IMPROVEMENT IN PRODUCTION AND STORAGE OF *TRICHOGRAMMA CHILONIS* (ISHII), *CHRYSOPERLA CARNEA* (STEPHENS) AND THEIR HOSTS FOR EFFECTIVE FIELD RELEASES AGAINST MAJOR INSECT PESTS OF COTTON

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Dedicated

To

My Late Mother.

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DECLARATION

I hereby affirm that the contents of this thesis "Improvement in production and storage of *Trichogramma chilonis* (Ishii), *Chrysoperla carnea* (Stephens) and their hosts for effective field releases against major insect pests of cotton" are the product of my own research and no part has been copied from any published source (except the references, standard mathematical or genetic models/equations/protocols etc.). I further declare that this work has not been submitted for award of any other diploma/degree. The University may take action if the information provided is found inaccurate at any stage.

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ABSTRACT

Present studies were conducted to improve production and storage extension of *Trichogramma chilonis* (Ishii), *Chrysoperla carnea* (Stephens) and their hosts for effective field releases against major insect pests of cotton. Different experiments comprised; the rearing of laboratory host, *Sitotroga cerealella* (Olivier), the impact of radiation on the shelf life extension of its eggs, storage of parasitoid (*T. chilonis*) and predator (*C. carnea*) at low temperatures, the searching ability of parasitoid under field conditions, evaluation of the field releases methods for parasitoid and predator and their field adaptations and effectiveness against target pests in the cotton.

Development and evaluation of the rearing of *S. cerealella* on its naturally available cereal foods, like maize, barley, sorghum and wheat revealed that the rearing of *S. cerealella* was as equally good on sorghum and barley as compared to wheat grains. Whenever, the rearing of healthy and heavy sized adults were required, the rearing on maize showed good results but with reduced fecundity and prolonged life span. The parasitism by *T. chilonis* on the gamma irradiated eggs of *S. cerealella* was successfully achieved at the dose of 50 Gy up to 7 days. The cumulative effect of radiation and low temperatures on the storage of host eggs at 6, 8, 10, 12, 14 and 16^{o}C from 5 to 90 days showed non-significant effect as compared to their individual effects. Storage of host, *S. cerealella* eggs at 6^{o}C for 5 to 50 days was a comparatively more suitable for both short and long durations, however, host eggs stored at 10, 12, 14 and 16^{o}C proved good only for short term duration. Storage of the parasitoid, *T. chilonis* at a temperature of 10^{o}C, proved to be effective for highest percent emergence, percent parasitism and adult longevity. Among different concentrations of honey as adult food, its 10% solution showed best results for male and female longevity and other biological parameters, however, reduced longevity was observed with increased in concentration of honey solution. The optimum rearing temperature for *T. chilonis* was found to be 28^{o}C at which developmental period was optimal; parasitism, adult longevity and emergence of *T. chilonis* from host eggs were higher as compared to other temperatures. Storage temperature of 8^{o}C seemed to be optimum for *C. carnea* eggs for 20 days with minimum

detrimental effects on developing embryo inside the egg. This temperature (10^{o}C) was almost good for short term (20 days) and long term (40 days) storage durations. Moreover, reproductive parameters of *C. carnea* adults remained good up to 90 days storage of eggs at this temperature. The impact of different rearing temperatures on the developmental and reproductive parameters of *C. carnea* proved best at 25^{o}C. Host eggs of *Plodia interpunctella* and *S. cerealella* showed no differences upon the quality of developmental traits of *T. chilonis* and *C. carnea*, and both hosts showed comparable results for rearing.

Evaluation of the field releases of parasitoid *T. chilonis*, through different methods inferred that micro-cages not only increased the releases and parasitism but also protected the parasitoids from unfavorable environmental conditions. Evaluation of *C. carnea* releases in the field showed that the releases of larvae were having more survival as compared to the releases in egg form. Therefore, it is suggested that predator should be released in the larval form to get more consistent field results. Parasitism by *T. chilonis* on host eggs at different distances under the field conditions revealed that the searching ability and parasitism were gradually decreased as the distance increased from the place of release. Survival of *T. chilonis* and *C. carnea* under field conditions varied according to the prevailing environment of the field. Comparative evaluation of the bio-control agents (*T. chilonis* and *C. carnea*) in management of *Helicoverpa armigera*, *Earias vittella*, *Bemisia tabaci*, *Thrips tabaci* and *Aphis gossypii* in cotton under natural field conditions during the years 2007 and 2008 exhibited that integration of bio-control agents, enhanced the suppression of these pests as compared to the untreated control.

INTRODUCTION

1.1 Overview of cotton

Cotton, *Gossypium hirsutum* L. is the life line of textile industry as well as the backbone of national economy of Pakistan and ranks at the top in foreign earnings. It is also one of the major fiber crops in the global perspectives. Due to its importance it is rightly called as the Queen of fiber crops and the white gold. Pakistan is the 4th largest cotton producer of the world. Cotton contributes towards 7.5% of the value goods added in Agriculture and 1.6% to the GDP of Pakistan economy. It was sown on an area of 3054 thousand hectares during the year 2007 with 0.6% less than that of the last year. Average production was 11.7 million bales less than 9.3% as compared to the last year. Its average yield is 649 kg/ha. In Pakistan, 1221 ginning factories and 521 textile units are directly dependent upon raw cotton, to produce yarn, cloth and ultimately all sorts of garments. Million of farmers are linked directly with the cultivation and harvesting of this crop and others are linked indirectly. The by products of cotton seed are oil, hulls and meal. Oil is used for edible purposes and sometimes to prepare high protein diets. Meal and hulls are used for the livestock, poultry and fish feed. Green sticks and leaves are used to graze animals and dried sticks are used as fire-wood in poor masses of the villagers. Due to lower production, Pakistan has imported 1.5 to 2 million cotton bales to meet the local demand for the industry (Anonymous, 2008). Low plant population, low potential of the crop varieties, low inputs, deficiency of irrigation water, poor weed eradication, higher pest attack intensity are the major contributors of the low yield of cotton. In this situation, it's a need to increase the local yield of the crop. Further gain in cotton production, is possible through effective control of the pests and low production cost per acre.

1.2 Insect pests of cotton

Cotton production, in Pakistan is suffering huge losses in yield and quality, due to crop pests which had developed diversified pest complexes. It is reported to be attacked by some 150 insects and mites, in Pakistan of which bollworms and sucking pests are the most notorious and the intensity of attack is sometimes so severe as to cause a major destruction of the crop (Attique and Rashid, 1983).

1.2.1 Bollworm pests

Bollworms are the most notorious pests of the cotton crop. Cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), larvae makes tunnel into small squares, terminal buds and flowers. In most of the cases, the excreta produced by larvae, can be seen on the surface of fed bolls, squares and flowers. The injured squares flare and drop from the plants within a week. The damaged bolls are frequently lost to become immature and sometimes, eaten up completely. Spotted bollworm, *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) larvae bore into the terminal shoots of young plants, leading towards the death of shoots and the development of side shoots with branches. Larvae can also bore into flower, buds, squares and young bolls. The entrance holes in bolls are in this case plugged with the excreta, in contrast to that in *H. armigera*. Severe attack consequently, leads towards the dropped off of young squares, flowers and bolls. Squares infested with the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) develop into sick blooms. Infested flowers developed petals, which are tied together to produce rosettes and do not open normally. Developing larvae tunnel through bolls, cuts through the lint fibers and move towards the seed and damage it. During the severe infestations, the damaged bolls when harvested become unpickable. Severe attack of bollworms may cause 20-25% of the yield losses. These bollworms have a concealed feeding habit of living inside the bolls, which hinder a lot in the chemical control of these pests in cotton. Outbreaks of secondary pests in cotton are generally observed, due to repeated applications of pesticides for management (Carruth and Moore,

1973). These insecticides not only increase the production cost of cotton crop per acre but also pollute the environment and create resistance, in the insects. The control of these bollworms often depends largely on the application of insecticides which has already induced resistance, in pests (Bariola and Lingren, 1984). Due to concealed feeding habits of bollworms, it is difficult to control them completely through insecticides (Toscano *et al*., 1974).

1.2.2 Sucking insect pests

Among the sucking pest complex of cotton, whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae), is the major sucking pests of cotton both adults and nymphs, suck the cell sap from the leaves. Whitefly secretes honeydew on the leaves that cause reduction in the food manufacture and the lint quality. Lack of vigor causes leaves to wilt, turn yellow and, the drying of leaves ultimately. Thrips, *Thrips tabaci* (Linderman) (Thysanoptera: Thripidae) damage cotton leaves and terminal buds. It's feeding upon the leaves rapture plant cells with crinkled leaves turned upward. Severely affected leaves developed silvery appearance. Aphids, *Aphis gossypii* Glover (Homoptera: Aphididae) suck the cell sap from the lower side of leaves, curl them and some times their shedding occurs. The leaves curl downwards and attain cup shaped appearance. Aphids secrete a sticky substance, in the form of honeydews. On this honey dews, black sooty mould grows, which sometimes in severe attacks, may create hindrance in the ginning processes. Spider mites, *Tetranychus urticae* Koch (Acarina: Tetranychidae) damage the cotton plants by feeding upon the cell sap of leaves, stem and squares. By sucking the cell sap from the leaves, the chlorophyll contents are reduced and the reduced photosynthetic activity leads to an abnormal maturation of cotton plants. In the beginning, small yellow spots appear on the upper surface of cotton leaves. In severe conditions, leaves may dry and wither. It causes more harm to the plants in a hot, dry weather, during the growth of cotton. These pests suck the cell sap and weaken the plants. Due to this, the plant growth is retarded and, without proper growth, the fruiting is directly affected. In all, the sucking insect pests are reported to cause 4.6% losses in the yield of seed cotton. (Satpute *et al*., 1988).

1.3 Pest control strategies in cotton

Pest control strategies include: cultural, host plant resistance, chemical, mechanical, genetically and biological control methods and are, in practice for the insect pest management in crops (Bull *et al*. 1979). Currently, most of the control strategies, for pest control, in cotton crop, depend upon the chemical use of pesticides. So, chemical control is the common practice in Pakistan for the control of insect pests of crops. The use of pesticides in agricultural crops in Pakistan is so common that it is rated to be the second largest country of Asia with respect to pesticide consumption. Pakistan imports 18034.00 tones of pesticide of worth Rupees 4323.00 million annually. Nearly 80% of our pesticides are being used on cotton crop, the only economy dependent crop of the country (Anonymous, 2008). This huge consumption has not necessarily leaded to increase the yield of crops (Ahmad and Poswal, 2000). The repeated use of insecticides against insect pests has made the pests, more serious for the crop. Indiscriminate use of these pesticides has troublesome ability to develop resistance in most of the insect pests against these chemicals, environmental pollution and also the destruction of natural insect fauna. The heavy reliance on costly and hazardous chemicals results in a higher cost of production to achieve effective plant protection measures. In this scenario, the chemical control of pests has become highly expensive, increasingly undesirable due to its environmental hazards. Present day Entomologists are facing difficulties in making decision for the control of major insect pests, especially in the cotton crop. So, the need of the day is to adopt alternative pest control strategies other than chemical control methods in order to get an effective, low cost, biodiversity protected and environmental friendly biological control methods for pest control.

1.4 Biological control

Biological control constitutes the use of predators and parasitoids present in the prevailing environment or their introduction from the other areas into places, where they are not already present. The method of biological control, with predators and parasitoids had the advantage over other methods of pest control and is gaining popularity in

integrated pest management of crops over the prevailing methods. Biological control is self perpetuating and does not need further expenditures, as the population of biological control agents is once established in a particular area it stays as such there for a longer period and hence it become an economical method of pest control as compared to others. In biological control: the conservation, augmentation and redistribution are the three main steps. Effective biological control management requires to introduce more than one species and to maintain the predator prey relationship. Success in biological control can be achieved by introducing exotic species of parasites and predators, conserving the existing population and by augmenting parasites and predators through the mass raring and releases.

The concepts of integrated pest management (IPM) with the use of predators and parasitoids, can give a low cost plant protection. Environment friendly nature of the biological control can save a huge amount of foreign exchange which is being spent on the import of insecticides, annually. In the absence of chemical insecticides, the natural enemies have a potential to maintain pest population at a sub economic level. The widespread introduction of chemical pesticides in cotton has shattered natural pests prey balance. Naturally occurring predators and parasitoids are important in controlling the pest population in one way or the other. Being an essential part of IPM the biological control, has the ability to reduce the pest populations by the use of natural enemies, *i.e.*, parasitoids and predators. So, it is anticipated that biological control has the potential to combat the pests. Several efforts have shown the presence of pesticide residues in cotton, above the permissible limits. Biological control based on IPM studies can be used effectively against the insect pests and have a sound effect on the environment with less expenditure and to saves huge amount that is spent annually on the import of pesticides for pest management. Now efforts are being made to use biological control with the help of natural enemies of pests as a safer and cheaper alternative method for the pest control.

1.5 Biological control agents

Parasitoid and predators, are being used in Pakistan on cotton crop for the last few years, with some constrains in their production and use. Potent egg parasitoid, *Trichogramma chilonis* (Ishii) has enormous potential to control lepidopterous pests of many crops and vegetables, especially the bollworms of cotton. Among the predators voracious feeders the common green lacewing, *Chrysoperla carnea* (Stephens) is widely distributed in Pakistan. Its larvae are very active feeders of soft bodied insects, their eggs, nymph, adults and sometime small larvae of many insect pests. It feeds upon aphids, whiteflies and cotton bollworm eggs. The quality of a particular bio-control agent includes: a high fecundity, good searching ability and short life cycle. Furthermore, the climatic requirements of the bio-control agents should be similar to that of the pest. Effective laboratory rearing of biological control agents and their hosts still needs much improvement in quality to develop a good system of biological control. So, aim of the present studies is to produce and evaluate a quality rearing of the bio-control agents of a potential/friendly insect fauna and their hosts that would ultimately lead towards the effective field releases against the sucking and bollworm pests in cotton.

1.5.1 *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae)

Egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae), from the friendly insect fauna, are being used as biological control agent against harmful insects of crops and vegetables in the fields, green houses and in the orchards. *Trichogramma* has been considered as one of the important parasitoids for more than 100 years (Hoffmann, 1988; Smith, 1996). However, trials with these parasitoids prior to 1975 were aimed at controlling lepidopterus pests, only in the sugarcane and corn crops. Afterwards, from 1975 to 1985, *Trichogramma* were applied for the control of cotton, cabbage, apple and tomato pests etc. (King *et al*., 1984). *T. chilonis* have an immediate effect not only on the target pests, but possibly, on the other insect population as well (Voegelé, 1988). It was reported that *T. chilonis* can be more effective when it's parasitizing potential and searching ability is well adapted in the field (Smith, 1996;

Hamed *et al*., 2004). It has been proved to be very beneficial as a biological control agent in cotton crop and have a great potential to control bollworms in cotton integrated pest management (Biever, 1972; Verma and Shenhmar, 1988; Wang and Zhang, 1991; Hassan, 1993; Mohyuddin *et al*., 1997; Ahmad *et al*., 1998; Suh *et al*., 1998; Asifulla *et al*. 1998; Romeis *et al*., 1999; Fournier and Boivin, 2000; Ahmad *et al*. 2001; Hamed *et al*., 2001 and Hassan, 2006). Trichogrammatid egg parasitoids are the most promising biological control agent in the world for inundative releases against many lepidopterous pests in Africa (Sithanantham *et al*., 2001).

This parasitoid has the immense ability to suppress the population of bollworms of cotton below economic threshold level when used along with cultural practices and insect resistant strains. Quality of *T. chilonis* can be improved by rearing it on different hosts and storing it at low temperatures to prolong its shelf life (Stinner *et al.*, 1974c; Hoffmann *et al*. 2001; Pitcher *et al*., 2002). With the proper storage at the pupal stage of the parasitoids, the life of parasitoids can be prolonged (Jalali and Singh, 1992; Prasad *et al.* 1999; Tezze and Botto, 2004). The effect of rearing temperature and adult food supplement increases the parasitization potential of *Trichogramma* spp. (Hegazi *et al*., 2000). The development of biological control programme with the use of egg parasitoids, involved the selection of suitable strains having effective control against their target pests in a particular environmental condition (Hassan, 1994).

1.5.1.1 Description

Extremely tiny, parasitoid wasp ranging from 0.2 to 1.5 mm in size. Egg parasitoid of more than 28 different caterpillars attacking cotton, corn, rice, sugarcane, sugar beet and vegetables. There are 145 described species in all. Host, in early stages of development are more suitable for parasitoids development.

1.5.1.2 Life history

The parasitoids incubation period is 7 days and completes its life cycle by consuming egg contents of its host inside the egg. Adults survive for about 4-5 days. Adult sucks the cell sap or honey dew from nectarines of leaves.

1.5.1.3 Searching ability

First of all, it selects its preferred host egg moving around and counting egg size. Female drills a hole on chorion of the egg and inject 1-3 eggs, depending upon the size of egg and contents inside. Parasitoids emerged out to locate its target eggs.

1.5.2 *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)

Predator, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), is recognized to be a voracious feeder of whiteflies aphids and other soft bodied insects (Hashami, 2001). This predator has a tremendous predacious potential and can consume many species of insect pests, such as whiteflies, aphids, thrips and eggs of bollworms (Atlihan *et al*. 2004). Gurbanov (1984) used *Chrysoperla carnea* against the thrips and aphids, the population of thrips fell down to 95.6% and those of aphids 98.5%. Jin (1998) has evaluated the effectiveness of *Chrysoperla carnea* against the *Heliothis armigera* (Hübner) and observed that pest infestation was reduced from 1.6 to 0.1%. Kunafin (1998) have tested that *Chrysoperla carnea*, larvae can consume up to 200 aphids a week. It's larvae have a broad range of prey upon insects (Hydron and Whitecomb, 1979; Reddy and Manjunatha, 2000). Effectiveness of larvae, against target pests has been demonstrated in crops, orchards and green houses (Hagley and Miles, 1987). Some times it gave about 100% lepidopteran pest control when used in a combination with *Trichogramma* spp. (RV Insectaries, 1999). A range of 33-99% reduction in bollworm and tobacco budworm, larval populations in cotton crop after its inundative releases were observed (Ridgway and Jones, 1969). At low temperature regimes, the shelf life of *C. carnea* eggs can be prolonged (Arroyo *et al*., 2000) and the environment effects upon the viability of green lacewing eggs (Gardner and Giles, 1996).

1.5.2.1 Habitats

Commonly present in many crop habitats and is useful in areas where humidity is high like in greenhouses and irrigated crops etc.

1.5.2.2 Description

It is present in larval and adult forms on leaves of crops, vegetables, fruit plants and weeds. Its adult has green colour with delicate wings. So, due to its appearance it is commonly called as green lace wing. Adults feed only on nectar, pollen and aphids honey dew. Adult size measures 12-20 mm long with long antennae and bright golden eyes. Adults have a body size of 6-8 mm with large transparent pale green wings and a delicate cylindrically body, grey brownish and alligator like with well developed legs and large pincers with which they suck the fluids from the prey body.

1.5.2.3 Life history

Its life cycle is completes in 4-6 weeks, depending upon the temperature of the prevailing environment.

1.5.2.4 Eggs

Oval shaped eggs are laid singly at the end of a long stalk of silken nature and are pale green in colour. Usually 200 to 400 eggs are laid by a single female, during its entire life span. Turning into grey after three days and hatch within 3-6 days depending upon the temperature.

1.5.2.5 Larvae

The larvae are very active predators. The larval stage has three instars and lasts for 2-3 weeks.

1.5.2.6 Pupae

Mature third instar larvae spin around, a parchment like, silken cocoon, usually in hidden places on plants. Pupal period last for about 7-10 days.

1.5.2.7 Adult

Emergence of the adults occurs from silken cocoons after the completion of pupal period. There may be two to several generations, in nature per year. Adults feed on nectar of the plants. Its adult, in favorable conditions may survive for one to many months.

1.5.2.8 Effectiveness

Its larvae are the voracious feeder of aphids, whiteflies eggs and nymphs, thrips and even small larvae of the pests. It can consume many aphids in its larval span.

1.5.2.9 Field releases

It is a good predator of field crop pests and its field releases to control pests of crops gave successful results.

1.5.3 *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae)

Angoumois grain moth, *Sitotroga cerealella* (Olivier), the pest of stored grain and its eggs are used for egg parasitoid, as factitious host in laboratories. Cosmopolitan in distribution and known as a pest of grain cereals, owing to factors that belong to the physical and chemical nature of grains (Cotton, 1960). Grain moisture contents, size, texture and color are the physical properties. Among chemical properties of grains: fats, protein and carbohydrate contents are responsible to their degree of susceptibility to this insect (Khattak and Shafique, 1981; Ragumoorthy and Gunathilagaraj, 1988). Carbohydrate and protein contents of grains affect the developmental period, adult weight, fecundity etc. (Slansky and Scriber, 1985). *S. cerealella* (Olivier) produces small size of parasitoids as the eggs of *S. cerealella* are comparatively small as compared to those reared on the actual field host (Kazmer and Luck, 1995). Due to their high cost of production, the rearing of natural field hosts is not practicable in insectaries (Laing and Eden, 1990). To get good quality parasitoids and predators, *Sitotroga cerealella* (Olivier), laboratory host play a key role and this host can be reared on different cereals (Calvin *et*

al., 1984; Bigler and Wagle, 1988; Nathan *et al*., 2006). It's shelf life can be improved by radiation doses to its eggs (Boshra, 2005; Hamed *et al*., 2009). *S. cerealella* can be used for larval rearing of *C. carnea* (Costa *et al*., 1999).

1.5.3.1 Description

It is a common pest of stored grains and distributed world wide, with poorly developed abdominal pro-legs. Ideal temperature for its development is 30- 32^{o}C at a relative humidity of 75%.

1.5.3.2 Life history

The active period of the adult moths are from April to October. In all, it's life cycle is completes in 27-30 days. In nature, several generations are completed in on year.

1.5.3.3 Eggs

Eggs are small and white in colour when freshly laid. Egg colour changes to pinkish after 24 hours of the time exposure. Each female lays 150 eggs singly or in clusters, on or near the grains, after mating within a week. In different temperature conditions, eggs hatch within 4-8 days and minute white larvae enter into the grains after boring throughout the kernel of grains.

1.5.3.4 Larvae

The full grown larvae have an average of 5 mm in length with white creamy body and a black head. The larvae are pale yellowish when mature with a yellow brown head and are about 5 mm long when full grown. Larval stage is completes within 3 weeks.

1.5.3.5 Pupae

Pupation takes place in a silken cocoon in the feeding cavity inside the grain kernel. Depending upon the conditions pupal stage is competes from 6-10 days.

1.5.3.6 Adult

The adults are small, buff to grey or yellow brown moths, with a wing spread of 13 to 17 mm. The hind, wing narrow down to an apex and are heavily margined with long hairs. The size of the adult depends on how much food the larva has consumed, and is usually 10-12 mm in size. Female adult tends to live longer as compared to the males.

1.6 Objective of the studies

1) To develop a good quality culture parasitoids, predator and their hosts.

i) To develop and test a good quality factitious host, *S. cerealella*, on its naturally available cereal foods. Here, we focus our plan to sort out suitable rearing cereals, like using maize, barley, sorghum and wheat.

ii) To improve the egg viability of laboratory host's by using different radiation doses. As the radiation, prolongs the egg hatching of factitious host.

iii) To sort out a suitable low temperature, for the prolongation of the storage life of parasitoids and predators as well as to induce diapause as compared to the standard and normal temperature of laboratory conditions.

2) To evaluate different laboratory cultured versions of the parasitoids and predators in both laboratory and field conditions for their searching ability and adaptation in the field for controlling bollworms (*Helicoverpa armigera* and *Earias vittella*) and sucking pests (whitefly, thrips and aphids) infesting cotton.

REVIEW OF LITERATURE

2.1 *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae)

2.1.1 Rearing on different hosts (cereals) no choice and free choice

Gross (1988) have studied the effect of selected temperatures (27, 32, 35, 38 and 43^{o}C), relative humidities (10, 20, 40, 60, 80 and 100%) and levels of free water (0.0, 0.1, 0.3, 0.5 saturation and 0.7 ml per filter paper substrate) at the time of eclosion, during development and emergence of the parasitoid, *Trichogramma pretiosum* Riley. At the time of eclosion, highest mean rates of emergence occurred at 32±1^{o}C and 60 and 80% RH. Significant declines in the adult have occurred above 80% and below 40% RH at all temperatures, evaluated. Largest mean number of *T. pretiosum*, per host emerged from host eggs, held for development and eclosion at 27 and 32±1^{o}C and 80% RH. Later on Schöller and Hassan (2001) have studied the comparative fecundity and life span of two parasitoids, *Trichogramma evanescens* Westwood and *T. cacoeciae* Marchal on host, *Ephestia elutella* (Hübner) at different temperatures (20, 26, 30 and 35^{o}C), in laboratory conditions. At 35^{o}C, no emergence of parasitoids was observed; while, at other temperature conditions longevity, parasitism efficiency and egg fertility were decreased as the temperature increased. Parasitism was recorded higher in *T. evanescens* as compared to *T. cacoeciae* at the observed temperatures. Because of it's higher temperature tolerance capabilities, *T. Evanescens* was evaluated as a best suited parasitoid to be used in high and low thermopile conditions. Nathan *et al*. (2006) have evaluated the emergence and survival of adults of *Trichogramma chilonis* (Ishii), for 24 h, by using host eggs *Corcyra cephalonica* (Stainton) reared on grains of millet, wheat, rice and sorghum. Nutritional indices for wheat and rice used for rearing of *C. cephalonica* larvae were intermediate between the indices for larvae reared on millet and sorghum. Results suggested that rearing of *C. cephalonica* larvae on high quality

nutritional source resulted in high quality eggs that ultimately resulted in a high quality *T. chilonis*, reared on these eggs.

