	0.28 (0.53)^{b}	0.22 (0.46)^{a}
T5	0.28 (0.54)^{b}	0.82 (0.91)^{c}	1.36 (1.16)^{d}	1.12 (1.08)^{c}	1.42 (1.19)^{c}	0.80 (0.89)^{d}	0.52 (0.71)^{c}	0.79 (0.87)^{d}
Mean	0.24 (0.49)	0.46 (0.68)	0.59 (0.76)	0.40 (0.59)	0.63 (0.79)	0.41 (0.64)	0.28 (0.52)	
S.Em±	0.02	0.04	0.05	0.04	0.06	0.03	0.04	0.016
CD @ 5%	0.06	0.12	0.16	0.12	0.18	0.10	0.12	0.049
CV (%)	8.38	11.38	13.10	12.31	14.32	11.23	14.81	6.40

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 41. Influence of treatments on the population of *C. carnea* on cotton

Treatments	Average population of *C. carnea* / plant at								
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**105 DAS**	**120 DAS**	**135 DAS**	**Mean**
T1	0.42 (0.65)[a]	1.82 (1.35)[a]	3.86 (1.97)[a]	4.20 (2.04)[b]	5.12 (2.26)[b]	6.82 (2.61)[b]	4.64 (2.15)[b]	3.48 (1.86)[b]	3.89 (1.97)[c]
T2	0.48 (0.69)[a]	1.94 (1.39)[a]	4.10 (2.02)[a]	6.12 (2.47)[a]	6.22 (2.48)[ab]	7.68 (2.77)[ab]	5.68 (2.38)[ab]	4.22 (2.05)[ab]	4.55 (2.13)[b]
T3	0.52 (0.71)[a]	2.00 (1.41)[a]	4.66 (2.15)[a]	6.72 (2.57)[a]	6.82 (2.61)[a]	9.00 (3.10)[a]	6.42 (2.53)[a]	5.20 (2.28)[a]	5.16 (2.27)[a]
T4	0.38 (0.61)[a]	0.62 (0.79)[c]	0.32 (0.57)[c]	0.42 (0.65)[d]	0.46 (0.68)[d]	0.64 (0.82)[d]	0.42 (0.65)[d]	0.40 (0.64)[d]	0.46 (0.67)[e]
T5	0.46 (0.68)[a]	1.10 (1.17)[b]	1.98 (1.40)[b]	2.10 (1.43)[c]	2.10 (1.45)[c]	2.20 (1.48)[c]	1.64 (1.28)[c]	1.42 (1.20)[c]	1.62 (1.27)[d]
Mean	0.45 (0.67)	1.50 (1.22)	2.98 (1.62)	3.91 (1.90)	4.14 (1.9)	5.27 (2.16)	3.76 (1.79)	2.94 (1.61)	
S.Em±		0.05	0.09	0.12	0.10	0.16	0.12	0.10	0.005
CD @ 5%		0.16	0.27	0.36	0.31	0.46	0.37	0.32	0.015
CV (%)		8.34	10.69	12.44	10.60	14.24	12.80	12.03	4.62

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 42. Mean population of *C. carnea* on Lucerne

Treatments	Average population of *C. carnea* / m. row length at					
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**Mean**
T1	0.58 (0.75)[a]	2.46 (1.56)[a]	4.10 (2.02)[a]	7.82 (2.79)[c]	8.54 (2.92)[b]	4.70 (2.17)[c]
T2	0.56 (0.72)[a]	2.82 (1.66)[a]	4.22 (2.05)[a]	8.48 (2.90)[b]	9.22 (3.03)[ab]	5.06 (2.25)[b]
T3	0.58 (0.75)[a]	3.00 (1.82)[a]	5.20 (2.28)[a]	9.42 (3.07)[a]	10.42 (3.22)[a]	5.72 (2.39)[a]
Mean	0.57 (0.68)	2.76 (1.68)	4.51 (2.17)	8.57 (2.92)	9.40 (3.06)	
S.Em±	---	---	---	0.08	0.09	0.012
CD @ 5%	NS	NS	NS	(0.16)	(0.27)	0.036
CV %	---	---	---	9.80	10.20	4.90

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

T1. 1. Seed treatment with imidacloprid (70 WS) (10 g / kg), 2. Intercropping of lucerne, 3. Application of 5% NSKE 4. Monitoring of *H.armigera* through sex pheromone traps (2 traps/ac), 5. Release of *C.carnea* thrice starting from early reproductive phase at 15 days interval (50,000/ha), **T2=T1**(1-4) + 75,000 *C.carnea* / ha**, T3=T1** (1-4) + 1,00,000 *C.carnea* / ha

noticed in T2 (6.12 / plant) and T3 (6.72 / plant), whereas, T1 (4.20 / plant) was inferior to T2 and T3 but superior to T4 (0.42 / plant) and T5 (2.10 / plant). RPP recorded significantly lowest population of 0.42 / plant. Almost similar trend in the efficacy of treatments was noticed from 90 DAS onwards till 135 DAS as that of 75 DAS. The mean population of *C. carnea* indicated significantly highest population in T3 (5.16 / plant) followed by T2 (4.55 / plant) and T1 (3.89 / plant). Least population was recorded in untreated check (T5) (1.62 / plant) but higher than RPP (T4) (0.46 / plant) (Table 41).

On Lucerne, the population of *C. carnea* was uniform in all the treatments as indicated by non significant differences at 30, 45 and 60 DAS. At 75 DAS significantly highest *Chrysoperla* population was recorded in T3 (9.42 / m.row) followed by T2 (8.48 / m.row). Significantly lowest population was noticed in T1 (7.82 / m. row). At 90 DAS, significantly highest population of 10.42 / m. row was recorded in T3 being on par with T2 (9.22 / m.row). T1 which recorded lowest population of 8.54 / m.row was on par with T2. The average population of *C. carnea* on lucerne indicated that significantly higher population was recorded in T3 (5.72 / m. row) followed by T2 (5.06 / m. row) and T1 (4.70 / m. row) (Table 42).

4.5.4. Fruiting bodies damage by *H. armigera* in different treatments

Fruiting bodies damage up to 45 DAS was below economic threshold level (< 10%) in all the treatments. However, significantly lowest fruiting bodies damage was noticed in T4 (2.46%), followed by T3 (5.84%). T1 and T2 were ineffective as they were statistically on par with untreated check (8.22%). At 60 DAS, T4 recorded significantly lowest fruiting damage of 5.44 per cent being on par with T3 (7.80%). T2 and T3 were equally effective. T1 (12.40%) was ineffective as it was on par with T5 (14.60%). At 75 DAS, T4 (8.42%), T3 (10.20%) and T2 (12.00%) were equally effective in recording the fruiting bodies damage. T1 (15.62%) and T2 were on par with each other. Untreated check (24.64%) recorded highest damage of the fruiting bodies being significantly inferior to all other treatments. At 90 DAS, T4 (7.24%) and T3 (8.20%) were equally effective. This was followed by T2 (10.20%) and T1 (13.68%). Significantly highest damage to the fruiting bodies was recorded in T5 (17.20%) being significantly inferior to all other treatments. Exactly similar trend in the efficacy of different treatments was observed at 105 DAS as that of 90 DAS. At 120 DAS, T4 (8.90%), T3 (10.20%) and T2 (10.40%) were equally effective when untreated check recorded significantly highest damage of 18.00 per cent to fruiting bodies. Almost similar trend in the efficacy of different treatments was noticed at 130 DAS as that of 120 DAS, The average fruiting bodies damage indicated that T4 (7.09%) and T3 (8.74%) were equally effective .T2 (10.25%) and T3 (8.74%) were on par with each other followed by T1 (13.20%). Significantly highest fruiting bodies damage of 18.00 per cent was noticed in T5.

4.5.5 Yield and yield parameters

T2 (21.96), T3 (22.60) and T4 (23.00) were equally effective in recording GOB / plant, followed by T1 (15.36). However, untreated check (7.00) recorded significantly lowest GOB / plant (Table 43).

Table 43: Influence of treatments on fruiting bodies damage due to bollworms

Similarly, T2 (13.94), T3 (12.86) and T4 (12.80) were equally effective in recording BOB / plant. T1 (15.60) and T2 (13.94) were ineffective as they were on par with untreated check (16.20) (Table 44).

Table 44: Yield and yield parameters of cotton as influenced by different treatments

Significantly lowest locule damage by pink bollworm was noticed in T4 (10.68%) being on par with T3 (15.44%). T1 (23.60%) and T2 (19.82%) were on par with each other. Significantly highest locule damage of 32.60 per cent was recorded in untreated check.

Significantly highest seed cotton yield was recorded in T3 (9.00 q / ha) and T2 (8.40 q / ha) being on par with RPP (9.10 q / ha). T1 (7.20 q / ha) and T2 (8.40 q / ha) were equally effective in recording the seed cotton yield. However untreated check recorded significantly lowest seed cotton yield of 5.20 q / ha (Table 44).

Table 43. Influence of treatments on fruiting bodies damage due to bollworms

Treatments	Per cent fruiting bodies damage at different DAS							Average
	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	
T1	8.00	12.40	15.62	13.68	16.82	13.20	12.60	13.20
	(16.43)^{c}	(20.62)^{cd}	(23.28)^{b}	(21.68)^{c}	(24.22)^{c}	(21.29)^{b}	(20.79)^{b}	(21.18)^{c}
T2	7.60	9.68	12.00	10.20	12.68	10.40	9.20	10.25
	(16.00)^{c}	(18.10)^{bc}	(20.27)^{ab}	(18.63)^{b}	(20.82)^{b}	(18.81)^{ab}	(17.66)^{a}	(18.63)^{b}
T3	5.84	7.80	10.20	8.20	10.68	10.20	8.06	8.74
	(13.96)^{b}	(16.22)^{ab}	(18.63)^{a}	(16.64)^{ab}	(19.09)^{ab}	(18.63)^{ab}	(16.54)^{a}	(17.10)^{ab}
T4	2.46	5.44	8.42	7.24	9.22	8.90	8.00	7.09
	(8.96)^{a}	(13.46)^{a}	(16.85)^{a}	(15.80)^{a}	(17.66)^{a}	(17.36)^{a}	(16.43)^{a}	(15.45)^{a}
T5	8.22	14.60	24.64	17.20	26.80	18.00	17.60	18.00
	(16.66)^{c}	(22.46)^{b}	(29.73)^{c}	(24.50)^{d}	(31.18)^{d}	(25.10)^{c}	(24.80)^{c}	(24.80)^{d}
Mean	6.42	9.98	14.17	11.30	15.24	12.44	11.09	
	(10.80)	(14.90)	(18.39)	(15.18)	(18.06)	(16.96)	(16.24)	
S Em +	0.63	0.96	1.26	0.75	1.10	0.87	0.91	0.85
CD at 5%	1.94	2.92	3.82	2.30	3.04	2.66	2.76	2.60
CV (%)	13.50	10.64	11.40	12.60	13.20	10.30	9.80	14.30

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are Arc sine transformed values

DAS: Days after sowing

Table 44. Yield and yield parameters of cotton as influenced by different treatments

Treatments	Parameters			
	GOB / Plant	BOB / Plant	% locule damage	Yield (Q/ha)
T1	15.36 [b]	15.60 [b]	23.60 (29.06)[c]	7.20 [b]
T2	21.96 [a]	13.94 [ab]	19.82 (26.48)[bc]	8.40 [ab]
T3	22.60 [a]	12.86 [a]	15.44 (23.11)[ab]	9.00 [a]
T4	23.00 [a]	12.80 [a]	10.68 (19.2)[a]	9.10 [a]
T5	7.00[c]	16.20 [b]	32.60 (34.82)[d]	5.20[c]
S.Em±	1.13	0.87	1.50	0.49
CD @ 5%	3.47	2.60	4.2	1.52
CV %	12.00	14.23	15.80	12.31

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are Arc sine transformed values.

GOB: Good opened bolls BOB: Bad opened bolls

4.5.6 Sucking pests incidence on sunflower in different treatments

The leafhopper, *A. biguttella biguttella* population at early stage of the crop growth was significantly lower (30 DAS) in T1, T2, T3 and T4 being at par (1.34, 1.30, 1.34 and 1.22 / 3 leaves, respectively) with each other. Untreated check recorded significantly highest population of 8.24 / 3 leaves. At peak incidence stage (40 DAS), all the *C. carnea* released plots recorded uniform leafhopper population being on par with each other but significantly superior to untreated check. RPP recorded significantly lowest population of 1.82 / 3 leaves. However untreated check recorded significantly highest population of 16.22 / 3 leaves. Exactly similar trend in the efficacy of treatments was seen at 50 DAS as that of 40 DAS. At 60 DAS, T2 (2.20 / 3 leaves) and T3 (2.00 / 3 leaves) recorded significantly lowest population being on par with RPP (2.00 / 3 leaves), while T1 (2.98 / 3 leaves) was significantly inferior to T2, T3 and T4. However, untreated check recorded significantly highest population of 6.80 / 3 leaves. Similar trend in the effectiveness of various treatments was observed at 70 DAS as that of 60 DAS. At 80 DAS, all the *C. carnea* released plots recorded significantly lowest leafhopper population being on par with each other but superior to RPP (1.68/ 3 leaves). Untreated check recorded significantly highest population of 3. 84 / 3 leaves. At 90 DAS, all the predator released plots including RPP were equally effective in recording the leafhopper population but superior to untreated check (1.84 / 3 leaves). The average population indicated that significantly lower leafhopper population in T3 (2.61 / 3 leaves) followed by T2 (2.72 / 3 leaves) and T1 (2.98 / 3 leaves). However RPP (T4) recorded significantly lower population of leafhoppers (1.61 / 3 leaves). Untreated check recorded significantly higher population of 7.52 / 3 leaves (Table 45).

Table 45: Influence of treatments on the population of leaf hopper on sunflower

In general, the average population of thrips, *Scirtothrips dorsalis* was on the increase up to 40 DAS. Later it gradually declined reaching a minimum of 1.12 / 3 leaves at 90 DAS in untreated check. At 30 DAS, significantly lowest population of thrips was noticed in all the *C. carnea* released plots and RPP, all being on par with each other. However, untreated check recorded highest thrips population of 12.10 / 3 leaves. At 40 DAS, all the *C. carnea* released plots were similar in their effectiveness in recording thrips population but inferior to RPP (0.61 / 3 leaves). Untreated check recorded significantly highest thrips population of 16.48 / 3 leaves. At 50 DAS, significantly lowest thrips population was noticed in T2 (1.22 / 3 leaves) and T3 (1.02 / 3 leaves), these two treatments were inferior to RPP (0.42 / 3 leaves) but superior to T1 (2.12 / 3 leaves). As expected, untreated check recorded significantly highest population of thrips (8.28 / 3 leaves). At 60 DAS, T2 (1.00 / 3 leaves), T3 (0.98 / 3 leaves) and RPP (0.86 / 3 leaves) were equally effective but superior to T1 (1.68/ 3 leaves) and untreated check (3.84 / 3 leaves). At 70 DAS, significantly lowest thrips population was observed in T2 (0.50 / 3 leaves) and T3 (0.48 / 3 leaves) being on par with each other but superior to T1 (0.74 / 3 leaves) and RPP (1.22 / 3 leaves). However untreated check recorded significantly highest population of 5.41 / 3 leaves. At 80 DAS, the trend in the efficacy of various treatments almost remained similar to that of 70 DAS. At 90 DAS, all the three *C.carnea* released plots recorded significantly lowest population being on par with each other but superior to RPP (0.96 / 3 leaves) and untreated check (1.12 / 3 leaves). RPP was ineffective in reducing the pest load as it was on par with untreated check. The trend in the efficacy of various treatments in recording thrips population remained exactly similar to that of leafhopper where T3 recorded significantly lower population (0.90 / 3 leaves) followed by T2 (1.01 / 3 leaves). However RPP recorded significantly lowest thrips population of 0.87 / 3 leaves (Table 46).

At 30 DAS, the whitefly, *B. tabaci* population in all the *C. carnea* released plots and RPP was uniform but significantly lower than untreated check (2.62 / 3leaves). At 40 DAS, significantly lowest whitefly population was observed in T2 (1.20 / 3 leaves) and T3 (1.12 / 3 leaves) both being on par with each other but inferior to RPP (0.40 / 3 leaves) and superior to T1 (1.62 / 3 leaves). However, untreated check recorded significantly highest population of 3.42 / 3 leaves. At 50 DAS, T3 recorded significantly lowest population of 1.52 / 3 leaves being statistically superior to T1 (3.00 / 3 leaves) and T2 (2.30 / 3 leaves), but inferior to RPP (0.48 / 3 leaves). Untreated check recorded significantly highest population of 8.66 / 3 leaves. At 60 DAS, T2 (1.12 / 3 leaves), T3 (0.90 / 3 leaves) and T4 (0.88 / 3 leaves) were equally effective in recording the whitefly population and they were significantly superior to T1 (1.64 /

Table 45. Influence of treatments on the population of leaf hopper on sunflower

Treatments	Average population of leafhopper / three leaves at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	1.34 (1.15)[a]	5.62 (2.37)[b]	6.24 (2.49)[b]	2.98 (1.73)[b]	2.28 (1.51)[b]	1.52 (1.22)[a]	0.88 (0.94)[a]	2.98 (1.72)[d]
T2	1.30 (1.14)[a]	5.70 (2.38)[b]	5.98 (2.44)[b]	2.20 (1.47)[a]	1.82 (1.35)[a]	1.20 (1.08)[a]	0.84 (0.92)[a]	2.72 (1.64)[c]
T3	1.34 (1.14)[a]	5.64 (2.37)[b]	5.66 (2.37)[b]	2.00 (1.41)[a]	1.80 (1.34)[a]	1.00 (1.02)[a]	0.84 (0.92)[a]	2.61 (1.61)[b]
T4	1.22 (1.10)[a]	1.82 (1.34)[a]	1.98 (1.41)[a]	2.00 (1.41)[a]	1.62 (1.27)[a]	1.68 (1.29)[b]	0.96 (0.98)[a]	1.61 (1.26)[a]
T5	8.24 (2.87)[b]	16.22 (4.03)[c]	10.82 (3.28)[c]	6.80 (2.6)[c]	4.86 (2.20)[c]	3.84 (1.96)[c]	1.84 (1.36)[b]	7.52 (2.74)[e]
Mean	2.68 (1.48)	7.00 (2.49)	6.13 (2.39)	3.19 (1.72)	2.47 (1.53)	1.85 (1.31)	1.07 (1.02)	
S.Em±	0.07	0.09	0.10	0.07	0.05	0.07	0.06	0.005
CD @ 5%	0.21	0.29	0.32	0.22	0.15	0.20	0.18	0.015
CV %	6.70	6.07	8.13	7.81	6.05	9.86	17.80	4.21

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 46. Influence of treatments on the population of thrips on sunflower

Treatments	Average population of thrips / three leaves at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	1.62 (1.27)[a]	2.98 (1.73)[b]	2.12 (1.45)[c]	1.68 (1.29)[b]	0.74 (0.86)[b]	0.30 (0.54)[b]	0.16 (0.40)[a]	1.37 (1.17)[d]
T2	1.54 (1.21)[a]	2.52 (1.60)[b]	1.22 (1.10)[b]	1.00 (1.02)[a]	0.50 (0.71)[a]	0.18 (0.43)[ab]	0.12 (0.35)[a]	1.01 (1.00)[c]
T3	1.56 (1.22)[a]	2.00 (1.40)[b]	1.02 (1.01)[b]	0.98 (0.99)[a]	0.48 (0.69)[a]	0.12 (0.34)[a]	0.12 (0.35)[a]	0.90 (0.95)[b]
T4	1.00 (102)[a]	0.61 (0.78)[a]	0.42 (0.65)[a]	0.86 (0.91)[a]	1.22 (1.10)[c]	1.00 (1.02)[c]	0.96 (0.98)[bc]	0.87 (0.93)[a]
T5	12.10 (3.48)[b]	16.48 (4.03)[c]	8.28 (2.87)[d]	3.84 (1.95)[c]	5.41 (2.32)[d]	3.20 (1.80)[d]	1.12 (1.06)[c]	7.20 (2.68)[e]
Mean	3.56 (1.64)	4.92 (1.96)	2.61 (1.42)	1.67 (1.23)	1.67 (1.14)	0.96 (0.82)	0.50 (0.63)	
S.Em±	0.11	0.10	0.04	0.07	0.05	0.05	0.07	0.005
CD @ 5%	0.33	0.31	0.12	0.23	0.14	0.14	0.21	0.015
CV %	13.21	10.41	5.24	11.86	7.86	12.97	14.60	6.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 47. Influence of treatments on the population of whiteflies on sunflower

Treatments	Average population of whiteflies / three leaves at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	0.90 (0.94)^{a}	1.62 (1.27)^{c}	3.00 (1.73)^{c}	1.64 (1.26)^{b}	0.54 (0.74)^{b}	0.52 (0.72)^{b}	0.32 (0.56)^{ab}	1.22 (1.10)^{d}
T2	0.90 (0.94)^{a}	1.20 (1.10)^{b}	2.30 (1.52)^{c}	1.12 (1.05)^{a}	0.38 (0.61)^{ab}	0.32 (0.56)^{a}	0.28 (0.53)^{ab}	1.06 (0.03)^{c}
T3	0.88 (0.93)^{a}	1.12 (1.06)^{b}	1.52 (1.23)^{b}	0.90 (0.94)^{a}	0.30 (0.55)^{a}	0.28 (0.53)^{a}	0.24 (0.49)^{a}	0.74 (0.86)^{b}
T4	0.86 (0.92)^{a}	0.40 (0.63)^{a}	0.48 (0.69)^{a}	0.88 (0.93)^{a}	0.42 (0.64)^{ab}	0.68 (0.82)^{b}	0.40 (0.63)^{b}	0.58 (0.76)^{a}
T5	2.62 (1.58)^{b}	3.42 (1.85)^{d}	8.66 (2.94)^{d}	10.22 (3.19)^{c}	9.22 (3.04)^{c}	3.92 (1.97)^{c}	2.20 (1.48)^{c}	5.75 (2.40)^{e}
Mean	1.23 (1.06)	1.55 (1.18)	3.19 (1.67)	2.96 (1.48)	2.17 (1.12)	1.15 (0.92)	0.68 (0.74)	
S.Em±	0.07	0.04	0.08	0.04	0.05	0.05	0.04	0.016
CD @ 5%	0.22	0.12	0.24	0.13	0.14	0.15	0.12	0.048
CV %	13.24	5.99	9.58	6.67	9.26	11.09	14.80	5.62

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

3 leaves). However, untreated check recorded significantly highest population of 10.22 / 3 leaves. Almost similar trend in the efficacy of various treatments was noticed at 70 DAS as that of 60 DAS. At 80 DAS, T2 (0.32 / 3 leaves) and T3 (0.28 / 3 leaves) were equally effective and they were significantly superior to T1 (0.52 / 3 leaves) and T4 (0.68 / 3 leaves). Untreated check recorded a highest of 3.92 / 3 leaves. At 90 DAS, the trend in the efficacy of different treatments was similar to that of 80 DAS. The pooled analysis of data of whitefly population once again indicated similar trend in the efficacy of various treatments in recording whitefly population as that of leafhoppers and thrips where T3 (0.74 / 3 leaves) was significantly superior followed by T2 (1.06 / 3 leaves). RPP (T4) recorded significantly lowest whitefly population of 0.58 / 3 leaves (Table 47).

Table 47: Influence of treatments on the population of whiteflies on sunflower

4.5.7 Capitulam borer incidence in different treatments on sunflower

The egg load of *H. armigera* in different treatments was uniform at 30 DAS as indicated by non-significant differences. At 40 DAS, the egg load in all the *C. carnea* released plots and RPP was uniform. However untreated check recorded maximum of 0.42 eggs / plant being significantly inferior to all other treatments. At 50 DAS, T3 recorded significantly lowest egg load of 0.30 / plant being on par with T2 (0.42 / plant), while T1 (0.54 / plant) was on par with T2. RPP (0.72 / plant) was ineffective as it was on par with untreated check (0.92 / plant).

At 60 DAS, once again T3 (0.46 / plant) recorded significantly lowest egg population. T1 (0.70 / plant) and T2 (0.68 / plant) were on par with each other. RPP (1.06 / plant) was inferior to all the predator released plots. Untreated check recorded a highest of 1.62 egg / plant. The efficacy of different treatments at 70 DAS was almost similar to that of 60 DAS. At 80 DAS, significantly lowest egg load was observed in T2 (0.28 / plant) and T3 (0.22 / plant), being on par with each other. Whereas, T1 (0.56 / plant) and RPP (T4) (0.66 / plant) were equally effective. Untreated check recorded significantly highest egg population of 1.20 / plant. At 90 DAS, all the *C. carnea* released plots were equally effective in recording the egg population which ranged from 0.12 to 0.20 / plant. RPP (0.62 / plant) was inferior to above treatments. Significantly highest egg load of 0.86 / plant was recorded in untreated check. The average *H. armigera* egg load was significantly lowest in T3 (0.29 / plant) and T2 (0.37 / plant) being statistically on par with each other. The next best treatment was T1 (0.48 / plant) followed by T4 (0.74 / plant). Significantly highest *Helicoverpa* egg load was recorded in untreated check (1.21 / plant) (Table 48).

Helicoverpa armigera larval population was uniform in all the treatments at 30 DAS and found non significant with each other. At 40 DAS, significantly lower larval population was recorded in T3 (0.06 larvae / plant), which was on par with RPP (0.04 larvae / plant). Whereas, T1, T2, and T5 recorded 0.12 larvae / plant being inferior to T3 and T4. At 50 DAS, both T2 and T3 recorded 0.12 larvae / plant being significantly superior to T1 (0.20 larvae / plant). RPP (0.04 larvae / plant) recorded significantly lowest larval population. Untreated check recorded significantly highest larval population of 0.42 larvae / plant. At 60 DAS significantly lower larval population was recorded in T2 and T3 compared to untreated control (1.12 larvae / plant). However, RPP recorded significantly lowest larval population of 0.12 larvae / plant. At 70 DAS, T3 (0.30 larvae/ plant), T2 (0.34 larvae / plant) and T1 (0.48 larvae / plant) recorded significantly lower larval population than untreated control (1.94 larvae / plant). Significantly highest larval population of 1.94 / plant was noticed in untreated control. At 80 DAS, the efficacy of T2 (0.24 larvae / plant), T3 (0.24 / larvae / plant) and T4 (0.26 / larvae / plant) remained same, whereas T1 (0.36 larvae / plant) was on par with T4 in recording the larval population. Significantly highest larval population of 1.24 / plant was recorded in untreated control. At 90 DAS, the efficacy of T1, T2 and T3 remained same, whereas RPP (0.40 larvae / plant) was inferior over all the treatments except T5 (0.96 larvae / plant). The average population of *Helicoverpa* larvae once again confirmed the superiority of T3 (0.16 larvae / plant) and T2 (0.19 larvae / plant) which were statistically at par with T4 (0.17 larvae / plant). Significantly higher larval population was recorded in T1 (0.28 larvae / plant) but significantly lower than untreated control (0.84 / plant) (Table 49).

4.5.8 *Chrysoperla carnea* population in different treatments on sunflower

Initially at 30 DAS, *C. carnea* population was uniform in different treatments which ranged from 0.52 to 0.60 / plant. At 40 DAS, the efficacy of T2 and T3 remained same in

Table 48. Influence of treatments on the population of *H. armigera* eggs on sunflower

Treatments	Average population of *H. armigera* eggs / plant at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	0.24 (0.48)^{a}	0.36 (0.60)^{ab}	0.54 (0.72)^{b}	0.70 (0.83)^{b}	0.82 (0.90)^{b}	0.56 (0.75)^{b}	0.20 (0.44)^{a}	0.48 (0.69)^{b}
T2	0.26 (0.51)^{a}	0.32 (0.56)^{a}	0.42 (0.65)^{ab}	0.68 (0.82)^{b}	0.52 (0.71)^{ab}	0.28 (0.53)^{a}	0.16 (0.40)^{a}	0.37 (0.60)^{a}
T3	0.26 (0.51)^{a}	0.32 (0.56)^{a}	0.30 (0.54)^{a}	0.46 (0.67)^{a}	0.36 (0.60)^{a}	0.22 (0.46)^{a}	0.12 (0.35)^{a}	0.29 (0.54)^{a}
T4	0.24 (0.48)^{a}	0.40 (0.63)^{ab}	0.72 (0.85)^{c}	1.06 (1.03)^{c}	1.46 (1.20)^{c}	0.66 (0.81)^{b}	0.62 (0.78)^{b}	0.74 (0.86)^{c}
T5	0.24 (0.48)^{a}	0.42 (0.65)^{b}	0.92 (0.96)^{c}	1.62 (1.27)^{d}	3.24 (1.79)^{d}	1.20 (1.10)^{c}	0.86 (0.92)^{c}	1.21 (1.09)^{d}
Mean	0.25 (0.47)	0.44 (0.66)	0.58 (0.74)	0.90 (0.92)	1.28 (1.05)	0.59 (0.74)	0.39 (0.58)	
S.Em±	---	0.03	0.04	0.04	0.06	0.03	0.03	0.022
CD @ 5%	NS	0.08	0.12	0.11	0.19	0.08	0.09	0.067
CV %	---	8.86	10.98	7.52	12.12	6.68	10.00	4.20

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 49. Influence of treatments on the population of *H. armigera* larvae on sunflower

Treatments	Average population of *H. armigera* larvae / plant at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	0.12 (0.34)^{a}	0.12 (0.35)^{b}	0.20 (0.45)^{c}	0.38 (0.61)^{c}	0.48 (0.69)^{b}	0.36 (0.60)^{b}	0.12 (0.35)^{b}	0.28 (0.52)^{b}
T2	0.08 (0.28)^{a}	0.12 (0.35)^{b}	0.12 (0.35)^{b}	0.32 (0.57)^{bc}	0.34 (0.57)^{ab}	0.24 (0.49)^{a}	0.08 (0.28)^{ab}	0.19 (0.43)^{a}
T3	0.08 (0.28)^{a}	0.06 (0.24)^{a}	0.12 (0.35)^{b}	0.28 (0.53)^{b}	0.30 (0.55)^{ab}	0.24 (0.49)^{a}	0.04 (0.2)^{a}	0.16 (0.40)^{a}
T4	0.10 (0.31)^{a}	0.04 (0.20)^{a}	0.04 (0.20)^{a}	0.12 (0.35)^{a}	0.22 (0.46)^{a}	0.26 (0.50)^{ab}	0.40 (0.63)^{c}	0.17 (0.41)^{a}
T5	0.12 (0.34)^{a}	0.12 (0.35)^{b}	0.42 (0.65)^{d}	1.12 (1.05)^{d}	1.94 (1.39)^{c}	1.24 (1.11)^{c}	0.96 (0.98)^{d}	0.84 (0.91)^{c}
Mean	0.10 (0.31)	0.09 (0.30)	0.17 (0.38)	0.46 (0.64)	0.65 (0.73)	0.47 (0.67)	0.32 (0.55)	
S.Em±	---	0.02	0.03	0.03	0.05	0.03	0.05	0.016
CD @ 5%	NS	0.04	0.08	0.09	0.14	0.10	0.14	0.048
CV %	---	15.91	14.52	9.65	11.31	7.76	8.20	5.66

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

Table 50. Influence of treatments on the population of *C. carnea* on sunflower

Treatments	Average population of *C. carnea* / plant at							
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**Mean**
T1	0.58 (0.76)[a]	0.98 (0.99)[b]	2.88 (1.69)[b]	4.28 (2.06)[b]	6.42 (2.53)[b]	4.12 (2.03)[b]	2.40 (1.55)[b]	3.09 (1.75)[c]
T2	0.60 (0.77)[a]	1.86 (1.36)[a]	3.86 (1.96)[b]	6.24 (2.49)[ab]	8.62 (2.93)[ab]	6.00 (2.44)[a]	3.62 (1.90)[ab]	4.40 (2.09)[b]
T3	0.60 (0.77)[a]	2.44 (1.56)[a]	5.22 (2.28)[a]	8.80 (2.95)[a]	10.44 (3.23)[a]	7.68 (2.77)[a]	4.22 (2.05)[a]	5.62 (2.37)[a]
T4	0.52 (0.72)[a]	0.22 (0.46)[c]	0.44 (0.66)[d]	0.48 (0.69)[d]	0.52 (0.72)[d]	0.62 (0.78)[d]	0.42 (0.65)[d]	0.46 (0.67)[e]
T5	0.60 (0.77)[a]	0.42 (0.64)[c]	1.22 (1.10)[c]	1.70 (1.30)[c]	2.20 (1.48)[c]	1.60 (1.26)[c]	1.22 (1.10)[c]	1.28 (1.13)[d]
Mean	0.58 (0.76)	1.18 (1.08)	2.72 (1.60)	4.22 (2.05)	5.64 (2.37)	4.00 (1.98)	2.37 (1.50)	
S.Em±	---	0.09	0.13	0.14	0.18	0.13	0.11	0.016
CD @ 5%	NS	0.28	0.36	0.46	0.58	0.39	0.36	0.048
CV %	---	6.41	8.44	12.88	12.00	8.66	9.20	6.42

Means followed by similar alphabets in the vertical columns do not differ significantly by DMRT

Figures in the parentheses are square root transformed values.

DAS: Days after sowing

recording *C. carnea* population but significantly superior to T4 (0.98 / plant) and untreated check (0.42 / plant). At 50 DAS, significantly highest *C. carnea* population was recorded in T3 (5.22 / plant) followed by T2 (3.86 / plant) and T1 (2.88 / plant) these two treatments were on par with each other. Significantly lowest population was registered in RPP (0.44 / plant). At 60 DAS, significantly highest *C. carnea* population was recorded in T3 (8.80 / plant) and T2 (6.24 / plant) being on par with each other. Whereas, T1 (4.28 /plant) was inferior to T3 and T2 but superior to T4 (0.48 / plant) and T5 (1.70 / plant). The trend in the efficacy of different treatments at 70 DAS was exactly similar to that of 60 DAS. At 80 DAS, significantly highest population of *C. carnea* was noticed in T2 (6.00 / plant) and T3 (7.68 / plant), whereas T1 (4.12 / plant) was inferior to T2 and T3 but superior to T4 (0.62 / plant) and T5 (1.60 / plant). RPP recorded significantly lowest population of 0.62 / plant. Almost similar trend in the efficacy of different treatments was noticed at 90 DAS as that of 80 DAS (Table 50). The pooled analysis of data on population of *C.carnea* indicated significantly highest population in T3 (5.62 / plant) followed by T2 (4.40 / plant). The next best treatment in recording highest *C.carnea* population was T1 (3.09 /plant). RPP (T4) recorded significantly lowest population of *Chrysoperla* (0.46 / plant) while T5 recorded 1.28 *C. carnea* / plant (Table 50).

Significantly highest grain yield was recorded in T2 (8.20 q / ha), T3 (9.40 q / ha) being on par with T4 (9.50 q / ha). T1 (7.30 q / ha) and T2 (8.20 q / ha) were equally effective in recording the grain yield. However untreated check recorded significantly lowest grain yield of 5.00 q / ha (Table 51).

Table 51. Influence of different treatments on yield of sunflower

Treatments	Yield (q/ ha)
T1	7.30 b
T2	8.20 ab
T3	9.40 a
T4	9.50 a
T5	5.00 c
S.Em±	0.56
CD @ 5%	1.68
CV (%)	16.40

V. DISCUSSION

The results obtained on the ovipositional preference, wind tunnel olfactometer response and electroantennogram (EAG) response of *Chrysoperla carnea* (Stephens) and *Helicoverpa armigera* (Hubner) against different genotypes of cotton and sunflower, feeding potential of chrysopid species on *H. armigera* eggs on different cotton and sunflower genotypes and utilization of *C. carnea* in the management of *H. armigera* on cotton and sunflower are discussed in the context of the earlier published information.

5.1 Ovipositional preference of the predator, *C. carnea* and the pest, *H. armigera* on different genotypes of cotton and sunflower under net house condition

5.1.1 Ovipositional preference of *C. carnea* and *H. armigera* on different genotypes of cotton

Tritrophic interaction studies between cotton genotypes with *H.armigera* and *C.carnea* provide a more meaningful and reliable approaches for pest management. Better understanding of behaviour and efficiency of the predators when interact with pest and the cotton genotypes determines the performance of chrysopids in an ecosystem. In absence of *H.armigera* eggs, *C. carnea* laid significantly more number of eggs on DHH-543, DLSA-17, DHH-11, LRA-5166 and Jayadhar at vegetative stage (Table 5). On the other hand, it showed least ovipositional preference for PA-255, Abadhita and AK-235. Chemical analysis of volatile compounds through Gas Chromatography Mass Spectrum (GCMS) in DHH-543 revealed detectable level of caryophyllene oxide (18.68%) followed by 1- hexanol (12.78%) and 1-pentanol (11.38%) (Table 31) while, in PA-255 caryophyllene oxide (2.31%), 1- hexanol (5.58%) and 1-pentanol (9.03%) content was very low (Table 32) compared to DHH-543. So, ovipositional preference of *C.carnea* may be more closely attributable to the presence of detectable level of caryophyllene in DHH-543 (intrahirsutum hybrid) compared to PA-255. The present findings are in line with Flint *et al.* (1979) who reported that chrysopids are more attracted to β-caryophyllene. Bakthavatsalam *et al.* (2002) correlated more attraction of *C. carnea* to MCU-10, MCU-9 and MCU-7 to the presence of detectable level of caryophyllene in addition to other terpenoid compounds. On the other hand, least ovipositional preference by *C. carnea* on PA-255 may be due to negligible quantity of caryophyllene oxide.

Table 5: Ovipositional preference of *Chrysoperla carnea* (Stephens) and *Helicoverpa armigera* (Hubner) on cotton genotypes at vegetative stage

Table 31: Head space volatiles identified from cotton cultivar, DHH – 543, using Gass Chromatography Mass Spectrum (GCMS)

Table 32: Head space volatiles identified from cotton cultivar, PA – 255, using Gass Chromatography Mass Spectrum (GCMS)

Chrysoperla carnea showed significantly higher ovipositional preference on DHH-543 than rest of the genotypes in the presence of *H. armigera,* followed by DHH-11, Jayadhar, DLSA-17, LRA-5166, DB-3-12, Sahana, NHH-44 and MCU-5 which may due to morphological characters and volatile compounds on both cotton genotypes and bollworm eggs. The morphological characters like creamy petal with yellow pollen and green leaf with pinkish washy in DHH-543 is attributable to higher number of egg laying by *C. carnea.* The reason for such a variation in egg laying could be the difference in varieties involved. Several studies have shown differential performance of predators and parasitoids on cultivars with different plant characteristics (Treacy *et al.,* 1983; Ramnath and Uthamasamy, 1992).

These findings are also in accordance with Hegde (1997) who reported kairomonal activity of hexane extract of scale and eggs of *Helicoverpa* to *C. carnea* grub attraction.