2.1.2 Radiation effects on the host eggs

The affect of radiation preservation on the host eggs (*Antheraea pernyis*), of *Trichogramma dendrolimi* in laboratory conditions indicated that host eggs, stored in a refrigerator after irradiated at low doses by the electron beam, gave prolonged storage, without detrimental effects as compared to the control. After 89 days of the storage of irradiated host eggs, when exposed to *T. dendrolimi* gave 80% parasitism of the host eggs while percent emergence, body size, growing period and sex ratio, were examined normal. So, it was concluded that an irradiation at low doses have, adverse affect on the developmental parameters of the *Trichogramma* spp. and their offspring as reported by Lianzhong *et al*. (1993). Gamma radiation for the economic production of egg parasitoid, *Trichogramma chilonis* (Ishii), at different doses from 5 to 50 Gy, with 5 Gy intervals, indicated a significant reduction in the percent hatching of irradiated eggs, at different doses. It was observed that the parasitoids preferred fresh eggs for parasitization and this preference decreased, as the age of host eggs increased. However, parasitization was comparatively higher at 20 and 25 Gy of radiation. Radiation of host eggs also decreased the age effect and significantly more number of eggs was parasitized on 2, 3 and 4 day old, irradiated host eggs as compared to the normal eggs as investigated by Fatima *et al*., 2005. The impact of irradiation on the Angoumois grain moth eggs, *Sitotroga cerealella* (Olivier), with sub sterilizing doses of 150, 180 and 210 Gy of gamma radiation increased the damage when pupae were kept at a high temperature (32.5^{o}C) for 24 h, before irradiation, when marked reduction in fecundity and egg hatching were obtained among the males and this reduction significantly increased as the dose increased. Laboratory mating competitiveness, indicated that the parental male, heat treated with 32.5^{o}C and irradiated with 150, 180 and 210 Gy and respective F_1 progeny, were fully competitive with their untreated siblings (Boshra, 2005). Later on Hamed *et al*. (2009) have deliberated the impact of gamma radiation for the improvement of mass production of *T. chilonis* (Ishii) and *C. carnea* (Stephens) to achieve an area wide control of cotton and

sugarcane pests. Host, *Sitotroga cerealella* eggs were irradiated with a dose of 5 to 55 Gy and used upto 7 days for parasitization by *T. chilonis*. Effect of radiation was similar for first 2 days, ranging from 78 to 94% parasitization, but decreased at lower doses. At highest dose (55 Gy) parasitization recorded was 45%. Findings allow for a reliable supply of viable host eggs to small insectaries, situated at remote distances. Feeding of irradiated eggs, by *C. carnea* showed increased survival, fecundity and female sex ratio. Larval survival was improved by 89% over the control when *C. carnea* was fed, irradiated at 45 Gy dose. At 45 Gy fecundity was observed to be highest with 444 eggs, per female, in the parent, 397 in F_1 and 311 in F_2 generation. Wereas, it decreased significantly at lower doses and control. Further improvement with the use of radiations to insects, was reported by Fatima *et al*. (2009) who used gamma radiation to the egg of parasitoid, *T. chilonis* (Ishii) larval parasite, *Cotesia flavipes* (Cameron) and host *S. cerealella* (Olivier) for the bio-control of sugarcane borers. Irradiation to host eggs, *S. cerealella* using 20-25 Gy had decrease the effect from 2, 3, 4 and 6 day old eggs and these were successfully parasitized as compared to the non irradiated host eggs. Low doses of radiation upto 15 Gy did not affect the hatching of eggs. Hatching was significantly reduced, at higher doses, with a negligible hatching at 50 Gy. Findings were used to release the bio-control agents, in 40000 hectares to suppress sugarcane borers at sub-economic level (10% infestation). The damage to sugarcane by borers was 5.9%, in treated blocks, as compared to 19.2% in the control. Irradiation of the host material proved beneficial to increase the practical development and cost effectiveness on an area wide augmentation in the bio-control based programmes under field conditions.

2.1.3 Storage of *Sitotroga cerealella*

The storage of the laboratory host for the rearing of bio-control agents (*Trichogramma chilonis* and *Chrysoperla carnea*), the *Sitotroga cerealella*, at low temperatures was investigated by El-Mandarawy (2003) who has investigated the preference of different egg ages (2, 4, 8, 24, 48 and 72 h) of the host, *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae) for comparative parasitism by the two parasitoids, *viz*.,

Trichogramma evanescens Westa and *Trichogramma cacoeciae* Marchal (Hymenoptera: Trichogrammatidae) within 24 hours when chilled for 2, 4, 8, 12, 24, 48 an 72 hours. The highest parasitism was observed at 4 h and lowest at 72 h old eggs. It was also observed that the number of host eggs attack decreased as the age of eggs increased. However, the eggs of all ages proved successful for the parasitoids. Chilled (-1^{o}C) host eggs, when exposed to two parasitoid species, the damage diminished as the period of chilling increased. Later on, Özder (2004) have premeditated the effect of different cold storage temperatures (0, 4 and 8^{o}C) periods (3, 7, 11, 14, 17, 21, 24, 28 and 31 days) on the host eggs, *Ephestia kuehniella* Zeller on parasitization by *Trichogramma cacoeciae* Marchal and reported that the parasitism was observed to be the lowest on the host eggs, held at 8^{o}C and highest on eggs held at 0^{o}C. Highest parasitism (97.8%) by the parasitoids was observed on eggs, held for 3 days, at 0^{o}C. Parasitism on eggs, stored at three temperatures decreased as the duration increased. Parasitoids emergence from the host eggs was 83% when stored at 8^{o}C for 3 weeks. Longevity, fecundity of the adult parasitoids was observed to be optimum at 4^{o}C. So, from this study, it was concluded that the host eggs can be stored at 0^{o}C, for 31 days, and so the parasitoids can be stored at 4^{o}C for upto 5 weeks, before release. Similarly, Tuncbilek *et al*. (2005) have also investigated the effects of 3 months of the storage of irradiated eggs of *Ephestia kuehniella* and *Sitotroga cerealella* on the wasp quality. No significant differences on parasitization as well as the female and male emergence, between irradiated and unirradiated eggs upto 60 and 30 days, for *E. kuehniella* and *S. cerealella* were observed. After the storage of eggs, more than that period and their offer to the *T. evanescens* females, for parasitization, were recorded. When diapause induction was considered for *T. evanescens* stored at 3^{o}C for 20, 70, and 100 and 150 days, it was observed that the parasitoids could be successfully stored at 3^{o}C. Long term storage of the host eggs and parasitoids, in diapause, allows an enlargement of the mass rearing potential of this species for further biological control releases, by allowing procedures to stockpile parasitoids at suitable time.

2.2 *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae)

2.2.1. Rearing on different host eggs

The laboratory rearing of hosts of *Trichogramma chilonis* was evaluated and techniques developed for the mass rearing of parasitoid, *Trichogramma* spp., on *Heliothis zea* (Boddie) eggs and compared the fecundity and longevity, for three generations in comparison to its rearing on *Anagasta kuehniella* (Zeller) and *Sitotroga cerealella* (Olivier). *Trichogramma* spp. reared on *E. kuehniella*, showed a higher fecundity (147.9 *vs*. 9.9) and longevity (19.9 *vs*. 4.5) than those of *S. cerealella*. To evaluate the parasitoid effectiveness, reared on *H. zea* eggs, field releases were made in cotton, soybean and corn crops. Parasitization rates were observed to be within a range of 30-75%, after 24 hrs of the release of 25000-60000 parasitoids per acre. It was also observed that *T. pretiosum*, reared on *H. zea*, has performed better in the field than that reared on other hosts (Lewis *et al*., 1976). Later on Hoffmann *et al*. (2001) have evaluated the performance of parasitoid *Trichogramma ostriniae* (Pang et Chen) on the eggs of four factitious hosts, *viz*., *Ostrinia nubilalis* (Hübner), *Sitotroga cerealella* (Olivier), *Trichoplusia ni* (Hübner) and irradiated *Ephestia kuehniella* (Zeller). Information gathered from different measures of parasitoid performance, on the longevity of individuals and population levels of parasitism, survival of the progeny to emergence and progeny sex ratio for 9-11 generations, and possible causes for the variation in performance over time, under laboratory conditions, were studied. Wasps reared from each source, were tested and under the test conditions, *E. kuehniella* proved to be a poor host; as against *T. ni*. and *O. nubilalis* that were good hosts and *S. cerealella* was intermediate one. Overall increase in performance of the wasps have however been recorded when it was reared on *S. cerealella* and *E. kuehniella.* Afterwards, Goncalves *et al*. (2005) have elaborated on improved laboratory rearing techniques for *Trichogramma* spp., capable of producing quality parasitoids. This study comprised by determining the emergence rate of *Trichogramma* adults (parasitoids), egg size of *Ephestia kuehniella* (host), fecundity of the host and sex ratio of the parasitoids. *Trichogramma* adult emergence was slightly lower than desired and was over 90%. This percentage can be easily avoided after

adjusting the number of host eggs per parasitoid female. It was concluded that the rearing techniques used for both parasitoid and host are acceptably productive and adequate to get required amount of parasitoids for a bioassay.

2.2.2 Food effect on rearing of *T. chilonis*

The importance and effectiveness of adult food for the rearing of parasitoid, *Trichogramma chilonis*, have been evaluated by Ashley and Gonzalez, in year 1974, after study leading to the prospective food substances and their effect on *Trichogramma* fecundity and longevity. Tested materials included 5 proteins with an agar agar base, glucose, fructose, cotton plant nectar, honey and beef extract in different combinations with honey and water. Results indicated that protein formulations and water did not increase the adult fecundity and longevity as compared to the unfed *Trichogramma*. Fructose, cotton plant nectar, honey and beef extract in different combinations with honey were evaluated to be equally nutritious. No significant difference in the fecundity and longevity to the unfed *Trichogramma vs*. those fed during 1.5 h period, on honey, 1.0% beef extract and fructose. Later on, McDougall and Mills (1997) have conducted feeding experiments with the parasitoid *Trichogramma platneri* Nagarkatti (Hymenoptera: Trichogrammatidae), reared on *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). It was observed that the longevity of *T. platneri* was inversely related to the temperature and it decreased from 53 to 3 days as the temperature increased from 10 to 35^{o}C with the honey fed parasitoids. More than 10% honey solution increased the longevity of the parasitoids, 10-13 folds within 15-20 days in comparison to the unfed ones. Aphid honey dew is a suitable field sugar source, which can provide longevity up to 10 days, but it is not as good as compared to the other sources of sugar available in the field. Comparable study, was prepared by Lundgren and Heimpel (2002) who have assessed three commercially produced *Trichogramma viz*., *T. pretiosum* Riley, *T. minutum* Riley and *T. brassicae* (Bezdenko), produced from same insectaries, with and without honey, for the emergence rate and sex ratio for a 5 weeks period. Emergence rates were over 75%, in 15 out of 17 shipments. Mean longevity of the honey fed individuals, was 7.16 days for *T. pretiosum*, 6.71 days for *T. minutum* and 4.02 days for

T. brassicae. Mean longevity of the unfed individuals was 2.68 days and 1.96 days, respectively. Fluctuations in all the fitness of parameters assessed for commercially produced *Trichogramma* were seen to be difficult to assess as to how these affect the biological control programme.

2.2.3 Storage of *T. chilonis* at low temperatures

To optimize the low storage temperature for *Trichogramma* spp. is very critical for a successful shipment and field releases of the parasitoid and for this purpose, a time by time study has been conducted on the storage of parasitoid like *Trichogramma pretiosum* Riley and it was concluded that the 1st day pupae can be stored at 16.7^{o}C from 4-10 days without any detrimental effects on the percent emergence and it can be prolonged upto 12 days, on the sixth days of storage. After storage, 93% of the adult emergence was evinced (Stinner *et al*., 1974c). Further sorting out of the storage temperature on other species of the parasitoid, was investigated by Mclaren and Rye, in year 1983, who have worked on the rearing storage and releases of *Trichogramma ivelae*, for the control of *Heliothis punctiger* on tomatoes. Rearing of *T. ivelae* was carried out on the eggs of *Sitotroga cerealella*. Active parasitoids were produced after 6 days of the incubation, at 27^{o}C and after 6-7 days, at 15^{o}C in darkness and it yielded adult parasitoids, after 2 or 1 hour, respectively at 23^{o}C. *T. iveae* was released, weekly @ 100000 numbers/ha, at site 1, in year 1980 and at 3 sites, to combat against *H. punctiger* on tomatoes. In the released sites, the damage on harvest was 0.2-28.9%, with a reduction of 98 and 55% respectively. It was conclude that *T. ivelae* can be effectively used for the control of *H. punctiger* on the commercial scale. In year 2002, Pitcher *et al*. have improved the parasitoid (*Trichogramma ostriniae*) production methods, reared on the host eggs (*Sitotroga cerealella*) and stored at 6, 9, 12, 15 and 24^{o}C for upto 8 weeks, after parasitism. At 15^{o}C, the emergence was completed, in two weeks and more than 80% as compared to the storage, at 9 and 12^{o}C for 4 and 6 weeks, respectively. Storage at 6^{o}C declined the percent emergence. Rate of parasitism, in stored *Trichogramma*, was similar to control after 2 to 4 weeks of storage at 9 and 12^{o}C but the parasitization declined with

an increase in storage more than 4 weeks. The storage period for the newely discovered species, *Trichogramma nerudai* Pintureau and *T. nerudai* Gerding (Hymenoptera: Trichogrammatidae) was carried by Tezze and Botto (2004) to see the cold storage effect on the quality aspects. Pupae of *T. nerudai* were stored for 25, 50, 75, 100, 125, and 150 days at 4 ± 1^{o}C with RH 75 ± 5% in complete darkness. Proportion of deformed adults and the mobility capacity of *T. nerudai* were affected, after 50 days of storage. Quality traits were combined and showed the added affect of low emergence and a loss of mobility of the non deformed individuals at the observed storage temperatures.

2.2.4 Radiation effects on *T. chilonis*

El-Mandarawy and Rizk (2002) have studied the effect of sub sterilizing doses of radiation, on the eggs of *Callasobruchus maculates* (Fabricius) and *Corcyra cephalonica* (Stainton) and offered them for parasitization to *Trichogramma evanescens* Westwood and *Trichogrammatoidea bacteriae* Nagaraja. A dose of 1, 3, 5 and 7 Gy for *C. maculatus* and 10, 30, 60, 90 and 120 Gy were given to the eggs of *C. cephalonica*. Percentage of parasitization and fecundity were different between the irradiated in comparison with non irradiated eggs. Highest rate of emergence was observed, in irradiated and non irradiated *C. cephalonica* eggs which were parasitized with *T. evanesces*. Developmental period and adult longevity of the two parasitoids had no effect of radiation.

2.2.5 Rearing temperatures for *T. chilonis*

Rearing of parasitoid, *Trichogramma*, needs an optimum temperature, where its biological parameters should be well established towards the quality production and for this purpose, Ramesh and Baskaran in year 1996 have conducted experiments to see the affect of high temperatures of 35, 40 and 45^{o}C on the performance of four parasitoids, *Trichogramma* strains *viz*., *T. chilonis*, *T. brasiliensis*, *T. pretiosum* and *T. japonicum* in

the laboratory. Results showed that at 35^{o}C, the heat shock gave a minimum effect on the development and biology of the parasitoids. However, 40^{o}C proved to be highly lethal to the developmental parameters of the adult, in almost all the strains except *T. chilonis*, which withstand the heat shock comparatively better as compared to the others. Similarly, Scott *et al*. (1997) examined the consequences of acclimation for survival and fitness components of the parasitoid, *Trichogramma carverae* (Oatman and Pinto). Heat hardening, at 33^{o}C during the development, resulted in a significant increase in the survivorship of adults, exposed to 40^{o}C. Developmental hardening reduced the longevity of the male and female wasps, with reduced parasitism. Parasitism rate was influenced, after rearing at 14, 25 or 30^{o}C, only females reared at 14^{o}C parasitized eggs, whereas, at 25 and 30^{o}C, parasitism was not influenced significantly. Laboratory results, suggest that the developmental acclimation, could help to increase parasitism under low to high temperature conditions. The studies on the effect of rearing temperature on flight of *Trichagramma sibericum* Sorkina, by Prasad *et al*. (1999), who used ambient temperature in the laboratory, at 16.2 and 26^{o}C. Results showed that proportion of insect and flight increased with an increase in temperature. Insects reared at 16^{o}C, were more likely to invite flight at 16^{o}C than insects reared at 21 or 26^{o}C. Subsequently, Rejendran (1999) have carried out his work on the emergence of *Trichogramma chilonis*, from parasitized host eggs pasted on paper cards, and reported that the emergence of *T. chilonis* were influenced by the variation in temperature. To obtain a high rate of emergence in the laboratory in hot summer, artificial manipulation in temperature is necessary for a successful rearing. Soon after, Malik (2000) have studied the life table of *Trichogramma bactrae* (Hymenoptera: Trichogrammatidae) as an effective biological agent against the pink bollworm, *Pectinophora gossypiella* (Lepidoptera: Gelechiidae), in cotton. Life history, were studied at 13, 18, 23 and 28^{o}C, at 55% relative humidity and 11/13 (light/dark) of the photoperiod. On an average, the development from the egg to the adult stages ranged from 50.3 to 8.7 days at a temperature from 13-28^{o}C, respectively. Immature mortality was recorded to be the highest (32.01%) at 28^{o}C and lowest (16.79%), at a rearing temperature of 18^{o}C. It was observed that the females tend to live longer as compared to the males at all rearing temperatures. Net highest reproductive rate was observed at 23^{o}C while it was minimum at 13^{o}C of temperature conditions. By the

end of year 2001, Thomson *et al*. have studied the effect of heat hardening upon the egg parasitoid, *Trichogramma carverea* in laboratory and their acclimation in the field. Heat hardening, in *T. carverae* was evaluated at the papal and adult stages and evinced the hardening effect, on heat resistance in laboratory. Heat hardening enhanced adult fitness in the field under hot conditions. So, hardening therefore has fitness benefits without costs under field and laboratory conditions and so, the process can be used to enhance parasitism rates in the inundative commercial releases of *Trichogramma*.

The role of temperature on diapause in *Trichogramma cordubensis* under laboratory conditions, by using eggs of *Ephestia kuehniella* Zeeler, was studied by Garcia *et al*. (2002), who have investigated that it was possible to create diapause conditions in the pre-pupae of *T. cordubensis*, through a preimaginl stage (just before the pupal stage), at 10^{o}C for 30 days and to achieve emergence without diapause when the exposure duration was only 10 or 20 days. Parasitoids did not enter diapause at pre-storage temperature of 7 or 12^{o}C without the effect of duration of exposure. Good percent emergence of the adults after a long storage at a low temperature of 10^{o}C for 30 or 40 days, followed by 6 months at 3^{o}C. Prolonged storage of the parasitoids in diapause conditions, permits, the producers to stockpile these parasitoids before field release to get an effective bio-control of the crop pests. The results of Shirazi (2006), on the biological parameters of *Trichogramma chilonis* (Ishii), who has studied the effect of temperature (20, 25 and 39^{o}C) and photoperiod (12:12, 14:10 and 16:8 h L:D) and concluded that an increase in the temperature from 20 to 30^{o}C also increased the fecundity, but decreased the longevity of the parasitoid. Highest fecundity (12:73 eggs/female/day) and lowest longevity of females (6:73 days/female) was observed at 30^{o}C. The photoperiod, significantly affected the biological parameters. A 14:10 h L:D resulted in an increased fecundity and adult emergence in the parasitoid. So, it was concluded that *T. chilonis*, preferred to gave maximum performance at 30^{o}C, with 14:10 h L:D suitable for laboratory rearing of this parasitoids. In a recent occasion, Nadeem and Hamed (2008) have studied the development and parasitization of two egg parasitoids *Trichogramma chilonis* (TC) and *Trichogrammatoidea bactrae* (TrB) and compared those, after exposure to different temperature regimes under laboratory conditions. Results revealed

that biological response of both species varied significantly temperature wise. Their development from the egg to the adult emergence, prolonged at 15^{o}C followed with by 20^{o}C and 25^{o}C for TC and TrB, respectively; whereas, it was reduced to 7 days, at 30 and 35^{o}C. Host parasitization was 90.6 and 90.4% at 25^{o}C followed by 88.4 and 87.5%, at 20^{o}C and 83.5 and 81.4% at 15^{o}C for TC and TrB respectively. The highest adult emergence was recorded at 25^{o}C and the lowest at 35^{o}C for TC and TrB, respectively. All the life parameters, of both egg parasitoids, were very favorable at 25^{o}C, for getting a maximum adult recovery; while, high temperatures (30 and 35^{o}C) and low temperatures (15 and 20^{o}C), affected adversely the fitness of the parasitoids.

2.2.6 Release methods of *T. chilonis* in field

Nordlund *et al*. (1974) have evaluated field application methods of *Heliothis zea* eggs and kairomones, for *Trichogramma evanescens*, and applied eggs to the plants with a pneumatic sprayer, using adhesive plantgard. Results indicated that the plantgards did not affect the acceptance of eggs by *T. evanescens* and no antagonistic effects upon the tricosane kairomones were observed. So, the pneumatic spray system is quite acceptable for the use of kairomones and releases/dispersal of the parasitoid eggs for the experimental studies in the field conditions.

2.2.7 Effect of the field temperature on the survival of *T. chilonis*

The effect of field temperature is very critical upon the survival and adaptation of the parasitoid and thus the studies on the effects of high temperature for 2 cultures of *Trichogramma pretiosum* Riley released in the cotton fields at high temperatures were conducted. Data reported here showed that the parasites inside the host eggs are susceptible at 37^{o}C for a short period of time. To reduce the mortality of parasites, application of host eggs for field releases should be made when temperature on the soil and plant surfaces did not exceed 37^{o}C (López and Morrison, 1980). King *et al*. (1984) tested the egg parasitoid, *Trichogramma pretiosum* in augmentative releases for

management of *Heliothis* in cotton. They concluded that the egg parasitism increased in response to the parasite releases, each year and the technology demonstrated for a parasite production, shipping and a release over large crop areas as well as monitoring and predicting pest occurrence may have a potential for management of lepidopterous pests in other crop. Harrison *et al*., 1985, have evaluated developmental time, parasitism and emergence of two strains of the parasitoid *viz*., *Trichogramma pretiosum* Riley and *T. exiguum* Pinto and Platner, using host (*Heliothis virescens* F.) at five constant temperatures of 15, 20, 25, 30, and 35^{o}C and have compared by and recorded that the developmental time of both parasite species, inside the host egg was decreased with an increase in temperature. Development rate was observed faster in *T. exiguum* at 25 and 30^{o}C and slow, at 20^{o}C. *T. pretiosum* completed the development at 35^{o}C; while, *T. exiguum* did not. In both species the adult longevity was decreased as the temperature increased. More female population was attained as compared to the males at all temperatures.

High temperature (35 and 44^{o}C) conditions, in the field when *Trichogramma brassicae* Bezdenko parasitoid, released in the form of white pupae (WP) and imago ready to leave (IRL) against the European corn borer, *Ostrinia nubilalis* Hübner with an ultimate aim to determine the parasitoid efficiency in relation to field temperature increases. WP and IRL stages of *T. brassica* were susceptible to the heat shocks at 44^{o}C. After WP exposure at 44^{o}C, the loss of parasitization was 85.8%. Female proportion of the progeny of heat exposed parasitoids decreased after 35 or 44^{o}C of treatment. So, it was concluded that IRLs methods of releases, proved most susceptible at high temperature as compared to WPs. So, it would be more suitable to release the parasitoids in WPs form for an inundative field releases as simulated by Chihrane and Lauge, 1995. To estimate the survival time of *Trichogramma platneri* Nagarkatti (Hymenoptera: Trichogrammatidae), in walnut orchards, at California. Parasitoid females were released in order to hold in dialysis tubing, in a batch of 2317. Survivorship in the unfed and fed parasitoids was 2.0±0.1 and 2.6±0.1 days respectively. Survivor time was inversely correlated with the mean temperature in all treatments. In the field, the survival time was less as compared with the laboratory survival time as reported by Mansfield and Mills in

year 2002. The assessment of parasitization rates, in six species/strains at six temperatures (10, 15, 20, 25, 30, and 35^{o}C) at two levels of humidities (40-50% and 70-80%) by using five host densities (6, 12, 18, 24 and 30 per adult female) was carried by Kalyebi *et al*., 2005 and temperature effect on parasitization was observed to be significant; while that of relative humidity did not leave any effect. Results suggest that for all the tested parasitoids parameters, the optimum temperature for parasitization was around 30^{o}C. An effective inundative programme by using trichogrammatids against *H. armigera*, the strain differences related to the thermal preference should not be ignored.

2.2.8 Searching ability of *T. chilonis*

Searching ability of the predator, *Trichogramma* has revealed it's effectiveness against the pests in a particular crop. The rate of searching by the female *Trichogramma minutum* Riley, *T. evanescens* Westwood, *T. semifumatum* Perkins and *Trichogramma* spp., increased as the temperature increased from 20-35^{o}C and decreased at 40^{o}C. These are the findings of Biever, 1972, who reported that in the bioclimatic rooms, with programmed temperature, the results suggested that designing a field release programme is a very complex task, as a single input of temperature alone appears to have a significant effect on the searching activity and thus on the potential effectiveness of *Trichogramma* in the field. Stinner *et al*. in year 1974a have studies the longevity, fecundity and searching ability of *T. pretiosum* by rearing on eggs of different hosts, *Heliothis* and *Sitotroga cerealella* and testing their viability in stored and unsorted conditions. They reported that the longevity of *T. pretiosum* is not affected by the host eggs. Longevity was observed more on the fed parasitoids as compared to the unfed ones. In fed caged studies, parasitoids survived for 54 hours and 100% mortality was observed in all the parasitoids, regardless of their host. In the same year in an other experiment Stinner *et al*. (1974b) have made releases of parasitoids, *Trichogramm* in 19000-387500 numbers per acre in field experiment and got an average parasitism of *Heliothis* eggs, in the range of 33-81% with 400 feet movement of the parasitoids in 2 days. Likewise, Saavedra *et al.* (1997) have carried out field experiment in 38 to 55 day old cotton in a

plot size of 625m^2 to study the dispersal and parasitism of *Heliothis verescens* (Fab.) (Lepidoptera: Noctuidae), eggs by parasitoid, *T. pretiosum* (Riley). Parasitoid adult releases, were made at two level of densities, *i.e.*, 16000 and 32000 numbers per ha with two strategies (1) one day prior to the adult emergence (pupae) (2) adults emerged one day old, fed with honey. Results revealed that the parasitoids released as pupae attained low parasitism as compared to parasitoids released as adult of one day old. Parasitism of eggs was found better developed, collected from leaves as compared to that from terminal buds. In the same way Wang *et al.* (1997), have released *T. ostriniae* (Hymenoptera: Trichogrammatidae) in sweet corn (*Zea mays* L.) for the control of European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae), to study the effects of plant size, distribution of egg masses and weather conditions on the parasitism of egg masses. Egg of *O. nubilalis* were stapled on leaves to the upper, middle and lower portions of the plants, 5 to 35 meters from the point of parasitoid releases. Results indicated that the egg parasitization (%) was decreased as the leaf area and distance increased. Eggs that were stapled on the middle and lower portion of the plant have got higher parasitization in comparison to eggs stapled on the upper portion. Temperature also had a significant effect on parasitization, as during severe hot and cold days recorded less parasitization. High parasitization was observed, when more exposure was given to the host eggs for 2 days. They suggested that temperature, plant height and leaf area, must be considered for the optimization of parasitoid releases.