Helicoverpa armigera showed no discrimination in egg laying on hybrids and varieties of cotton. However, differential ovipositional preferences were evident among different cotton

genotypes, irrespective of hybrids or varieties. *Helicoverpa* laid more number of eggs on Sahana, AK-235, NHH-44, LRA-5166, DHH-11, MCU-5 and DHH-543 at vegetative stage of the crop growth. On the other hand it showed least ovipositional preference for DB-3-12, Abhadita, DLSA-17, Jayadhar, MCU-5 and PA-255 which may be due to lower trichome density on these genotypes. The present findings are in line with Ramnath and Uthamasamy (1995) who observed that moths preferred to oviposit on genotypes that had more leaf trichomes. Similarly, preference of *H. armigera* adults for hirsutum cotton is a known phenomenon (Lukefahar *et al.,* 1971).

Helicoverpa armigera showed least ovipositional preference on genotypes which have less trichome density, except Sahana. More number of eggs were laid on genotypes which had high trichome density except DHH-543. However, Butter and Singh (1996b) observed maximum oviposition of *H. armigera* on *G. hirsutum* than *G. arboreum* which had more trichome length on the upper surface of the leaf and was positively correlated than the density of trichomes for egg laying.

Helicoverpa armigera oviposition on some of the genotypes (LRA-5166 and DHH-543) observed no relation with trichome density which may be attributable to volatile composition of the cotton genotypes. Similar observations were also made by Yan *et al.* (2002).

5.1.2 Ovipositional preference of *C. carnea* and *H. armigera* at flowering and boll formation stages on cotton genotypes

The predator, *C. carnea* laid significantly more number of eggs on the genotypes DHH-543, DLSA-17 and LRA-5166 in the absence of *H. armigera* at flowering stage and DHH-543 and DLSA-17 at boll formation stages of the cotton genotypes which may be attributable only to morphological and volatile compounds present in the genotypes. DHH-543 is having more quantity of caryophyllene oxide (18.68%) which is one of the important attractants and stimulant for *Chrysoperla* which may be the reason for more number of egg laying.

Flint *et al.* (1979) has reported that chrysopids were more attracted to β - caryophyllene. Such preference of predators (Chrysopids and Coccinellids) was observed to open pollinated cultivars of cotton (Vennila, 1998). On the other hand, in absence of *H. armigera*, *C. carnea* laid significantly least number of eggs on PA-255 and Abadhita at both flowering and boll formation stage of cotton, which may be due to lesser quantity of caryophyllene oxide and non preference characteristics of these genotypes.

Ovipositional response of *C. carnea* showed no discrimination in egg laying on DHH-543, Jayadhar, Sahana, LRA-5166, DLSA-17, DHH-11 and NHH-44 genotypes in the presence of *H. armigera* at flowering and DHH-543, DHH-11, Sahana, LRA-5166 and MCU-5 at boll formation stages which may be attributable to morphological and volatile compounds of cotton genotypes, presence of bollworm eggs and moth scale from the tip of the abdomen while laying eggs. The present findings are also in line with Nordlund *et al.* (1977) who observed the presence of kairomone in the eggs of *H. zea* which was responsible for attraction of *C. carnea.* These findings are also in accordance with Venkateshalu (2005) who reported that more number of eggs are laid by *C. carnea* on RCH-2, MECH-184, RCH-144 and MECH-162 cotton genotypes in the presence of *H. armigera.* The present findings are in line with Varenik and Khavruk (1977) who observed that chrysopids like *C. carnea* and *C. formosa* were present on aphid infested plants and laid more number of eggs than on non infested plants. However, *C. carnea* laid least number of eggs on Abadhita and PA-255 at both flowering and boll formation stages of the genotypes even in presence of *H. armigera* which may be due to lower quantity of caryophyllene oxide (2.31%) in PA-255.

The pest *H. armigera* laid more number of eggs on Sahana, NHH-44, AK-235, DHH-11 and LRA-5166 both at flowering and boll formation stage, while, on MCU-5 genotype, at flowering stage. On the other hand, *Helicoverpa* showed least ovipositional preference for PA-255, Abhadita, DB-3-12, Jayadhar, DLSA-17 and DHH-543 at flowering and DB-3-12, Abadhita followed by PA-255, DLSA-17 and DHH-543 at boll formation stage which may be due to lower quantity of preferred volatile compounds and also non-preference characteristics

of the plants. The present findings are in line with Butter and Singh (1996b) who observed maximum oviposition of *H. armigera* on *G. hirsutum* than on *G. arboreum.* Similarly Anon. (2002) stated that among the entries evaluated, Sahana, a variety of *G. hirsutum* received maximum number of *Helicoverpa* eggs and lowest on KC-2 genotype.

Sundaramurthy and Chitra (1992) reported cultivated species of cotton such as Abadhita, SH-131 and SV-213 escape from attack of bollworms which might be due to less preference by *H.armigera* as evident in the present findings.

Differential ovipositional preferences of *H.armigera* to different host plants due to physical factors (leaf pubescence) and chemical cues (volatiles or surface chemicals) of the host plants was also documented by various authors (Jackson *et al.* 1984; Tingle and Mitchell, 1984; Ramaswamy *et al.,* 1987; Firempong and Zalucki, 1990; Navasero and Ramaswamy, 1991 and Jallow, 1998).

Helicoverpa showed least ovipositional preference on genotypes which have less trichome density, except Sahana and more number of eggs were laid on genotypes which had high trichome density. So, overall, the hairy verities were preferred more for egg laying compared to glabrous varieties where the leaf trichomes might have served as better attachment of eggs against wind or rain. A similar opinion was also expressed by Lukefahar *et al.* (1971), Jayaraj and Murgesan (1988); Jenkins (1989); Shvetsova *et al.* (1989); Navon *et al.* (1991); Ramnath and Uthamsamy (1995); Khadi *et al.* (1998) and Singh (2000) who reported that various morphological traits of cotton plant like hairiness which resulted in high incidence of *Helicoverpa* as against glabrous trait which provides resistance to bollworms.

When compared across the stages, the mean egg laying by *C. carnea* was significantly higher on DHH-543 both in presence and absence of *H. armigera* which may be due to more detectable level of caryophyllene oxide (18.28%) which is already confirmed in GCMS.

On the other hand it laid significantly lower egg load on VRF-21 both in presence and absence of *H. armigera* which may be due to lesser or nill quantity of caryophyllene oxide and also non-preference characters of the genotype.These finding are in line with Flint *et al.*(1979) who reported that chrysopids were more attracted to β-caryophyllene.

When compared across the stages of cotton, *C. carnea* laid more eggs at flowering stage compared to boll formation and vegetative stage both in presence and absence of *H. armigera* eggs. The reason for more egg laying at flowering stage may be due to availability of more pollen and nectar, more volatile compounds and more glands for adult *Chrysoperla* for feeding compared to other stages of crop. These results are in line with Doutt *et al.* (1966), Roome and Matthews (1971), Jayaraj and Rabindra (1995) and Hegde (1997) who reported the peak population of *Chrysoperla* coinciding with peak flowering stage. The present findings are also in line with Geetha and Swamiappan (1998) who reported significantly more egg laying by *Chrysoperla* at flowering stage of the cotton.

Coll and Bottrell (1991) also reported that cultivar that produces greater amounts of more nutritious pollen over larger periods of time may be a viable strategy for increasing the effectiveness of the predator.

When compared across the stages, the mean number of eggs laid by *H. armigera* was significantly lower on DB-3-12 followed by Jayadhar and PA-255 which may be due to lesser trichome density and non-preference characters of these genotypes. On the other hand it laid significantly more number of eggs on Sahana followed by NHH-44, AK-235, DHH-11 and LRA-5166 which may be due to higher trichome density and preferred characteristics of these genotypes.

These findings are in line with Lukefahar *et al.* (1971), Jayaraj and Murgesan (1988), Ramnath and uthamasamy (1995) and Khadi *et al.* (1998)

Comparative studies on *Helicoverpa* egg laying across the stages of cotton shows

more number of egg laying at flowering followed by boll formation stage and vegetative stage. Higher egg load at flowering and boll formation stage might be due to availability of extrafloral nectar coupled with availability of fruiting bodies.

The present findings are in agreement with Roome (1975), Wardhaugh *et al.* (1980), Firempong (1987) and Firempong and Zalucki (1990) who reported that the stage of the crop known to influence oviposition behaviour in *H. armigera.* Female *H. armigara* preferred MHR-11 (Multiple host–plant resistant) flowers more for oviposition than MHR-11 leaves suggesting higher chemicals concentration in cotton flowers compared to cotton leaves. The association between peak oviposition and peak flowering was correlated to the nectar availability for food (Maafo and Wilson, 1983a, b).

On the other hand *H. armigera* laid significantly lower eggs on DB-3-12 followed by Abhadita, Jayadhar and PA-255 which may be due to less volatile compounds and also glabrous nature of these genotypes. These findings are also in line with Mohite and Uthamasamy (1998).

5.1.3 Ovipositional preference of *C. carnea* and *H. armigera* on sunflower genotypes

5.1.3.1 Ovipositional preference of *C. carnea* and *H. armigera* on sunflower genotypes at vegetative stage

In the absence of *H. armigera, Chrysoperla* laid more eggs on Morden, KBSH-1, MSFH-17, DSH-1, PCSH-243 and RSFH-1. On the other hand, *Chrysoperla* laid least number of eggs on DSF-2, VRF-21, SFL-107 and Jwalamukhi genotypes of sunflower. Chemical analysis of KBSH-1 through GCMS showed higher concentrations of heptadecane (38.28%), linalool (21.80%), caryophyllene oxide (9.74%) and hexadecane (7.24%) which might have acted as stimulant for higher oviposition by the predator. These results are in corroboration with Arora *et al.* (1996) who reported that colonization of predators on RHA-274 and RHA-421-6 was more compared other genotypes of sunflower. These results are in agreement with the report of Anon. (2000) who stated that KBSH-1 was most preferred and SFL-107 as least preferred for egg laying by *Chrysoperla.*

In presence of *H. armigera,* ovipositional response of *Chrysoperla* showed no discrimination in egg laying among KBSH-1, Morden, RSFH-1 and SFL-107 genotypes and received significantly higher number of eggs than other genotypes which may be attributable to morphological and volatile compounds of both cotton genotypes and bollworm eggs.

In general, in the presence of *H. armigera, C. carnea* laid more number of eggs compared to without *H. armigera* which may be due to volatile compounds released from plants and host insect which harbour more natural enemies than host plant alone. In support of present findings, Vennila (1998) reported higher incidence of sucking pests on hybrids than on varieties. Predators were almost four times higher on hybrids than on varieties. This suggests a density dependent interaction between sucking pests and their native predator.

Even in presence of *H. armigera* eggs*, Chrysoperla* laid significantly less number of eggs on VRF-21 and DSF-2 which may be due to the non preference characters of the genotypes and also surface chemicals. The present findings show that not only host plant, host insect also play a key role in attraction and stimulation of *Chrysoperla* for egg laying.

Except VRF-21 and KBSH-1 *H. armigera* laid significantly more eggs on other genotypes of sunflower which may be due to the morphological characters and trichome density of the genotypes. The present findings are in line with Ramnath and Uthamasamy (1995) who observed that moth preferred to oviposit on genotypes that had more leaf trichomes on cotton. *Helicoverpa* ovipositional preference did not show any relation with trichome density at vegetative stage. However least oviposition was recorded on VRF-21 which has less trichome density.

5.1.3.2 Ovipositional preference of *C. carnea* and *H. armigera* at capitulam farmation stage of the sunflower genotypes

At capitulam formation stage of sunflower, *C. carnea* showed ovipositional preference on KBSH-1, Morden, MSFH-17, PCSH-243, DSH-1 and RSFH-1 in the absence of *H.armigera* eggs which may be attributable only to morphological and volatile compounds of plant. Whereas *chrysoperla* laid more number of eggs on KBSH-1, Morden, MSFH-17, RSFH-1 and SFL-107 genotypes in the presence of *H. armigera* which may be attributable to morphological and volatile compounds of host plant and capitulam borer eggs.

In support of the present study, Anon. (2000) reported more oviposition of *C. carnea* on KBSH-1, SFL-103 and 6D-1R genotypes of sunflower under caged condition. Arora *et al.* (1998) also observed that significantly lower population of phytophagous insects and greater population of predatory insects especially, *Chrysoperla* on GKSFH-2002 genotypes. The present findings are also in accordance with Geetha and Swamiappan (1998) who reported that *C.carnea* laid more number of eggs on cotton and sunflower than coriander.

Helicoverpa armigera laid maximum number of eggs on SFL-107 followed by DSF-2, PCSH-243, MSFH-17 and Jwalamukhi which may be due to higher trichome density on these genotypes and also due to presence of preferred volatile compounds. *Helicoverpa* oviposition on some of the genotypes (Jwalamukhi and RSFH-1) observed no relation with trichome density which may be attributed to volatile composition of these genotypes. Bhat *et al.* (1996) recorded lower *H.armigera* egg load on KBSH-6, 7, 8, 9, TNSU-3, RHA-263, 291B, EC-109281 and BRS-3 while screening the germplasm lines which supports the present findings.

5.1.3.3 Ovipositional preference of *C. carnea* and *H. armigera* at flowering stage of the sunflower genotypes

At flowering stage of sunflower genotypes in the absence of *H. armigera, Chrysoperla* laid significantly more eggs on KBSH-1 and Morden which may be attributable only to surface chemicals and volatile compounds of the genotypes. While, least numbers of eggs were laid on DSF-2 followed by VRF-21 and SFL-107. GCMS analysis revealed higher quantity of caryophyllene oxide in KBSH-1 compared to VRF-21. So, the presence of caryophyllene oxide played important role in eliciting higher oviposition by *C. carnea.* The presence of only ten volatile compounds in VRF-21 as compared to more than 25 in KBSH-1 might have also influenced higher ovipositional preference of *C.carnea* on KBSH-1 compared to VRF-21. Likewise similar relation may be simulated to other genotypes.

Egg laying behaviour of *C. carnea* showed no much difference among Morden, KBSH-1 and RSFH-1 in the presence of *H. armigera* at flowering stage which may be due to volatile compounds released by host plant as well as head borer eggs. The present study is in line with Vet and Dicke (1992) who observed greater influence of host plant chemical cues on tritrophic interactions. The present findings are also in support of Flint *et al.* (1979) who reported higher production of β-caryophyllene by damaged sunflower plants to attract *C. carnea.* Ballal and Singh (1999) reported strong preference of chrysopids towards sunflower and cotton for oviposion compared to pigeonpea.

On the other hand, the predator laid significantly lower egg load on VRF-21 and DSF-2 which may be due to non preference characters of these genotypes or lower quantity of detectable hydrocarbon like caryophyllene. Hence host plant volatile chemical play a key role in attraction or repulsion or stimulation of the *Chrysoperla* for egg laying.

At flowering stage, *Helicoverpa* laid significantly more number of eggs on SFL-107 followed by PCSH-243, DSF-2 and MSFH-17 when compared to Morden, RSFH-1 and KBSH-1 which received less number of eggs. When compared across the different stages of the sunflower, *C. carnea* laid more eggs at flowering stage compared to capitulam formation stage and was least at vegetative stage both in presence and absence of *H. armigera* (Table 14 and 15). More egg laying by *C.carnea* at flowering stage may be due to the availability of pollen and nectar and kairomone released from host eggs. Even at capitulam formation stage, it laid more eggs than at vegetative stage which may be due higher production of volatile compounds released from matured plants compared to early stage. These findings are in line with Roome and Matthews (1971) and Jayaraj and Rabindra (1995) who observed peak population of natural enemies coinciding with peak flowering stage. Many natural enemies feed directly on plants or plant products such as pollen, floral nectar and extra floral

nectar (Smith, 1969; Ridgway and Jones 1968; Aguilar and Ehler, 1977; Maafo and Wilson, 1983b; Naranjo and Stimac, 1985; Scott *et al.,* 1988; Shepard and Rapusas, 1989).

Table 14: Ovipositional preference of *C. carnea* across the crop stages on sunflower genotypes without *H. armigera*

Table 15: Ovipositional preference of *C. carnea* across the stages on sunflower genotypes with *H. armigera*

When comparison is made across the stages, the mean egg laying by *C. carnea* was significantly higher on KBSH-1 and Morden both in presence and absence of *H. armigera* which may be due to the preferred volatile compounds (caryophyllene oxide) in higher quantity and also volatiles produced from eggs and scales of *H. armigera.* The present findings are in line with Anon. (2000) who reported more egg laying by *C. carnea* on KBSH-1 than other genotypes. On the other hand, it laid significantly lower eggs on DSF-2 and VRF-21 without *H. armigera* and only VRF-21 with *H. armigera* which may be due to less quantity of preferred volatile compound especially caryophyllene oxide.

Even at flowering and capitulam formation stage, *Chrysoperla* laid significantly lower eggs on VRF-21, DSF-2 and SFL-107 in absence of *H. armigera* and VRF-21, DSF-2 and Jwalamukhi in presence of *H. armigera* which may be due to non-preference characteristics of these genotypes and lower level of preferred volatile compounds (caryophyllene oxide). These findings are in close relation with Reddy (2002) who reported that *C. carnea* did not respond to volatiles from tomato. Reddy *et al*. (2004) also reported lower egg laying by *Chrysoperla* on other crops like broccoli and kohlrabi due to their non preference characters.

Chrysoperla laid more eggs in the presence of *H.armigera* compared to in its absence irrespective of the genotypes which indicates the role of volatile compounds released from eggs and scales of *H. armigera* for egg lying by *C.carnea*. These findings are in line with Varenic and Kharvuk (1977) who reported higher colonization of chrysopids like *C. carnea* and *C. formosa* on aphid infested plants than on non-infested plants. However, it contradicts with the report of Ananthakrishnan (1992) that natural enemies initially seek an environment and can recognize host plant factors, regardless of the presence or absence of its host.

Comparative studies on egg laying by *H. armigera* across the stages of sunflower show that, it laid more eggs at flowering stage followed by capitulam formation and vegetative stages of the genotypes. The highest egg load at flowering stage compared to capitulam formulation and vegetative stage may be due to availability of floral nectar to *Helicoverpa* and release of higher quantity of preferred volatile compounds at flowering stage. These findings are in line with Firempong and Zalucki (1990) who reported that some plant properties especially flowers help for selection and oviposition by noctuid, *H. armigera.*

Among the different genotypes, KBSH-1 and Morden were preferred less by *H. armigera* for oviposition at all the stages followed by RSFH-1 at only capitulam formation stage coupled with their more attraction to *C. carnea* can form a best option for pest management. Where, they naturally enhance the activity of chrysopid at the same time preferred less by *H. armigera.*

5.2 Behavioural response of *C. carnea* under wind tunnel olfactometer towards the extracts of different cotton and sunflower genotypes

In the present investigation, the orientation behaviour of *C. carnea* against the extract of different cotton and sunflower genotypes was studied using eight arm olfactometer.

5.2.3 Behavioural response of *C. carnea* to different genotypes of cotton

Chrysoperla carnea adults showed differential orientational response to hexane leaf extracts of different cotton genotypes. Significantly higher number of *C.carnea* adults reached olfactometer arms containing the leaf extracts of DHH-543 followed by DHH-11 and DLSA-17

compared to the rest. Hexane, a very good laboratory solvent extracted higher quantity of plant volatiles. Similar to the present findings, Vet (1983) and Bakthavatsalam *et al.* (2000) also used wind tunnel olfactometer to screen different semiochemicals and plant compounds against *H. armigera* and *C. carnea*.