The releases of *Trichogramma chilonis*, in cotton field for the control of *Helicoverpa armigera* to study the impact of weather factors on dispersal distance in China, was carried by QingWen *et al.* (1998), and reported that the dispersal of *T. chilonis*, was influenced by both sunshine and temperature. During the months of June-August, the effective dispersal distance was between 10 to 25 m, in cotton fields. Rain fall adversely affected the dispersal of parasitoids, in field. Humidity above 89% caused the shortening of dispersal. Later on Fournier and Boivin (2000), have studied a comparative dispersal of *Trichogramma evanescens* and *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) in relation to the environmental conditions. In *T. evanescens*, the solar acclamation at temperature > 15^{o}C had a significant affect on the

dispersal as compared to that on *T. pretiosum*. So, *T. evanescens* appears to be a warm climate spp. and its higher sensitivity against temperature and wind indicates that this spp. is adapted in the field more favorably as compared to *T. pretiosum* for more flight control, to locate their targets. Not long, Hamed *et al*. (2004), have released the egg parasitoid *Trichogramma chilonis*, in cotton crop, to find out its dispersal and parasitizing potential. Percent parasitization was taken at distances of 1-5 metre from the fixed releasing sites. Dispersal of *T. chilonis* was physically affected by the crop growth, in late September and in early October. Intensity of parasitization was more after 24 h as compared to 48 h post release of the parasitoids. Gingras *et al*. (2008) have studied the effect of plant structure on the searching efficiency of *Trichogramma turkestanica*. Results, showed that the female wasp of *T. turkestanica*, were less active on simple plants as compared to the complex structural plants. While, plant structure, did not show any effect on the handling time of eggs. This finding demonstrates that the structure of plants can modulate searching activities and oviposting behavior of the parasitoid for the host finding success. In year 2008, Singh and Shenhmar have studied the searching abilities of genetically improved high temperature tolerant strains of *Trichogramma chilonis* (Ishii) in sugarcane crop, under natural field conditions. Searching range of high temperature tolerant (h+t) strain and local Ludhiana strains of *T. chilonis* traveled a distance of 10 and 8 m respectively from a fixed release point after parasitizing host (*Corcyra cephalonica*) eggs. Parasitism of the host was decreased as the distance increased. Both the strains showed a negative and positive correlation with the temperature and humidity of the field respectively. Slight decline in the searching range in May as compared in April increased in June and July as the temperature increased. Searching range of host strains was observed better as compared to that of Ludhiana strains irrespective of the temperature from April to October.

2.2.9 Pest control by the releases of *T. chilonis*

After successful rearing of the parasitoids in the laboratory, their triumph against pests in natural field conditions describes their effectiveness and the previous investigators have compared different control strategies in small cotton field by the

application of commercial formulation of *Bacillus thuringiensis* Berliner (BT) (1121 g/ha), which gave an insufficient results to suppress *Heliothis* larvae. Chlordimeform (140 g/ha) along with the same dose of BT, gave an increased control but did not exceed that given by chlordimeform alone against *Heliothis* spp. Direct comparison in the efficacy of two microbial BT formulations (561 g/ha) and a commercial formulation of *Baculovirus heliothis* (BH) (148 g/ha) against *Heliothis* larvae, provided moderate level of control, against larvae. When BH formulation (148 g/ha) or BT (560 g/ha) applied with the release of *Trichogramma* (110000/ha), in test plots, with diflubenzuron (70 g + 4.7 liter crop oil/ha) it gave significant reduction for both small and large *Heliothis* larvae as compared to those in the check (Bull *et al*., 1979).

Efforts has been made, on the interactions of host plant resistance between plant trichomes density and level of successful attacks on *Heliothis zea* eggs in cotton with a predator (*Chrysopa rufilabris*) and parasitoid (*Trichogramma pretiosum*) by Treacy *et al*., in year 1985 and observed that the plant damage due to *H. zea*, was reduced on glabrous cotton phenotypes due to anti oxeious and increased entomophagous efficacy in comparison to that in the hirsute and pilose phenotypes. Symbiotic relationship between the host plant, its associated predator and parasitoid complex, may significantly influence the expression of host plant resistance in cotton. Later on Hassan (1993) has collected information on mass production of egg parasitoid, *Trichogramma*, being commercially used to control lepidopterous pests, particularly European corn borer, *Ostrinia nubilalis* (Hb.), in Germany, since 1980. Treated area reached about 6200 ha, in 1992. Use of *Trichogramma dendrolimi* (Matsumura) was started in 1990 to control the codling moth, *Cydia pomonella* (L.), and summer fruit tortix moth, *Adoxophyes orana* (F.R). Research are being in progress to select effective *Trichogramma* species to control pests as grape berry moth, *Eupoecilia ambiguella* (Hüb.), plum fruit moth, *Cydia funebrana* Tr. and diamondback moth, *Plutella xylostella* (L.). After wards Mohyuddin *et al*., 1997, have evaluated the feasibility of biological control agents by conservation and augmentation of natural enemies with reduced use of pesticides to control sucking and bollworm complex of cotton. *Coccinellids* were conserved on aphid in alfalfa crop and redistributed in cotton. *Trichogramma chilonis* was reared in laboratory and released in cotton field from

August to October for bollworms in fields where predators were conserved. The population of whitefly, jassid and thrips were lower as compared to those where farmer have usually sprayed insecticides 5-7 times. At Falaksher farm, jassid population both in biological control and farmer's practice plots were about 1.2 per leaf during first fortnight of July and decreased to 0.2 per leaf in August both in biological control and unsprayed plots. Bollworm infestation started in the first fortnight of August. At Khokhar farm bollworm infestation increased upto 10 where insecticides were used and 9% in unsprayed fields in second fortnight of October; while it was 2.4% in biological control field. Likewise, Ahmad *et al*. (1998) reported the efficacy to parasitize the eggs of different cotton bollworms, by *Trichogramma chilonis*. Significantly higher parasitization was observed in pink bollworm eggs as compared to the spotted and spiny bollworms. Parasitizing potential was decreased as the age of host eggs increased. Age of the parasitoids, itself affects the parasitization from 1st to 2nd day. By the next year in 1999, Romeis *et al.* have conducted field studies to evaluate parasitism ability of *Trichogramma* ssp. (Hymenoptera: Trichogrammatidae) on egg of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in pigeonpea (*Cajanus cajan* L.) and sorghum (*Sorghum bicolor* L) in intercropped plants. On pigeonpea plants, *H. armigera*, deposited 4.8% of eggs, on calyx and pods; while, the parasitism level of 3.6, 0.3 and 40.7% by *T. chilonis* in eggs collected from calyx, pods and leaves, respectively. The parasitism level from 279 to 100% was recorded from the *H. armigera* eggs on plants of sorghum. This study showed that parasitism levels were positively correlated with the eggs collected from, the leaves as compared to those from other plant parts.

To evaluate the effective releases of *Trichogramma exiguum* wasps for heliothine management, in cotton two years field trials were conducted. Nine and six releases of *T. exiguum*, in cotton fields were made in year 1996 and 1997, respectively. The quality traits observed in laboratory as parasitism, adult emergence (92%) and adult female longevity (15 days) were almost the same as was observed under field conditions. In year 1996, mean percent parasitism of heliothine eggs, in experimental field plots ranged from 67 to 83% and 25 to 55% in the control plot. During 1997, parasitism level by *T. exiguum* was ranged from 74 to 89% in treated plots, whereas, 18 to 69% was recorded in control

plots. Comparison of the yield and damage caused by heliothine pest during two years of trial showed that Trichogramma spp. alone is insufficient to give a good pest control although in field it gives a reasonable range of pest suppression (Suh *et al*. 2000). Later on Prasad (2002), have too evaluated that rearing temperature, had a significant effect on the potential fecundity and parasitism rate of *Trichogramma sibericum* on the host eggs (*Ephestia kuehniella* Zeeler). Parasitsm recorded at 21^{o}C, was significantly more as compared to that 16 and 26^{o}C. Also, the parasitization was recorded to be more in between the temperatures of 16 and 26^{o}C. Marginal analysis showed that rearing at 16^{o}C, is more cost effective, when ambient temperature was expected to be cool. In the very next year (2003), Ballal and Singh have evaluated the effectiveness of three *Trichogramma* species, *viz*., *T. chilonis, T. pretiosum* and *T. brasilionse*, against *Helicoverpa armigera* in laboratory, and screen house conditions. Laboratory studies showed that *T. chilonis* and *T. pretiosum* were more effective against *H. armigera* as compared to that against *T. brasiliense*. In screen house, *T. chilonis* was the most effective among the parasitoids on eggs of *H. armigera*, on sunflower plants. A release of 5000 parasitoids per ha on sunflower and red gram, gave 50.1 and 11.4% parasitism on *H. armigera* eggs by *T. chilonis* respectively. The position of *H. armigera* eggs on different parts of plants has no effect on the parasitism by parasitoids. On the same way Doyon and Boivin (2005), have observed a significant relationship between size, adult longevity and lifetime fecundity on the fitness of female *Trichogramma evanescens*. Early emerging females had the same sex ratios as that of the females emerged later, but produced there longer and more fecund progeny which gave 18.8% more progeny. It was concluded, that the early emerging females have a higher fitness than the late emerging females of *T. evanescens*. A significant relationship was found between size of females and both longevity and life time fecundity.

2.3 *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)

2.3.1 Biology

Studies on the fecundity and longevity of *Chrysopa externa*, in laboratory after using *Sitotroga cerealella* showed that the eggs laid by female were 1082 and average number per day was observed as 15.7 per female. Longevity of males and female was 74.5 and 77.2 days, respectively (Costa *et al.*, 1999). The feeding potential and life history characteristics of the generalist predator, *Chrysoperla carnea* (Neuroptera: Chrysopidae) at different prey densities of *Hyalapterus pruni* (Geoffer) (Homoptera: Aleyrodidae), under laboratory conditions were recorded under the parameters; including functional response, developmental time, mortality rate and fecundity of predator. Prey was provided with 5, 10, 20, 40, 80, 160 and 2350 aphids, per larva per day. From the results it was evident that *C. carnea* responded with an increased prey consumption with increased in larval growth. Increased prey consumption reduced the higher net reproduction (Atlihan *et al.*, 2004). The feeding potential of *Chrysoperla carnea* on the host eggs (*Sitotroga cerealella*), by using different combinations of measured amount, i.e., 12, 24, 36, 48 and 60 mg of host eggs on 1, 2, 3 and 4 g eggs of predator, in 20 different combinations was studied and highest larval length was recorded in treatments, where 48 and 60 mg of eggs were used for feeding. Larval period (10.17 to 12.67 days) was also observed in different treatments (Nasreen *et al.*, 2004).

2.3.2 Storage of *Chrysoperla carnea*

Shelf life extension of the voracious predator, *Chrysoperla carnea*, is particularly critical, during delivery and the maintenance of culture in rearing laboratories. So, the study of the rate of development and reproduction of *Chrysoperla externa* (Hageen), have straight relationship to temperature between 15.6 and 26.7^{o}C. Lower thermal thresholds, for development of immature stages, fell between 11 to 12.5^{o}C. At 21.1^{o}C, the oviposition was 284 eggs, during 30 days. It was concluded from the present study that *C. extrena* is well suited as a biological control agent in pest management programmes, in

the regions of central and southern states (Albuquerque *et al*., 1994). To learn the effects upon the survival and reproductive aspects of life history, after the storage of non-diapausing *Chrysoperla externa*, Tauber *et al.*, 1997a, have carried out studies and observed that the survival decreased as the storage time increased and the survival was observed to be more than 85%. Reproduction, after 30 and 60 days of storage at 10^{o}C, was almost very similar to that of the control (un-stored), at 24^{o}C, which started oviposition after 6 days. All females laid fertile eggs and the average rate of oviposition was 15-18 eggs/day, with 97% fertile eggs. At 120 days of storage, the reduction in reproductive performances was in comparison to that of 30 and 60 days of storage. Again, Tauber *et al*., 1997b, have reported the variation in life history in *Chrysoperla carnea* in storing at low temperature and their results showed that storage of either diapausing adults, at 5^{o}C temperature for about 13 weeks yielded better survivor ship and reproduction performance than those stored/ reared at 24^{o}C (control). To induce diapause in insect population for storage, the insect larvae should be reared under long day photoperiods and the prepupae under short days.

In year 2000 Arroyo *et al*., have worked on the short term storage capacity and relatively good post storage quality and sorted out an optimum temperature for the maximum days of storage with a minimum effect on the quality after studying life history by exposing the predators at low to moderate temperature. Egg storage of three Neotropical species such as *Ceraeochrysa externa* (Hagen), *C. smith* (Navas) and *Chrysoperla externa* (Hagen) were tested under five temperatures between 4.5 to 15.6^{o}C for 3 weeks. Results indicated that newly laid eggs of three species can be stored without hatching for 2 weeks at 15.6^{o}C and storage of *C. externa* eggs extended to 3 weeks, at 12.8^{o}C. In the same way, Chang *et al.*, (2003), have determined mass rearing, production and storage of diverse populations and biotypes of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) having four *Carnea* biotype and one *Mohave* biotype. *Mohave* population had a delayed oviposition as compared to the *Carnea* populations. Survival of diapasing adults was observed during the first 18 weeks of storage and it was recorded to be high among all the four populations and adults of three populations showed high survival, after 35 weeks of storage. Six or more weeks of storage produced average

fecundity ranging from 400-900 eggs/female. In recent past, Silva *et al.* (2007) have focused their study on the life history of a widespread Neotrapical predator, Chrysopodes at constant temperatures between 18 and 28.5^{o}C. The life cycle ranged from 64 to 27 days, respectively, whereas, a temperature slightly below 15^{o}C has prevented development. Hence, it is proved from the present study that the developmental rate is directly dependent upon temperature. At 25^{o}C, the reproduction rate was the highest, as females oviposited 10 days after emergence, with 9 eggs per day and a total of 200 eggs per female. When the life cycle of *Ch. (Ch.) lineofrons* was compared with other lacewing spps., it appeared better than others, with a tremendous nature of adaptive potential in Neotropical orchards for effective mass releases.

2.3.3 Field adaptability of *Chrysoperla carnea*

The enormous significant quality of a predator is to establish its population, under natural field conditions against their target pests. Here, the life history and feeding behavior of green lacewing, *Chrysoperla carnea* Stephens in laboratory conditions, were adopted by (Afzal and Khan, 1978) and the various instars of *C. carnea* were offered to feed aphids, *Aphis gossypii* and whitefly, *Bemisia tabaci*, nymphs and pupae. All instars were observed to feed on soft bodied insects. *C. carnea* larvae, preferred to feed on aphids and on the whitefly pupae, in the absence of aphids. A single larva consumed 487.2 aphids and 510.8 whitefly pupae in it's entire life span. It was also observed that feeding potential of *C. carnea* was increased in the advanced instars. Like vise, Gardner and Giles, 1996, have worked on commercially produced green lace wing, *Chrysoparla rufilabris* Burmeisler (Neuroptera: Chrysopidae), eggs for their mechanical field releases and distribution, through prototype distributors. Hatching rate from all the treatments has no difference in comparison with the untreated control. The results establish the feasibility of mechanical distribution of the viable eggs of green lacewing.

2.3.4 Pest management by *Chrysoperla carnea*

The predation potential of *Chrysoperla* to it's natural enemies under field conditions was carried out by the previous investigators, like that of Butler and Hennebery, 1988, who have studied the predation of *Chrysoperla carnea* (Stephen) upon *Bemisia tabaci* in the field conditions and observed that the first instar larvae of *C. carnea*, consumed both eggs and larvae of *B. tabaci*, at the same time; while, the second instar larvae consumed more eggs rapidly than the first instar larvae. Third instar larvae of *C. carnea*, consumed the prey larvae in 33-78 seconds. Presence of *C. carnea* larvae on cotton leaves inhibited the visit and oviposition by *B. tabaci.* This affect lasted for quite sometime, even after the predator larvae had left one plant to an other one. Afterwards, Pawar (1991) concluded his experiments on the control of insect pests of cotton, by the use of predator, *Chrysoperla* spp. releases in field. The effective control of pests, were attained at the rate of releases of one lakh per hectare thrice at fortnightly intervals.

In very next year, Breene *et al*., 1992, have evaluated second instar *Chrysoperla rufilabris* (Burmeiste), as bio-control agent against the sweet potato whitefly, *Bemisia tabaci* (Gennadius), in a green house, on *Hibiscus rosa-sinensis* L., in two releases of 25 or 50 larvae of *C. rufilabris*, per plant with 2 week interval. In other releases 100 *C. rufilabris*, larvae towards the centre of 12 plants, had given an effective control. Release of 25 or 50 larvae, per plant treatment had a healthy effect on plants. Quantitative evaluation of plant was based on the presence of sooty mold and physical effects of *B. tabaci*, on the plants, 2 weeks after the last release of *C. rufilabris* larvae. Kabissa *et al*. (1995), have studied the comparative developmental biology of *Mallada desjardinsi* (Navas) and *Chrysoperla congrua* (Walker), on *Helicovera armigera* (Hübner) and *Aphis gossypii* (Glover), in laboratory conditions. Larval period of 14.4 and 14.8 days was observed in *M. desjardinsi* and *C. congrua* respectively, on eggs of *H. armigera* as against 14.9 and 13.5 days, for *M. desjardinsi* and *C. congrua*, respectively on *A. gossypii*. Feeding *C. congrua*, the consumption of *H. armigera* was observed to be higher than that of *M. desjardinsi*, which appears to be a promising control measure against *H.*

armigera. Again, Kabissa *et al*. in very next year (1996) have conducted a field experiment, on the occurrence of chrysopids on cotton crop, in the pest management of *Helicoverpa armigera* (Hübner) and *Aphis gossypii*. After 8 weeks of the germination of cotton crop among the chrysopid species, only *Mallada desjardinsi* and *Chrysoperla* spp. were observed in the presence of *H. armigera* and *A. gossypii* which were abundant in cotton field between 12^{th} and 15^{th} weeks after germination. Peak activities of *H. armigera*, were observed between 8^{th} and 13^{th} week and at the same time, population of chrysopids was also present. However, since population of predator, on cotton was low to meet the control management of pest, hence use of compatible pesticides in the management of *H. armigera* and *A. gossypii* was needed to be explored.

The adaptability of biological control agents, on crops was investigated by Farkade *et al*. (1999), in vegetables, in 10 villages of India. Adoption of biological control measures varied from 15-65%. Among them *Chrysoperla* spp. share was about 7% for the control of sucking pest complex of crops and vegetables in the experimental sites. In the same year (1999), Zaki *et al*., have released two predators, *Chrysoperla carnea* Stephens and *Coccinella undecimpunctata* Reich, as well as two parasitoids *Diaeretiella rapae* and *Eretmocerus numdus*, both in natural field and in green house conditions, against *Aphis gossypii*, *A. fabea, Brevicorine brassicae* and *Bemisia tabaci*. Release of *C. carnea* (1:5: aphids), attained 100% control of *A. gossypii* after 12 days; whereas, release of *C. undecimpunctata* (1:50 predator: aphids) got 99.97% reduction in *A. gossypii*. From the results, it was concluded that a single or a double release of *C. carnea* at the rate of 1:5, 1:10 and 1:20 (predator: aphid), proved effective to get a high reduction in aphid population, in okra vegetation, in a span of two weeks.

Relative consumption of three aphid spps., Aphis *gossypii* Glover, *Myzus persicae* (Sulzer) and *Lipahis erysimi* (Kaltenbach) (Homoptera: Aphididae), by the lacewing, *Chrysoperla rufilabris* (Burmeister) (Neuroptera: Chrysopidae) was such in laboratory conditions, after studying it's development and survival. Number of the prey (aphid), consumed by *C. rufilabris* varied among the species. It was observed that *C. rufilabris*, consumed *A. gossypii* (141.6 nos.) and *M. persicae* (168 nos.); while, *L. erysimi* caused a

lethal affect on the predator. Developmental duration of *C. rufilabris*, after consuming *A. gossypii* was 18.0 days, and for *M. persicae* 19.2 days. Therefore, ability of lacewing feeding and development processes, on aphid preys, is critical to the sustained existence, in vegetable ecosystem (Chen and Liu, 2001). The predation, potential of green lacewing, *Chrysoperla plorabunda* (Fitch) (Neuroptera: Chrysopidae), against *Toxoptera citricida* (Kirkaldy) (Homoptera: Aphididae), in citrus, both under laboratory and field condition was investigated and the larvae of *C. plorabunda* were found to have consumed, on an average of 1676, 1297, 392, 165 and 130 nymphs and apterous adults from 1st to 4th instars respectively. The average population rate was recorded to be 37.5%, but the survival rate was only 6.3%. Developmental time of *C. plorabunda* and survival varied with life stages of aphids, consumed. Two separate doses of larval releases *i.e.*, 275 and 116, per tree, were performed, in the field, against *T. citricida*. Results of field releases in comparison to the laboratory, were not at par, in field as for as the performance of *C. plorapunda* against *T. citricida* was concerned (Michaud, 2001). In cotton crop, for management of insect pests, with bio-control agents by the augmented releases of parasitoids, *Trichogramma chilonis* and predators, *Chrysoperla carnea* showed that this bio-control technology has suppressed the pest population to a sub economic level. The population of parasitoid was recorded low (2.5%) in the early crop growing months and it increased gradually and attained it's highest position (70%), in the month of October; whereas, the highest number (230) of predator in the fields was observed in the month of August. So, it was concluded that the bio-control based technology with parasitoids and predators has a potential to control cotton pests as reported by Ahmad *et al.* (2003).

Biology and searching ability of *Chrysopa phyllochroma* Wesmeal (Neuroptera: Chrysopidae) for *Aphis gossypii* Glover (Homoptera: Aphididae), nymphs and adults under laboratory and in the green house and on potted cotton plants, was carried and investigated by Su, *et al.* (2004) and the results revealed that in cages, with potted cotton plants, *C. phyllochroma* larvae on an average, have consumed 13.3 and 29.4 aphids/day, for 1st and 2nd instars, respectively. *C. phyllochroma* larvae preferred more aphids from upper portion as compared to that of the leaves at lower portion. Under laboratory conditions, in Petri dish/glass vessels, the predacious efficiency of *C. phyllochroma*

larvae was varied with the predator density. Subsequently, Gao *et al.* (2007), have evaluated the feeding potential of Chinese green lacewing, *Chrysopa sinica* (Tjeder) (Neuroptera: Chrysopidae), and it's potential for the biological control of the cotton aphid (Homoptera: Aphididae), under laboratory conditions. Potential of *C. sinica* as a biological control agent was evaluated according to ingestion by the predator and energy contents of *A. gossypii*. Larval stage of *C. sinica*, have consumed, on an average, 1281.4, 1018.7, 6269, 393.5, 312.1 and 203.5 aphids at the age of 1, 2, 3, 4, 5 and 9 days. Results of these findings, suggested that *C. sinica* is an important natural enemy of cotton aphid and it's energetic methods, proved useful to quantify for the biological control efficacy of natural enemies. In the recent past, Zia *et al.* (2008), have conducted an experiment to investigate the usefulness of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), against *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae), in six advanced genotypes of cotton, *viz*., MNH-553, CIM-707, SLH-284, IR-FH-901, CIM-496 and FH-115. From the results it was evinced that *C. carnea* have the highest reduction of whitefly population (57.35%), during 4th week of August in MNH-552, followed by that in 2nd week of September, in MNH-552 (57.14%). The lowest reduction of whitefly population was recorded, during 2nd week of July, in MNH-552 (22.56%) and concluded that, the use of *C. carnea*, in a bio intensive pest control programme, have the capability to combat the pest and reduce the cost of production of cotton crop.

MATERIALS AND METHODS

3.1 Selection of *Trichogramma chilonis, Chrysoperla carnea* and *Sitotroga cerealella* strains

Fresh strains of egg the parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) and a predator, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) were collected from the cotton, sugarcane and lucern crops and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), was collected from wheat stores and reared in the mass rearing laboratories of beneficial insects at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, where all the laboratory experiments in present studies were conducted under controlled laboratory temperature and humidity conditions.

3.2 Rearing of *Sitotroga cerealella* on different hosts

Four cereals, *viz*., maize, barley, sorghum and wheat, were taken from the breeding section of the Ayub Agricultural Research Institute (AARI), Faisalabad. After careful cleaning, hot water treatment at the boiling point (100^{o}C) was given for about 5 minutes, to free these cereals from any pathogen and mite infestations. All the grains were sun dried to retaining moisture contents of 8-10%. Chilling treatment, for 24 hours, below 0^{o}C was given to the cereals by keeping them in a cooled incubator, to make grains free of any contamination. In this experiment *S. cerealella*, was reared, with four treatments, having three replicates each in glass jars, of 250 g size. For each cereal, 300 grains and 200 number of *S. cerealella* eggs were used. Rearing of *C. carnea* was also carried out in each cereal having similar number of eggs and grains were kept in free choice rearing

chambers of three repeat each. All the four cereals were kept separately in free choice chamber. At the central place of the rearing chamber 800 counted eggs were placed. After ten days of the date of egg provision in chambers, each cereal from the free choice chamber was taken carefully and poured into the glass jars, separately. Data regarding the life span, percent emergence of adults, size of eggs, and size of the adults, fecundity and host, were recorded and compared with the no choice and free choice rearing methods. Duration of experiment continued up to the selection of the cereal to be used for rearing *S. cerealella*. Selected best cereal (wheat) for *S. cerealella*, among the treatments, was further tested to have a radiation dose to see the impact on rearing of host having same number of grains and eggs on same parameters of adult studied by using 10, 20, 30 and 40 Krad radiation doses, from Gamma cell of Cobalt 60 source at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad.

3.3 Effect of radiation on eggs of host, *Sitotroga cerealella*

This experiment was conducted, to study the impact of irradiated eggs of *S. cerealella*, on their prolonged storage and preference by *Trichogramma chilonis*, for parasitization. The eggs of *S. cerealella* were exposed from low to high doses of radiation, from Gamma cell of Cobalt 60 at NIAB, Faisalabad. The doses for experiment were selected as 10, 20, 30, 40, 50, 75, 100, 125, 150, 175, 200, 300, 400, 500 and 600 Gy. Thus, there were sixteen treatments, including a control having three repeats, each. The eggs at each dose were exposed to the parasitoids (*T. chilonis*) before hatching. Incubation period of the parasitoids, percent emergence and percent parasitization by the parasitoids were recorded.

3.4 Development of *Trichogramma chilonis* on stored eggs of host, *Sitotroga cerealella*

This experiment was carried out in cooled incubators to evaluate the effect of long and short term storages for the host eggs. Storage temperatures selected were 6, 8, 10, 12, 14 and 16°C; whereas, the storage durations were 5, 10, 15, 20, 25, 30, 40, 50, 60, 70,

80 and 90 days. Thus, there were 6 temperatures and 12 storage treatments, with three repeat each. After completing the storage duration, at particular temperature under study, the eggs were pasted on paper cards using natural gum and offered to the parasitoids, confined in glass jars of 250 g capacity for parasitization. Exposure time to host eggs by the parasitoids confined in glass jars was 24 hrs. The parasitoid cards were taken out from the glass jars and kept in the laboratory at a temperature of 25±2^{o}C and 65±5% humidity for the completion of their life cycle. On the third day the changed colour of host eggs indicated parasitization. At this time, the percent parasitism was counted. After incubation of the parasitoids the percent emergence and parasitization by the parasitoids were recorded and compared.