The lower orientation of *C.carnea* towards few genotypes (Jayadhar, Sahana and NHH-44) can be attributed to lower quantity of caryophyllene oxide as evidenced in PA-255 (2.31%) when compared to DHH-543 (18.68%). Presence of detectable level of hydrocarbons especially caryophyllene oxide in DHH-543 (18.68%) compared to PA-255 (2.31%) once again explained maximum orientation of *C.carnea* towards DHH-543 compared to PA-255. So, the concentration (quantity) of caryophyllene oxide in different cotton genotypes might be the possible reason for differential response of *C.carnea* to different cotton genotypes. Influence of the caryophyllene oxide in leaf extracts on the differential ovipositional response of *C.carnea* was also explained in the tritrophic interaction studies at vegetative stage. These findings are in close agreement with Flint *et al.* (1979) who reported that adult *C. carnea* are attracted by caryophyllene, a volatiles released by actively growing plant tissues.

The number of adult *C. carnea* reaching the kairomone source of various genotypes of flower extract was higher than their respective leaf extract. Of the total number of *C. carnea* adults released in to the test chamber, the greatest number moved towards flower extract of DHH-543 and honey solution. Higher quantity of oviposition attractant especially, caryophyllene oxide (18.68%) in the genotype DHH–543 resulted in orientation of more number of adult *Chrysoperla* towards the flower extract compared to rest of the genotypes. In the present study 50 per cent honey solution was also found equally good for attraction of adult *Chrysoperla*. These findings are in close agreement with Elzen *et al.* (1983) who observed attraction of *C. sonorensis* to the flowers of some plants even in the absence of its host in an olfactometer. Bakthavatsalam and Singh (1996) also reported attraction of *C. carnea* to 50 per cent honey solution under four arm olfactometer which supports the present findings. Significantly lower number of *C. carnea* oriented towards the flower extracts of DB-3-12, Abadhita and Sahana genotypes when compared to DHH-543. The lower orientation of *C.carnea* towards some of the genotypes may be attributed to lower quantity of caryophyllene oxide as evidenced in PA-255 (2.31 %) when compared to DHH-543 (18.68%).

The orientation of *C. carnea* adults towards the boll extract of different cotton genotypes was slightly lower compared to their respective flower extracts but the trend was similar as evidenced at flowering stage. Highest number of *C. carnea* oriented towards the extract of DHH-543 and 50 per cent honey solution. The results are in agreement with the earlier reports of Bakthavatsalam *et al.* (2000) who reported that adults of *C. carnea* spent more time in the synomone arm containing the extracts of cotton boll damaged by *H. armigera*. Other parts like leaf and flower did not evoke any significant behavioural response.

When compared across the plant parts, the mean orientation rate of *C. carnea* was higher towards flower extract followed by boll and leaf extract. This may be due to higher quantity of detectable hydrocarbons, especially caryophyllene oxide, pentanol in the flowers compared to bolls and leaf. Lower orientation of adult *C. carnea* towards the leaf extract of cotton may be attributable to very less quantity of plant volatile compounds at early stages of crop growth. These results are in accordance with Scott *et al.* (1988) who reported that many natural enemies feed directly on plants or plant products such as pollen, floral nector and extra floral nector.

5.2.3 Behavioural response of *C. carnea* towards different sunflower genotypes

The behavioural response of *C. carnea* towards the leaf extracts of sunflower genotypes showed that significantly more number of *C.carnea* adults reached the olfactometer arms containing the extracts of KBSH-1 and Morden followed by RSFH-1. More attraction of *C. carnea* towards the extract of these genotypes may be due to the presence of higher quantity of preferred volatile compounds like linalool (21.80%), caryophyllene oxide (9.74%) and heptadecane (38.28%) (Table 33).

Table 33: Head space volatiles identified from sunflower cultivar, KBSH-1,

using Gass Chromatography Mass Spectrum (GCMS)

On the other hand, significantly least number of adult *C. carnea* oriented towards the leaf extracts of SFL-107, DSF-2 and VRF-21. Chemical analysis of VRF-21 recorded nil or negligible quantity of caryophyllene which may be the reason for lower number of adult *C. carnea* attraction. In the present study, more number of *C. carnea* also oriented towards 50 per cent honey solution which may be due to the honey as a food source to the natural enemy.

In general, the mean orientation of adult *C.carnea* against the capitulam and flower extract was higher than leaf extract. Of the total number of *C. carnea* adults released in the test chamber, highest number moved towards capitulam and flower extracts of KBSH-1, Morden, RSFH-1, MSFH-17 and SFL-107 which may be attributable to the presence of higher quantity of detectable hydrocarbons in these genotypes. The volatile compounds of KBSH-1, identified through GCMS revealed presence of higher quantity of preferred volatiles especially heptadecane (38.28%), linolool (21.80%), caryophyllene oxide (9.74%) and hexadecane (7.24%) followed by pentanol, hexanol and limonene explained the reasons for higher orientation of *C. carnea* under olfactometer.

On the other hand, significantly lower number of adult *C. carnea* oriented towards capitulam and flower extracts of DSF-2, DSH-1, PCSH-243, SFL-107 and VRF-21 genotypes of sunflower which may be due to more quantity of non preferred volatile compounds and lesser quantity of preferred volatile compounds in these genotypes. The volatile compounds identified through GCMS from VRF-21 genotype indicated the absence of preferred attractive compound caryophyllene oxide and presence of only ten volatile compounds as against the presence of 25 compounds in KBSH-1. The reason for such a variation could also be due to difference in varieties involved. Several studies have shown differential performance of parasitoids and predators in cultivars with different plant characteristics (Treacy *et al.* 1983; Ramnath and Uthamasamy, 1992).

When compared across the plant parts of sunflower genotypes, the orientation of adult *C. carnea* was more towards flower extract followed by capitulam and leaf extract. The reason for orientation of more number of *C. carnea* adults towards flower extract may be due to availability of more floral nector and preferred volatile compounds as compared to other parts. As the crop stage advances more number and quantity of volatile compounds were produced in a healthy plant. These findings are in line with Elzen *et al.* (1983) who reported that female parasitoid and predators were attracted to the flowers of some plants in olfactometer.

5.2.4 Kairomone source of *C. carnea* adult

It has been already proved that the kairomone plays an important role for natural enemies to locate their hosts. Hexane extract of moth scales and eggs of *H. armigera* increased the attraction of *C. carnea* adults under olfactometer. The findings showed that as the concentration of hexane extract increases the orientation of *C. carnea* adults also increases up to certain level (0.5% scale extract and 100 eggs / 10 ml of hexane). Further, increase in concentration of scale and egg extract of *H. armigera* resulted in decreased orientation of adult *C. carnea*. Similar observation has also been documented (Anon 1995b) from Bangalore which supports the present findings. The present findings are also in accordance with Hegde (1997) who reported more attraction of *C. carnea* larvae to their host eggs sprayed with *H. armigera* moth scale and egg extract. The higher response exhibited by the *C. carnea* adult to moth scale extract was in agreement with Lewis *et al,* (1972).

5.3 Electroantennogram (EAG) response of *C. carnea* and *H. armigera* on different cotton and sunflower genotypes

Electroantennogram (EAG) recording technique facilitated identification of chemical signals used by insects including orientation to host plants and signaling conspecifics. These considerations led to determine the receptivity of the antennal olfactory receptor system of *C.*

carnea and *H. armigera* towards the extracts of cotton and sunflower genotypes by electroantennogram recording technique.

5.3.1 Electroantennogram (EAG) response of *C. carnea* and *H. armigera* against the extracts of cotton genotypes

The EAG response of mated *C. carnea* male was similar to the leaf extracts of all the cotton genotypes and honey solution than control (without kairomone). On the other hand, mated female of *C.carnea* gave significantly higher EAG response than mated male. Among the leaf extracts of cotton genotypes, significantly higher EAG response was evoked for DHH-543, DHH-11, DLSA-17, Jayadhar, LRA-5166. However lower EAG response was evoked towards the extracts of PA-255 and AK-235, NHH-44, MCU-5, Abadhita and DB-3-12.

The mated female of *C. carnea* gave higher EAG response than mated male to the leaf extracts of cotton genotypes and honey solution, obviously because of the purpose of oviposition, induced by an array of kairomones from the host plants. After mating, female *C.carnea* seeks better site for oviposition that may be the reason for higher EAG response than mated male. Among the genotypes of cotton DHH-543, DHH-11, DLSA-17, Jayadhar and LRA- 5166 recorded higher EAG response which may be due to the presence of higher quantity of detectable volatile compounds. It was also confirmed under GCMS that, the genotype DHH-543 having higher quantity of caryophyllene oxide (18.68%) might be an important volatile compound stimulated *Chrysoperla* for egg laying. Under ovipositional preference studies, this genotype received higher eggs of *C. carnea* which confirmed the higher EAG response. On the other hand, mated male of *C.carnea* showed similar response to all the genotypes which may be because of lack of egg laying function. These findings are in line with Bakthavatsalam and Singh (1996) who noticed the highest EAG response in the mated females than males and was also confirmed in the olfactometer studies. EAG response of female *C. carnea* antennae to extracts of corn leaves was greater than that of male (Zhu *et al*., 1999) which confirms the present findings. The EAG response of male *H. armigera* to the leaf extract of different cotton genotypes was similar, but significantly superior to air (Fig. 1 & 2).

Fig. 1: Electroantennogram response of female *C. carnea* to cotton leaf extract

Fig. 2: Electroantennogram response of female *H. armigera* to cotton leaf extract

Higher EAG response by female *H. armigera* to the leaf extracts of Sahana, DHH-11 may be due to higher quantity of preferred volatile compounds present in these genotypes. Lower EAG response by female *H. armigera* to the extracts of the remaining genotypes of cotton was obviously because of lower quantity of preferred volatile compounds and higher quantity of non preferred volatile compounds. The present findings are in agreement with Anon. (2000) who reported higher EAG response of *H. armigera* females to the plant volatile compounds than the males. EAG studies have facilitated identification of chemical signals used by insects including orientation to host plants and signaling conspecifics. A similar response was also reported by several investigators (Visser, 1979; Kozlowski and Visser, 1981; Dickens and Boldt, 1985; Light and Jang, 1987).

5.3.2 Electrophysiological response of *C. carnea* and *H. armigera* to cotton boll extracts

The EAG response of mated *C. carnea* male to the boll extracts of different cotton genotypes was almost similar to the leaf extract but higher than air. However, higher response was noticed with honey solution compared to different cotton genotypes.

Mated female of *C. carnea* showed similar EAG response to the boll extracts of different cotton genotypes except AK-235 and PA-255 where the response was significantly less which may be due to presence of higher level of detectable volatile compounds especially, β-caryophyllene present in higher quantity which act as a ovipositional stimulant for *C. carnea*. On the other hand, it showed least EAG response towards the boll extract of PA-255 and AK-235 which may be due to presence of lower level of detectable volatile compounds especially β- caryophyllene. These findings are in line with Boo *et al*. (1998) and

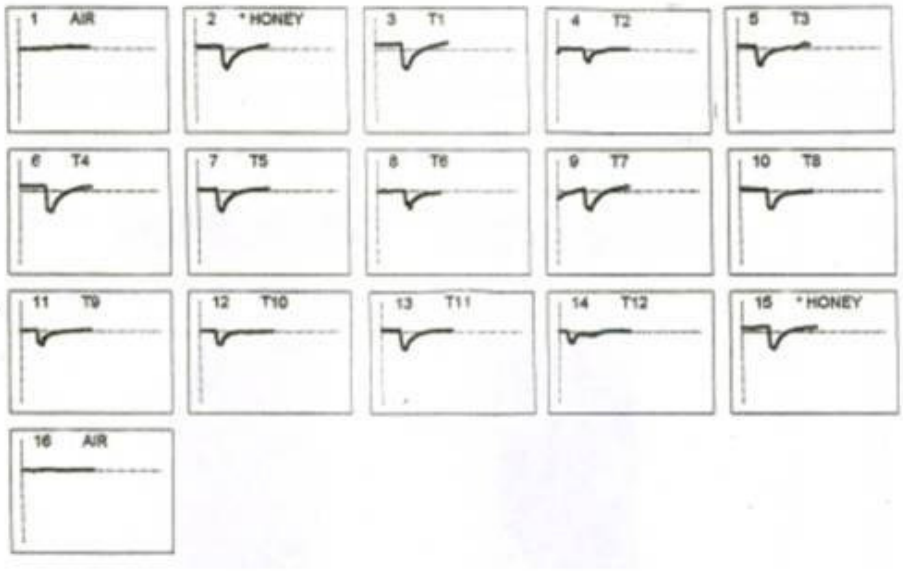

Fig.1. Electroantennogram response of female *C. carnea* to cotton leaf extract

Fig 1. Electroantennogramresponse of female C. carnea to cotton leaf extract

T1 : LRA – 5166,	T2: DB – 3 – 12,	T3 : Jayadhar,	T4: DHH – 543,
T5 : DHH – 11,	T6: Abadhita,	T7 : Sahana,	T8: MCU – 5,
T9 : NHH – 44,	T10: AK – 235,	T11: DLSA – 17,	T12: PA – 255

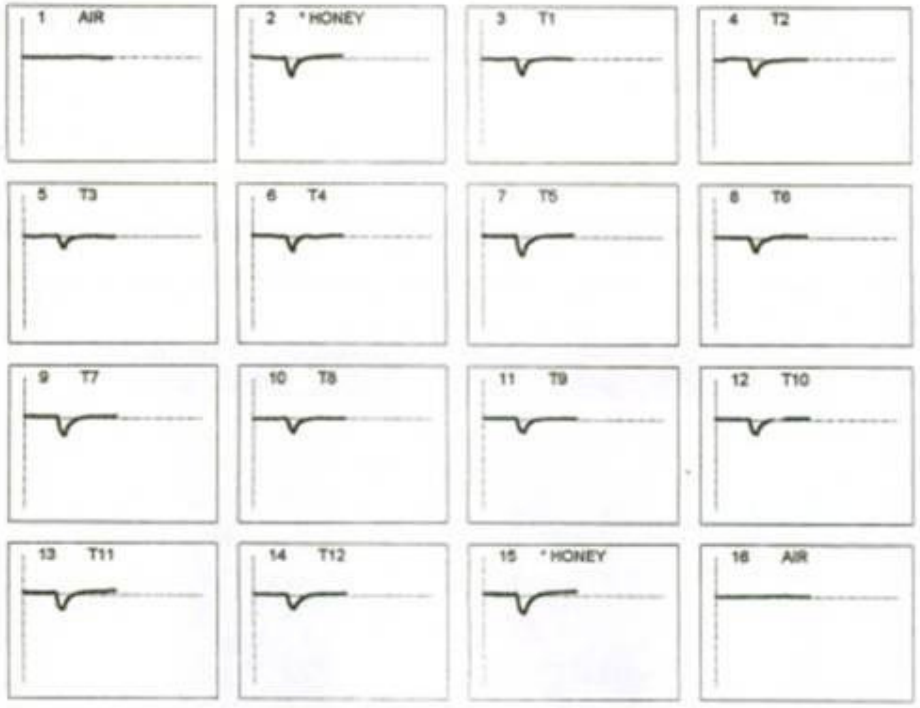

Fig. 2. Electroantennogram response of female *H. armigera* to cotton leaf extract

Fig 2. Electroantennogram response of female H. armigera to cotton leaf extract

Zhu *et al*. (1999). Similar to the present findings, *Chrysopa pallens* (Rambur) and *C. carnea* also showed electroantenogram response to kairomones (Bakthavatsalam *et al.,* 2000). They also reported that highest EAG response was noticed in the mated females and their increased behavioural response was also confirmed in the olfactometer studies (Bakthavatsalam and Singh, 1996). EAG response of female *C. carnea* to extracts of corn leaves was greater than that of males (Zhu *et al*., 1999). The present findings are also in corroboration with Anon. (2000) who reported higher response of female *C. carnea* to synthetic plant volatile compounds than male. Bakthavatsalam *et al*. (2002) also opined that mated female of *C.carnea* showed better EAG response than male due to preference for oviposition.

The EAG response of male *H. armigera* remained same in all the cotton genotypes, which were exactly similar to that of leaf extract. Mated female of *H. armigera* moths has evoked stronger EAG response than mated male of the same age to the cotton boll extracts (Fig. 3 & 4). Mated female *H. armigera* had significantly stronger EAG response to the cotton boll extracts of Sahana, DHH-11 and LRA-5166 suggesting the role of allelochemicals in promoting oviposition. The present findings are in agreement with Ding *et al*. (1997b) who reported that mated females of *H. armigera* had significantly stronger EAG responses to allelochemicals of cotton, maize and peanut than virgin females suggesting that these plant released chemicals are capable of promoting oviposition. But, the present findings are contradictory to the findings of Prasuna *et al*. (1998) who reported that males of *Achea janata* Linn. were more receptive to plant volatiles than the females, confirming the presence of more number of olfactory sensillae on the male antenna. In the present study lower response in male than female *H. armigera* may be due to less number of olfactory sensillae on the male antennae.

Fig. 3: Electroantennogram response of female *C. carnea* to cotton boll extract

Fig. 4: Electroantennogram response of female *H. armigera* to cotton boll extract

On the other hand, least EAG response of mated female of *H. armigera* was recorded against the allelochemicals from boll extracts of the remaining cotton genotypes which may be due to lower level of preferred volatile compounds which were required for oviposition by female *H. armigera* moths. These findings are in line with Light and Jang (1987) who reported that, laboratory reared oriental fruitfly, *Dacus dorsalis* (Hendel) female elicited significantly stronger EAG's from aldehyde and alcohols.

5.3.3 Electroantennogram response of *C. carnea* to sunflower leaf and capitulam extract

The mated male and female *C.carnea* showed a typical electroantennogram response to kairomonal substances of leaf and capitulam extracts of sunflower.

Mated male of *C. carnea* showed significantly higher response to 50 per cent honey solution than leaf and capitulam extracts tested under EAG, obviously because after mating male *C.carnea* requires food to recover energy which was lost during mating. Among the sunflower genotypes, higher EAG response by male *C. carnea* was recorded to the leaf extracts of Morden and RSFH-1. The mated male *C. carnea* showed significant positive EAG response to the extracts of Morden, RSFH-1 and KBSH-1 which may be due to the presence of volatile compounds in sunflower. On the other hand, it showed significantly lower EAG response to the kairomones of rest of the genotypes of sunflower except KBSH-1. EAG responsivenes were apparently affected by age, sex and mating status. As expected mated females were more sensitive to monoterpenes than males or virgin females of the same age as documented by Zhu *et al*. (1999).