3.5 Effect of radiation and low temperatures on eggs of host, *Sitotroga cerealella*

The combined effect of storage and low temperatures on host eggs, irradiated with 15 doses of low to high as 10, 20, 30, 40, 50, 75, 100, 125, 150, 175, 200, 300, 400, 500 and 600 Gy. Thus there were sixteen treatments of different doses of exposure including a control, having three repeats, each. Eggs were stored at 6 tested temperatures of 6, 8, 10, 12, 14 and 16°C in cooled incubators, for 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 days. Eggs from each repeat of a treatment were pasted on paper cards, with natural gum and were offered to the parasitoids confined in glass jars for parasitization. After 24 hours of the exposure time the host eggs on paper cards were taken out from the glass jars. After the completion of incubation of parasitoids, the percent parasitization and emergence of parasitoids were recorded.

3.6 Effect of adult food nutrition on development of *Trichogramma chilonis*

This study was conducted into evaluate the effect of adult feed, in the form of honey solution, to the parasitoid, *Trichogramma chilonis* (Ishii) by rearing under

laboratory conditions. Concentrations of honey solutions were prepared by making 5, 10, 15, 20 and 25%, using pure honey in distilled water and offered to the parasitoids as adult food in comparison to the control. Host eggs, *Sitotroga cerealella* (Olivier) were used to rear the parasitoids (Hoffmann, 2001). Rearing of the egg parasitoid, *T. chilonis* was carried out in glass vessels, according to Morrison (1970). Fresh host, eggs 150 in number, were pasted on the paper cards strips and exposed to *T. chilonis* adults of uniform age (24 hrs aged) confined in glass vessels of 250 g capacity and closed with a heavy cloth lid. Host egg strips were kept inside the glass vessels, for 24 hours for parasitism. After 24 hours of their exposure to the parasitoids, the host eggs, on strip were taken out from the glass vessels and kept separately in glass vessels plugged with cotton wool and placed at a laboratory temperature of 25±2^{o}C. Light and dark period was provided to the parasitoids were 14:10, according to Shirazi (2006). Three repeats, in each treatment were made. Data observed on the biological parameters of the adult parasitoids were: parasitism (%), male adult longevity (days) and female adult longevity and compared to such estimates from the control.

3.7 Optimization of short and long term storage duration for *Trichogramma chilonis* at low temperatures*

Experiment was conducted to find out the optimum storage temperature and duration of the parasitoid, *Trichogramma chilonis* (Ishii) at pupal stage, in the cooled incubators. Experiment was carried out using host eggs, *Sitotroga cerealella* (Olivier), reared on wheat grains. Egg parasitoid, *T. chilonis* was reared in glass vessels as described by Morison (1970). Host eggs 200, in number, were pasted on the paper card strips and exposed for 24 h to the 24 h aged parasitoids confined in glass vessels. Honey solution (10%) was fed to parasitoid, provided on paper strip, as adult diet, inside the glass vessels.

Host eggs on strips after exposure of 24 h to the parasitoids referred as parasitoid were taken out from glass vessels and kept under standard laboratory conditions *i.e.*, 25±2^{o}C,

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and 65±5% RH, at 14:10 light and dark period until the pupated seven days after parasitism. *T. chilonis* parasitoids, in the pupal stage, were stored at, six temperature regimes *viz*., 6, 8, 10, 12, 14 and 16°C each at 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 days, in complete darkness keeping three repeats for each treatment of the respective temperature and storage days in cooled incubators. After completing the respective storage duration, the parasitoid strips were taken out from the cooled incubator and placed at the standard conditions, where they emerged after 4 h. Data on the fitness parameters of adult parasitoids, as emergence (%), parasitism (%) and adult longevity (days) were recorded and compared such estimates from the control.

3.8 Comparative rearing of *Trichogramma chilonis* at different temperature conditions**

Study was conducted to evaluate the effective rearing temperature for the parasitoids, *Trichogramma chilonis* (Ishii), by testing different temperature conditions in incubators. Host eggs, *Sitotroga cerealella* (Olivier), were used to rear parasitoids (Hoffmann, 2001). Rearing of egg the parasitoid, *T. chilonis* was carried out, in glass vessels, according to Morrison (1970). Fresh 150 host eggs were pasted on the paper card strips and exposed to the *T. chilonis* adults (20 pairs) of uniform age (24 hrs aged) confined in glass vessels of 250 g capacity closed with heavy cloth lid. Host egg strips were kept inside the glass vessels, for 24 h for parasitism. After 24 h of exposure to the parasitoids, host eggs on strip, were taken out from the glass vessels and kept separately, in glass vessels plugged with cotton wool and placed at 6 constant temperatures, of two low, moderate and high ranges *viz*., 20, 25, 28, 31, 35 and 40^{o}C at 65% RH in incubators. Light and dark periods was provided to the parasitoids were 14:10 according to Shirazi (2006).

Three repeats, in each treatment of the respective temperature, were made. During the experiment, 10% honey solution was fed to the adult parasitoids, in all treatments, on

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paper strips as diet, inside the glass vessels. Data on the observed biological parameters of the adult parasitoids included: estimation on emergence (%), developmental period (days), parasitism (%) and adult longevity (days).

3.9 Effect of storage duration and low temperatures on developmental parameters of eggs of *Chrysoperla carnea*

The eggs of the predator, *C. carnea*, were stored separately at 6, 8, 10, 12, 14 and 16°C, in cooled incubators for 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 days. At each temperature and storage duration, 50 eggs were placed, after completing the storage period, according to each treatment for each temperature regime. The eggs were kept at normal prevailing laboratory temperature *i.e.*, 25±2^{o}C and 65±5% relative humidity. Biological life parameters of predator as percent larval emergence from eggs, larval duration (days), percent pupation, percent pupal recovery, fecundity and life span were recorded and compared.

3.10 Effect of storage duration and temperature on reproductive parameters of the adult of *Chrysoperla carnea* at different temperature conditions

Adult of the predator, *C. carnea*, were stored, separately at 6, 8, 10, 12, 14 and 16°C, in cooled incubators for 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 days. At each temperature and storage duration, 30 adults were kept. After completing the storage period according to each treatment and duration, adults were kept at normal prevailing laboratory temperature *i.e.*, 25±2^{o}C and 65±5% relative humidity. Biological life parameters of the predator such as percent survival, fecundity and life span were recorded and compared according to treatment.

3.11 Effect of different rearing temperatures on developmental and reproductive parameters of *Chrysoperla carnea*

In this experiment rearing of the predator was carried out at four constant temperature regimes such as 20, 25, 28, 31, 35 and 40^{o}C in incubator. Seven treatments, including a control, having 10 adults each were prepared. Egg hatching, larval duration in all the instars, percent pupal formation, pupal duration, pupal recovery and adult life span were studied and compared.

3.12 Effect of different host eggs on quality of developmental parameters of *Trichogramma chilonis*

Rearing of *T. chilonis* on the factitious host, *Sitotroga cerealella* was compared by using the eggs of *Plodia interpunctella*. Three replicates of each treatment were made. Experiment was carried out in a standard prevailing laboratory temperature and relative humidity of 25±2^{o}C and 65±5%, respectively. Data on the percent parasitization, percent adult emergence, adult longevity and number of parasitoids per egg was recorded.

3.13 Effect of different host eggs on quality of developmental parameters of *Chrysoperla carnea*

Larval rearing of *C. carnea* was compared by rearing their larvae on eggs of *S. cerealella* and *Plodia interpunctella*, in the laboratory under a temperature and relative humidity of 25±2^{o}C and 65±5%, respectively. Data on the biological life parameters, such as larval food consumption in all the instars, larval duration, life span, pupal formation, pupal recovery and adult emergence were recorded using standard adult diet.

3.14 Evaluation of different releases methods of *Trichogramma chilonis* under field conditions

Field releases of the parasitoid were compared by three methods. Parasitoids after completing laboratory experiments were released under natural field conditions. Eggs of *S. cerealella* pasted on paper cards and in loose form in laboratories were parasitized. After completing incubation period, these were released in the field, separately. Releases of parasitoids in the field were made and compared by three methods as under.

3.14.1 Evaluation of releases of *Trichogramma chilonis* through micro-cages in cotton under field conditions

Small micro-cages, having openings on both ends, were designed and fabricated, locally to test the parasitoid performance in a field release of parasitoids. These cages were installed on twigs and branches of cotton plants, in the natural field conditions. Known number of parasitoids, were filled inside the field cages. Host eggs, pasted on paper cards and placed in the field, on a fixed distance after 24, 48 and 72 hours of the post release time. These field collected parasitoid cards were kept in the laboratory conditions, at 25±2^{o}C and 65±5% temperature and relative humidity respectively for the completion of incubation period, until the wasp emergence was completed from the parasitoid host eggs. Data on the percent parasitization, percent releases and percent survival were recorded and compared.

3.14.2 Evaluation of releases of *Trichogramma chilonis* through paper cards in cotton under field conditions

Parasitoids pasted on the paper cards with gum, were installed on the plants in natural field conditions, in cages by making three replications. The percent parasitoids emerged from the paper cards were counted. Host eggs pasted on cards were placed in each plot of replication. Survival of these parasitoids in the field was calculated 24, 48 and 72 h of their post release. Field collected parasitoid cards were kept in the laboratory

conditions at 25±2^{o}C and 65±5% temperature and relative humidity respectively for the completion of incubation period until the wasps emerged from the parasitoids eggs. Data on the percent parasitization, percent releases and percent survival were recorded and compared.

3.14.3 Evaluation of releases of *Trichogramma chilonis* through broadcasting in cotton under field conditions

Parasitoids in lose form were mixed with saw dust and released through a broadcast methods in the field cages to evaluate the parasitoid releases and percent parasitization after 24, 48 and 72 hours of the post releases using host eggs. Field collected parasitoids, pasted on paper cards were kept at 25±2^{o}C and 65±5% temperature and relative humidity respectively, in laboratory conditions for the completion of incubation period, until the completion of wasp emergence from the parasitoids eggs. Data on the percent parasitization, percent releases and percent survival were recorded and compared.

3.15 Evaluation of *Chrysoperla carnea* releases under natural field condition

Releases of the predator *C. Carnea* in the field cages were made at the egg and larval stages and their percent release and percent survival recorded 24, 48 and 72 hours of the post release period of the predator.

3.15.1 Evaluation of *Chrysoperla carnea* releases at egg stage

Predator eggs along with the host eggs were releases inside the cages, installed on the leaves of plants. Percent emergence from eggs in the field conditions were observed and recorded in comparison of each other. Eggs of factitious hosts were provided to the larvae, in the field plants.

3.15.2 Evaluation of 2nd instar larval releases of *Chrysoperla carnea*

First instar counted larvae were taken from the laboratory and released in the cages installed on leaves. Host eggs were provided inside the cages, as larval diet. Survival of the predator present on plants was counted visually and data were recorded.

3.16 Parasitism and searching ability of *Trichogramma chilonis* on host eggs at different distances

In this experiment, the parasitoids movement inside the field was observed and recorded at four different distances of 5, 10, 15, 20 and 25 m from the fixed site of parasitoid release. Data, was recorded after 24, 48 and 72 hours of post release period of the parasitoids, by the installation of host eggs, pasted on paper cards placed, at three heights of the plant *i.e*., upper, middle and lower portion of plants separately.

3.17 Survival of *Trichogramma chilonis* under field conditions

Field survival of laboratory released population of the parasitoid (*T. chilonis*) was estimated after every week of the month from the post release of parasitoids. Host eggs placed in micro-cages, were positioned in the field near the site of release to evaluate the population of parasitoids according to treatment. Metrological data was obtained from the Ayub Agricultural Research Institute (AARI), Faisalabad. Fluctuations in predator and parasitoids populations were correlated with the prevailing field temperature.

3.18 Survival of *Chrysoperla carnea* under field conditions

Laboratory reared population of the predator, *C. carnea* under field survival was estimated every week of the months of post release of bio-control agents. Host eggs provided inside the leaf cages installed on the leaves of plants in field were used to evaluate the survival according to treatments. Metrological data was obtained from the Ayub Agricultural Research Institute, Faisalabad. Fluctuations in the predator and parasitoid populations were correlated with the prevailing field temperature.

3.19 Comparative evaluation of bio-control agents in management of cotton pests under field conditions

Present field studies were carried out at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, by the plantation of cotton cultivar NIAB-111, in the year 2007 and 2008. Randomized complete block design, was constructed with each three replicate. Plot size of 30×30 m was made each of bio-control, pesticide treated and control plots having 3 repeats each 24×6 m in size in each plot with row to row and plant to plant distance was maintained as 76 and 30 cm respectively. Each treatment was situated distant apart from each other. Both the years, the crop was sown during 2nd week of May. Before sowing, the seed was delinted and treated with pensidor 72% WP @ 100g/10 kg of seed. At the time of sowing, weedicide (clean up 41SL @ 750 ml/acre), was used to protect the crop from initial onset of weeds. Standard agronomic practices were adopted throughout the year, in all the three plots under experiment. No insecticide was sprayed both in control and bio-control treatments. Pesticide sprays, 6 in number, were carried out in insecticide treatment by using imidacloprid 20 SL with recommended dose (625 ml/hectare) and timer 1.9 EC @ 500 ml/hectare. *Trichogramma chilonis*, releases through micro-cages were made on weekly basis, in the bio-control treatment plots @ rate 100000 parasitoid per hectares and *Chrysoperla carnea* larvae @ 4500, per hectare.

3.19.1 Comparative evaluation of bio-control agents in management of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in cotton under field conditions

Ten plants were observed in each replication of treatments at random for recording the pest infestation in the field. Data was taken from 4th week of June to the 2nd week of October on weekly basis. The bollworms *Helicoverpa armigera* (Hüb.) data was collected from flowers, buds, squares and bolls and converted into percent infestation.

3.19.2 Comparative evaluation of bio-control agents in management of *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in cotton under field conditions

Ten plants were selected in each replication of treatment, at random for recording the pest infestation in the field in natural conditions. Data were taken from 4th week of June to the 2nd week of October on weekly basis. The spotted bollworm, *Earias vittella* data were collected from flowers, buds, squares and bolls. Observed plants were tagged to avoid repeat of data. Collected data, on per plant basis was converted into percent infestation.

3.19.3 Comparative evaluation of bio-control agents in management of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton under field conditions

Ten plants were observed in each replication of treatment at random, for recording the pest population. Data were taken from 1st week of July to the 4th week of September on weekly basis. Whitefly, *Bemisia tabaci* data was collected from the leaves, at upper middle and lower portions of plant, and made their average. Observed plants were tagged to avoid any repetitions.

3.19.4 Comparative evaluation of bio-control agents in management of *Thrips tabaci* (Linderman) (Thysanoptera: Thripidae) in cotton under field conditions

Ten plants were selected, in each replication of treatment at random, for recording the pest population in the field. Data was observed from the 1st week of June to the 4th week of September, on weekly basis. Thrips, *Thrips tabaci* population data was collected from the leaves from their upper, middle and bottom parts of plant and averaged. Observed plants were tagged to avoid any mistake in data collection.

3.19.5 Comparative evaluation of bio-control agents in management of *Aphis gossypii* Glover (Homoptera: Aphididae) in cotton under field conditions

Ten plants were observed at random for recording the pest population, in the plot of respective replicates of treatments in natural field conditions. Data was taken from the 2nd week of September to the 4th week of October on weekly basis. Aphids, *Aphis gossypii*, data was recorded from the leaves at upper, middle and bottom portion of plant and averaged. Observed plants were tagged in order to avoid any mistake.

3.20 Data analysis

All the collected data was statistically analyzed following Steel *et al*. (1997), with MSTAT-C software programme and mean values compared with the help of Duncan's multiple range test (DMRT) at 5% probability levels.

RESULTS

4.1 Selection of *Trichogramma chilonis*, *Chrysoperla carnea* and *Sitotroga cerealella* strains

Fresh strains of the egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) and predator, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) were collected from the cotton, sugarcane and lucern crops and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) collected from the wheat stores and conserved their cultures in rearing laboratories.

4.2 Rearing of *Sitotroga cerealella* on different hosts

The results, on the rearing of factitious host, *Sitotroga cerealella* on different cereal are presented in table 4.1, which showed non significant differences among the cereals, on the developmental period of *Sitotroga cerealella* (F = 1.15, df = 3, P = 0.3842). Significant differences, among the percent emergence (F = 15.14, df = 3, P = 0.0012) of the host from the cereals, were recorded. Highest adults emerged from wheat followed by statistically at par emergence of adults from sorghum (158.3) and barley (148.3); whereas, the lowest (125.6) adult emergence was recorded from maize. Size of eggs (F = 12.73, df = 3, P = 0.0124) was the highest (14.2 mg/500) in adults, reared from maize, followed by those on wheat (13.4), and barley (12.7); while, the lowest (9.5) from sorghum. Size of the adults (F = 54.22, df = 3, P = 0.0002), was highest (18.5mg/10 adults) from maize followed by those from wheat (11.8), barley (10.3) and the lowest (8.9) from sorghum. Fecundity (F = 27.42, df = 3, P = 0.0001) was observed to be the highest (115.6 no./female) in maize, followed by that in wheat (110.0), barley (115.6) and the lowest in sorghum (98.3). The eggs of *S. cerealella* received, after rearing it on

different cereals (F = 52.42, df = 3, P = 0.0000), when exposed to the parasitoid, *T. chilonis*, for 24 hours; the highest (92.8%) parasitism was observed on eggs obtained from maize and it was statistically, at par with eggs from wheat (89.3%) and barley (85.9%). Whereas, the lowest parasitism (71.6%) was observed on eggs, that were obtained from sorghum.

So, it is concluded that the rearing of *S. cerealella* on sorghum is as equally good as on wheat; where, the fecundity of adults was statistically at par with it. When healthy and heavy sized adults are required, the rearing of host on maize gives good results, but with reduced fecundity and enlarged life span.

In free choice rearing method (F = 75.49, df = 3, P = 0.0000) the host, *Sitotroga cerealella*, preferred wheat grains 35.4% more followed by those of barley (32.3%) and sorghum (17.75%); whereas, the maize grains was the least preferred (14.6%) (Table 4.2).

The effect of radiation doses of 10, 20, 30 and 40 Krad on the wheat grains, used in the rearing of host, *Sitotroga cerealella* have shown that the adult emergence, adult duration and female fecundity in comparison to control was similar to that in other case with respect to these characters.

Table 4.1 Different life parameters of the *S. cerealela* reared by no choice method.

Cereals	Life span (days)	Emergence (%)	Size of eggs (mg/500)	Size of adults (mg/10 adults)	Fecundity (no/♀)	Eggs parasitism (%) by *T. chilonis*
Maize	30.0±2.08a	125.6±4.10b	14.2±0.96a	18.5±1.24a	085.3±2.41c	92.8±1.66a
Barley	26.3±0.88a	148.3±2.73a	12.7±0.91a	10.3±0.70b	115.6±1.86a	85.9±1.10a
Sorghum	29.3±1.45a	158.3±3.85a	09.5±0.47b	08.9±0.68b	098.3±3.29b	71.6±0.96b
Wheat	28.0±0.58a	160.0±5.20a	13.4±0.67a	11.8±0.71b	110.0±2.52a	89.3±1.22a

Means SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.2 Adult emergence and preference of different cereals by *Sitotroga cerealella* from the free choice rearing method.

Cereals	Adult Emerged (nos.)	Preference (%)
Maize	90.6±2.40b	14.6
Barley	200±7.54a	32.3
Sorghum	110±6.43b	17.7
Wheat	219±10.74a	35.4

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

4.3 Effect of radiation on the eggs of host, *Sitotroga cerealella*

Results showed significant differences in the different doses of radiation on the host eggs, *S. cerealella* and their parasitism by *T. chilonis*. (Table 4.3). The 1 day old host egg were preferred by the *T. chilonis* more when exposed to a dose of 20 Gy (95.6%) and it gradually decreased to 62.8% parasitism at a dose of 600 Gy respectively. A similar trend of parasitism was observed on 2 day old host eggs as that on 1 day and here, 86.8 and 41.6% parasitism was observed at doses of 20 and 600 Gy respectively. The 3 day old host eggs, were parasitized only upto an exposure of 150 Gy dose and gave 81.3% parasitism at 50 Gy, while the host eggs exposed to 200, 400, 500 and 600 Gy were not parasitized, due to the changes in the egg contents. Low parasitism at the doses of 5, 10 and 20 Gy may be due to the maturation of eggs, towards hatching which was delayed. Parasitism of the 4 day old eggs was obtained up to a dose of 100 Gy and there was 81.1% parasitism in eggs to a dose of 50 Gy. Almost, similar trend was observed in the 5 day old host eggs except that, the parasitism were recorded upto a dose of 50 Gy. In the 6 day old irradiated host eggs, the highest (58.1%) and lowest (38.4%) parasitism was observed at dose of 50 and 10 Gy, respectively. In the case of 7 day old irradiated host eggs, an exposure to the parasitoids gave 55.8% parasitism at a dose of 50 Gy and at this dose the parasitoids did not parasitize the eggs irradiated with 5 and 10 Gy.

It is concluded that the irradiated host eggs, at 50 Gy have the ability to prolong the host eggs that can be used for parasitization by the parasitoids, *T. chilonis* up to 7 days in comparison to those of the control where host eggs were parasitized only up to 3 days prior to emergence.

Table 4.3 Effect of different doses of radiations on the parasitism of *Sitotroga cerealella* eggs by *T. chilonis* at different days of exposure.

Doses of radiation	Days of parasitism						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Control	98.3±0.85	90.2±0.57	75.6±1.18	0.00	0.00	0.00	0.00
05	91.3±1.71	89.2±1.72	43.0±1.28	43.0±1.28	41.4±0.99	39.4±0.61	0.00
10	92.8±1.46	88.0±1.05	43.1±1.43	41.1±1.43	41.3±0.90	38.4±0.85	0.00
20	95.6±0.85	86.8±1.38	40.4±0.82	40.4±0.82	40.3±0.72	40.6±1.16	37.0±0.77
30	89.4±1.13	85.9±1.08	81.1±1.15	80.0±1.34	79.6±0.75	57.5±1.30	48.7±1.01
40	87.5±2.43	80.9±1.39	80.9±0.78	80.9±0.78	80.6±0.89	52.5±0.85	45.5±0.78
50	87.3±1.16	82.4±1.40	81.3±1.34	81.1±1.15	80.7±0.56	58.1±1.28	55.8±1.65
75	86.7±0.76	79.7±0.49	70.7±0.62	51.6±0.46	0.0	0.0	0.0
100	84.3±1.13	78.1±0.88	67.7±1.21	46.8±0.61	0.0	0.0	0.0
125	84.2±1.15	75.5±0.75	43.8±1.74	0.0	0.0	0.0	0.0
150	84.0±1.01	74.9±1.26	42.4±2.79	0.0	0.0	0.0	0.0
200	77.7±1.10	55.4±1.48	0.0	0.0	0.0	0.0	0.0
300	72.0±1.93	45.3±1.75	0.0	0.0	0.0	0.0	0.0
400	70.6±2.61	43.2±1.00	0.0	0.0	0.0	0.0	0.0
500	70.4±1.25	43.4±1.46	0.0	0.0	0.0	0.0	0.0
600	62.8±1.77	41.8±1.47	0.0	0.0	0.0	0.0	0.0

Means ± SE.

4.4 Development of *Trichogramma chilonis* on stored eggs of host, *Sitotroga cerealella*

Results of the present study on the emergence of parasitoids, *Trichogramma chilonis* from host, *Sitotroga cerealella* eggs after being held at low temperatures (6, 8, 10, 12, 14 and 16^{o}C), for different durations (5-90 days) upon the fitness parameters of the parasitoid *i.e.*, percent emergence, percent parasitism and adult longevity (day) in comparison to the control are as follows.

4.4.1 Emergence of *T. chilonis*

Emergence of *T. chilonis* from stored eggs has shown significant differences after storage at various temperatures and durations (Table 4.4). After a 5 day storage of host, *Sitotroga cerealella* eggs in cooled incubators at 6, 8, 10, 12, 14 and 16^{o}C, the parasitoids, *Trichogramma chilonis* showed significant differences of emergence (F = 19.51, df = 5, P = 0.0000). The highest (90.4%) emergence was observed by the parasitoids, from the host eggs, stored at 6^{o}C and it was statistically at par to that of control (97.2%) and followed by that of 85.7 and 82.3% at 8^{o}C and 10^{o}C, respectively. Almost similar emergence was observed both at 14 and 12^{o}C, with 70.4 and 70.2% respectively. The lowest (60.3%) emergence was evinced on host eggs, used after stored at 16^{o}C. After 10 day of the storage of host, *Sitotroga cerealella*, eggs in a cooled incubator, the parasitoids, *Trichogramma chilonis* showed significant differences of emergence (F = 95.89, df = 5, P = 0.0000). Almost a similar trend of parasitoids emergence, from the host eggs was observed in case of 5 days of stored eggs with 89.3 and 40.2% the highest and lowest emergence at 6 and 16^{o}C respectively.

After 15 day of storage of host , *Sitotroga cerealella* eggs in a cooled incubator at 6^{o}, 8^{o}, 10^{o}, 12^{o}, 14^{o} and 16^{o}C, the parasitoids emergence showed significant differences in emergence (F = 87.95, df = 5, P = 0.0000). At this storage periods, the parasitoids emerged out at all temperatures with 80.3 and 35.4% the highest and lowest at 6 and 16^{o}C respectively. After 20 day storage, in a cooled incubator at 6, 8, 10, 12, 14 and 16^{o}C , the

parasitoid emergence showed significant differences on eggs of the host, *Sitotroga cerealella* (F = 387, df = 5, P = 0.0000). The highest (78.2%) and lowest (46.5%) emergence were observed from the eggs stored at 6 and 12^{o}C respectively. Parasitoids did not emerge from the host eggs kept at 14 and 16^{o}C. The emergence was recorded only from eggs stored at 6, 8 and 10^{o}C. After a 25 day storage of host , *Sitotroga cerealella* eggs in a cooled incubator, at 6, 8 and 10^{o}C the parasitoid emergence, showed significant differences on stored eggs of the host, *Sitotroga cerealella* (F = 599.92, df = 5, P = 0.0000) with 75.2 and 35.4% emergence at 6 and 10^{o}C respectively. After a 30 days storage in a cooled incubator at 6, 8 and 10^{o}C, the parasitoid emergence showed significant effects on the stored eggs of the host, *Sitotroga cerealella* (F = 495.29, df = 5, P = 0.0006) where emergence was witnessed to be 62.4, 50.8 and 41.3% at 6, 8 and 10^{o}C respectively, at this storage conditions. After 40 days storage at 6^{o} and 8^{o}C, the parasitoids emergence showed significant differences on stored eggs of host, *Sitotroga cerealella* (F = 704.22, df = 5, P = 0.0000) and recorded 49.3 and 45.0% at 6 and 8^{o}C respectively. After 50 days storage in a cooled incubator, at 6 and 8^{o}C, the parasitoid emergence showed significant differences in the stored eggs of the host, *Sitotroga cerealella* (F = 263.03, df = 5, P = 0.0000) and only 30.9 and 25.7% emergence was observed respectively, when kept at standard temperature conditions.