Electroantennogram (EAG) response of mated female of *C. carnea* showed significantly higher response to allelochemicals of leaf and capitulam extracts of KBSH-1, Morden and 50 per cent honey solution (Fig. 5 & 6). On the other hand, mated female of *C. carnea* showed least EAG response to the volatile compounds of leaf extract of VRF 21, DSF-2, and SFL-107 and capitulum extract of VRF-21 and DSF-2. The present study is in accordance with Bakthavatsalam *et al*. (2002) who reported that adult *C. carnea* showed

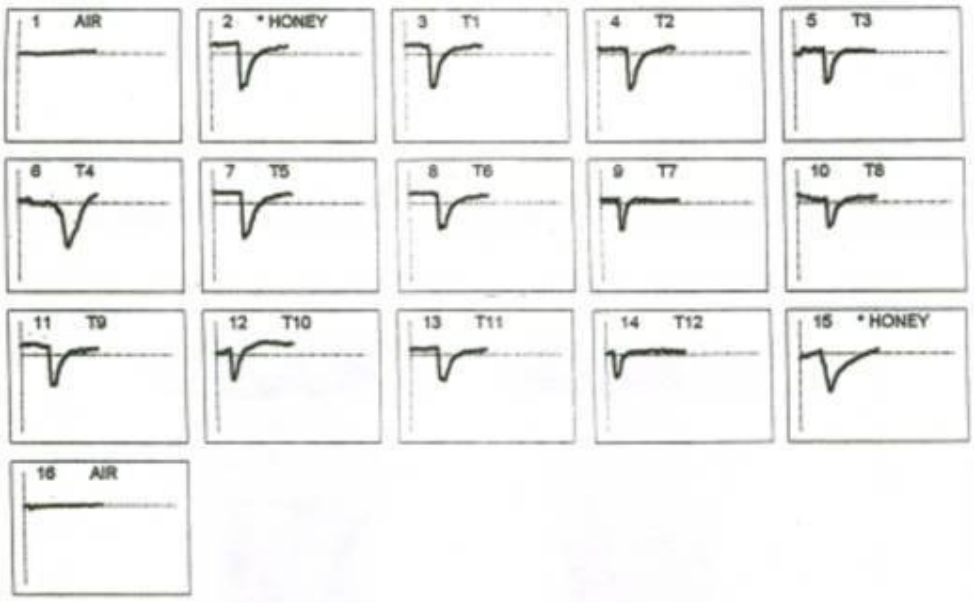

Fig. 3. Electroantennogram response of female *C. carnea* to cotton boll extract

Fig 3. Electroantennogram response of female C. carnea to cotton boll extract

T1 : LRA – 5166,	T2: DB – 3 – 12,	T3 : Jayadhar,	T4: DHH – 543,
T5 : DHH – 11,	T6: Abadhita,	T7 : Sahana,	T8: MCU – 5,
T9 : NHH – 44,	T10: AK – 235,	T11: DLSA – 17,	T12: PA – 255

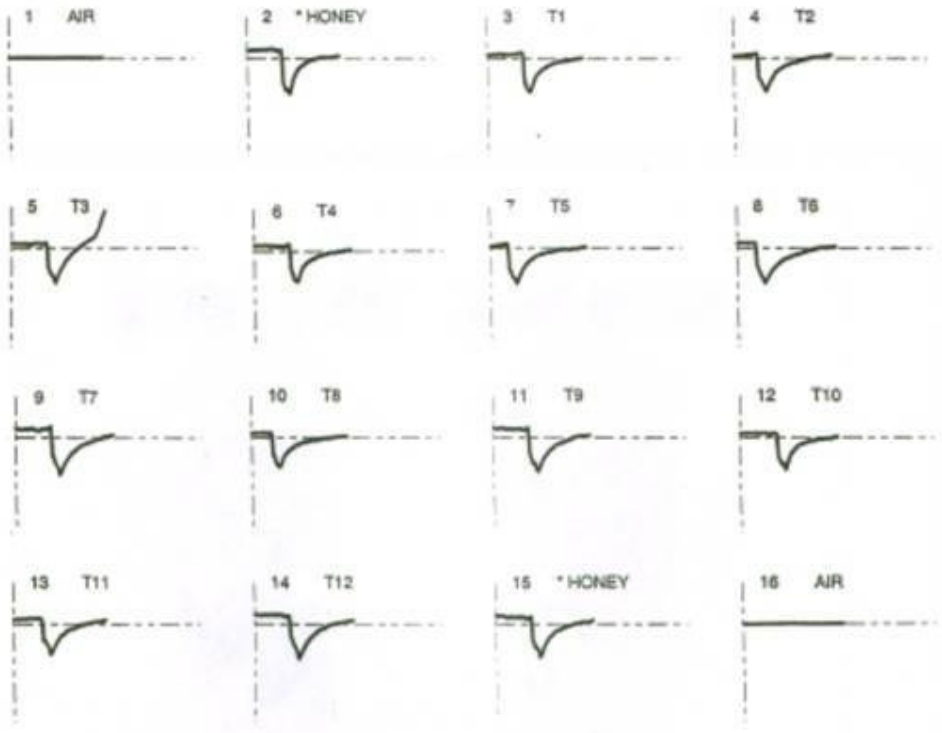

Fig.4. Electroantennogram response of female *H. armigera* to cotton boll extract

Fig 4. Electroantennogram response of female H. armigera to cotton boll extract

typical EAG response to kairomonal substance. Among the sexes, the mated females of predator showed highest response to the kairomones than males. The results of the present study are in agreement with Zhu *et al*. (1999) who reported greater EAG response of female *C. carnea* to the extracts of corn leaves than males.

Fig. 5: Electroantennogram response of female *C. carnea* to sunflower leaf extract

Fig. 6: Electroantennogram response of female *H. armigera* to sunflower leaf extract

In general, irrespective of the genotypes, mated female of *H. armigera* showed stronger (Fig. 7 & 8). EAG response to the allelochemicals of sunflower than mated male. However mated male and female of *H. armigera* did not show any significant EAG response to any of the sunflower genotypes including 50 per cent honey solution but, stronger response than control. The study is in accordance with Hansson *et al*. (1989) who reported sexual differences in EAG response to plant volatiles by turnip moth *Agrotis segetom* Schiff.

Fig. 7: Electroantennogram response of female *C. carnea* to sunflower capitulam extract

Fig. 8: Electroantennogram response of female *H. armigera* to sunflower capitulam extract

On the contrary, male *H. armigera* evoked significantly higher response to the capitulam extract of SFL-107, PCSH-243, RSFH-1 and DSF-2. Least EAG response by *H. armigera* was recorded to the capitulam extracts of KBSH-1 and Morden which may be due to less preferred volatile compounds compared to SFL-107, PCSH-243 and DSF-2. These results are in agreement with Ding *et al* (1997b) who reported that mated females of *H. armigera* showed significantly stronger EAG response to allelochemicals of host plants like cotton, maize and peanut, where the plant released chemicals are capable of promoting oviposition. The present findings are also in accordance with Hartlieb and Rembold (1996) who reported better response of female *H. armigera* to each of the compounds of the sebsquinterpene mixture through electrophysiological recordings. *Helicoverpa armigera* evoked higher response to capitulam extracts of SFL-107, PCSH-243 and DSF-2 because of higher quantity of preferred volatile compounds. The present study clearly showed that female always evoked stronger response than male to both sunflower leaf and capitulam extracts suggesting role of chemicals in promoting oviposition.

5.3.4 Head space volatile compounds from cotton and sunflower genotypes

Gas chromatography studies of cotton leaf extract of the genotype DHH-543 indicated the presence of caryophyllene oxide at very high quantity (18.68%) followed by 1–hexanol (12. 98%) and 1-petnanol (11.38%). The highest oviposition, higher behavioural response in Wind Tunnel Olfactometer, stronger EAG response and also higher feeding by *C. carnea* could be due to sufficiently large quantity of β-caryophyllene oxide which might have acted as stimulant. These results are in close confirmation with Anon. (2000) who reported higher β-caryophyllene content in most of the cotton genotypes which is one of the most important oviposition attractant.

On the other hand, the cotton genotype PA-255 recorded lower quantity of β-caryophyllene oxide 1-pentanol and 1-hexanol compared to DHH-543 which resulted in lower response by *C. carnea*. These results are in line with Bakthavatsalam *et al*. (2002) who also recorded higher β- caryophyllene in MCU-10 genotype of cotton which received more number of eggs of *C. carnea* compared to other cotton cultivars.

Sunflower genotype, KBSH-1 recorded heptadecane (38.28%), linalool (21.80%), caryophyllene oxide (9.74%) and hexadecane (7.24%) at very high quantity which were identified through GCMS. The higher response of *C. carnea* to KBSH-1 under wind tunnel olfactometer, EAG and feeding potential was due to the presence of caryophyllene at higher quantity. Anon. (2000) from PDBC, Bangalore also confirmed the presence of β-caryophyllene in KBSH-1.

However, lower level of detectable hydrocarbons was present in Jwalamukhi genotype of sunflower. The negligible quantity or absence of β-caryophyllene in VRF-21 may

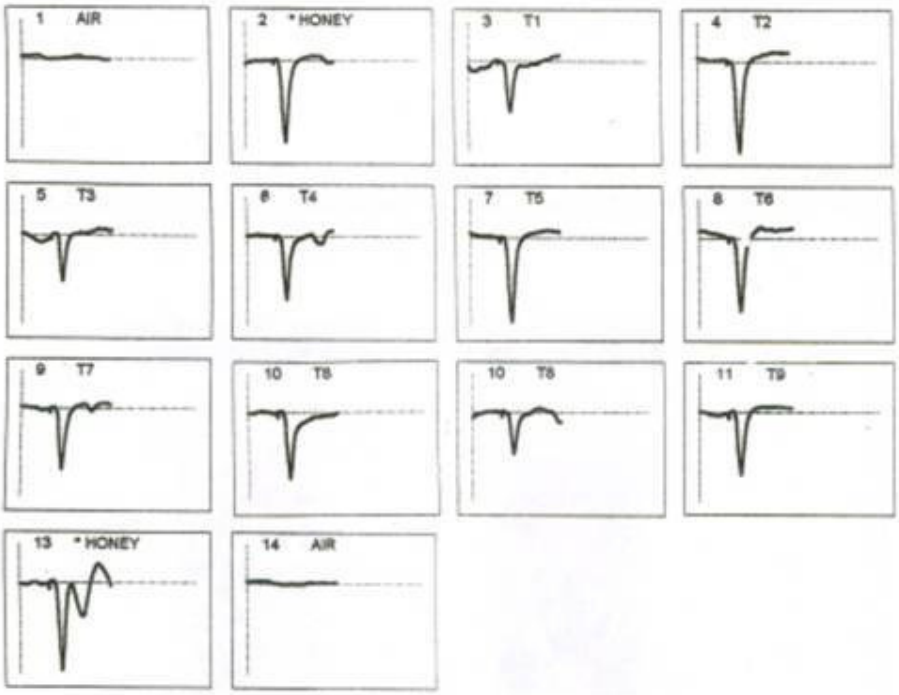

Fig. 5. Electroantennogram response of female *C. carnea* to sunflower leaf extract

Fig 5. Electroantennogram response of female C. carnea to sunflower leaf extract

T1 : DSH – 1	T2 : KBSH – 1	T3: PCSH – 243	T4: MSFH – 17
T5 : Morden	T6 : RSFH – 1	T7: SFL – 107	T8: Jwalamukhi
T9 : DSF – 2	T10: VRF - 21		

Fig.6. Electroantennogram response of female *H. armigera* to sunflower leaf extract

Fig 6. Electroantennogram response of female H. armigera to sunflower leaf extract

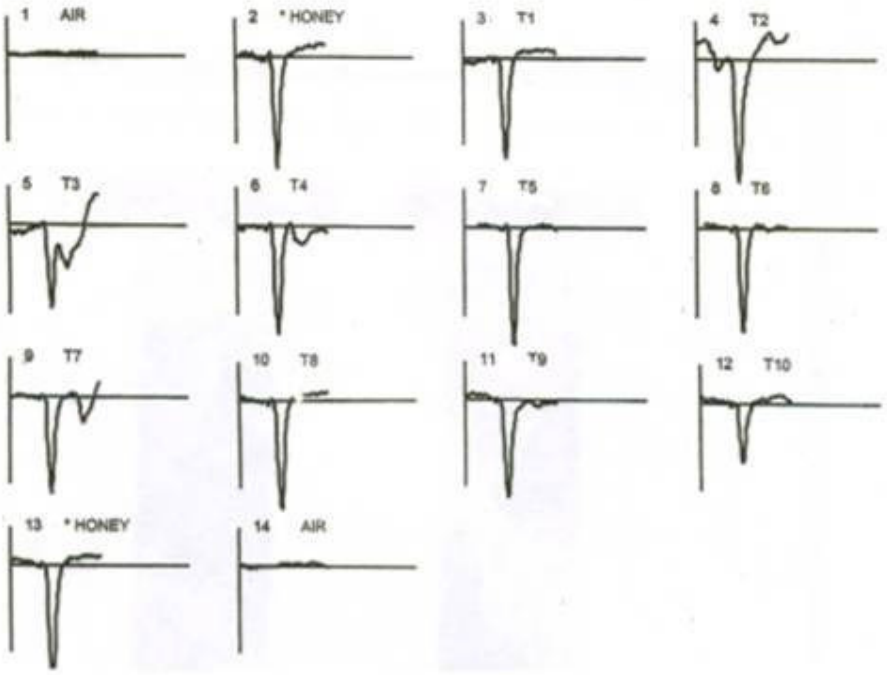

Fig. 7. Electroantennogram response of female *C. carnea* to sunflower capitulam extract

Fig 7. Electroantennogram response of female C. carnea to sunflower capitulam extract

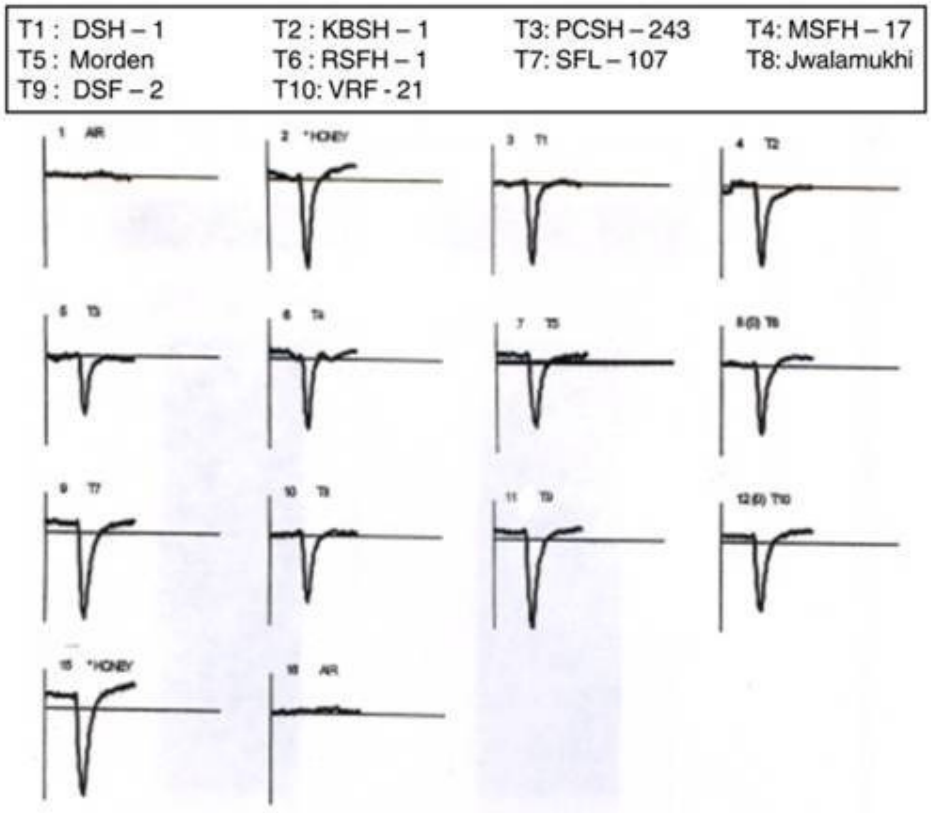

Fig. 8. Electroantennogram response of female *H. armigera* to sunflower capitulam extract

Fig 8. Electroantennogram response of female H. armigera to sunflower capitulam extract

be the reason for lower response of *C. carnea*. These finings are in line with Flint *et al*. (1979) who reported that caryophyllene and β-caryophyllene compounds may be able to attract the green lace wings under field conditions.

5.4 Feeding potential of chrysopids on *H. armigera* eggs on different genotypes of cotton and sunflower

The efficiency of the predation of the three species of chrysopids *viz., C.carnea, Mallada aster* (Bank) and *Mallada boninensis* (Okamoto) varied among the different genotypes of the cotton which can be presumably attributed to the various volatile profiles as well as to the allelochemical complex of the genotypes.

5.4.1 Feeding potential of chrysopids on *H. armigera* eggs on different cotton genotypes

The highest predatory potential of *C. carnea against H. armigera* eggs was noticed on DLSA-17, DHH-543, Abhadita, DHH-11, MCU-5 and PA-255 where the average trichome density of these genotypes was less. On the other hand, predation of *H. armigera* eggs by *C. carnea* was significantly lower on DB-3-12, Sahana, AK-235 where the average trichome density was more. Thus it can be concluded that the predation rate was negatively associated with trichome density which is in agreement with the work of Ramnath and Uthamasamy (1992). Cotton leaf with higher number of trichomes inhibits the movement of the predatory grub on leaf surface as mechanical barriers consequently reduced the predation by chrysopid grubs.

The present findings are also in conformity with Treacy *et al.* (1983) who found that predation of *Heliothis zea* (Boddie) eggs by *Chrysoperla rufilabris* (Burmeister) was low on pilose varieties and high on glabrous verities. Further, the glandular trichomes secrete sticky substances that may inhibit movement as reported by Obrycki and Tauber (1984) and Coll and Ridgway (1995).

In the present study, all the three species of chrysopids (*C. carnea, M. aster* and *M. boninensis)* devoured significantly lower number of *H. armigera* eggs on DB-3-12, Sahana and AK-235, which may be due to higher trichome density on these genotypes which inturn inhibited the movement and searching ability of the predatory grubs. Cotton trichomes served as mechanical barriers which reduced mobility and consequently predating ability of the chrysopid grubs which is in agreement with the findings of Ramnath and Uthamasamy (1995). Shepard and Sterling (1972) also reported that hirsute genotypes generally supported fewer beneficial arthropods.

Even though the trichome density was higher on DHH-543 and NHH-44, the mean number of *H. armigera* eggs consumed by all the three species of chrysopids was more. The present study is in agreement with Tracy *et al.* (1983), Mohite and Uthamasamy (1998) but contradictory with the reports of Ramnath and Uthamasamy (1995). This indicated that not only the host insect, the host plants also influence the activity of natural enemies, which may due to the presence of higher quantity of detectable hydrocarbons especially cryophyllene oxide (18.69%) which arrest the predatory grubs in stimulating more predation. Similarly, Flint *et al.* (1979) and Annadurai *et al.*(1995) reported that presence of caryophyllene in cotton cultivars helps in increased rate of predation by the larvae of *C. scelestes and C. carnea.*

Among the three species of chrysopids evaluated for their predatory potential on cotton genotypes, *C. carnea* devoured more eggs followed by *M. boninensis* and *M. aster,* which may be due to the fact that *C.carnea* were able to search for their prey at a much greater speed than *M.boninensis* and *M. aster*. Further the feeding preference of *C. carnea* on *H. armigera* eggs was more than the other two species.

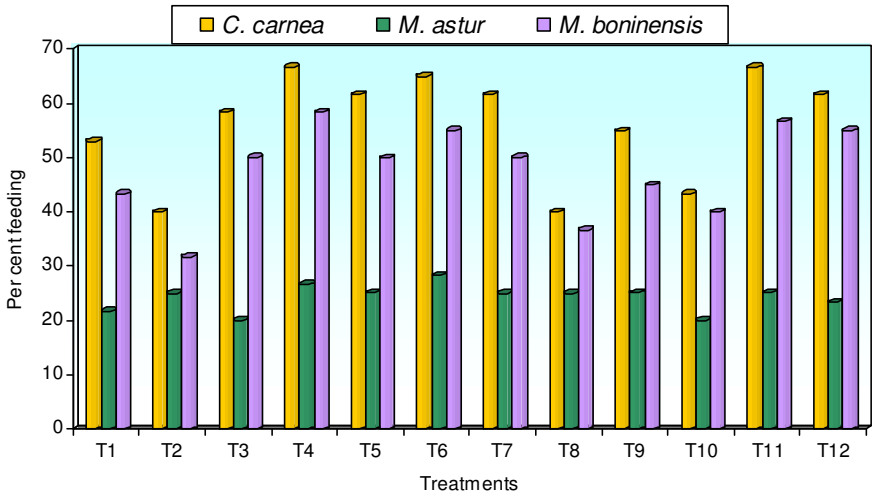

Fig 9. Feeding potential of Chrysopids on *H. armigera* eggs on genotypes on cotton

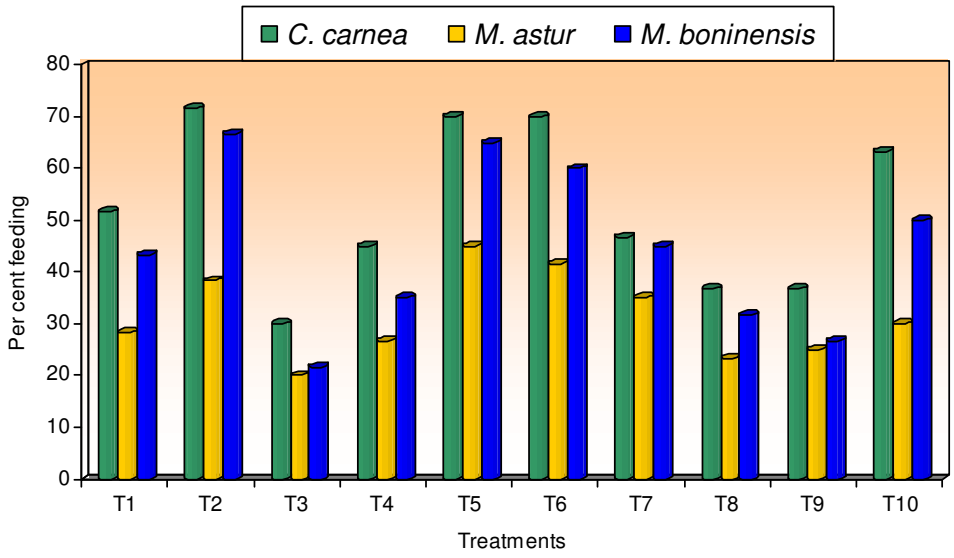

Fig 10. Feeding potential of Chrysopids on *H. armigera* eggs on genotypes on sunflower

5.4.2 Feeding potential of chrysopids against *H. armigera* eggs on different genotypes of sunflower

Significantly more number of *H. armigera* eggs were devoured by all the three species of chrysopids (*C. carnea, M. aster* and *M. boninensis*) on KBSH-1, Morden and RSFH-1 which may be due to lower leaf trichomes, which helps the predatory grubs to devour more eggs (Fig. 9 & 10). Apart from lower trichome density, the genotype KBSH-1 was also having higher level of caryophyllene oxide (9.74%) an volatile compound which may arrest the predatory grub and increases the searching capacity on these genotypes. The lower trichomes on these genotypes may also help the grub for easy movement and more predation. Ramnath and Uthamasamy (1995) opined that predation of eggs and neonate *H. armigera* by *Chrysopa scelestes* grub was maximum on genotypes with fewer trichomes. These findings are also in line with Treacy *et al.* (1983), who found that predation of *H. zea*

eggs by *C. rufilabris* was low on pilose varieties and was high on glabrous cotton. Caryophyllene from a variety of host plant source was reported to be an attractant for *C. carnea* by Flint *et al.* (1979).

Fig. 9: Feeding potential of *Chrysopids* on *H. armigera* eggs on genotypes of cotton

Fig. 10: Feeding potential of *Chrysopids* on *H. armigera* eggs on genotypes of sunflower

On the other hand, these predators devour lower number of *H. armigera* eggs on MSFH-17, PCSH-243 and SFL-107 which may be due to higher trichome density on these genotypes which hindered the searching rate of the predatory grubs. These findings are in accordance with Annadurai *et al* (1995), Mohithe and Uthamasamy (1998) who reported that higher trichome density reduces the predation of *Chrysopa* on cotton.

Even though the trichome density of Jwalamukhi was very less but the predation was lower than other genotypes which were having more trichome density which may be due to volatile chemicals or non preference characteristics of the genotypes. These findings are in line with Mohithe and Uthamasamy (1998) who reported that there was no direct linear relationship between trichome density and predation of eggs. Plant volatiles may be important in guiding predators to their prey.

5.5 Use of *C. carnea* in cotton Integrated Pest Management

The results obtained from the studies involving selected genotype of cotton (DHH-543), with release of *C. carnea* at different doses along with seed treatment with imidacloprid, intercropping with lucerne, application of NSKE @ 5 per cent, monitoring of *H. armigera* using pheromone traps was carried out during 2002 kharif season.

5.5.1 Incidence of sucking pests in different treatments

Leafhopper (*Amrasca bigutalla bigutalla* Ishida) incidence at the early stage of the crop growth (30 DAS) showed lower incidence in T1, T2, T3 and T4 treatments as a result of seed treatment with imidacloprid when compared to untreated control plot (T5). From 45 DAS to 75 DAS (during peak incidence of leafhopper), T4 (RPP) was superior in reducing leafhopper population followed by T1, T2 and T3. The mean population of leafhopper was significantly less in T4 followed by T3 and T2.

Aphid (*Aphis gossypii* Glover) infestation was significantly low in T1, T2, T3 and T4 at 30 DAS. From 45 to 75 DAS T4 recorded significantly lower aphid population followed by T3, T2, and T1 than T5. At later stages *viz.,* 90 and 120 DAS all the bioagent treatments recorded lower aphid population than RPP. Subsequently, at later stages aphid incidence increased in RPP. The mean population showed the superiority of T2, T3 and T4 followed by T1 (at 0.75 and 1.00 lakhs) than T5 (UTC).

Thrips (*Thrips tabaci* Lind) population was noticed throughout the cropping season with a heavy population during early stages of the crop growth. Significantly lowest population was recorded in T4 (RPP) and T3 followed by T2 treatment throughout the cropping period. The mean population of thrips indicated significantly lower population in T3 which was superior to T1 and T2 but inferior to T4.

Whitefly (*Bemisia tabaci* Gennadium) population was noticed at later stages of the crop growth period. Even at peak incidence, the population of whitefly was below ETL in almost all the treatments. At, 60 DAS the incidence of whitefly population was negligible, but later the population increased gradually up to 105-DAS with a decline at later stages. The mean population was significantly lowest in T3 followed by T2.

All the sucking pests during the season were below ETL except aphid at 60 DAS. The comparative analysis of average population of all the four sucking pests reveal that T3 was as effective as RPP against aphids and whiteflies but inferior to RPP against leafhopper and thrips.

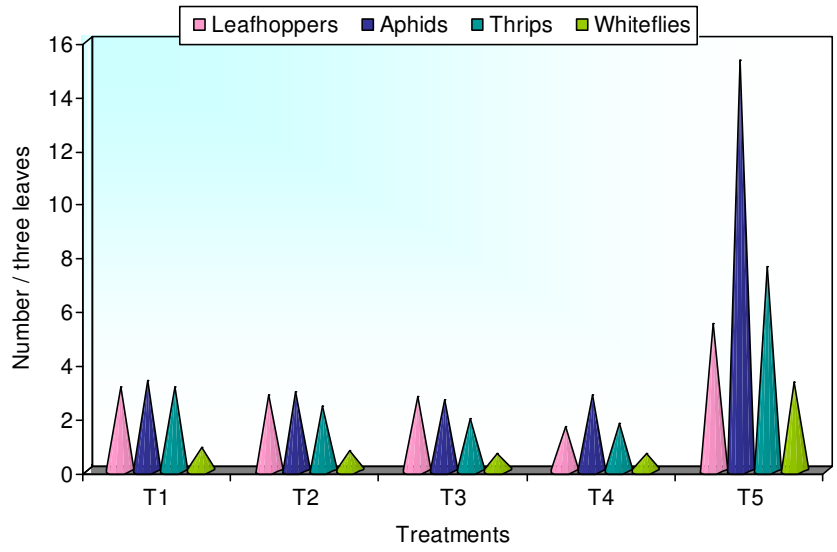

Fig 11. Influence of treatments on the mean population of sucking pests on cotton

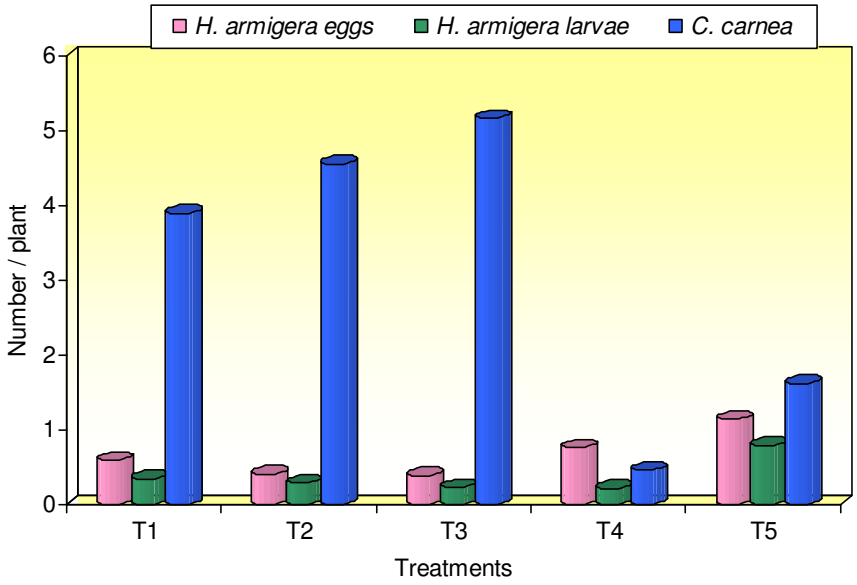

Fig 12. Influence of treatments on population of *H. arimgera* (eggs and larvae) and *C. carnea* on cotton

Due to initial seed treatment with imidacloprid, the treatments T1, T2, T3 and T4 recorded lower population of sucking pests up to 45 days of sowing. As the days advanced, the sucking pest population in untreated control increased but in T4 (RPP) and other treatments the population decreased gradually due to application of toxic chemicals in RPP and following applications of NSKE 5 per cent followed by release of *C. carnea* at different doses *viz.,* 0.50, 0.75 and 1.0 lakh per ha in T1, T2 and T3 treatment, respectively.

The present findings are in line with Kumar and Santharam (1999) who reported that seed treatment with imidachloprid (Gouch) at 7.0 g per kg of seeds was found effective against both aphids and leafhoppers on cotton. The lower incidence of sucking pests in all the imidacloprid seed treated plots in the present study is also in line with Mote *et al*. (1995), Toda and Kashio (1997) and Satpute *et al*. (2002) who reported that, seed treatment with imidacloprid or thiamethoxam was not only safe but also attracted the population of

coccinellid adults and *C. carnea* for egg laying due to increase in chlorophyll and nitrogen content in the plant.

Application of biorational *i.e.* NSKE 5 per cent and release of *C. carnea* @ 0.50, 0.75 and 1.00 lakh per ha in T1, T2 and T3 treatments, respectively also suppressed the population of aphids, thrips and leafhoppers throughout the crop growth. RPP (T4) suppressed leafhopper, aphid, thrips and whitefly incidence at initial stages but recorded higher population at later stages of the crop growth which might be because of elimination of natural enemies especially *Chrysoperla* and *coccinellids* due to periodic application of insecticides.

Kulkarni *et al*. (2004) observed high incidence of sucking pests complex at initial stages but reduced after 45 DAS due to release of *C. carnea*, which was attributed to high buildup of *C. carnea* which agrees with the present findings.

The present findings indicated significantly lower population of natural enemies (*Chrysoperla*) (Table 41) and also lower incidence of sucking pests in T4 which may be due to application of toxic insecticides that effectively suppressed sucking pests and natural enemies. The present findings are in line with Patil *et al*. (2004) who reported that seed treatment followed by application of systemic insecticide effectively suppressed all the sucking pests and natural enemies in conventional cotton hybrids.

Table 41: Influence of treatments on the population of *C. carnea* on cotton

5.5.2 Bollworm population in different treatments

Helicoverpa armigera being the main target pest on cotton was noticed in two peaks as indicated by egg load during cropping season of 2002. First peak egg load was noticed around 60-75 DAS coinciding with flowering and square formation stage followed by second peak at 105 DAS coinciding with boll formation stage. At early stage of the crop growth the incidence of egg load was negligible. After release of *C. carnea,* the egg load of *H. armigera* drastically reduced in T3 and T2 followed by T1 treatment as compared to T4 (RPP) and T5 (UTC). *Helicoverpa* egg load reduced after 120 DAS. The average egg load per plant showed the superiority of T3 and T2 compared to other treatments (Fig. 11 & 12). The release of biocontrol agent (*C. carnea*) in the present study has a significant impact on the population of cotton bollworm. The actual reduction due to release of predator and application of NSKE @ 5 per cent was noticed in T3 , T2 and T1 treatments released with 1.0 , 0.75 and 0.50 lakhs grubs of *C. carnea* per ha, respectively. The potentiality of *C. carnea* to reduce the eggs of *H. armigera* and other lepidopterous pests has been placed on document by Ewing and Ivy (1943), Juan *et al*. (1976), Krishnamoorthy and Mani (1982), Megahed *et al.*(1982), Gurbanov (1984), Sengonca and Grootirmorst (1985), Anon. (1994b), Anon. (1997a), Longanathan *et al*. (2000) and Reddy and Manjunath (2000).

Fig. 11: Influence of treatments on the mean population of sucking pests on cotton

Fig. 12: Influence of treatments on population of *H. armigera* (eggs and larvae) and *C. carnea* on cotton

The trend of *H. armigera* larval population was similar to that of egg load at different intervals on cotton. Larval population was below ETL up to 60 DAS in all the treatments. However, its population was significantly lower in RPP up to 105 DAS followed by T3 and T2 treatments. At 120 and 135 DAS the larval population in T4 (RPP) was slightly higher than in biocontrol treatments *viz.,* T3 and T2. Based on the mean larval population of *H. armigera* it is clear that T3 was as effective as RPP in reducing the larval load. The efficiency of *C. carnea* in reducing the larvae of *H.armigera*, *H. virescens* in cotton, has been reported by Pearson (1940), Lingren *et al*. (1968), Ridgway and Jones (1968 and 1969), Smith *et al*. (1980), Gurbanov (1984), Yadav and Patel (1987a), Anon. (1994c), Patel and Yadav (1993), Sreenivasa (1995) and Patil (1996) which agrees with the present findings.

In general, *Helicoverpa* was suppressed effectively throughout the crop growth period in all the treatments though egg load and larval population crossed ETL several times in untreated control during crop growth period indicating effectiveness of all the treatments.

The green lacewing, *C. carnea* is the potential predator of small and comparatively soft bodied arthropods. Although aphids are the primary preys, eggs and larvae of many lepidopterons are readily accepted by the neuropterans.

The study made by Praveen and Dhandapani (2001) by the release of predator, *C.carnea* and application of econeem 0.3 per cent for three times at 15 days intervals starting from 45 DAS was found to be effective in reducing sucking pests and fruitborer effectively on bhendi which supports the present findings.

In the present study all the bioagent treatments were moderately effective at the early stage and showed much effectiveness at the later stages which may be due to self perpetuation of *C. carnea* and also non application of insecticides.

The preliminary study made by Canard *et al.* (1984) , Morrison (1985), Anon. (1992a), Bharpoda *et al*. (2000), Longanathan *et al*. (2000), Singh and Kumar (2000), Kumar *et al*. (2001), Kulkarni *et al*. (2004) and Panchabhavi *et al*. (2004) regarding the release of *C. carnea* and other biocontrol agents at different days intervals gave significant reduction of *H. armigera* and other sucking pests as good as RPP which also supports the present findings.

Slightly higher bollworm larval population in T4 at later stages (120 and 135 DAS) may be attributed to disturbance to natural enemies population at early stages by insecticides which is in agreement with Turnipseed *et al*. (1999) and Venkateshalu (2005) who observed more bollworm population in early disturbed Bt cotton plots than in undisturbed Bt cotton and non Bt cotton plots.

Neem Seed Kernel Extract (NSKE) 5 per cent was found to be effective against *H. armigera* and other sucking pests in cotton ecosystem due to its repellent, antifeedent activity and development abnormality in larval, pupal and adult stages of *H. armigera*. The present study is also in line with Saxena and Rembold (1984), Jhansi and Singh (1996), Kundu *et al*. (1998) and Bajpai and Sehgal (2003) who reported that NSKE @ 5 per cent and other neem based pesticides were very effective to cotton pests and safer to the natural enemies.

Chrysoperla carnea population was significantly higher in T3 followed by T2 and T1 where inoculative release of *C. carnea* (1.0, 0.75 and 0.50 lakhs / ha), was made along with intercropping with lucerne and application of NSKE 5 per cent which helped in multiplication of *C. carnea* compared to T5 (UTC). Significantly lower *Chrysoperla* population was recorded in T4 (RPP) which may be due to the toxic effect of insecticides used in the treatments.

Intercropping with lucerne along with different doses of *C. carnea* release recorded significantly higher population of *C. carnea* in T3 followed by T2 and T1 which may be due to provision of pollen and nectar for the natural enemy which enhanced egg laying and multiplication of *Chrysoperla* and inturn brought down the pest load drastically. Stern (1969), Fly (1972), Root (1973), Risch (1981), Van Emden (1989), Edward *et al*. (1992), Risch *et.al.* (1983), Venugopal Rao *et al*. (1994), Saminathan *et. al.* (1999), Saminathan and Mahadevan (2000) and Saminathan *et al*. (2003a and 2003b) reported that intercrops acted as ecofeast crops and conserved large number of natural enemies by providing pollen and nectar. They also opined that intercropping system increased the diversity of the ecosystem and the population of natural enemies and there by reduced the pest population which agrees with the present findings.

5.5.3 Bollworm damage in different treatments

Fruiting bodies damage was recorded as an indication of bollworm incidence. Fruiting bodies damage included flared up squares, damaged green bolls and dropped squares and bolls due to damage mainly by *Helicoverpa*, spotted bollworm and pink bollworm.

Fruiting bodies damage throughout the cropping season was significantly lower in T4, T3 and T2 when compared to T1 and T5 (UTC). T3 was as effective as RPP in reducing the fruiting bodies damage, followed by T2. The present findings are in agreement with Patil *et al*.

(2002) who ranked the performance of modules in the order of RPP > biointensive module with respect to bollworm damage.

5.5.4 Yield parameters and yield in different treatments

The efficacy of T2 and T3 remained same in recording GOB / plant which was comparable with RPP. Whereas T1 where 0.5 lakh *C. carnea* grubs were released proved ineffective in recording GOB / plant. Almost the similar trend in the efficacy of various treatments was noticed with regard to BOB / plant. Lowest percent locule damage was noticed in T3 being on par with RPP, while T1 and T2 were on par with each other but superior to untreated check.

Seed cotton yield followed similar trend as that of good opened bolls, where T3 (9.00 q ha) and T2 (8.4q/ha) were at par with each other and recorded higher yield, obviously due to increased predation resulting in lower boll damage and higher yield (Fig. 13). The superiority of T4 (recommended package of practices) in registering highest yield was due to effective control of sucking pests and bollworms and recorded more number of good opened bolls and less number of bad opened bolls and finally higher seed cotton yield. These results are in line with the reports of Anon. (1990) and Gill *et al*. (1993).

Fig. 13: Influence of treatments on yield of cotton

The present findings clearly indicated that, the release of *C. carnea* at 0.75 and 1.0 lakhs per ha along with lucerne as intercrop and application of NSKE @ 5% can effectively manage the insect pests of cotton. However, due to higher cost of *C. carnea* grubs, an analysis of cost effectiveness of release of predator, showed negative net returns under dry land situation in Dharwad district of Karnataka.