4.4.2 Parasitism by *T. chilonis*

Parasitism, by *T. chilonis* on stored host eggs has shown significant differences, after being stored at various temperatures and durations (Table 4.5). After 5 days storage, in a cooled incubator at 6^{o}, 8^{o}, 10^{o}, 12^{o}, 14^{o} and 16^{o}C, the parasitoids showed significant differences in the parasitism of stored eggs of the host, *Sitotroga cerealella* by the parasitoids (F = 44.72, df = 5, P = 0.0000) with their highest parasitism (92.3%) from the eggs stored at 6^{o}C which was at par with that of the control (97.6%) and the lowest (65.3%) observed at 16^{o}C. After 10 days storage, at 6, 8, 10, 12, 14 and 16^{o}C, the parasitoids showed significant differences in parasitism of the stored eggs of host, *Sitotroga cerealella* by the parasitoid (F = 240.85, df = 5, P = 0.0000) with the highest (90.2%) and lowest (16.9%) being witnessed at 6 and 16^{o}C, respectively. After 15 days

storage at 6, 8, 10, 12, 14 and 16^{o}C, the parasitoids, showed significant differences in parasitism of the stored eggs of host, *Sitotroga cerealella* and the parasitism (F = 344.56, df = 5, P = 0.0000) was got highest (87.0%) and lowest (14.7%) at 6 and 16^{o}C, respectively. After 20 days storage, 6, 8, 10 and 12^{o}C, the parasitoids showed significant differences in the parasitism of stored eggs of the host, *S. cerealella* (F = 2325.89, df = 5, P = 0.0000) and parasitoids preferred only those eggs stored at 6, 8, 10 and 12^{o}C with 77.7, 67.8, 37.2 and 23.5% emergence respectively. After 25 days storage in a cooled incubator, at 6, 8 and 10^{o}C, the parasitoids showed significant differences in parasitism of the stored eggs of host, *S. cerealella* (F = 327.39, df = 5, P = 0.0000) and they preferred only those eggs, stored at 6, 8 and 10^{o}C with a parasitism of 70.5, 62.9 and 32.4%, respectively. After 30 days storage at 6, 8 and 10^{o}C, the parasitoids showed significant differences in parasitism of the stored eggs of host (F = 516.85, df = 5, P = 0.0000), where the highest (50.9%) being in from the case of eggs stored at 6^{o}C. Storage of egg after 40 days, at 6^{o}C and 8^{o}C, the parasitoids showed significant differences of parasitism on host eggs (F = 325.64, df = 5, P = 0.0000) where only the host eggs preferred after being stored at 6 and 8^{o}C. After 50 days storage in cooled incubator, at 6^{o}C and 8^{o}C the parasitoids showed significant differences (F = 362.64, df = 5, P = 0.0000) in parasitism of the stored eggs of host, *S. cerealella* and they only preferred eggs after stored at 6 and 8^{o}C.

4.4.3 Longevity of *T. chilonis* adults

Longevity of the *T. chilonis* adults increased from the stored eggs, have shown significant differences after being stored at various temperatures and durations (Table 4.6). After 5 days storage in a cooled incubator at 6, 8, 10, 12, 14 and 16^{o}C, the parasitoids showed significant differences in the of adult longevity, after reared on the host eggs of host, *S. cerealella* (F = 10.42, df = 5, P = 0.0005) and they live longer (13.7 days), at 16^{o}C, whereas, the eggs stored at a low temperature reduced their longevity (10.7 days) from eggs kept at 8 and 10^{o}C. After storage of 10 days at 6, 8, 10, 12, 14 and 16^{o}C, the parasitoids showed a non significant difference in their adult longevity, after being reared on the stored eggs of the host (F = 2.60, df = 5, P = 0.0813) and they tended

to live from 10.3 to 11.7 days at almost all the temperatures. After a storage of 15 day, the parasitoids showed significant differences of adult longevity (F = 10.32, df = 5, P = 0.0005) where, the prolonged longevity (10.3 days) was observed at 14^{o}C which was statistically at par to that obtained at 12^{o}C. After the storage of 20 days, at 6, 8, 10 and 12^{o}C the parasitoids, showed significant differences of adult longevity (F = 212.65, df = 5, P = 0.0000), and it was observed to be 7.3 days at 8^{o}C. A storage of 25 days, at 6, 8, 10 and 12^{o}C, the parasitoids showed significant differences in the of adult longevity after being reared on stored eggs of the host, *S. cerealella* (F = 202, df = 5, P = 0.0000) and it was observed to be 7.3 to 8.3 and 8.0 days at 6, 8 and 10^{o}C. After a 30 day storage, at 6^{o}C, 8^{o}C and 10^{o}C the parasitoids, showed significant differences in the of adult longevity, after being reared on the stored eggs of host (F = 124.96, df = 5, P = 0.0000), and the longevity was observed to be highest (7.3 days) at 8^{o}C. After 40 days, storage in a cooled incubator at 6 and 8^{o}C the parasitoids showed significant differences in the adult longevity when reared on stored eggs of the host, *S. cerealella* (F = 304.50, df = 5, P = 0.0000) and it was to be 6.3 and 6.7 days at 6 and 8^{o}C respectively. Longevity was only observed at 6^{o}C and 8^{o}C, after 50 days storage, showed significant differences of adult longevity (F = 184.80, df = 5, P = 0.0000) reared on stored eggs of *S. cerealella* where, parasitoids longevity was 5.7 and 4.3 days at 6 and 8^{o}C respectively.

It is concluded from the present experiment that cold storage of host eggs, *S. cerealella* at 6 and 8^{o}C, has resulted in an effective and highest preference by the parasitoid *T. chilonis*, for 5 to 50 days and the comparative more suitable temperature was 6^{o}C for both short and long term storages of the host eggs; whereas, the storage of eggs at 10, 12, 14 and 16^{o}C temperature proved only to be a short term duration.

Table 4.4 Effect of different temperatures on the emergence (%) of *T. chilonis* from the stored host eggs.

Temp.	Storage Duration (Days)							
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**
6°C	90.4±2.56 a	89.3±2.26 a	80.3±1.70 a	78.2±1.70 a	75.2±1.99 a	62.4±2.42 a	49.3±1.50 a	30.9±1.52 a
8°C	85.7±2.73 a	80.4±1.25 b	76.2±1.39 a	70.4±2.08 b	55.0±1.35 b	50.8±1.33 b	45.0±1.68 a	25.7±1.63 a
10°C	82.3±1.00 a	72.2±1.95 c	50.0±2.74 b	49.2±2.15 c	35.4±2.23 c	41.3±1.60c	-	-
12°C	70.2±3.21 b	60.4±1.23 d	42.4±1.44 c	46.5±2.41 c	-	-	-	-
14°C	70.4±3.04 b	50.0±1.99 e	40.2±3.03 cd	-	-	-	-	-
16°C	60.3±2.34 c	40.2±2.42 f	35.4±1.41 d	-	-	-	-	-
Control	97.2±1.42							

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.5 Effect of different temperatures on the parasitism (%) by *T. chilonis* on stored host eggs.

Temp.	Storage Duration (Days)							
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**
6°C	92.3±1.21 a	90.2±1.17 a	87.0±1.33 a	77.7±0.97 a	70.5±2.96 a	50.9±0.79 a	39.3±0.70 a	24.9±0.50 a
8°C	82.4±1.62 b	77.6±1.22 b	69.4±1.90 b	67.8±0.79 b	62.9±3.28 b	35.3±1.81 b	30.4± 2.37 b	17.4±1.32 b
10°C	80.3±1.07 b	56.2±1.11 c	46.2±1.39 c	37.2±0.90 c	32.4±0.51 c	12.4±1.27 c	-	-
12°C	75.2±1.58 c	44.1±2.92 d	36.4±1.52 d	23.5±0.67 d	-	-	-	-
14°C	69.4±2.04 d	27.4±2.60 e	21.3±1.71 e	-	-	-	-	-
16°C	65.3±0.83 d	16.9±0.90 f	14.7±1.06 f	-	-	-	-	-
Control	96.8±1.36							

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.6 Effect of different storage durations and temperatures on adult longevity (d) of *T. chilonis* on stored eggs.

Temp.	Storage Duration (Days)							
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**
6°C	12.3±0.33 b	11.7±0.33 a	7.7±0.33 cd	7.7±0.33 b	7.3±0.33 a	6.7±0.67a	6.3±0.33 a	5.7±0.33 a
8°C	10.7±0.33 c	11.3±0.33 ab	8.7±0.33 bc	7.3±0.33 bc	8.3±0.33 a	7.3±0.33 a	6.7±0.33 a	4.3±0.33 b
10°C	10.7±0.33 c	10.3±0.33 b	8.3±0.33 c	6.7±0.33 c	8.0±0.58 ab	6.3±0.33 a	-	-
12°C	12.7±0.33 ab	10.7±0.33 ab	9.7±0.33 ab	8.7±0.33 a	-	-	-	-
14°C	13.0±0.58 ab	11.1±0.00 ab	10.3±0.33 a	-	-	-	-	-
16°C	13.7±0.33 a	10.7±0.33 ab	7.0±0.58 d	-	-	-	-	-
Control	15.3±0.33							

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

4.5 Effect of radiation and low temperatures on eggs of host, *Sitotroga cerealella*.

The collaborative effect of radiation and low temperature on the storage of host, *Sitotroga cerealella* eggs, at 6^{o}, 8^{o}, 10^{o}, 12^{o}, 14^{o} and 16^{o}C for 5-90 days have shown almost similar effects as that of individual effect of storage after the results obtained from fitness parameters of the parasitoid, *Trichogramma chilonis i.e.*, emergence (%), parasitism (%) and adult longevity (days) in comparison to control.

4.6 Effect of adult food nutrition on development of *Trichogramma chilonis*

Results of the present study on the effect of adult food on the biological parameters of *Trichogramma chilonis i.e.*, parasitism (%), male and female adult longevity (days) in comparison to those of control are as under (Table 4.7).

4.6.1 Parasitism by *T. chilonis* adults

Parasitism by the *T. chilonis*, after being fed on different concentrations, have shown significant differences (F = 64.48, df = 5, P = 0.0000). The highest parasitism (93.0%) on the host eggs was recorded by the parasitoids fed upon 10% honey solution, and it had 22.1% increase over the control; whereas, the lowest parasitism (76.4%) was observed in case of parasitoids fed on 25% honey solution with only 5.3% increase over the check. Parasitism observed in the parasitoids fed on 10 and 5% honey solutions was to be at par and had recorded as an increase of 22.1% over the check. Parasitism was observed to gave a decreasing trend (86.9, 82.1 and 76.5% after 15, 20 and 25% respectively), as the concentration of honey solution increases towards 25%.

4.6.2 Male adult longevity of *T. chilonis*

Male adult longevity of *T. chilonis* fed on different concentrations, have shown significant differences (F = 19.87, df = 5, P = 0.0000). Longevity of *T. chilonis*, male adults, prolonged to 6.0 days in parasitoids fed on 10% honey solution with an increase of 70.0% over the check and it was at par to that of 5.8 days of longevity in the case of parasitoids after fed on 5% honey solution with 68.9% increase over the check. The lowest adult longevity was observed to be 2.8 days in parasitoids fed on 25% honey solution with an increase of 35.7% over the control. Adult longevity in male parasitoids, fed at 15, 20 and 25% honey solution was recorded to be as 4.5, 3.7 and 2.8 days, respectively.

4.6.3 Female adult longevity of *T. chilonis*

Female adult longevity of *T. chilonis* fed on different concentrations have shown significant differences (F = 29.10, df = 5, P = 0.0000). Longevity of *T. chilonis* female adults was prolonged to 7.3 days in parasitoids, fed on 10% honey solution with an increase of 66.6% over the check. Female adult longevity (7.4 d) with 65.7% increases over control was recorded after fed on 5% honey solution, at par to longevity of parasitoids at 10%. Female adult longevity of 6.1, 5.1 and 4.2 days with decreasing trend were obtained after fed upon 15, 20 and 25% honey solution. So, it was concluded from the present study, that biological parameters like parasitism, male and female adult longevity of *T. chilonis* survived the best after being fed on 10% honey solution, which was equally at par to the effect of 5% honey solution. Over all decreasing trend of biological parameters, was obtained with the concentration of honey solution. So, in order to get a good development of the parasitoids, 10% honey solution gave best results.

Table 4.7 Effect of different concentrations of honey on various biological parameters of *T. chilonis*.

Concentration (%)	Parasitism (%)	Increase over control (%)	Male adult longevity (days)	Increase over control (%)	Female adult longevity (days)	Increase over control (%)
05	93.0±1.20 a	22.1	5.8±0.44 a	68.9	7.4±0.35 a	65.7
10	94.6±0.66 a	25.0	6.0±0.15 a	70.0	7.7±0.42 a	66.6
15	86.8±0.66 b	16.6	4.5±0.66 b	60.0	6.1 ±0.12 b	58.3
20	82.1±1.10 c	11.8	3.7±0.32 bc	51.3	5.1 ±0.64 bc	50.0
25	76.4±0.57 d	5.3	2.8±0.15 cd	35.7	4.2±0.27 c	37.5
Control	72.4±1.58 e	-	1.8±0.25 d	-	2.6±0.07 d	-

Means (± SE; n= 3) sharing same letters are statistically non significant ($P < 0.05$).

4.7 Optimization of short and long term storage duration for *Trichogramma chilonis* at low temperatures*

Results of the present study on the storage of parasitoids, *Trichogramma chilonis*, after being held at low temperatures (6 to 16^{o}C), for different durations (5-90 days), upon the fitness parameters of the parasitoid *i.e.*, percent emergence, percent parasitism and adult longevity (days) in comparison to those from the control are as follows.

4.7.1 Percent emergence of *T. chilonis*

Emergence of *T. chilonis* after storage at various temperatures and durations, has shown significant differences (Table 4.8). After 5 days of storage, the highest (96.6%) emergence was observed from *T. chilonis* parasitoids held at, 10^{o}C of storage and it was near to that of the control (97.4%) followed by 94.1, 90.7, 89.9, 88.5 and 64.7% in case of those held at 8, 12, 14, 16 and 6^{o}C, respectively. Similar trends of the parasitoid emergence were observed at 10, 8, 14, 12, 16 and 6^{o}C after 10 days of the storage, with an emergence of 94.3, 91.6, 88.6, 88.4, 86.8 and 49.2%, respectively. The Highest and the lowest emergence, was observed at 10 and 6^{o}C respectively, after 15, 20, and 25 days of the storing periods. At 6^{o}C, the parasitoids did not survive after 25 days of storage, due to the continuous low temperature; while, at 16^{o}C, the parasitoids completed their development, due to a moderate temperature and emerged, after 25 days. Similarly at 14 and 12^{o}C, the parasitoids completed their development and emerged out after 30 and 40 days old storage respectively. Parasitoids emergence was recorded at 8 and 10^{o}C up to 90 days of storage conditions. So, here it is clear that for short term storage, the parasitoid emergence was best upto 25 days at 10^{o}C and the parasitoid can be used for the field releases. The prolonged storage however gradually decreased the percent emergence after 90 days of storage and gave only 21.0 and 22.8% emergence at 8 and 10^{o}C, respectively.

4.7.2 Percent parasitism by *T. chilonis*

Parasitism, by *T. chilonis* after being stored at various temperatures and durations, has shown significant differences (Table 4.9). The highest (97.4%) parasitism was recorded from, the *T. chilonis* held at 10^{o}C after 5 days of storage; which was close to the values in the control treatment with 97.8%. Parasitism by the parasitoids held at 8, 14, 12, 16 and 6^{o}C were 96.3, 95.2, 95.1, 92.5 and 92.4%, respectively. Storage of parasitoids after 10 days, have got the parasitism to be 96.3, 95.7, 94.3, 92.6, 90.7 and 91.4% at 10, 8, 12, 14, 16 and 6^{o}C respectively. Temperature of 6^{o}C did not provide storage more than 25 days, due to continuous cold effect and hence did not achieve the parameter of parasitism. At 16^{o}C, however the parasitoids completed their development during storage due to appropriate temperature for growth. At 14^{o}C, after 30 days of parasitoids storage, parasitism by the parasitoid was zero due to the completion of their development during storage. At 10^{o}C, from 50 to 90 days of storage, the parasitoids gave 72.5 to 42.2% parasitism. Here, it is clear that for short term storage, the parasitoids give best parasitism, for 25 days at 10^{o}C and can be viable for field releases; whereas, a prolonged storage gradually decreases the parasitism after 90 days of storage with 38.7 and 42.2% at 8 and 10^{o}C, respectively.

4.7.3 Longevity of *T. chilonis* adults

Longevity of *T. chilonis* after storage at various temperatures and durations has shown significant differences (Table 4.10). Developmental period of *T. chilonis* was prolonged to 6.3 days, after being held at 10^{o}C followed by 6.3, 5.6, 4.6 and 4.6 days at 8, 6, 12, and 14^{o}C respectively. Duration of the development reduced upto 4 days at 16^{o}C, after 5 days of storage. At 6, 8, 10, 12, 14 and 16°C storage of 10 days, showed a similar trend in adult longevity of 5.3, 6.3, 6.3 4.6, 4.6 and 4.3 days respectively. The prolonged and reduced adult longevity was observed at 10 and 16^{o}C respectively after being stored for 15, 20, and 25 days. Temperature of 6 and 16^{o}C, proved to be effective only for 25 days of storage but the further observations on the adult longevity, was not possible due to the unavailability of parasitoids owing to continuous lower and high temperature

respectively. At 16^{o}C, the parasitoids completed their development during storage. Similarly, parasitoids emerged during storage, at 14 and 12^{o}C. Adult longevity, gradually decreased as the storage duration increased from 5-90 days, at 6-16^{o}C. Prolonged storage, gradually decreased the adult longevity and after 90 days of storage, parasitoids survived only for 3 days, at 10^{o}C.

It is concluded from the above study that 10^{o}C, was evaluated to be an effective temperature, for the storage of *T. chilonis* parasitoids; where, the highest emergence, parasitism and adult longevity was recorded and this temperature was suited, both for long and short term storages that ensures the availability of parasitoids in insectaries for research and field releases.

**Research article has been published as per appendix 32 at page 187.*

Table 4.8 The effect of different temperatures on the emergence (%) of *T. chilonis* after stored at various time durations.

Temp.	Storage duration (days)											
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
6°C	64.7±1.20 d	49.2±2.40 c	45.2±1.74 c	23.5±1.73 b	08.0±1.42 c	-	-	-	-	-	-	-
8°C	94.1±0.87 ab	91.6±2.09 ab	89.7±1.10 ab	88.2±2.06 a	87.5±1.53 a	82.5±0.82 b	78.6±1.13 ab	77.6±1.91 a	72.9±1.27 a	62.4±1.44 a	47.6±1.16 a	21.0±0.80 a
10°C	96.6±1.46 a	94.3±1.12 a	91.8±1.04 a	88.7±2.27 a	84.8±1.77 ab	85.5±0.57 a	80.4±0.42 a	78.8±0.73 a	76.6±0.50 a	70.6±0.48 b	45.2±2.07 a	22.8±1.58 a
12°C	90.7±1.46 bc	88.4±1.58 ab	84.8±2.43 b	86.0±0.90 a	80.2±2.28 b	79.3±0.57 c	77.6±0.61 b	-	-	-	-	-
14°C	89.9±1.47 c	88.6±1.33 ab	84.0±2.47 b	85.5±1.86 a	83.7±0.76 ab	80.3±0.69 c	-	-	-	-	-	-
16°C	88.5±0.82 c	86.8±1.87 b	88.6±1.65 ab	87.8±1.19 a	85.9±1.62 ab	-	-	-	-	-	-	-
Control	97.4 ±0.52 A											

Means ± SE, sharing with same alphabets are statistically non significant ($P < 0.05$).

Table 4.9 The effect of different temperatures on the parasitism (%) of *T. chilonis* after stored at various time durations.

Temp.	Storage duration (days)											
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
6°C	92.4±1.32 b	91.4±0.65 c	82.4±0.32 c	80.3±0.60 c	48.5±1.16 d	-	-	-	-	-	-	-
8°C	96.3±0.45 a	95.7±0.31 a	92.6±1.07 a	91.0±0.69 a	88.6±1.22 b	80.2±0.49 b	78.1±0.64 b	74.0±0.97 A	72.7±0.78 a	69.3±1.01 a	59.6±1.21 a	38.7±1.69 a
10°C	97.4±0.81 a	96.3±0.60 a	91.9±1.33 a	92.3±1.18 a	91.5±0.41 a	88.3±0.72 a	84.1±0.83 a	72.5±1.05 A	74.5±1.10 a	72.6±0.60 a	63.4±1.32 a	42.2±4.19 a
12°C	95.1±0.52 a	94.3±0.37 ab	91.4±0.72 a	90.1±0.96 a	86.4±0.83 b	81.1±0.78 b	71.2±0.75 c	-	-	-	-	-
14°C	95.2±0.49 a	92.6±1.19 bc	90.0±0.64 a	85.4±0.57 b	82.3±0.60 c	80.5±0.72 b	-	-	-	-	-	-
16°C	92.5±0.34 b	90.7±1.41 c	84.1±1.99 b	82.9±1.12 b	80.2±0.69 c	-	-	-	-	-	-	-
Control	97.8±0.40 a											

Means ± SE, sharing with same alphabets are statistically non significant ($P < 0.05$).

Table 4.10 The effect of different temperatures upon adult longevity (days) of *T. chilonis* stored at various time durations.

Temp.	Storage duration (days)											
	5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
6°C	5.6±0.33 a	5.3±0.33 abc	6.0±0.00 a	5.6±0.33 a	5.3±0.33 bc	-	-	-	-	-	-	-
8°C	6.3±0.33 a	6.3±0.33 ab	6.3±0.33 a	5.6±0.33 a	6.3±0.00 a	5.3±0.33 ab	4.6±0.33 a	3.3±0.33 a	3.6±0.33 A	3.6±0.33 a	2.6±0.33 a	2.6±0.33 a
10°C	6.3±0.33 a	6.3±0.00 a	6.6±0.00 a	5.3±0.33 ab	5.6±0.33 ab	5.6±0.33 a	3.6±0.33 a	3.6±0.33 a	3.3±0.33 A	3.3±0.33 a	2.3±0.33 a	3.0±0.33 a
12°C	4.6±0.33 ab	4.3±0.33 c	5.0±0.57 ab	4.3±0.33 b	5.6±0.33 ab	4.6±0.33 ab	3.6±0.33 a	-	-	-	-	-
14°C	4.6±0.33 ab	4.6±0.33 bc	6.0±0.00 a	4.6±0.33 ab	5.3±0.33 abc	4.3±0.33 b	-	-	-	-	-	-
16°C	4.0±0.57 b	4.6±0.33 bc	5.0±0.33 b	4.3±0.33 b	4.6±0.33 bc	-	-	-	-	-	-	-
Control	5.0±0.57 Ab											

Means ± SE, sharing with same alphabets are statistically non significant ($P < 0.05$).

4.8 Comparative rearing of *Trichogramma chilonis* at different temperature conditions**

Results of the present study, on the evaluation of effective rearing temperatures for parasitoids, *Trichogramma chilonis* on the biological parameters of parasitoids *i.e*., parasitism (%), developmental period (days), emergence (%) and adult longevity (days) given in table 4.11.

4.8.1 Developmental period of *T. chilonis*

Developmental period of *T. chilonis* inside the host eggs at tested temperatures has showed significant differences (F = 123.78, df = 4, P = 0.0000). At 20^{o}C, the development was prolonged (17.3 days) and it was evaluated to be the highest, when compared with the developmental period, at other temperatures. Prolonged developmental period was attained due to the low temperature and that affected the quality of the parasitoids. At 28^{o}C, the developmental period of 7.3 days, was observed suitable for rearing and it was statistically, similar to the developmental period at 25 and 31^{o}C, where the developmental periods of 8.3, 7.6 days, were recorded respectively. The shortest developmental period of 7 days was recorded at 35^{o}C as against no development of the parasitoids observed at 40^{o}C.

4.8.2 Parasitism by *T. chilonis* adults

Parasitism, by *T. chilonis* inside the host eggs at tested temperatures has shown significant differences (F = 86.46, df = 4, P = 0.0000). The highest parasitism (95.6%), by *T. chilonis* on the host eggs, was recorded from the parasitoids reared at 28^{o}C and lowest parasitism (60.1%) was observed at, 35^{o}C. After 28^{o}C a parasitism of 92.8% was seen at 25^{o}C and then at 20 and 30^{o}C, with 85.9 and 89.1% respectively. Whereas at 40^{o}C parasitism was not observed due to mortality of adults at this high temperature where, the parasitoids could not survive.

4.8.3 Emergence of *T. chilonis* adults

Emergence of *T. chilonis* from the host eggs, at tested temperatures has shown significant differences (F = 357.01, df = 4, P = 0.0000). The highest emergence (98.0%) of *T. chilonis*, adults from the host eggs was observed, after rearing at 28°C. Lowest emergence (33.7%) was demonstrated, at 35°C of the rearing temperature. Rearing conditions at 40°C did not support the emergence due to the mortality of parasitoids. At 20, 25 and 31°C, the emergence of parasitoids were observed to be 90.4, 96.2 and 89.3% respectively.

4.8.4 Longevity of *T. chilonis* adults

Longevity of *T. chilonis*, at tested temperatures, has shown significant differences (F = 69.55, df = 4, P = 0.0000). Longevity of *T. chilonis*, adults was prolonged to 11.6 days in the parasitoids, after rearing at 20°C and the lowest adult longevity of 2.3 days was observed, at 35°C but this prolongation and reduction in longevity, affected the parasitoids quality badly to give lowest parasitism due to the reason that parasitoids did not survive longer. At 25, 28 and 31°C, the parasitoids longevity was recorded as 10.0, 9.0 and 5.6 days respectively, that provided the parasitoids with an ample opportunity to give high parasitism, which is among the main quality criteria of the parasitoids.

It is accomplished from the present study that the biological parameters of *T. chilonis*, *viz*., emergence, developmental period, parasitism and adult longevity were very favorable at 28°C, to give highest parasitism and emergence from the host eggs as compared to other temperatures.

***Research article has been published as per appendix 31 at page186.*

Table 4.11 The effect of different rearing temperatures on some biological parameters of *T. chilonis*.