5.5.5 Sucking pests incidence on sunflower in different treatments

Leafhopper population at the early stage of the crop growth (30 DAS) was significantly less in all the bioagents released plots and RPP at 40 and 50 DAS. RPP performed better in reducing the leafhopper population compared to bioagents released plots. At 60 and 70 DAS, bioagent treated plots, *viz,* T3 and T2 were as effective as RPP but significantly inferior to T1. The over all efficacy of different treatments based on the mean population revealed that T3 was significantly superior to T1 and T2 but inferior to RPP.

Thrips, *T. tabaci* incidence was below ETL throughout the cropping season during 2002 at Dharwad situation. However, in the early stages of the crop growth (30 DAS), all the seed treatment plots with imidacloprid (T1, T2, T3 and T4) recorded lower thrips population than T5 (UTC). At peak incidence (40 DAS), T4 (RPP) recorded significantly lower thrips population followed by bioagent treated plots (T1, T2 and T3). As the days advanced T4 (RPP) and higher dosages of bioagent treated plots (T3 and T2) recorded lower thrips population than its lower dosage treated plot (T1). The mean population indicated the superiority of T3 compared to T1 and T2 but inferior to RPP.

Whitefly, *B. tabaci* population was negligible up to 40 DAS and peak incidence was noticed at 60 DAS. Significantly lower population was recorded in T3 and T2 being on par with RPP at 70 DAS. The mean population indicated the superiority of T3 compared to T1 and T2 but inferior to RPP.

The population of sucking pests *viz.,* leafhopper, thrips and whitefly were recorded during the season. Among the different dosages of bioagent released treatments, T3 was found superior which recorded lower incidence of all the sucking pests compared to other treatments. Seed treatment with imidacloprid recorded lower population of sucking pests in all the treatments compared to T5 in the early stage of the crop growth. Population of sucking pests were lower in T4 (RPP) throughout the season due to application of toxic chemical and also in T1 , T2 and T3 treatments due to application of NSKE and release of bioagent (*C.carnea*) at different dosages compared to untreated check. Self perpetuation of bioagent in the middle stages brought drastically reduction in the pest population at later stages. The present findings are in line with Basappa and Sriharan (1999) and Bhat *et al*. (2003) who

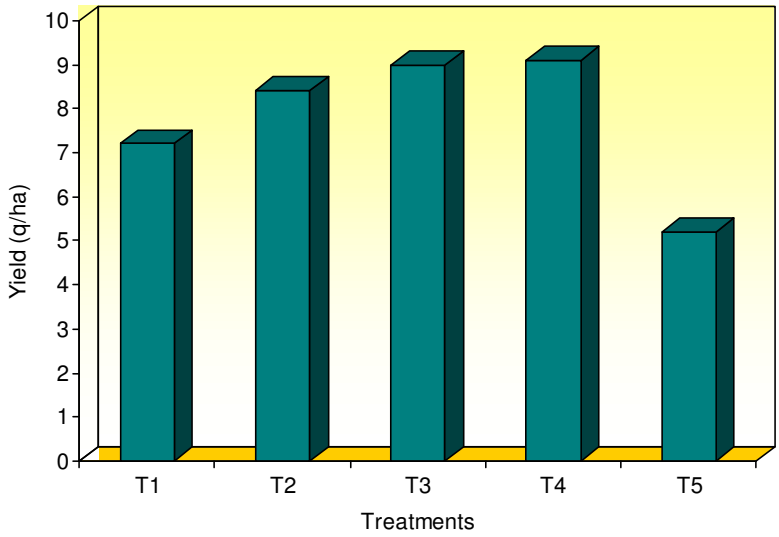

Fig 13. Influence of treatments on yield of cotton

reported that sunflower seeds treated with imidacloprid (Gouch) @ 5, 7.5 and 10.0 g per kg of seeds gave significant control of sucking pests in sunflower up to 45 DAS.

The efficacy of NSKE and other neem based products are well documented by Basappa (1996), Anon. (1997a), Anon. (1998), Sridevi (1998) and Basappa and Sriharan (1999) for the management of sucking pests in sunflower which supports the present findings.

The potentiality of *C. carnea* @ 0.6 and 0.4 lakhs per ha for the management of sucking pests in sunflower in the present study is also in line with Goel and Kumar (1990), Venkatesan *et al*. (1997), Kumar *et al*. (2001), Gautam and Tesfaye (2002) who reported that release of *C. carnea* @ 1 to 2 per plant along with neem based pesticides effectively controlled the early sucking pests population in sunflower ecosystem. They also opined that neem based pesticides were safer to the predatory Chrysopids in sunflower ecosystem.

5.5.6 Head borer population in different treatments

The head borer, *H. armigera* being major pest of sunflower was noticed in its peak at 70 DAS as indicated by egg load during cropping season. The egg load of *H. armigera* was below ETL (< 1 egg / plant) up to 50 DAS in all the treatments including T5 (UTC). The peak egg load was noticed at around 60 to 70 DAS coinciding with capitulam formation and flowering stage. Among the treatments T3 and T2 recorded significantly lower egg load which was followed by T1 at peak egg load stages of the crop. The average egg load indicated the superiority of T3 and T2 followed by T1, while RPP was inferior to all the bioagents released plots in reducing the egg load.

Helicoverpa armigera larval population also followed similar trend as that of *H. armigera* egg load at different days after sowing in sunflower ecosystem. The head borer larval population was below ETL up to 50 DAS. At peak larval incidence (70 DAS), higher doses of bioagent released plots (T3 and T2) were as affective as RPP. But at later stage (90 DAS) T3 and T2 were significantly superior to RPP. The average population indicated the superiority of higher dosage of bioagent treated plots (T3 and T2) being on par with RPP.

Helicoverpa armigera was suppressed effectively throughout the crop growth period in higher dosage of biocontrol released plots (T3 and T2) and RPP though egg load and larval

population crossed ETL several times in untreated control indicating effectives of higher dosages of bioagent treatments and RPP with KBSH-1 genotype.

The release of biocontrol agents in the present study had a significant impact in reducing the incidence of head borer in sunflower ecosystem. The actual reduction in pest incidence was due to release of predator @ 0.60, 0.40 and 0.20 lakh per ha application NSKE 5 per cent evident in T3, T2 and T1 treatments, respectively. The potential of chrysopids in reducing egg and larvae of *H. armigera* and other lepidopteron pests and soft bodied insects has been documented on several crops by Longanathan *et al.* (2000) and Reddy and Manjunath (2000) and many others.

The study made by Bhat *et al.*(1993) and Anon. (1994c) by releasing of predator, *C.carnea* @ 1 grub per head lead to the reduction in eggs and neonate larvae of *H. armigera* in sunflower ecosystem. The present findings are also in line with Goel and Kumar (1990) who reported that release of the predator in sunflower play vital role in suppression of lepidopterous eggs and neonate larvae.

The head borer larval abundance was below ETL up to 50 DAS. At 60 days after sowing all the bioagent treated plots (T3, T2 and T1) recorded lower larval population but higher than T4 (RPP) and continued up to 70 DAS. At the end of the cropping season T4 (RPP) recorded higher larval population when compared to bioagent treated plots because of elimination of natural enemies due to application of toxic chemicals in T4. On the other hand, lower larval population in all the bioagent treatments was due to self perpetuation of bioagents and application of NSKE which conserved the natural enemies to a larger extent by devouring the *Helicoverpa* larval population.

The reduction in laraval population in the present study can be mainly attributed to release of *C. carnea* and application of NSKE 5 per cent. These results are in support of the findings of Bhat *et al*. (1993), Anon. (1994c), Venkatesan *et al*. (1997) and Ballal and Singh (1999).

The superiority of RPP over other treatments in reducing the larval population might be due to application of toxic molecules especially endosulfan spraying. The superiority of endosulfan spray has been reported by Panchabhavi *et al*. (1977), Abdule and Kadam (1978), Bhosle *et al*. (1990), Bijjur (1990) and Arya *et al*. (1996) which supports the present findings.

The efficacy of NSKE 5 per cent against *H. armigera* is in conformity with Kareem (1980), Kumar and Sangappa (1984), Gohokar *et al*. (1987), Thakur *et al*. (1988), Dubey *et al*. (1991), Kukkapalli (2000), Bajpai and Sehgal (2003), Basappa (1998) and Basappa and Sriharan (1999).

The population of predator, *C. carnea* was very low in the early stage of the crop growth but after inaculative release of *C. carnea* significantly higher *C. carnea* population was recorded in bioagent released plots in T3 and T2 throughout the cropping season. Significantly, lower *Chrysoperla* population was recorded in RPP. The average population of *C. carnea* was significantly higher in T3 followed by T2 and T1. While the population was significantly less in RPP due to intervention by insecticidal application.

More number of *Chrysoperla* populations in bioagent released plots (T3, T2 and T1) was attributable to non application of toxic chemicals and self perpetuation of *Chrysoperla* (Fig. 14 & 15). On the other hand, application of toxic chemicals in T4 (RPP) reduced the population of *Chrysoperla* drastically compared to untreated check (T5). The present findings are in agreement with the reports of Manjunath (1995), Venkatesan *et al*. (1997) who stated sunflower crop as a reservoir of natural enemies due to availability of pollen and nectar.

Fig. 14: Influence of treatments on the mean population of sucking pests on sunflower

Fig. 15: Influence of treatments on population of *H. armigera* (eggs and larvae) and *C. carnea* on sunflower

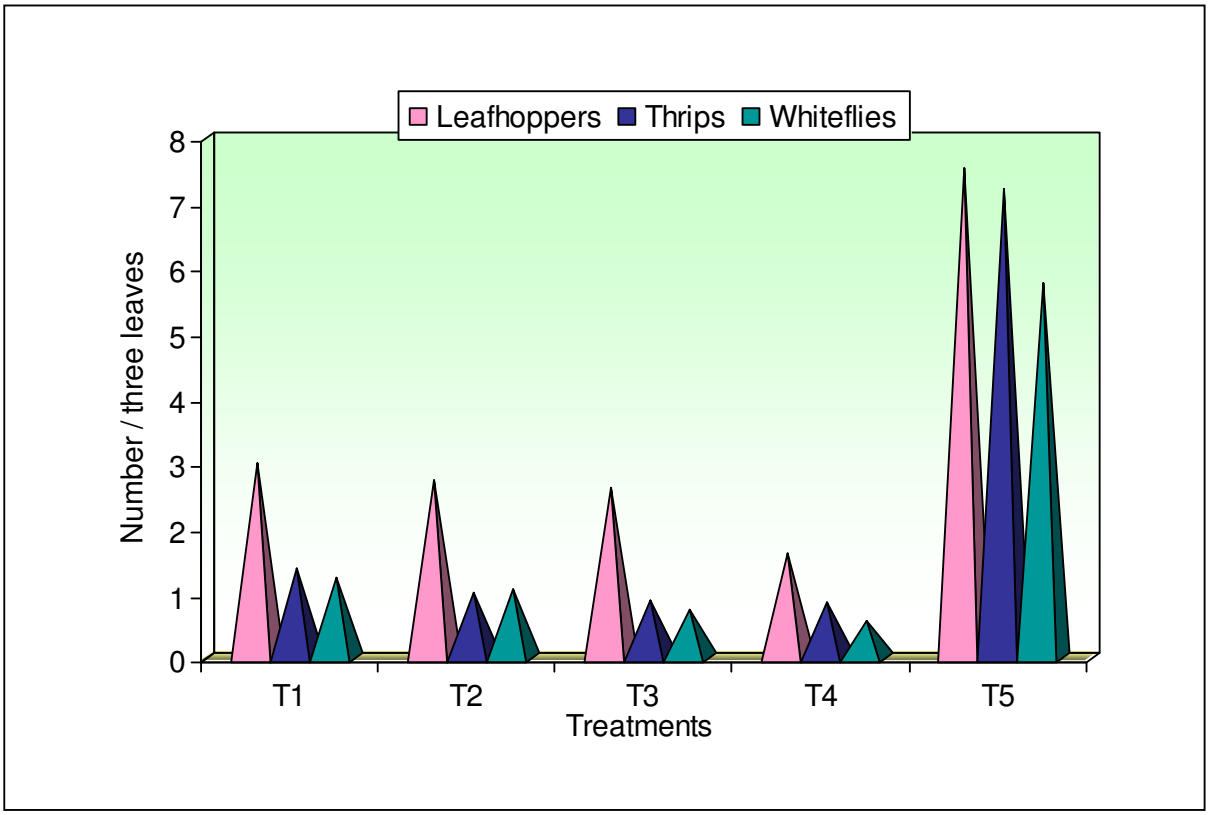

Fig 14. Influence of treatments on the mean population of sucking pests on sunflower

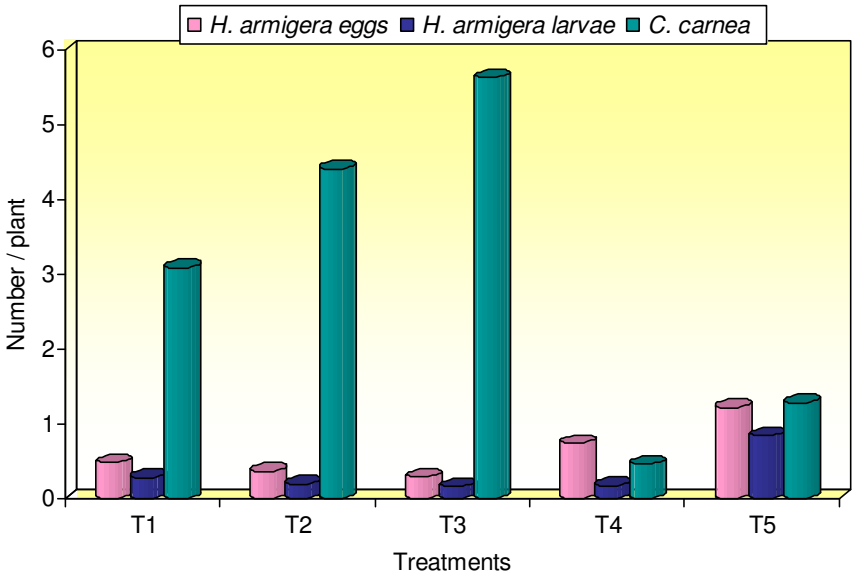

Fig 15. Influence of treatments on population of *H. arimgera* (eggs and larvae) and *C. carnea* on sunflower

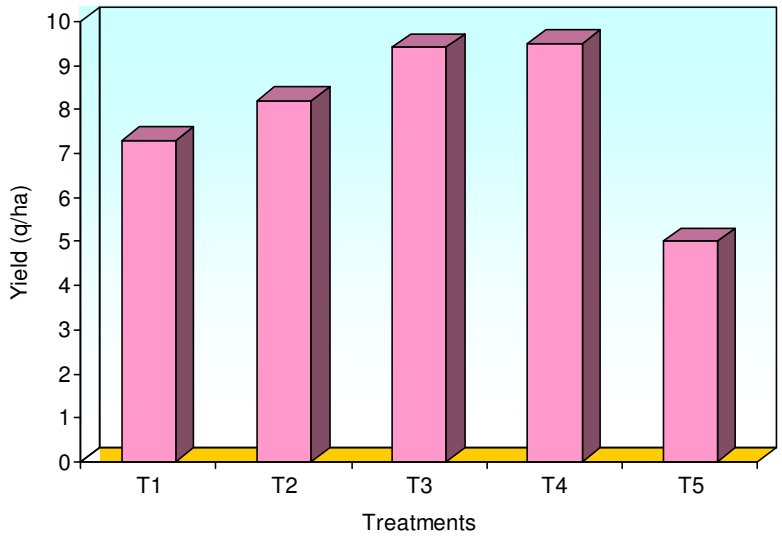

Fig 16. Influence of treatments on yield of sunflower

Application of neem based pesticides did not affect the population of *C. carnea* but toxic chemicals like synthetic pyrethroids adversely affected the population of *Chrysoperla* (Muralidharan and Chari , 1990 ; Rao *et al*., 1990 and Kundu *et al*. , 1998) which is in close akin with the present findings.

5.5.7 Influence of different treatments on yield of sunflower

Significantly higher seed yield of 9.40 q per ha was recorded in T3 being on par with T2 (8.20 q / ha) and T4 (9.50 q / ha) followed by T1 (7.30 q / ha) (Fig. 16). Significantly lowest yield of sunflower was recorded in T1 but higher than the T5 (5.00 q/ha).

Fig. 16: Influence of treatments on yield of sunflower

The increase in grain yield in T3 and T2 might be due to higher population of predatory chrysopids which intern managed the insect pest population. On the other hand, T4 (RPP) registered significantly higher grain yield as a result of application of toxic chemicals. The present findings are in agreement with the reports of Panchabhavi *et al*. (1977); Bhat *et al*. (1993), Anon. (1994a) and Arya *et al*. (1996).

Future line of work

1) Large scale field evaluation of oviposition preference by old world bollworm, *H. armigera* and the predator *C. carnea*,

2) Identification of actual plant volatile compounds (GCMS) responsible for attraction or repulsion of *C. carnea* from all the popular cultivars,

3) Exploration of synthetic plant volatile compounds to evaluate the behaviour of *C. carnea* and

4) Identification and evaluation of suitable intercrops in cotton and sunflower ecosystem to evaluate the performance of *C. carnea* and other natural enemies in the management of *H. armigera.*

VI. SUMMARY

Results of the experiments carried out on ovipositional preference of the pest, *Helicoverpa armigera* (Hubner) and the predator, *Chrysoperla carnea* (Stephens) on different genotypes of cotton and sunflower, behavioural response of *C. carnea* to cotton leaf, flowers and boll wash and sunflower leaf, capitulum and flower wash of different genotypes of cotton and sunflower using wind tunnel olfactometer, electroantennogram (EAG) response of *H. armigera* and *C. carnea* to different genotypes of cotton and sunflower, feeding potential of three species of chrysopid predators against *H. armigera* eggs on different genotypes of cotton and sunflower and use of *C. carnea* in the management of insect pests of selected genotypes of cotton and sunflower are summarized hereunder.

Ovipositional preference studies indicated that in the absence of *H. armigera, C. carnea* showed significantly higher oviposition preference for DHH -543 (9.33/ plant), DLSA-17 (8.80/ plant), DHH-11 (7.66 / plat), LRA-5166 (7.33/ plant) and Jayadhar (7.33 / plant) and showed significantly lowest oviposition on PA – 255 (5.33/ plant) Abadhita (6.33/ plant) and AK – 235 (6.66/ plant) at Vegetative stage of the cotton genotypes. Whereas in the presence of *H. armigera* it laid significantly higher number of eggs on DHH – 543 (12.66/ plant) and it showed significantly lowest on PA-255 (5.33/ plant), Abadhita (6.33/ plant) and AK – 235 (6.66/ plant) genotypes. While *H. armigera* showed significantly highest ovipositional preference for Sahana (30.33/ plant), AK – 235 (26.33/ plant), LRA- 5166 (26.33/ plant) , DHH- 11 (24.33/ plant), NHH – 44 (24.00/ plant), MCU –5 (21.66/ plant) and DHH – 543 (21.00/plant) and significantly lowest ovipoistion on DB- 3- 12 (13.99/ plant), Abadhita (15.00/ plant) and PA-255 (15.66/ plant).