Temperature	Parasitism (%)	Developmental period (days)	Emergence (%)	Adult longevity (days)
20°C	89.1±1.71 bc	17.3±0.66 a	90.4±1.63 b	11.6±0.57 a
25°C	92.8±1.45 ab	08.3±0.33 b	96.2±0.72 a	10.0±0.57 b
28°C	95.6±0.85 a	07.3±0.33 bc	98.0±0.41 a	09.0±0.57 b
31°C	85.9±2.08 c	07.6±0.33 bc	89.3±2.27 b	05.6±0.33 c
35°C	60.1±1.27 d	07.0±0.33 c	33.7±1.30 c	02.3±0.33 d

Means ± SE, sharing similar letters are statistically non significant ($P < 0.05$).

4.9 Effect of storage duration and low temperatures on developmental parameters of eggs of *Chrysoperla carnea*

Results of the present study on the developmental parameters of the predator, *Chrysoperla carnea* after its eggs were held at low temperatures (6°C, 8°C, 10°C, 12°C, 14°C and 16°C) for a delayed embryonic development without higher rates of mortality to embryo inside the eggs in incubators, for different durations (5, 10, 15, 20, 25, 30 and 40 days) in comparison to the control are as follows (Table 4.12, 4.13).

Developmental parameters of the predator included were: egg hatching, larval duration, larval survival, pre pupal duration, pupal duration, pupal recovery and total development considerably comparable to those of the control after the eggs were stored at 6, 8 and 10°C of temperature conditions after duration of 5 to 20 days. Storage of eggs, at 6 and 8°C of temperatures has affected the development traits almost equal by up to 40 days of storage. However as duration increased the quality of developmental traits was reduced. After a storage of 20 days at 10°C, the egg quality was better, at this temperature as compared to a storage for 25, 30 and 40 days. The storage at a temperature of 12°C was obtained for only upto 20 days and has not only considerably affected the embryo, but has also adversely affected the developmental parameters of *C. carnea*, after 20 days of storage. At 14 and 16°C, the developmental traits of the predator were observed only for 15 days and the slow development at these temperatures affected the

hatching of eggs during storage. So, the storage temperatures 12, 14 and 16^{o}C, can only be used when short term storage of eggs, is desired in insectaries.

It was accomplished from the data that the storage of predator, *C. carnea* eggs at 10^{o}C can give storage for 20 days with minimum detrimental consequences to the developing embryo inside the egg, for a short term storage and up to 40 days for a long term storage at this temperature; whereas, 8^{o}C temperature was comparatively better among the tested temperatures for the developmental parameters of *C. carnea*.

Table 4.12 Effect of different storage temperatures and durations on the developmental parameters of *C. carnea* egg.

Developmental Traits	Storage period (days)						
	5	10	15	20	25	30	40
Storage at 6°C							
Egg hatching (total 50 nos.)	48	47	45	44	30	18	12
Egg hatching (%)	96	94	90	88	70	48	36
Egg hatching (days)	6.3±0.12	6.7±0.11	6.8±0.11	6.5±0.11	6.7±0.11	6.8±0.12	7.1±0.11
Larval duration (days)	16.6±0.01	15.0±0.11	15.7±0.14	16.9±0.10	16.7±0.10	17.1±0.11	17.9±0.12
Larval survival (nos.)	19 (25)	20(25)	18 (25)	17 (25)	15(25)	13 (25)	12(25)
Larval survival (%)	76	80	72	68	60	52	48
Pre- pupation (days)	4.2±0.11	4.5±0.11	4.7±0.11	4.9±0.10	5.2±0.10	5.1±.10	5.5±0.10
Pupation (days)	9.5±0.10	10±0.14	9.7±0.10	9.9±0.12	10.3±0.10	11.3±0.01	12.0±0.10
Pupal recovery (nos.)	17 (19)	18 (21)	15 (18)	14(17)	12(15)	10 (13)	9(12)
Pupal recovery (%)	89.4	90.0	83.3	82.3	80.0	76.9	75.0
Developmental period (days)	35.6	36.2	36.9	38.2	38.9	40.3	42.5
Total survival (nos.)	17	18	15	14	12	10	9
Total survival (%)	68	72	60	56	48	40	36
Storage at 8°C							
Egg hatching (total 50 nos.)	49	48	47	45	33	20	14
Egg hatching (%)	98	96	94	88	76	40	46
Egg hatching (days)	4.2±0.11	4.4±0.12	4.5±0.11	4.4±0.10	4.6±0.10	4.9±0.11	5.4±0.10
Larval duration (days)	13.0±0.01	11.7±0.12	13.4±0.13	13.7±0.10	13.9±0.13	15.0±0.11	14.2±0.12
Larval survival (nos.)	20	21	19	18	17	16	14
Larval survival (%)	80	84	76	72	68	64	56
Pre- pupation (days)	4.1±0.12	4.0±0.13	4.6±0.10	4.8±0.11	4.9±0.010	5.2±0.11	5.3±0.11
Pupation (days)	8.4±0.11	8.5±0.10	8.7±0.11	8.5±0.02	9.1±0.14	9.4±0.02	10.1±0.11
Pupal recovery (nos.)	18 (20)	18 (21)	16 (19)	13 (18)	15 (17)	13 (16)	11 (14)
Pupal recovery (%)	90.0	85.7	84.2	72.2	88.2	81.2	78.5
Developmental period (days)	29.7	28.6	31.2	31.4	32.5	34.3	35
Total survival (nos.)	18	18	16	13	15	13	11
Total survival (%)	72	72	64	52	69	52	44
Storage at 10°C							
Egg hatching (total 50 nos.)	48	48	45	44	34	21	11
Egg hatching (%)	96	96	90	92	80	42	42
Egg hatching (days)	5.1±0.11	4.4±0.12	5.4±0.12	5.3±0.12	5.3±0.11	5.2±0.11	5.9±0.11
Larval duration (days)	14.2±0.11	12.9±0.10	13.6±0.14	14.0±0.11	14.6±0.10	14.8±0.12	16.1±0.10
Larval survival (nos.)	19	20	18	17	17	15	13
Larval survival (%)	76	80	72	68	68	60	52
Pre- pupation (days)	5.6±0.11	5.9±0.10	5.8±0.13	5.6±0.10	6.0±0.11	6.4±0.12	6.8±0.10
Pupation (days)	10.0±0.10	10.1±0.11	10.4±0.11	10.9±0.01	11.0±0.02	11.2±0.01	11.9±0.10
Pupal recovery (nos.)	17 (19)	17 (20)	15 (18)	14 (17)	15 (17)	12 (15)	8 (13)
Pupal recovery (%)	89.4	85.0	83.3	82.3	88.2	80.0	61.5
Developmental period (days)	29.3	34.6	35.2	35.8	36.9	37.6	40.7
Total survival (nos.)	17	17	15	14	15	12	8
Total survival (%)	68	68	60	56	60	48	32

Means ±SE.

Table 4.13 Effect of different storage temperatures and durations on the developmental parameters of *C. carnea* egg.

Developmental Traits	Storage period (days)						
	5 d	10 d	15 d	20 d	25 d	30 d	40 d
Storage at 12°C							
Egg hatching (total 50 nos.)	49	48	45	41	-	-	-
Egg hatching (%)	98	96	90	82	-	-	-
Egg hatching (days)	4.8±0.10	4.5±0.11	4.3±0.11	3.0±0.10	-	-	-
Larval duration (days)	13.6±0.10	13.7±0.11	14.2±0.13	15.1±0.13	-	-	-
Larval survival (nos.)	20	19	18	18	-	-	-
Larval survival (%)	80	76	72	72	-	-	-
Pre- pupation (days)	5.6±0.11	6.0±0.12	6.3±0.11	6.8±0.14	-	-	-
Pupation (days)	10.8±0.12	11.3±0.11	11.5±0.12	11.8±0.16	-	-	-
Pupal recovery (nos.)	17 (20)	16 (19)	14 (18)	14 (18)	-	-	-
Pupal recovery (%)	89.4	84.2	77.7	77.7	-	-	-
Developmental period (days)	34.8	35.5	36.3	36.8	-	-	-
Total survival (nos.)	17	16	14	14	-	-	-
Total survival (%)	68	64	56	56	-	-	-
Storage at 14°C							
Egg hatching (total 50 nos.)	47	47	40	-	-	-	-
Egg hatching (%)	94	94	80	-	-	-	-
Egg hatching (days)	4.6±0.11	4.2±0.13	4.0±0.11	-	-	-	-
Larval duration (days)	12.9±0.10	12.1±0.11	12.8±0.14	-	-	-	-
Larval survival (nos.)	20	19	18	-	-	-	-
Larval survival (%)	80	76	72	-	-	-	-
Pre- pupation (days)	5.0±0.12	5.4±0.11	5.8±0.10	-	-	-	-
Pupation (days)	10.1±0.11	10.7±0.13	5.8±0.10	-	-	-	-
Pupal recovery (nos.)	18 (20)	15 (19)	14 (18)	-	-	-	-
Pupal recovery (%)	90	78.9	77.7	-	-	-	-
Developmental period (days)	32.6	32.4	33.8	-	-	-	-
Total survival (nos.)	18	15	14	-	-	-	-
Total survival (%)	72	60	56	-	-	-	-
Storage at 16°C							
Egg hatching (total 50 nos.)	48	48	45	-	-	-	-
Egg hatching (%)	96	96	90	-	-	-	-
Egg hatching (days)	4.4±0.10	3.1±0.10	3.0±0.12	-	-	-	-
Larval duration (days)	12.8±0.11	12.9±0.12	12.9±0.11	-	-	-	-
Larval survival (nos.)	19	19	18	-	-	-	-
Larval survival (%)	76	76	72	-	-	-	-
Pre- pupation (days)	5.5±0.11	5.7±0.11	5.9±0.11	-	-	-	-
Pupation (days)	10.3±0.12	10.2±0.10	11.8±0.10	-	-	-	-
Pupal recovery (nos.)	17 (20)	16 (18)	15 (18)	-	-	-	-
Pupal recovery (%)	85	88.8	83.3	-	-	-	-
Developmental period (days)	33.0	32.4	33.6	-	-	-	-
Total survival (nos.)	17	15	15	-	-	-	-
Total survival (%)	68	60	60	-	-	-	-

Means ±SE.

4.10 Effect of storage duration and temperature on reproductive parameters of the adult of *Chrysoperla carnea* at different temperature conditions

The results showed that, among the tested storage temperatures and durations, significant variations were observed in the reproductive parameters of the adults of *C. carnea* (Table 4.14). Reproductive parameters including; adult survival, pre-oviposition period, fecundity/female/day, total eggs/female and adult female longevity were close not only to those of the control (unsorted) but also with each other after being stored at 6, 8 and 10^{o}Cfrom 5 to 30 days. At 6 and 8^{o}C of the storage temperatures from 40 to 90 days duration, the trend of the reproductive traits changed and it declined to become at par with those of at 10^{o}C. However, the comparatively better reproductive traits were observed at 10^{o}C temperature. After 30 days of storage at 10^{o}C, the percent survival of the adults was observed to be 93.3, 90.0, 86.6, 83.3, 80.0 and 73.3%, at 40, 50, 60, 70, 80 and 90 days of storage, respectively. Pre-oviposition was increased as the storage period increased, with the lowest (5.4 days) being at 5 days of storage while it was the highest (9.0 days) at 90 days of storage. The highest per day fecundity, and the total egg laid by each female, was 19.2 and 192 respectively, whereas, they were the lowest (12.3 and 101) at 90 of days storage, respectively. At 5 days storage, the female tends to live longer (33.3 days) as compared to other storage conditions; where, the female longevity gradually decreased and was observed to be as 25.7 days, the lowest at 90 days of storage.

From the results it was inferred that although adults were survived after storage at 6, and 8^{o}C of temperature conditions but the reproductive parameters were comparatively better, at 10^{o}C conditions, for up to 90 days; whenever needed to conserve susceptible or resistant strains in the insectaries for experimentation or field releases either in the controlled or natural conditions.

Table 4.14 Effect of different low temperatures on the reproductive parameters of *C. carnea* adults, storage for different durations.

Developmental traits	Un stored control	5 days	10 days	15 days	20 days	25 days	30 days	40 days	50 days	60 days	70 days	80 days	90 days
	At 25°C	Storage at 6°C											
Survival to adult (nos)	30	30	30	29	27	27	27	26	25	24	24	22	20
Survival to adult (%)	100	100	100	96.6	90.0	90.0	90.0	86.6	83.3	80.0	80.0	73.3	66.6
Pre-oviposition period (days)	5.9±0.12	6.7±0.11	6.9±0.11	7.0±0.33	7.2±0.11	7.3±0.33	8.9±0.11	9.0±0.11	9.2±0.10	9.7±0.13	13.0±0.11	13.3±0.11	14.0±0.11
Fecundity/female/day (nos.)	22.7±0.10	19.0±0.11	18.6±0.11	18.0±0.33	17.2±0.12	15.9±0.13	15.2±0.13	14.0±0.01	14.2±0.33	13.7±0.14	11.0±0.11	11.0±0.11	8.3±0.33
Total eggs/female (nos.)	96	181	180	179	169	159	150	135	121	115	102	100	92
Adult female longevity (days)	34.0±0.14	33.7±0.10	33.0±0.10	32.8±0.11	32.1±0.11	30.7±0.11	28.9±0.11	27.4±0.11	27.1±0.11	26.4±0.13	24.3±0.01	23.3±0.11	20.1±0.11
Storage at 8°C													
Survival to adult (nos)	-	30	30	29	29	28	27	27	25	25	24	23	21
Survival to adult (%)	-	100	100	96.6	96.6	93.3	90.0	90.0	83.3	83.3	80	76.6	70.0
Pre-oviposition period (days)	-	7.0±0.33	7.3±0.22	7.5±0.57	7.6±0.33	7.9±0.11	7.9±0.12	7.0±0.10	7.7±0.11	9.9±0.11	12.7±0.11	13.1±0.12	12±0.12
Fecundity/female/day (nos.)	-	18.4±0.13	16.3±0.33	16.6±0.57	16±0.11	15.7±0.11	15.5±0.11	15.2±0.02	14.9±0.57	14.2±0.12	13.1±0.12	12.3±0.10	9.4±0.57
Total eggs/female (nos.)	-	180	176	170	166	160	157	125	102	112	97	98	90
Adult female longevity (days)	-	34.0±0.12	33.2±0.12	32.1±0.01	33.6±0.12	31.2±0.10	29.4±0.11	27.2±0.11	26.5±.10	25.9±0.11	25.8±0.00	24.1±0.01	22.4±0.11
Storage at 10°C													
Survival to adult (nos)	-	30	30	30	29	28	28	28	27	26	25	24	22
Survival to adult (%)	-	100	100	100	96.6	93.3	93.3	93.3	90.0	86.6	83.3	80.0	73.3
Pre-oviposition period (days)	-	5.4±0.57	5.5±0.10	5.4±0.33	5.5±0.33	5.2±0.12	5.5±0.11	5.6±0.12	5.6±0.11	5.8±0.12	8.1±.10	8.9±.11	9.0±0.13
Fecundity/female/day (nos.)	-	19.2±0.20	19±0.57	18.3±0.33	17.9±0.02	17.0±0.33	16.8±0.10	16.1±0.33	15.4±0.33	15.9±0.11	14.3±0.11	14.2±0.12	12.3±0.14
Total eggs/female (nos.)	-	192	196	180	186	171	169	141	139	125	112	118	101
Adult female longevity (days)	-	33.3±0.11	32.1±0.11	32.8±0.10	31.1±0.11	30.0±0.11	30.6±0.10	29.1±0.12	28.0±0.11	28.4±0.11	28.0±0.01	26.4±0.01	25.7±0.10

Means ±SE.

4.11 Effect of different rearing temperatures on developmental and reproductive parameters of *Chrysoperla carnea*

Results of the study on the evaluation of effective rearing temperature for the predator, *Chrysoperla carnea***,** on the developmental parameters (Table 4.15) *i.e.*, eggs, larvae and pupae and reproductive traits of the adult are as under (Table 4.16).

4.11.1 Developmental parameters of *C. carnea*

Among the tested rearing temperatures, at 28, 31 and 35^{o}C, 100% egg hatching within 4.5, 4.0 and 4.0 days, respectively was observed; whereas, at 20 and 25^{o}C, 92 and 96% egg hatching with prolonged hatching period of 10.3 and 5.9 days respectively were observed compared to those at other rearing temperatures. Cumulative larval duration of all three instars was prolonged (20.4 days) at 20^{o}C and reduced to 12.9, 11.0, 10.2 and 10.0 days, at 25, 28, 31 and 35^{o}C, respectively. Highest larval survival (100%) was evinced, at 28^{o}C, followed by 95.8, 91.3, 72.0 and 28.0% at 25, 20, 31 and 35^{o}C respectively. The highest pre pupation (7.4 days) was recorded, at 20^{o}C followed by that of 5.9 days at 25^{o}C; whereas, it was equal to 3 days at 28, 31 and 35^{o}C respectively. Almost a similar trend of pupation period (days) was observed at all the tested rearing temperatures. Pupal recovery (%) was the highest (95.2) at 20^{o}C and the lowest (42.8%) at 35^{o}C; whereas, 91.3, 92.0 and 77.7% was observed at 25, 28 and 31^{o}C respectively. Total highest percent survival (92) among the rearing temperatures was recorded, at 28^{o}C followed by that of 84% at 25^{o}C, 80% at 20^{o}C, 56% at 31^{o}C and no survival at 35^{o}C. So, from these results, it was concluded that rearing at 28^{o}C gave a good rearing results. A temperature of 25^{o}C was also closer to favor rearing; whereas, 20^{o}C gave a prolonged rearing, which does not reflect upon the developmental traits. However whenever prolonged development needed, this temperature can be effective, for rearing. From our findings, it was clear that rearing at 31 and 35^{o}C was not favored positively upon the developmental traits; however when rapid development is desired 31^{o}C may be useful.

4.11.2 Reproductive parameters of *C. carnea*

The highest pre-oviposition period (15.2 days) of *C. carnea* was observed at 20^{o}C rearing temperature and it gradually decreased as the temperature increased up to 25, 28 and 31^{o}C, it was recorded to be 10.5, 10.0 and 7.0 days, respectively. Almost similar trend of oviposition was observed as that of the pre-oviposition period and it decreased as the rearing temperature increased from 20 to 31, with 18.3 and 6.3 days of oviposition, which were the highest and lowest, respectively. The highest egg laying (179.3) was observed at 25^{o}C, followed by that of 113.0, 62.6 and 33.0, at 28, 20 and 31^{o}C respectively. Here, it is concluded that 25^{o}C temperature favored, egg laying as compared to other the rearing temperatures. Total life span of females and males was observed to be the highest (51.6 and 18.2 days) at 20^{o}C and lowest (13.3 and 7.0 days) at 31^{o}C respectively; which, were not intended to increase the egg laying potential. Almost a similar trend of life span of females and males was recorded at 25 and 28^{o}C respectively.

Our findings demonstrated that rearing of *C. carnea*, could be carried out in a range of temperature from 20 to 31^{o}C and 25^{o}C proved to be the best, where reproductive traits were comparatively better to those at other temperatures.

Table 4.15 Effect of different rearing temperatures on the developmental parameters of *C. carnea*.

Developmental parameters	Rearing temperatures ^{o}C				
	20	**25**	**28**	**31**	**35**
Egg hatching (total 50)	23	24	25	25	25
Egg hatching (%)	92	96	100	100	100
Days (nos.)	10.3±0.31	5.9±0.39	4.5±0.57	4.0±0.00	4.0±0.01
Larval duration (days)	20.4±0.12	12.9±0.21	11.0±0.14	10.2±0.11	10.0±0.10
Survival to larvae (nos.)	21	23	25	18	2
Survival to larvae (%)	91.3	95.8	100	72	0.5
Pre Pupation (days)	7.4±0.13	5.9±0.11	3.1±0.30	3.0±0.10	-
Pupation (days)	16.3±0.11	902±0.12	8.11±0.10	8.0±0.11	-
Pupal recovery (nos.)	20	21	23	14	-
Pupal recovery (%)	95.2	91.3	92.0	77.7	-
Developmental period (days)	44.1	28.1	22.2	21.2	-
Total survival (nos.)	20	21	23	14	-
Total survival (%)	80	84	92	56	-

Means ±SE.

Table 4.16 Effect of different rearing temperatures on the reproductive parameters of *C. carnea* adults.

Reproductive parameters	Rearing temperatures ^{o}C				
	20 (n)	**25 (n)**	**28 (n)**	**31 (n)**	**35 (n)**
Preoviposition period (days)	15.2±0.13 (10)	10.5.5±0.11 (10)	10.0±0.18 (9)	7.0±0.11 (8)	-
Oviposition period (days)	18.3±0.23 (7)	27.2±0.17 (9)	25.4±0.20 (9)	6.3±0.14 (8)	-
Total eggs laid per female	62.6±0.09 (7)	179.3±0.13 (8)	113.0±0.16 (8)	33±0.18 (7)	-
Life span (female)	51.6±0.18 (5)	45.2±0.11 (5)	42.7±0.13 (5)	13.3±0.15 (5)	-
Life span (male)	18.2±0.22 (5)	16.4±0.08 (5)	15.5±0.17 (5)	7.0±0.12 (4)	-

Means ±SE, (n) number of individuals.

4.12 Effect of different host eggs on quality of developmental parameters of *Trichogramma chilonis*

Comparative study, on the rearing of parasitoid, *T. chilonis* on eggs of two lepidopteran factitious hosts *i.e*., *Sitotroga cerealella and Plodia interpunctella* on different biological parameters *viz*., , parasitism (%), emergence (%) and adult longevity (days) as shown in table 4.17. The parasitism by *T. chilonis* was observed to be 93.2 and 92.1% on eggs of *S. cerealella* and *P. interpunctella* respectively. The adult emergence was as 95.3 and 96.4, which was statistically at par, to that of both host eggs respectively. The male adult longevity was observed to be as 4.2 and 4.5 days; whereas, that of the female were 10.3 and 11.1 days after rearing on two host eggs, respectively. Females emerged from *P. interpunctella*, eggs tended to live longer as compared to the female emerged from *S. cerealella*. Development of only one parasitoid was observed from both the eggs under study. Overall results manifest that there are no significant differences among the biological parameters, that were observed in comparison.

Table 4.17 Effect of different host eggs on the quality of various developmental parameters of *T. chilonis*.

Host eggs	Parasitism (%)	Adult emergence	Adult longevity (days)		No. of parasitoid per egg
			Male	Female	
Sitotroga cerealella	93.2±0.34	95.3±0.51	4.2±0.33	10.3±0.39	1
Plodia interpunctella	92.1±0.53	96.4±0.57	4.5±0.25	11.1±0.30	1

Means ± SE, sharing identical alphabets are statistically non significant ($P < 0.05$).

4.13 Effect of different host eggs on quality of developmental parameters of *Chrysoperla carnea*

Comparative study on the rearing of predator, *C. carnea* larvae on the eggs of two lepidopteros factitious hosts as *Sitotroga cerealella and Plodia interpunctella* on different biological parameters, like larval food consumption of eggs, larval survival, larval life span, prepupal period, pupal period, adult emergence and pupal recovery are shown in table 4.18. The average larval food consumption by the *C. carnea* larvae, in all its larval instars, was observed to be 811 and 792 eggs of *S. cerealella* and *P. interpunctella* respectively. Out of 25 larvae, 24 survived after feeding upon the two host eggs. The larval life span was recorded to be 12.3 and 11.2 days from the two host eggs respectively and again it was statistically at par. Pre pupal period lasted for 4.2 and 4.1 days upon the two host eggs, respectively. Again the pupal period was observed to be at par to each host eggs, fed to the larvae. The pupal recovery of adults was also at par for the two rearing eggs provision. So, from here it is inferred that rearing on *S. cerealella* in comparison to *P. interpunctella* have no differences and both have good results for rearing.

Table 4.18 Effect of larval food consumption, on two hosts upon different life traits of *C. carnea*.

Host eggs	Larval food consumption eggs	Larval survival	Larval life span (days)	Pre pupal period (days)	Pupal period (days)	Adult emergence	Pupal recovery (%)
Sitotroga cerealella	811±0.37	24	12.3±0.59	4.2±0.57	8.2±0.47	24	100
Plodia interpunctella	792±0.31	24	11.2±0.63	4.1±0.33	8.1±0.61	23	95.8

Means ± SE, sharing identical letters are statistically non significant ($P < 0.05$).

4.14 Evaluation of different releases methods of *Trichogramma chilonis* under field conditions

Releases of *T. chilonis* were evaluated in field by following three methods.

4.14.1 Evaluation of releases of *Trichogramma chilonis* through micro-cages in cotton under field conditions

The results revealed that the parasitoids, *T. chilonis* confined in small micro-cages when released in cotton field have recorded significant differences (Table 4.19). After 24 hours of the released time, parasitoid released from the cages was 62.3% (F = 143.85, df = 2, P = 0.7056) from the total and gave 87.2% parasitism (F = 38.37, df = 2, P = 0.0025) on the host eggs. After 48 and 72 hours, the releases were followed by 20.8 and 14.6% (F = 43.85, df = 2, P = 0.7056) with a parasitism of 60.5 and 45.2% (F = 38.37, df = 2, P = 0.0025) respectively. However, a total of 94.7% releases were completed from the paper cards into the field with 64.3% parasitism.

4.14.2 Evaluation of releases *Trichogramma chilonis* through paper cards in cotton under field conditions

The results revealed significant differences of the parasitoid, *T. chilonis* releases in cotton field (Table 4.19). After 24 hour of the releases time, the parasitoids emerged from the cages was as 45.4% (F = 74.62, df = 2, P = 0.0007) from the total and got 61.3% parasitism (F = 9.99, df = 2, P = 0.0278) of the host eggs. After 48 and 72 hours releases, the emergence was 12.8 and 9.6% respectively (F = 74.62, df = 2, P = 0.0007) from the paper cards and had a parasitism of 43.9 and 27.1% (F = 9.99, df = 2, P = 0.0278), respectively. However, a total of 67.9% releases and 43.6% parasitism were completed from the cages in the field.

4.14.3 Evaluation of releases of *Trichogramma chilonis* through broadcasting in cotton under field conditions

The results revealed that all the parasitoids, *T. chilonis* were released into the cotton field through broadcasting with a saw dust as given in table 4.19. After 24 hours of the released time, parasitoids have got 70.3% (F = 74.76, df = 2, P = 0.0007) parasitism of the host eggs. After 48 and 72 hours of the releases a parasitism of 40.7 and 12.9% (F = 74.76, df = 2, P = 0.0007) was observed, respectively. However, a total of 51.9% parasitism was completed into the field.

On comparing the releases of parasitoids, into the field by three different methods, it is concluded that a total of 94.7, 67.9 and 100% releases, were completed with 64.3, 43.6 and 51.9% parasitism from the micro-cages, paper cards and through the broadcast method respectively. The micro-cages not only increased the releases and parasitism, but also protected the parasitoids from adverse environmental conditions.

Table 4.19 Effect of different exposure periods on the releases, parasitism and survival of *T. chilonis* through different methods.

Exposure period	*T. chilonis* releases through micro-cages		*T. chilonis* releases through paper cards		*T. chilonis* releases through dust	
	Releases (%)	**Parasitism (%)**	**Releases (%)**	**Parasitism (%)**	**Releases (%)**	**Parasitism (%)**
24 hrs	62.3± 1.94 a	87.2±1.46 a	45.4±2.87 a	61.3±3.44 a	100±	70.3±3.83 a
48 hrs	20.8±1.70 b	60.5±3.83 b	12.8±1.62 b	43.9±4.67 ab	-	40.7±5.38 b
72 hrs	14.6±2.13 b	45.2±2.92 c	9.6±0.76 b	27.1±5.64 b	-	12.9±4.36 c
Overall Means	94.7	64.3	67.9	43.6	-	51.9

Means ± SE, sharing identical letters are statistically non significant at $P < 0.05$.

4.15 Evaluation of *Chrysoperla carnea* releases under natural field condition

Releases of *C. carnea* were evaluated in the field by the following methods.

4.15.1 Evaluation of *Chrysoperla carnea* releases at egg stage

The results on the hatching of three day old eggs of *C. carnea* from the single cage installed on the leaves of plant are given in table 4.20. Out of 25, separately leaf caged eggs, 16 were hatched inside the cages with 64% hatching was attained under the natural field conditions.

Table 4.20 Survival at egg stage.

Total eggs	Egg hatching (nos.)	Hatching survival (%)
25	16	64
Mean	18.0	72.0

4.15.2 Evaluation of 2nd instar larval releases of *Chrysoperla carnea*

The results of 2nd instar larval survival of *C. carnea* from a single leaf-cage installed on the leaves of plant are given in table 4.21. Out of 25, separately caged 2nd instar larvae, 23 were survived and completed the 2nd instar and entered into the 3rd instar inside the cages with 92% larval survival under natural field conditions.

Table 4.21 Survival at larval stage.

Total larvae	Larval survival (nos.)	Larval survival (%)
25	23	92
Mean	23	92

Results, when compared it was evinced that the releases of larvae had more survival, as compared to the releases in the egg form. So, in order to get more consistent field releases, the predator should be released in the field in the larval form.

4.16 Parasitism and searching ability of *Trichogramma chilonis* on host eggs at different distances

The parasitism by the parasitoid, *T. chilonis* on host (*S. cerealella*) eggs at 5, 10, 15, 20 and 25 m distances from the fixed distance of releases are presented in table 4.22. Before the releases, no evidence of parasitoids was observed. At a 5 m distance from a fixed release points, it revealed to have a non significant differences among the parasitism observed from three portions, after 24 h (F = 0.56, df = 2, P = 0.6093), 48 h (F = 0.19, df = 2, P = 0.0.8309) and 72 h (F = 0.53, df = 2, P = 0.6274); whereas, comparatively more host eggs were parasitized on the middle portion to that of upper and lower portion of cotton plants. Parasitism was observed to have a non significant difference among 24, 48 and 72 hours of the releases with 63.6, 77.7 and 78.7% parasitism respectively, which ranked to be, the highest parasitism as compared to the other treatments, at various distances.

At 10 m distance, from a fixed release point it revealed non significant differences, among the parasitism observed from three portions, i.e., upper, middle and lower after 24 h (F = 0.04, df = 2, P = 0.9581), 48 h (F = 0.15, df = 2, P = 0.8635) and 72 h (F = 0.12, df = 2, P = 0.8896). At this distance, the parasitism of the host eggs was 54.0, 58.1 and 58.0% after 24, 48 and 72 hours with non significant differences.

At a 15 m distance, from a fixed release point, revealed non significant differences, among the parasitism observed from three portions i.e., upper, middle and lower after 24 h (F =1.38, df = 2, P = 0.3505), 48 h (F = 0.75, df = 2, P = 0.5295) and 72 h (F = 0.62, df = 2, P = 0.5809). At this distance (F = 0.19, df = 2, P = 0.8309) the values of parasitism were recorded to be 23.4, 28.7 and 29.1% after 24, 48 and 72 h, respectively and had a non significant difference among the hour values.

At a 20 m distance, from a fixed release point, revealed non significant differences among the parasitism observed from three plant portions *i.e*., upper, middle and lower after 24 h (F = 0.54, df = 2, P = 0.6180), 48 h (F = 27.90, df = 2, P = 0.0045)

and 72 h (F = 0.20, df = 2, P = 0.8239); while, the parasitism by parasitoids were observed to be 20.4, 23.2 and 23.0% following 24, 48 and 72 hours, respectively.

At 25 m distance from a fixed release point, revealed a non significant differences among the parasitism observed from three plant portions *i.e*., upper, middle and lower following 24 h (F = 0.15, df = 2, P = 0.8615), 48 h (F = 0.15, df = 2, P = 0.8643) and 72 h (F = 0.74, df = 2, P = 0.5311). The lowest parasitism was observed at this distance with 14.3, 16.7 and 17.1% parasitism after 24, 48 and 72 h respectively. When the parasitism, among the various distances was compared, it was evinced that parasitism gradually decreased as the distance increased and in field conditions, *T. chilonis* have traveled upto 25 m distance. Hence in order to get parasitism, augmentative releases of the parasitoids should be released up to maximum of 25 m.

Table 4.22 Effect of different releases distances and plant portions on the parasitism by *T. chilonis* at different time duration of releases.

Distance	Hours	Upper	Middle	Lower	Total parasitism
5 mtrs	24	62.8±5.13 a	67.8±5.29 a	60.2±3.20 a	63.6±4.5
	48	75.6±3.58 a	80.4±2.62 a	77.2±6.67 a	77.7±4.3
	72	76.7±3.51 a	81.6±5.39 a	77.8±3.62 a	78.7±4.2
	Total	71.7	76.6	71.7	73.3± a
10 mtrs	24	54.1±3.86 a	54.9±6.18 a	52.9±3.56 a	54.0±4.5
	48	57.1±7.17 a	60.4±3.59 a	56.8±2.95 a	58.1±4.6
	72	58.4±3.73 a	59.3±4.07 a	56.4±3.58 a	58.0±3.8
	Total	56.5	58.2	55.3	56.7± b
15 mtrs	24	21.5±3.64 a	25.9±3.71 a	22.7±2.25 a	23.4±3.2
	48	25.2±2.75 a	31.3±3.94 a	29.6±2.18 a	28.7±3.0
	72	27.4±4.05 a	32.7±4.00 a	27.2±2.88 a	29.1±3.6
	Total	24.7	29.9	26.5	27.0± c
20 mtrs	24	20.6±1.12 a	21.4±3.27 a	19.3±2.20 a	20.4±2.2
	48	22.5±1.48 b	25.9±1.48 a	21.2±2.01 b	23.2±1.7
	72	21.7±3.09 a	24.2±1.07 a	23.2±2.31 a	23.0±2.2
	Total	21.6	23.8	21.2	22.2± d
25 mtrs	24	13.9±3.38 a	15.2±2.05 a	13.9±4.25 a	14.3±3.2
	48	15.2±2.86 a	17.7±4.08 a	17.3±1.68 a	16.7±2.9
	72	14.2±1.41 a	19.2±4.38 a	18.0±1.82 a	17.1±2.5
	Total	14.4	17.3	16.4	16.0± e

Means ± SE, sharing same letters are statistically non significant (P < 0.05).

4.17 Survival of *Trichogramma chilonis* under field conditions

Results on parasitism by parasitoids, *T. chilonis* on the host eggs, under field conditions during June having significant difference, among the weeks as presented in table 4.23 (F = 329.53, df = 3, P = 0.0000). Average parasitism on host eggs was recorded to be the highest (73.9%) during 3rd week of June, when the average maximum temperature was 33.7°C. In this month, the lowest parasitism (56.5%) was observed, during the 2nd week when average temperature was 44.7°C; while, 64.0 and 66.6% parasitism were observed during 1st and 4th week, respectively and it was in between the highest and lowest values. During the month of June, the average cumulative parasitism was recorded as 65.2%.

In the month of July, the parasitism by parasitoids, *T. chilonis* on host eggs, under field conditions, had non significant differences, among the weeks has presented in table 4.24 (F = 1.10, df = 3, P = 0.4182). Average parasitism of the host eggs was recorded highest (69.2%), during the 1st week of July when average maximum temperature was 36.9°C. In this month, the lowest parasitism (65.1%) was observed during the 4th week, when average temperature was 37.0°C; while, 68.7 and 67.9% parasitism were observed during the 2nd and 3rd week, respectively and in between the highest and lowest, when the maximum temperature was 36.7 and 35.6°C. During the month of July, the average cumulative parasitism was recorded to be as 67.7%, a bit more than that observed in June (68.6%). In the month of July, fluctuations in the average weekly temperatures were observed very closely, as these resulted in non significant parasitism, by parasitoids.

During the month of August, parasitism by the parasitoid, *T. chilonis*, on the host eggs under field conditions had non significant differences, among the weeks as presented in table 4.25 (F = 0.90, df = 3, P = 0.4931). Average parasitism on the host eggs was recorded to be the highest (69.9%) during 1st week of August, when average maximum temperature was 36.7°C. In this month the lowest parasitism (65.2%), was observed during the 4th week, when average temperature was 37.7°C. While, 64.2 and 66.3% parasitism was observed during the 2nd and 3rd week, respectively and it was in

between the highest and lowest when the maximum temperature was 38.2 and 37.7^{o}C. During the month of August, the average cumulative parasitism was recorded to be 66.7%. In the month of August, fluctuations in average weekly temperatures were observed very closely that caused the significant parasitism by the parasitoids.

In the month of September, the parasitism by the parasitoid, *T. chilonis* on the host eggs under field conditions had non significant differences, among the weeks and are presented in table 4.26 (F = 320.0, df = 3, P = 0.0000). Average parasitism on the host eggs, was recorded to be highest (82.3%) during 1st week of September, when the average maximum temperature was 35.3^{o}C, with a mild minimum temperature (25.5^{o}C), that favored the parasitism. In this month, the lowest parasitism (67.2%) was observed, during the 3rd week when average field temperature was 36.8^{o}C. While, 77.8 and 81.6% parasitism was observed during the 2nd and 4th week, respectively when maximum temperature being 35.1 and 34.2^{o}C. During this month the average cumulative parasitism was recorded to be 77.0% which was the highest among the observed months.

Outcome of the results on comparative parasitism by the parasitoids, *T. chilonis*, on the host eggs under field conditions during June, July, August and September upon prevailing field temperatures showed that the mild temperature in September has favored more the parasitoid survival and effective parasitism on host eggs as compared to those in other months of the study.

Table 4.23 Mean parasitism (%) by *T. chilonis* on host eggs during different weeks of June, 2007.

Weeks	Parasitism (%)	Average temperatures °C	
		Minimum	Maximum
1st	64.0±4.4 ab	25.1	41.6
2nd	56.5±4.5 b	28.8	44.7
3rd	73.9±3.9 a	23.4	33.7
4th	66.6±4.6 a	26.2	37.5
Mean	65.2	25.8	39.3

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.24 Mean parasitism (%) by *T. chilonis* on host eggs during different weeks of July, 2007.

Weeks	Parasitism (%)	Average temperature °C	
		Minimum	Maximum
1st	69.2±2.3a	27.1	36.9
2nd	68.7±4.3 a	24.1	36.7
3rd	67.9±2.3a	27.7	35.6
4th	65.1±2.5 a	25.7	37.0
Mean	67.7	26.1	36.6

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.25 Mean parasitism (%) by *T. chilonis* on host eggs, during different weeks of August, 2007.

Weeks	Parasitism (%)	Average temperature °C	
		Minimum	Maximum
1st	69.9± 5.6a	26.3	36.7
2nd	64.2± 3.4a	26.9	38.2
3rd	66.3± 3.9a	25.9	37.9
4th	65.2± 2.6a	23.7	37.7
Mean	66.4	25.7	37.6

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.26 Mean parasitism (%) by *T. chilonis* on host eggs during different weeks of September, 2007.

Weeks	Parasitism (%)	Average temperature °C	
		Minimum	Maximum
1st	82.3±4.4 a	25.5	35.3
2nd	77.8±2.0 a	22.2	35.1
3rd	67.6±2.9 b	24.7	36.8
4th	81.6±2.7 a	21.1	34.2
Mean	77.0	23.3	35.2

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

4.18 Survival of *Chrysoperla carnea* under field conditions

During June, survival of the predator, *C. carnea* under field conditions revealed the non significant differences, among the four weeks of June, and showed that the adaptability of this predator, in a wide range of fluctuating temperature, prevailed during the whole month (F = 3.09, df = 3, P = 0.1114) (Table 4.27). The highest (86.1%) survival was observed during the 3rd week of June, when average maximum temperature was 33.7°C. In this month, the lowest survival (66.6%) was recorded during the 2nd week, when average temperature was 44.7°C. During this month, the collaborative survival was observed like 77.7%.

In July, the survival of predator, *C. carnea* under field conditions, revealed the non significant differences among the four weeks of July and indicated a wide range of adaptability of this predator in the fluctuation temperatures prevailed during the whole month (F = 1.38, df = 3, P = 0.3376) (Table 4.28). The highest (88.8%) survival was observed during 2nd and 3rd week of July when average maximum temperature was 36.7 and 35.6°C, respectively. In this month, the lowest survival (83.3%) was recorded in the 4th week, when average temperature was 37.0°C. During this month, the collaborative survival was observed to be as 86.7% which was comparatively better to that observed during June (77.7%).

In the month of August, the survival of predator, *C. carnea*, under field conditions revealed non significant differences, among the four weeks of August and indicated wide range of adaptability of this predator in the fluctuating temperature, prevailed during the whole month (F = 0.38, df = 3, P = 0.7718) (Table 4.29). The highest (88.8%) survival was observed during the 3rd week of August, when average maximum temperature was 37.9°C, respectively. In this month the lowest survival (83.3%) was recorded in the 1st week when average temperature was 36.7°C. During this month, the collaborative survival was observed like 85.3% comparatively closer to that observed during July (86.7%).

During September, the survival of predator, *C. carnea*, under field conditions revealed non significant differences among the four weeks of September and indicated a wide range of adaptability for this predator, in the fluctuating temperature prevailed during the whole month (F = 1.99, df = 3, P = 0.2167) (Table 4.30). The highest (97.2%) survival was observed during the 1st week, when average maximum temperature was 35.3^{o}C. In this month, the lowest survival (88.8%) was recorded in the 4th week when average temperature was 34.2^{o}C. During this month, the collaborative monthly survival was observed to be 94.4%, which is quite better as compared to the survival in August (85.3%). Parasitoid, *C. carnea* was survived under field conditions for the period of months June, July, August and September and has shown a wide range of adaptability in the prevailing field temperature conditions.

Table 4.27 Mean survival (%) of *C. carnea* under field conditions during different weeks of June, 2007.

Weeks	Survival (%)	Average temperatures ^{o}C	
		Minimum	Maximum
1	75.0±4.8a	25.1	41.6
2	66.6±4.8a	28.8	44.7
3	86.1±5.5a	23.4	33.7
4	83.3±4.8a	26.2	37.5
Mean	77.7	25.8	39.3

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.28 Mean survival (%) of *C. carnea* under field conditions during different weeks of July, 2007.

Weeks	Survival (%)	Average temperature ^{o}C	
		Minimum	Maximum
1	86.0±2.8a	27.1	36.9
2	88.8±2.8a	24.1	36.7
3	88.8±2.8a	27.7	35.6
4	83.3±4.8a	25.7	37.0
Mean	86.7	26.1	36.6

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.29 Mean survival (%) of *C. carnea* under field Conditions during different weeks of August, 2007.

Weeks	Survival (%)	Average temperature ^{o}C	
		Minimum	Maximum
1	83.3±4.8a	26.3	36.7
2	83.3±4.8a	26.9	38.2
3	88.8±2.8a	25.9	37.9
4	86.1±2.8a	23.7	37.7
Mean	85.3	25.7	37.6

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

Table 4.30 Mean survival (%) of *C. carnea* under field conditions during different weeks of September, 2007.

Weeks	Survival (%)	Average temperature ^{o}C	
		Minimum	Maximum
1	97.2±2.8a	25.5	35.3
2	94.4±2.8a	22.2	35.1
3	97.2±2.8a	24.7	36.8
4	88.8±2.8a	21.1	34.2
Mean	94.4	23.3	35.2

Means ± SE, sharing same letters are statistically non significant ($P < 0.05$).

4.19 Comparative evaluation of bio-control agents in management of cotton pests under field conditions

The comparative field evaluation of bio-control agents *i.e., T. chilonis* and *C. carnea* in different treatments are depicted as under.

4.19.1 Comparative evaluation of bio-control agents in management of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in cotton under field conditions

The results showed significant differences, among the infestation of *Helicoverpa armigera*, during different weeks of August, September and October, 2007 in bio-control treatment (F = 9.99, df = 11, P = 0.0000) (Table 4.31, fig. 4.1). The lowest (4.5%) infestation of *H. armigera* was observed during the 1st weeks of August, and the highest (11.3%) was observed during the 1st week of September. Whereas, the population trend during other weeks lay among the lowest and highest values. When, it is compared to the infestation, recorded in the control (F = 24.64, df = 11, P = 0.0000), where the lowest (6.1%) and highest (18.7%) infestation was observed during the 1st week of August and September respectively. The reduction in the bio-control, in comparison to the control was in the range of 26.2 to 44.4%, the highest and lowest during the 1st week of August and 4th week of September respectively. In the insecticide treatment (F = 16.79, df = 10, P = 0.0003), it was ranged from 0.8 to 4.7%, the highest and lowest respectively.

Low trend of infestation of *H. armigera* was recorded during the year 2008, in the bio-control (F = 15.39 df = 10, P = 0.0000), control (F = 25.96, df = 10, P = 0.0000) and insecticide treated plot (F = 19.83, df = 10, P = 0.000) as compared to the year 2007 (Table 4.32, fig. 4.2). Due to high infestation, the reduction in the bio-control as compared to the control was in the range of 16.6 to 42.6%, the lowest and highest respectively. The comparative infestation of *H. armigera* for the years 2007 and 2008 are accessible in figure 4.1 and 4.2, respectively. Here it is clear that weekly releases of *T. chilonis* and *C. carnea* suppressed the *H. armigera*, infestation near to the economic threshold level in biological control treatments.

Table 4.31 Mean comparative infestation (%) of *H. armigera* in different treatments from July to October, 2007.

Treatments	July	August				September				October	
	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2
Bio-control	0.0e	4.5±0.95 cd	5.7±0.29 cd	6.7±0.36 bcd	9.4±0.51 ab	11.3±1.33 a	9.1±1.92 ab	7.8±1.10 bc	8.9±0.45ab	8.4±1.12 abc	5.4±1.01 d
Insecticide	0.0c	0.8±0.20 c	4.1±0.78 b	5.4±1.21 b	8.0±1.02 a	10.3±1.54 a	4.7±0.59 b	3.6±0.82 b	3.9±1.17 b	4.2±0.96 b	3.8±0.57 b
Control	0.0e	6.1±0.81 d	8.3±0.67 cd	10.1±1.53 c	16.0±0.67 ab	18.7±1.19 a	15.3±0.99 ab	13.4±0.66 b	15.9±1.92 ab	14.3±0.55 b	8.9±1.94 cd
Reduction (%) in bio-cont. vs. control	0.0	26.2	31.3	33.6	41.2	39.5	40.5	41.7	44.0	41.2	39.3

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$.

Table 4.32 Mean comparative infestation (%) of *H. armigera* in different treatments from July to October, 2008.

Treatments	July	August				September				October	
	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2
Bio-control	1.0±0.36 f	1.0±0.44 f	12.1±1.15 a	10.3±1.45 ab	9.2±1.10 bc	7.1±1.08 cd	6.5±0.93 cde	8.8±0.71 bcd	6.1±0.70 de	6.1±1.01 de	4.1±0.96 e
Insecticide	0.2±.10 d	0.7±0.15 d	1.0±0.21 d	6.7±0.87b	8.7±1.16 a	5.1±0.47 bc	3.6±0.61 c	3.9±0.59 c	4.7±0.90 c	4.9±0.49 c	3.7±0.31 c
Control	1.2±0.25 f	1.4±0.15 f	17.2±0.20 e	15.4±.34 e	14.2±.58 de	12.2±0.94 de	11.5±2.3 ab	15.1±0.81 ab	10.2±2.13 a	9.4±1.08 bc	7.2±1.93 cd
Reduction(%) in bio-cont. *vs*. control	16.6	28.5	29.6	33.1	35.2	41.8	42.6	41.7	40.1	41.1	43.0

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$.

Fig. 4.1 Mean comparative infestation (%) of *H. armigera* during the year 2007.

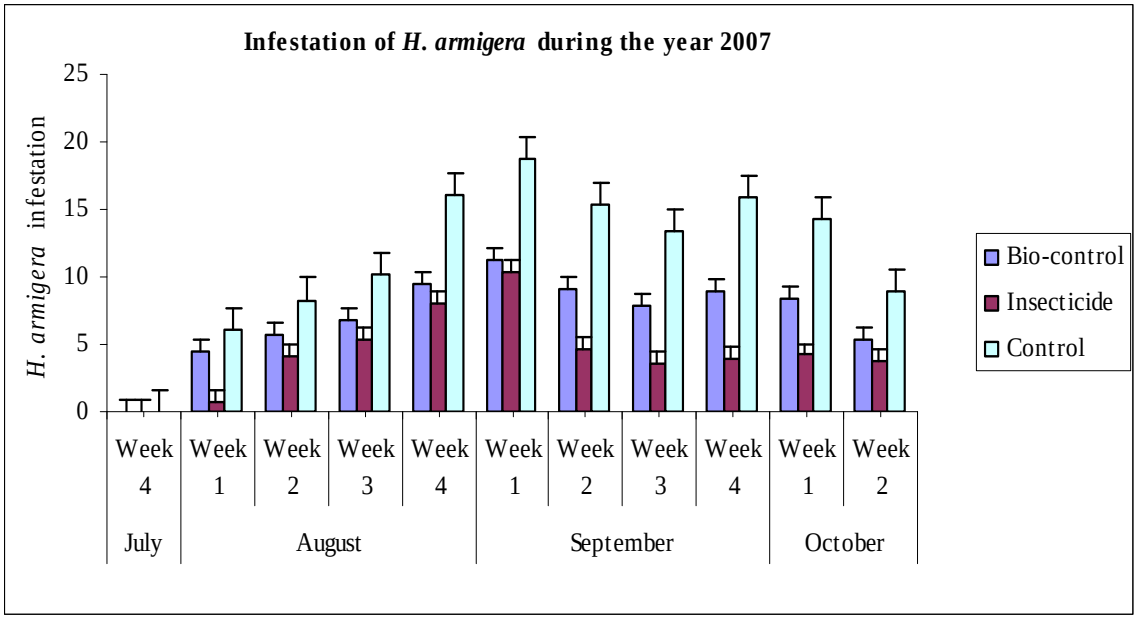
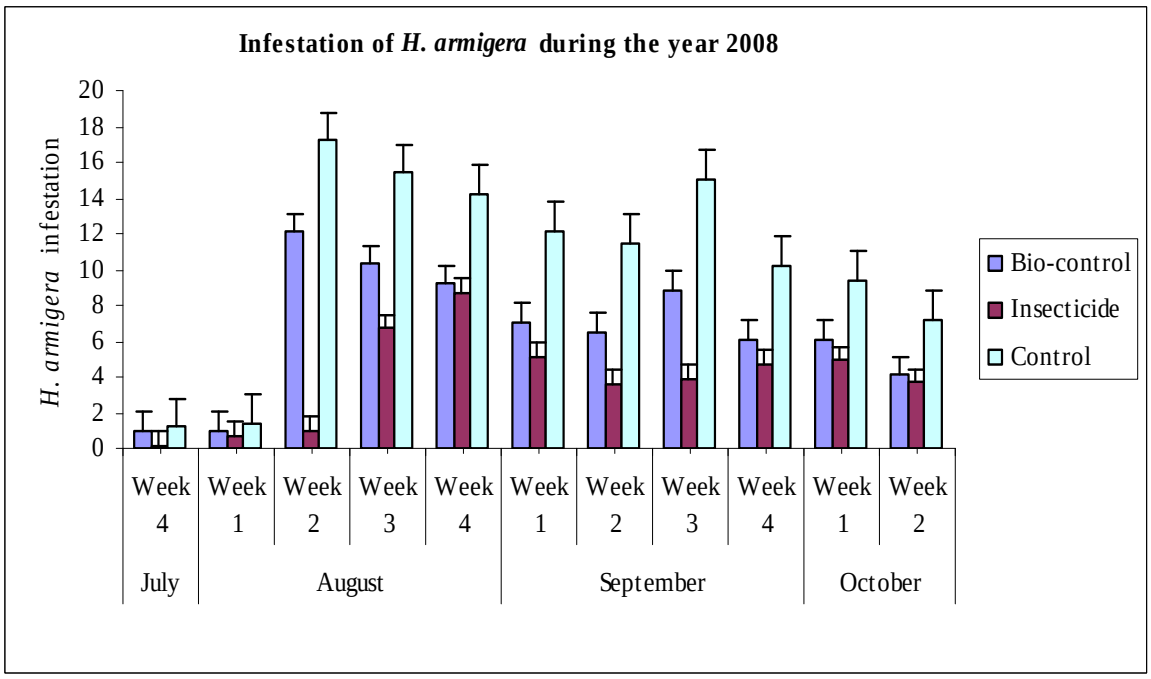


Fig. 4.2 Mean comparative infestation (%) of *H. armigera* during the year 2008.



4.19.2 Comparative evaluation of bio-control agents in management of *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in cotton under field conditions

The outcome of the results in bio-control treatment showed, significant differences among the infestation of *Earias vittella* during different weeks of July, August, September and October, 2007 (F = 17.6, df = 11, P = 0.0000) (Table 4.33, fig. 4.3). The lowest (2.1%) infestation of *E. vittella* was observed, during the 3rd week of July and the highest (18.0%), during the 2nd week of September. Whereas, the infestation trend during other weeks, were lies among the lowest and highest values. When it was compared to the infestation recorded in the control (F = 35.41, df = 11, P = 0.0000), where the lowest (2.7%) and highest (30.7%) infestations were observed, during the 3rd week of July and 2nd week of August, respectively. The percent reduction in the bio-control treatment in comparison to the control was in the range of 22.2 and 45.5, the highest and lowest during the 3rd week of July and 1st week of October respectively. The highest and lowest efficacy of bio-control agents was due to the highest and moderate temperature, respectively. In the insecticide treated plot, (F = 14.78, df =11, P = 0.0000), it ranged from 1.0 to 10.1% the highest and lowest during the 3rd week of July and 1st week of September, respectively.