At flowering stage of the cotton genotypes, *C. carnea* in the absence of *H. armigera* laid significantly higher number of eggs on DHH 543 (13.33/ plant), DLSA-17 (12.99/ plant) and LRA-5166 (11.66/ plant) and it laid significantly lower number of eggs on PA-255 (6.33/ plant) and Abadhita (6.99/ plant). Whereas in the presence of *H. armigera,* it laid significantly higher egg load on DHH -543 (15.99/ plant), Jayadhar (13.99/ plant), Sahana (13.66/ plant), LRA–5166 (13.33/ plant), DLSA–17 (13.00/ plant), DHH 11(12.66/ plant) and NHH-44 (12.33/ plant). It laid significantly lower number of eggs on PA 255 (6.33/ plant) and Abadhita (6.66/ plant). While *H. armigera,* laid significantly more number of eggs on Sahana (33.99/ plant), AK–235 (28.33/ plant), DHH-11 (28.33/ plant), LRA – 5166 (28.33/ plant) and MCU-5 (28.33/ plant) and on the other hand it laid significantly lower egg load on DB-3-12 (18.00/ plant), Abadhita (20.33/ plant), PA-255 (21.66/ plant), DLSA–17 (22.33/ plant), Jayadhar (22.99 / plant) and DHH–543 (26.00/ plant).

At boll formation stage in the absence of *H. armigera, C.carnea laid* significantly highest egg load on DHH-543 (12.99/ plant) and DLSA–17 (10.99/ plant) and it laid significantly lowest number of eggs on Abadhita (5.66/ plant) and PA-255 (6.00/ plant). Whereas in the presence of *H. armigera* it laid significantly higher number of eggs on DHH-543 (15.66/ plant), DHH–11 (14.33/ plant), Sahana (13.66/ plant), LRA-5166 (13.33/ plant) and MCU-5 (12.66/ plant) and in presence of *H. armigera,* it laid significantly lower number of eggs on PA – 255 (5.00/ plant) and Abadhita (7.00/ plant). While, *H. armigera* laid significantly higher egg load on Sahana (28.99/ plant), NHH –44 (28.66/ plant), AK – 235 (27.33/ plant), LRA- 5166 (27.33/ plant), DHH-11 (26.33/ plant) followed by MCU- 5 (25.99/ plant) and it laid significantly lower egg load on DB – 3-12 (16.99/ plant), Jayadhar (17.99/ plant) and Abadhita (19.00/ plant).

When compared across the different stages, the mean number of egg laying by *C. carnea* in the absence of *H. armigera* was on DHH- 543 (11.88/ plant) and it laid significantly lower number of eggs on PA-255 (5.44/ plant) and Abadhita (5.77/ plant). In the presence of *H. armigera*, it laid significantly more number of eggs on DHH-543 (14.77/ plant) and lower number of eggs on PA-255 (5.55/ plant). While, *H. armigera* laid significantly higher egg load on Sahana (31.10/ plant) and least number on DB-3-12 (16.66/plant) followed by Abadhita (18.11/plant). When compared across the stages of cotton genotypes *C. carnea* both in the presence and absence of *H. armigera,* laid more number of eggs at flowering followed by boll formation and vegetative stage. While, *H. armigera* also followed the similar trend in its egg laying pattern.

At vegetative stage of the sunflower genotypes in the absence of *H. armigera, C.carnea* laid significantly higher number of eggs on Morden (8.33/ plant), KBSH-1 (8.00/ plant) MSFH-17 (7.99/ plant), DSH-1 (6.66/palnt), PCSH-243 (6.33/ plant) and RSFH–1 (6.00/ plant) and lower egg load on DSF-2 (2.99/ plant), VRF-21 (3.33/plant), SFL–107 (4.33/plant) and Jwalamukhi (5.00/ plant). Whereas in the presence of *H. armigera* it laid significantly higher egg load on KBSH-1 (11.00/plant), Morden (10.00/ plant), RSFH-1 (9.00/ plant) and SFL-107 (8.33/ plant) and significantly lower eggs on VRF-21 (4.00/ plant) and DSF-2 (4.33/ plant). Whereas *H. armigera* recorded significantly higher oviposition on DSF-2 (31.00/ plant), SFL-107 (28.99/ plant), PCSH-243 (28.00/ plant), MSFH-17 (21.99/ plant) RSFH-1 (21.99/ plant), DSH-1 (20.66/ plant), Jwalamukhi (20.33/ plant) and Morden (19.00/ plant) and the genotypes which received lower number of eggs under tritrophic interaction studies was VRF-21 (13.66/ plant).

At capitulam formations stage in the absence of *H. armigera* , *C. carnea* laid significantly more number of eggs on KBSH-1(10.66/ plant), Morden (10.00/ plant), MSFH-17 (10.00/ plant), PCSH-243 (8.33/ plant), DSH-1 (8.33/ plant) and RSFH-1 8.33/ plant) and it laid significantly lower eggs on DSF-2 (4.99/ plant), VRF-21 (5.33/ plant) and SFL-103 (6.00/ plant). While in the presence of *H. armigera* it laid more eggs on KBSH-1 (14.00/ plant), Morden (13.00/ plant), MSFH-17 (11.99/ plant), RSFH-1 (11.66/ plant) and SFL-107 (11.33/ plant) and least on VRF-21 (6.00/ plant), DSF-2 (6.33/ plant) and Jwalamukhi (7.99/ plant). Whereas *H. armigera* laid significantly higher eggs on SFL-107 (40.33/ plant) and least on VRF-21 (16.33/ plant).

At flowering stage in the absence of *H. armigera, C. carnea* laid significantly highest number of eggs on KBSH-1 (15.66/plant) and Morden (14.99/ plant) and it was least on DSF-2 (6.00/ plant). While in the presence of *H. armigera,* it laid significantly more number of eggs on Morden (16.99/ plant), KBSH-1 (16.66/ plant) and RSFH-1 (15.66/ plant) and least number of eggs on VRF-21 (7.66/ plant) and DSF-2 (9.33/ plant). However *H. armigera* laid significantly higher oviposition on SFL-107 (48.66/ plant) and it laid least number of eggs on VRF-21 (18.00/ plant).

When compared across the stages, the mean number of eggs laid by *C.carnea* in the absence and presence of *H. armigera* was significantly highest on KBSH-1 and Morden and it laid least number of eggs on VRF-21 and DSF-2 genotypes of sunflower. Whereas *H. armigera* laid significantly lower eggs on VRF-21 (15.99/ plant).

When compared across the stages of sunflower, *C. carnea* in the absence and presence of *H. armigera* laid more eggs at flowering stage followed by capitulum formation and vegetative stage. While *H. armigera* also followed the similar trend in its egg laying pattern. Behavioural response of *C. carnea* towards the extract of different genotypes of cotton leaf, flower and boll extracts was studied under laboratory using eight arm olfactometer.

The behavioural response of *C. carnea* towards the leaf, flower and boll extract of DHH-543 (3.33, 3.99 and 3.66/ arm at leaf, flower and boll extract, respectively) was significantly higher and its response was significantly lower towards the extract of DB-3-12 (1.0, 1.66 and 1.33/ arm at leaf, flower and boll extract, respectively). However the mean behavioural response of *C. carnea* towards the extract of DHH -543 (3.66/ arm) and DHH –11 (2.89 / arm) was significantly more and least response by *C. carnea* was recorded towards the extract of DB-3-12 (1.33/ arm).

The orientation response of *C. carnea* towards the sunflower leaf extract of KBSH-1 (3.66/ arm) and Morden (3.66/ arm) was significantly higher and it was lowest on VRF–21 (1.99/ arm), DSF–2 (2.00/ arm) and SFL-107 (2.00/ arm). Whereas towards the capitulam extract, it showed more orientation towards the extract of KBSH-1 (4.00/ arm), Morden (3.99/ arm) and RSFH-1 (3.99/ arm) and it showed least response to the extract of VRF-21 (2.00/ arm). The orientation response of *C. carnea* to flower extract of KBSH-1 (4.99/ arm), Morden (4.66/ arm) and RSFH-1 (4.66/ arm) was significantly higher and least response was recorded towards the extract of PCSH-243 (3.00/ arm), Jwalamukhi (2.99 / arm), DSF-2 (2.66/ arm), DSH-1 (2.66/ arm) and VRF–21 (2.66/ arm). However the mean behavioural response of *C. carnea* towards the extract of KBSH-1 (4.22/ arm), Morden (4.10/ arm) and RSFH-1 (3.99/ arm) showed least response towards the extract of VRF-21 (2.22/ arm) and DSF-2 (2.33/

arm). Further, the response of *C. carnea* towards the extract of *H. armigera* scale 0.5 per cent and eggs at 100 eggs/ 10 ml of hexane was higher than its lower concentrations.

The feeding potential of *C. carnea* on *H. armigera* eggs on genotypes of cotton was significantly higher on DHH -543 (13.33 / grub), DLSA – 17 (13.33/ grub), Abadhita (13.00/ grub), DHH-11 (12.33/ grub), MCU-5 (12.33/ grub) and PA-255 (12.33 / grub) and it was least on AK –235 (8.66/ grub), Sahana (8.00/ grub) and DB-3-12 (7.99/ grub). While *M. boninensis* recorded highest feeding on DHH–543 (11.66/ grub), Abadhita (11.00/ grub) and DLSA- 17 (11.33/ grub) and least was on DB-3-12 (6.33/ grub) and Sahana (7.33/ grub).

Among the species of chrysopids, feeding on potential of *C.carnea* on cotton was more followed by *M. boninensis* and *M. aster*. However, among the genotypes, the mean feeding potential of chrysopids was significantly more on DHH- 543 (10.11/ grub), Abadhita (9.88/ grub), DLSA–17 (9.88/ grub), PA- 255 (9.33/ grub), MCU-5 (9.11/ grub) and DHH–11 (9.10/ grub) and significantly least feeding was recorded on AK–235 (6.88 / grub), Sahana (6.77/ grub) and DB- 3- 12 (6.44/ grub).

The potentiality of *C. carnea* for feeding *H. armigera* eggs on sunflower genotypes was significantly higher on KBSH-1 (14.33/ grub), Morden (14.00/ grub), RSFH-1 (13.99/ grub) and VRF-21 (12.66/ grub) and least was on PCSH–243 (6.00/ grub). While *M. aster* consumed more eggs on Morden (8.99/ grub), RSFH-1 (8.33/ grub) and KBSH-1 (7.66/ grub). Whereas, *M. boninenesis* also consumed more eggs on KBSH-1 (13.33/ grub), Morden (12.99/ grub) and RSFH-1 (12.00/grub) and it was least on PCSH–243 (4.33/ grub).

Among the species of chrysopids, feeding potential of *C. carnea* on sunflower was more followed by *M. boninensis* and *M. aster*. Whereas, among the genotypes, the mean feeding potential of chrysopids was significantly more on Morden (11.99/ grub), KBSH-1 (11.77/ grub) and RSFH-1 (11.44/ grub) and it was least on PCSH- 243 (4.78/ grub).

Among the sexes of *C. carnea* and *H. armigera,* higher EAG response was recorded in mated females than mated males. Among the different genotypes of cotton, significantly highest EAG response was observed by mated female *C. carnea* to the leaf extract of DHH 543 (1.924 mv), DHH-11(1.552 mv) Jayadhar (1.551 mv), DLSA-17 (1.541 mv) and LRA-5166 (1.454 mv). On the other hand it showed weaker response to AK- 235 (1.082 mv). Whereas, it showed significantly highest response to the boll extract of all the cotton genotypes except PA – 255 (1.114 mv) and AK- 235 (1.315 mv). However, mated female *H. armigera* showed significantly highest EAG response to the leaf and boll extract of Sahana, DHH-11 and LRA–5166 and it showed least response to PA–55 and Jayadhar.

Electroantennogram response of mated female *C. carnea* to the sunflower leaf and capitulum extract showed stronger EAG response to KBSH-1 and Morden and it showed lowest response to VRF-21 and DSF-2. Whereas the mated female *H. armigera* showed stronger EAG response to the capitulam extract of SFL–107 (3.826 mv) and it showed significantly lowest response to Morden (2.800 mv) and KBSH–1 (2.902 mv).

Gas chromatography of cotton leaf extract of DHH–543 indicated the presence of caryophyllene oxide at very high quantity (18.68%) and it was 2.31 per cent in case of PA - 255 genotype of cotton. Whereas in KBSH-1 genotype of sunflower, the presence of caryophyllene oxide was 9.74 per cent and it was negligible in case of VRF – 21.

Among the different treatments involving *C. carnea* as a major component in managing insect pests of cotton, T3 (release of 1.0 lakh *C.* carnea grub/ ha) was significantly superior in recording lower incidence of sucking pests like leafhopper, aphids , thrips and whiteflies. With respect to *H. armigera* eggs, T3 (0.39/ plant) recorded significantly lowest egg load followed by T2 (0.41/ plant), T1 (0.59/ plant) and RPP (0.76 / plant). However, H. *armigera* larval population was significantly lowest in T3 (0.23 / plant) and was on par with RPP (0.22/ plant).

With respect to natural enemies conservation, T3 recorded higher natural enemy like *C.carnea* (5.16/ plant) followed by T2 (4.55/ plant) and T1 (3.89/ plant). Whereas significantly least number of *C. carnea* recorded in RPP (0.46/ Plant) compared to untreated check (1.62/ plant).

Significantly lowest fruiting bodies damage due to bollworms was recorded in T3 (8.74%) and was on par with RPP (7.09%). Significantly highest GOB (22.60/ plant) and lowest BOB (12.86/ plant) were registered in T3 which was at par with RPP. The per cent locule damage was significantly lower in T3 (15.44%) and recorded highest seed cotton yield (9.00 q/ ha) and was on par with T4 (9.10 q/ ha).

Among the different treatments imposed to manage insect pests complex of sunflower, T3 (release of 0.60 lakh *C. carnea*/ ha) recorded lower sucking pests (leafhopper, thrips and whiteflies) but higher than RPP.

Helicoverpa armigera egg load was significantly lower in T3 (0.29/ plant) and T2 (0.37/ plant) and it was significantly higher in RPP (0.74/plant). Whereas its larval population was significantly lower in T3 (0.16/plant) and T2 (0.19/ plant) which were on par with RPP (0.17/ plant). With respect to natural enemies conservation, T3 (where 0.60 lakh of *C. carnea* ha was released) recorded significantly highest *C. carnea* (5.62/ plant) and least number of *C. carnea* was recorded in RPP (0.46/ plant).

Among the treatments, T3 and T2 are superior in reducing the insect pest complex and conservation of *C. carnea* and intrun registered higher seed yield (9.40 and 8.20 q/ ha in T3 and T2, respectively) with minimum insecticidal interventions.

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Appendix-I

Weekly Weather data at Main Agricultural Research Station, University of Agricultural Science, Dharwad

Std Week	Temperature (◦c)		Relative Humidity (%)		Rainfall (mm)	Rainy days
	Maximum	Minimum	Morning	Evening		
23	32.79	22.76	81.14	54.29	6.0	1
24	29.71	21.91	92.00	79.43	4.89	3
25	26.84	21.16	92.86	80.57	4.79	5
26	28.04	21.69	88.29	79.57	6.58	5
27	28.41	21.93	86.43	77.29	2.78	6
28	29.14	21.41	84.57	68.57	3.37	5
29	27.20	20.56	87.00	74.71	3.7	4
30	28.13	20.97	85.86	70.29	5.69	6
31	29.20	21.03	90.43	70.00	0.00	0
32	24.16	20.49	91.57	86.14	32.7	7
33	25.19	21.24	90.00	80.43	9.50	7
34	26.36	20.47	89.29	76.57	5.58	6
35	29.44	19.43	80.14	64.14	0.09	0
36	26.86	20.61	88.57	77.14	3.99	4
37	29.24	19.87	84.86	65.29	0.00	0
38	31.87	19.09	73.86	51.29	0.00	0
39	32.06	20.66	83.00	60.29	2.70	1
40	33.40	21.13	74.57	49.57	2.19	3
41	30.59	21.00	82.71	63.71	21.09	5
42	28.96	20.79	87.86	65.71	66.30	3
43	31.03	18.20	63.86	43.14	0.00	0
44	28.80	19.09	78.86	59.00	0.20	1
45	30.67	17.97	72.57	57.00	7.00	1
46	30.24	18.14	84.00	63.29	0.00	0
47	30.26	16.16	68.43	55.86	0.00	0

TRITROPHIC INTERACTION IN THE MANAGEMENT OF *Helicoverpa armigera* (Hubner) ON COTTON AND SUNFLOWER USING *Chrysoperla carnea* (Stephens)

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ABSTRACT

The investigations on ovipositional preference studies indicated that when compared across the different stages (Vegetative, flowering and boll formation) the mean number of egg laying by *C. carnea* in absence and presence of *H. armigera* was significantly highest on DHH-543 and it laid significantly lower number of eggs on PA -255 and Abhadita. While *H. armigera* laid significantly higher egg load on Sahana and least on DB -3-12 followed by Abhadita. Among the different stages of cotton genotypes, *C. carnea* both in presence and absence of *H. armigera* laid more number of eggs at flowering followed by boll formation stage, while *H. armigera* also followed the similar trend in its egg laying pattern. When compared across the stages of sunflower, the mean number of eggs laid by *C. carnea* in absence and presence of *H. armigera* was significantly highest on KBSH-1 and Morden and it laid least number of eggs on VRF-21 and DSF-2, whereas *H. armigera* laid significantly lower number of eggs on VRF-21. Among the stages, *C. carnea* in absence and presence of *H. armigera* laid more eggs at flowering stage followed by capitulum formation stage. *H. armigera* also followed the similar trend in its egg laying pattern.

Behavioral response of *C. carnea* using eight arm olfactometer indicated that the mean orientation response of *C. carnea* towards the extract of DHH-543 and DHH-11 was significantly more and least response was recorded towards the extract of DB -3-12. In case of sunflower, the response was more towards the extract of KBSH-1, Morden and RSFH-1 and it was lowest on VRF -21 and DSF-2. Further, the response of *C. carnea* towards the extract of *H. armigera* scales at 0.5 per cent and 100 eggs /10ml of hexane was higher than its lower concentrations.

The feeding potential of chrysopid species on *H. armigera* eggs on different genotypes of cotton was significantly higher on DHH-543, DLSA-17, Abhadita, DHH-11, MCU-5 and PA-255. Whereas in case of sunflower genotypes their feeding potential was significantly higher on KBSH-1, morden and RSFH-1. Among the species of chrysopids, feeding potential of *C. carnea* on cotton and sunflower was more followed by *Mallada boninensis* (Okamoto) and *Mallada astur* (Bank).

Electroantennogram response of *C. carnea* and *H. armigera* indicated that, higher EAG response was recorded in mated females than mated males. Among the different genotypes of cotton significantly highest EAG response was observed by mated female *C. carnea* to the leaf and boll extracts of DHH-543, DHH-11, Jayadhar, DLSA-17 and LRA-5166. In case of sunflower its response was towards the extracts of KBSH-1 and morden. However, mated female *H. armigera* showed significantly highest EAG response to the extract of Sahana, DHH-11and LRA-5166. Whereas the mated female *H. armigera* showed stronger EAG response to the extract of SFL-107 and it showed significantly lowest response to morden and KBSH-1. Gas chromatography of cotton leaf extract of DHH-543 indicated the presence of caryophyllene oxide at very high quantity (18.68 %) and it was 2.31 per cent in case of PA-255 genotype of cotton . Whereas in KBSH-1 genotype of sunflower, the presence of caryophyllene oxide was 9.74 per cent and it was negligible in case of VRF-21.

Among the different treatments involving *C. carnea* as a major component in managing insect pests of cotton , seed treatment with imidachloprid , application of NSKE (5%) and release of *C. carnea* (1.0 lakh /ha) was significantly superior in recording lower incidence of sucking pests (leafhopper, aphid, thrips and whiteflies) and bollworm and highest seed cotton yield. Whereas in case of sunflower, seed treatment with imidachloprid, application of NSKE (5 %) and release of *C. carnea* @ 0.60 lakh /ha was better in the management of insect pests of sunflower by recording highest seed yield.