Almost a similar trend of *E. vittella* infestation was recorded during the year 2008 (Table 4.34, fig. 4.4). In the bio-control treatment, the lowest (6.9%) infestation of *E. vittella* was observed during the 3rd week of July and the highest (16.2%) was recorded during the 4th week of July (F = 8.90, df = 11, P = 0.0000). When it was compared to the infestation recorded in the control (F = 12.10, df = 11, P = 0.0000) where, the lowest (9.0%) and highest (28.9%) infestation was observed during 3rd week of July and 2nd week of September, respectively. The reduction in the bio-control treatment in comparison to the control was in the range of 23.3 and 43.5%, which were the highest and lowest during the 3rd week of July and the 1st week of October, respectively. In insecticide treated plots the lowest (0.7%), in 3rd week of July and highest (9.3%) in 2nd week of September, respectively (F = 16.00, df = 11, P = 0.0000). Here, it is clear that weekly releases of *T. chilonis* and *C. carnea*, suppressed the *E. vittella* infestation near to the economic threshold level in the biological control treatment.

Table 4.33 Mean comparative infestation (%) of *E. vittella* in different treatments, from July to October, 2007.

Treatments	July		August				September				October	
	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2
Bio-control	2.1±0.46 g	6.0±1.57 f	6.9±1.81 f	17.1±1.22 ab	14.2±0.78 bcd	13.7±0.93 bcde	13.2±0.66 cde	18.0±1.02 a	15.0±1.65 abc	14.2±1.10 bcd	11.1±0.96 de	10.3±0.45 e
Insecticide	1.0±0.55 e	1.3±0.12 e	1.7±0.15 e	2.8±0.38 de	6.3±0.90 bc	8.4±0.63 ab	10.1±1.78 a	9.3±1.19 a	8.4±1.49 ab	6.2±0.96 bc	5.2±0.46 cd	3.7±1.00 cde
Control	2.7±0.84 g	9.5±0.85 f	10.1±0.67f	30.7±1.11ab	24.1±1.37 cd	22.4±1.17 cde	20.4±2.61 de	31.4±0.95 a	26.6±2.37 bc	22.1±1.02 cde	20.4±1.33 de	18.7±1.51 e
Reduction (%) in bio-cont. *vs.* control	22.2	36.8	31.6	39.1	41.0	38.8	35.2	42.6	43.6	35.7	45.5	44.9

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$

Table 4.34 Mean comparative infestation (%) of *E. vittella* in different treatments, from July to October, 2008.

Treatments	July		August				September				October	
	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2
Bio-control	6.9±0.93 f	16.2±1.33 a	10.9±1.71 cde	12.3±2.01 bcd	7.9±0.26 ef	12.4±1.19 bc	13.3±0.72 abc	16.1±0.63 a	15.2±1.36 ab	9.8±0.70 cdef	8.7±1.60 def	6.9±0.57 f
Insecticide	0.7±0.24 d	1.0±0.31 d	1.3±0.31 d	1.9±0.06 d	5.2±0.45 c	6.1±0.72 c	8.4±0.67 b	9.3±1.68 ab	9.0±1.30 a	8.2±1.28 a	7.1±0.70 ab	5.1±1.23 ab
Control	9.0±1.19 f	25.9±2.29 ab	18.1±1.70 cd	18.4±0.72 cd	13.6±1.36 def	21.1±2.58 bc	23.4±1.58 bc	28.9±1.34 a	21.9±1.99bc	14.1±1.88 def	15.4±1.41 de	11.4±1.56 ef
Reduction (%) in bio-cont. vs. control	23.3	37.4	39.7	33.1	41.9	41.2	43.1	44.2	30.5	34.4	43.5	39.4

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$

Fig. 4.3 Mean comparative infestation (%) of *E. vittella* during the year 2007.

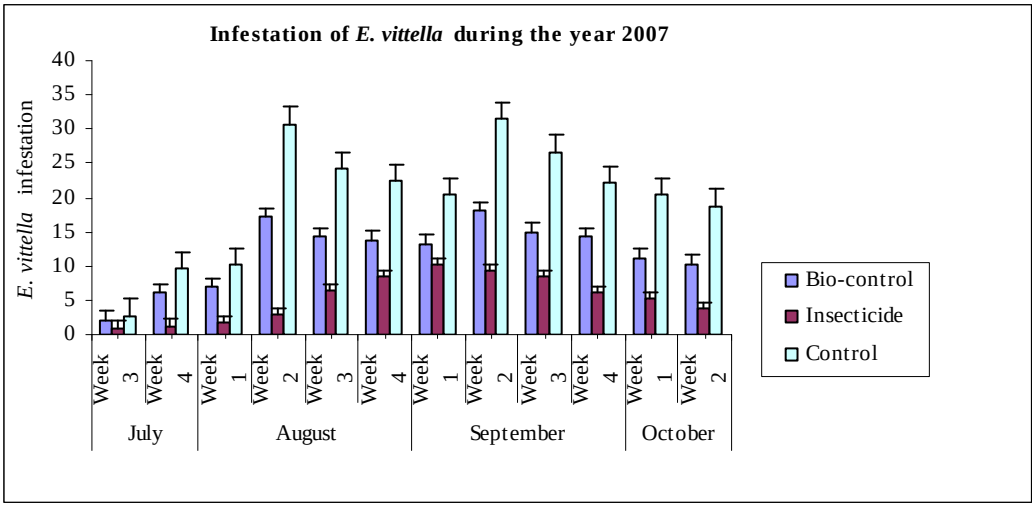
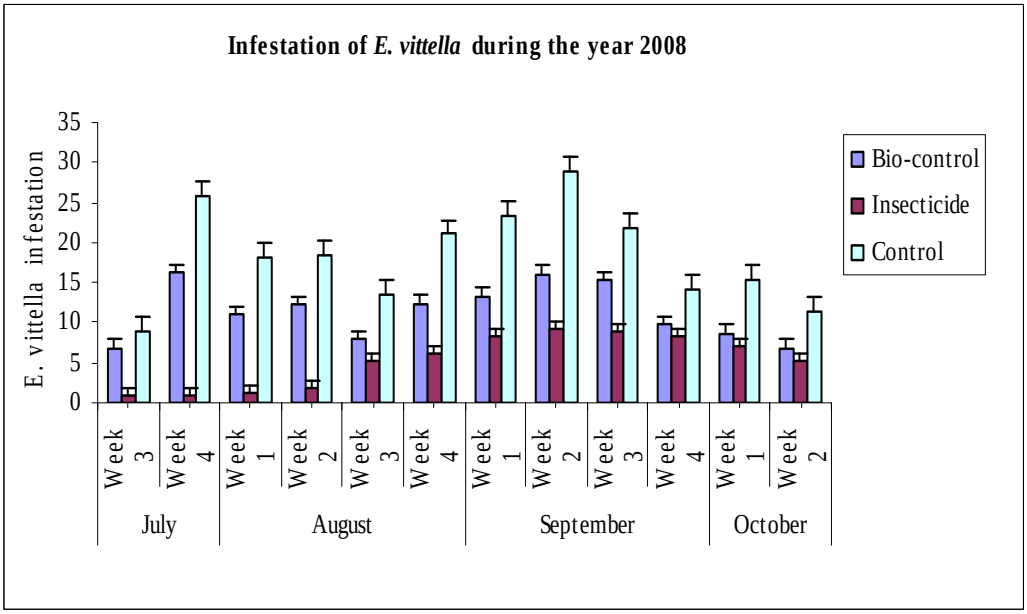


Fig. 4.4 Mean comparative infestation (%) of *E. vittella* during the year 2008.



4.19.3 Comparative evaluation of bio-control agents in management of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton under field conditions

The population of *Bemisia tabaci* in bio-control treatment during different weeks of July, August and September, 2007 showed significant differences (F = 4.35, df =11, P = 0.0016) (Table 4.35, fig. 4.5). The lowest (6.3 nos./leaf) population of *B. Tabaci* was observed during the 4th week of August and the highest (10.2 no/leaf) during the 4th week of July. Whereas, the population trend during other weeks was observed to be among the lowest and highest values. When it was compared to the population recorded, in control (F = 3.71, df = 11, P = 0.0043) where the lowest (9.1 no/leaf) and highest (15.7 nos./leaf) population was observed during the 1st week of July and the 4th week of August, respectively. The reduction in the bio-control treatments in comparison to the control was ranged from 17.6 to 39.8% the highest and lowest during the 1st week of July and the 3rd week of September, respectively. In the insecticide treated plot (F = 4.48, df = 11, P = 0.0014), the population was ranged from 1.7 to 5.2 (nos./leaf) the highest and lowest during 4th week of July and 3rd week of August respectively.

The population of *B. tabaci* was higher in year 2008 as compared to 2007 (Table 4.36, fig. 4.6). During year 2008, in the bio-control treatments was observed the highest (12.3 nos./leaf) and lowest (6.5 nos./leaf) during 3rd week of July and 2nd week of September, respectively (F = 2.97, df = 11, P = 0.0143). In insecticide treatment, the non significant population of *T. tabaci* was highest (3.6 nos. /leaf) during the 3rd week of August and the lowest (2.0 nos. /leaf) during the 3rd week of September while, in other weeks, the observations ranged in between them (F = 1.47, df = 11, P = 0.2135). In the control treatment, the highest (18.2 nos./leaf) and lowest (9.2 nos./leaf) population observed were during 3rd week of July and 4th week of September, respectively (F = 11.23, df = 11, P = 0.0211). The percent reduction in the bio-control treatment in comparison to the control, it was evinced to be the highest (38.0) and lowest (25.2), during the 1st and 2nd of week August, respectively. The relative population of *B. tabaci*, for the years 2007 and 2008, are presented in figure 4.5 and 4.6 respectively. It is inferred that integration of *T. chilonis and C. carnea*, enhanced the suppression of *Bemisia tabaci*, and maintained the pest population, under sub-economic level.

Table 4.35 Mean comparative population (nos./leaf) of *B. tabaci* in different treatments from July to September, 2007.

Treatments	July				August				September			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Bio-control	7.3±0.61 bc	7.9±1.30 bc	8.3±0.52 bc	10.2±1.25 a	8.1±0.59 bc	9.0±0.35 ab	9.2±0.53 ab	6.3±0.45 c	7.2±0.72 bc	7.9±0.36 bc	6.2±0.96 c	6.9±0.66 c
Insecticide	2.2±0.12 cd	3.7±0.66 bc	2.4±0.35 cd	1.7±0.47 d	2.4±0.36 cd	3.6±0.26 bc	5.2±0.12 a	2.2±0.47 cd	3.5±0.52 bc	2.3±0.53 cd	4.2±0.90 ab	3.1±0.35 bcd
Control	9.1±0.64 c	10.7±0.60 c	11.6±0.71 bc	15.7±1.24 a	11.2±1.04 bc	13.4±0.56 ab	14.3±1.49 a	9.2±1.62 c	10.3±0.64 c	11.2±0.83 bc	10.3±1.14 c	10.2±0.99 c
Reduction (%) in bio-cont. vs. control	17.6	26.1	28.4	35.0	27.6	24.6	35.6	31.5	30.0	29.4	39.8	32.3

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$

Table 4.36 Mean comparative population (nos./leaf) of *B. tabaci* in different treatments from July to September, 2008.

Treatments	July				August				September			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Bio-control	7.2±0.61 bc	9.2±0.25 abc	12.3±1.10 a	11.4±2.53 a	8.6±1.13 abc	8.9±1.93 abc	10.2±1.72 abc	11.2±0.72 a	8.3±1.82 abc	6.5±0.61 c	6.9±0.99 c	6.3±0.57 c
Insecticide	3.5±0.26	2.6±0.60	3.4±0.31	2.3±0.15	3.4±0.25	3.1±0.38	3.6±1.36	2.4±0.38	2.6±0.26	2.5±0.21	2.0±0.38	2.1±0.21
Control	11.3±0.57 cdef	12.4±0.64 bcd	18.2±0.96 a	16.6±0.86 a	13.4±0.61 bc	11.9±0.75 bcde	14.1±0.47 b	13.4±1.31 bc	12.6±1.64 bcd	9.4±0.56 ef	10.3±0.53 def	9.2±0.47 f
Reduction (%) in bio-cont. vs. control	36.2	25.8	32.4	31.3	38.0	25.2	27.6	16.4	34.1	30.8	33.0	31.5

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$

Fig. 4.5 Mean comparative population of *B. tabaci* during the year 2007.

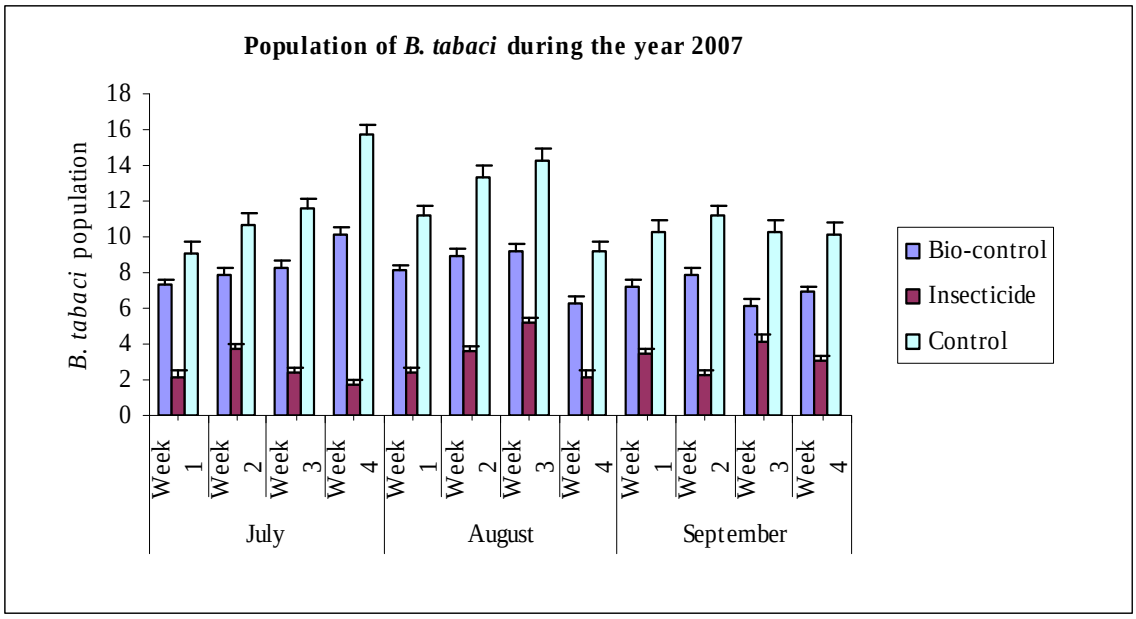
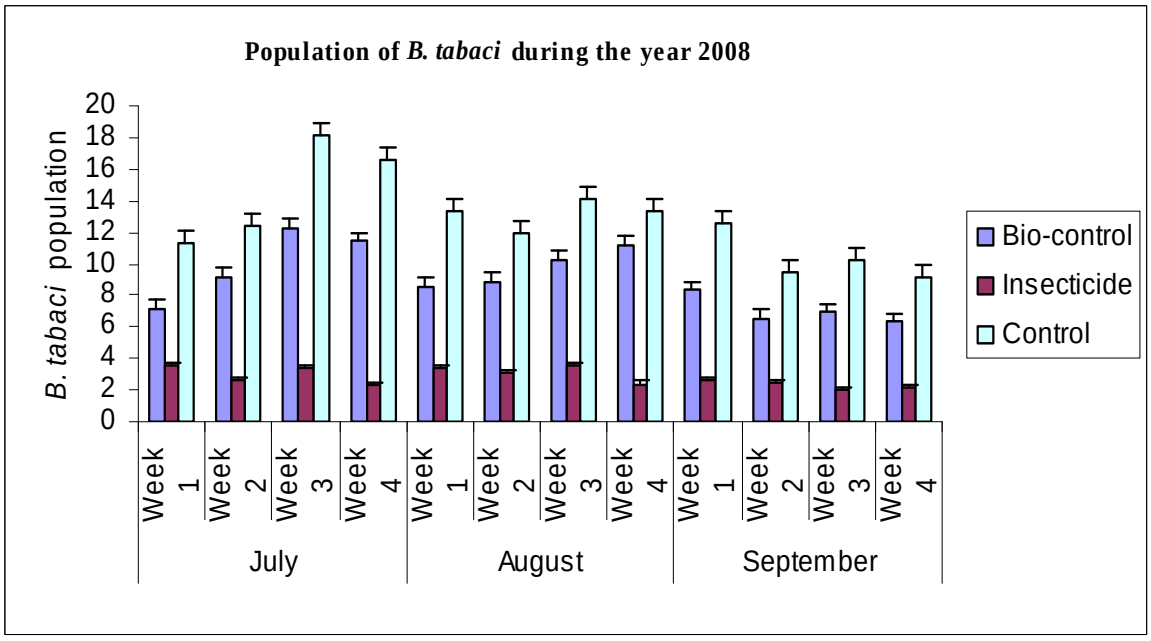


Fig. 4.6 Mean comparative population of *B. tabaci* during the year 2008.



4.19.4 Comparative evaluation of bio-control agents in management of *Thrips tabaci* (Linderman) (Thysanoptera: Thripidae) in cotton under field conditions

The results showed, significant differences, among the population of *Thrips tabaci* in bio-treatment, during different weeks of July, August and September, 2007 (F = 3.44, df = 11, P = 0.0066) (Table 4.37, fig. 4.7). The lowest (7.1 no/leaf) population of *T. tabaci*, was observed during the 1st week of July and the highest (13.4 nos./leaf) was observed during 3rd week of August. Whereas, the population trend, during other weeks, were in between the lowest and the highest values. When, it was compared to the infestation recorded in control (F = 8.41, df = 11, P = 0.0000), where the lowest (9.4 no/leaf) and highest (18.2 no/leaf) population was observed during the the 1st and 2nd week of July, respectively. The percent reduction in bio-control in comparison to the control was in the range of 24.4 to 31.8% which was the highest and lowest, during the 1st and 2nd week of July, respectively. In the insecticide treatment (F = 2.05, df = 11, P = 0.0736), the population was ranged 2.1 to 4.3 nos./leaf, the highest and lowest during different weeks of observed months, respectively.

The population of *T. tabaci* was higher in all the treatments during year, 2008 as compared to 2007 (Table 4.38, fig. 4.8). During the year 2008, in bio-control treatment, the highest (15.6 nos./leaf) and the lowest population (6.8 nos./leaf) during different weeks of observations (F = 5.73, df = 11, P = 0.0024) were recorded. In insecticide treatment plot, the population of *T. tabaci*, was the highest (6.2 nos./leaf) during the 1st week of August and the lowest (2.7 nos./leaf) during the 3rd week of July and in other weeks of observations it ranged in between them (F = 3.76, df = 11, P = 0.0040). In the control treatment, the highest (22.1 nos./leaf) and the lowest (7.7 nos./leaf) populations were observed, during 1st week of August and July respectively (F = 4.66, df = 11, P = 0.0010). Percent reduction in bio-control treatments in comparison to the control concerned, it was evinced that highest (35.6) and lowest (16.1) populations were witnessed during 2nd week of July and 3rd week of August respectively. The comparative population of *T. tabaci* for years 2007 and 2008 are presented in figure 4.7 and 4.8 respectively. So, the integration of *T. chilonis and C. carnea*, enhanced the suppression of *T. tabaci* and maintained the pest population under sub-economic levels.

Table 4.37 Mean comparative population (nos./leaf) of *T. tabaci* in different treatments from July to September, 2007.

Treatments	July				August				September			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Bio-control	7.1±1.02 c	12.4±2.57 ab	11.2±1.64 ab	10.1±1.63 abc	10.7±1.78 ab	12.3±1.02 ab	13.4±1.07 a	10.7±0.91 bc	12.2±0.15 ab	12.9±0.67 a	13.4±0.64 a	8.9±0.70 bc
Insecticide	3.7±0.86	2.1±0.21	2.9±0.12	2.1±0.21	4.3±0.44	4.1±0.35	3.7±0.81	3.6±0. 70	4.0±0.45	2.1±0.31	2.9±0.77	3.9±0.91
Control	9.4±0.56 d	18.2±2.02 a	16.3±0.61 ab	14.3±1.01 bc	15.9±1.38 ab	16.1±0.67 ab	17.1±0.64 a	15.1±0.61 b	16.9±0.93 ab	17.2±1.29 a	18.1±0.76 a	12.5±0.51 c
Reduction (%) in bio-cont. vs. control	24.4	31.8	25.7	29.3	32.7	23.6	21.6	29.1	27.8	25.0	23.2	28.8

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$.

Table 4.38 Mean comparative population (nos./leaf) of *T. tabaci* in different treatments from July to September, 2008.

Treatments	July				August				September			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Bio-control	5.4±0.64 e	6.8±0.95 de	10.6±0.65 bc	12.7±1.13 abc	15.6±1.62 a	11.4±0.64 bc	11.3±0.63 bc	13.2±0.89 ab	10.4±1.56 bcd	9.3±0.56 cd	10.2±1.94 bcd	9.8±1.22 bcd
Insecticide	2.8±0.49 cd	3.4±0.47 bcd	2.7±0.44 cd	2.6±0.31 d	6.2±0.61 a	4.8±1.36 abc	5.3±0.36 ab	4.4±0.47 abcd	5.5±0.63 ab	2.7±0.67 cd	3.8±0.59 bcd	4.7±0.67 abcd
Control	7.7±0.60 d	12.9±1.10 c	14.1±0.97 bc	16.2±1.10 bc	22.1±1.52 a	17.5±2.79 abc	15.3±0.96 bc	18.4±2.86 ab	15.3±1.22 bc	14.1±1.74 bc	14.9±1.30 bc	13.4±2.06 bc
Reduction (%) in bio-cont. vs. control	29.8	35.6	24.8	21.1	30.9	34.8	16.1	28.2	32.0	34.0	30.1	26.8

Means (±SE, n=3) sharing same alphabets are statistically similar at $P < 0.05$.

Fig. 4.7 Mean comparative population of *T. tabaci* during the year 2007

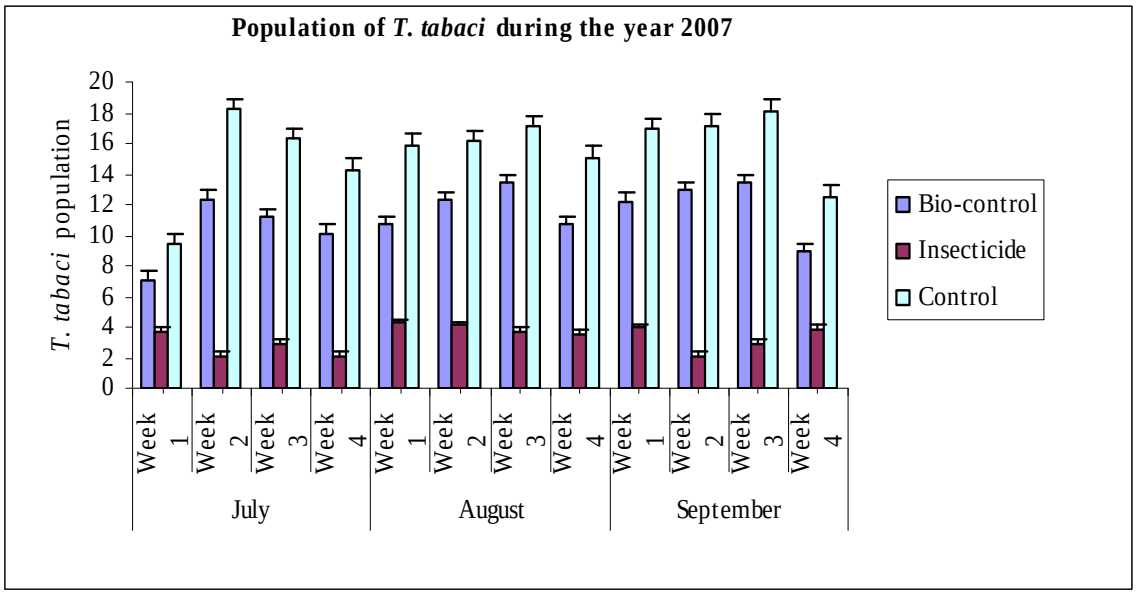
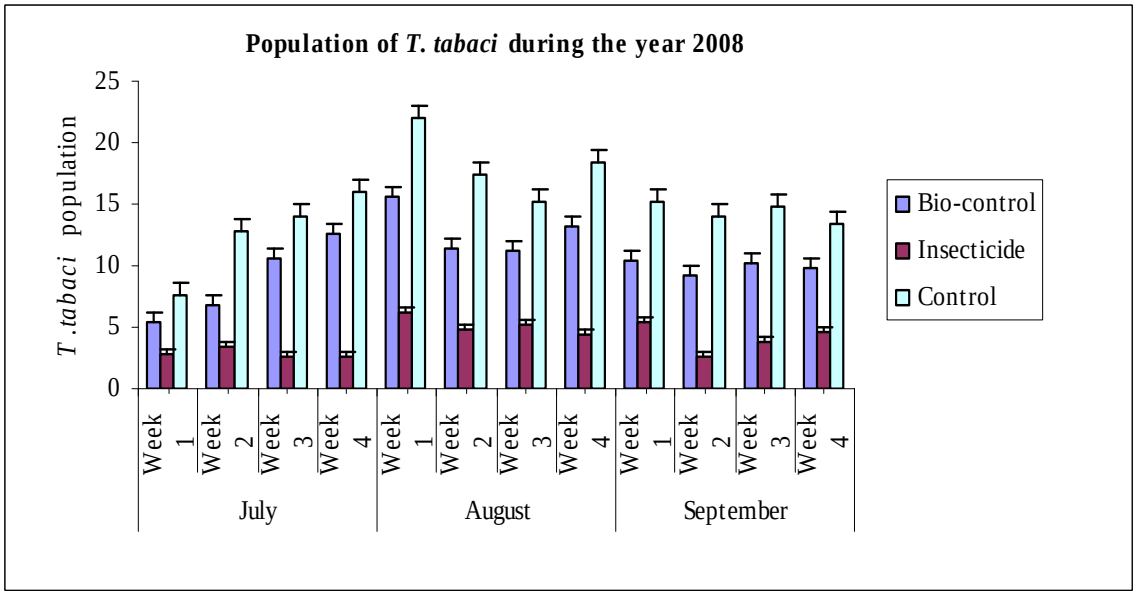


Fig. 4.8 Mean comparative population of *T. tabaci* during the year 2008



4.19.5 Comparative evaluation of bio-control agents in management of *Aphis gossypii* Glover (Homoptera: Aphididae) in cotton under field conditions

The onset of *Aphis gossypii* population was delayed in all three experimental plots and it was appeared in the month of September during year 2007 (Fig. 4.9). Results showed non significant differences among the population of *A. gossypii*, in the bio-treatment, during different weeks of September and October, 2007 (F = 2.99, df = 3, P = 0.1175) (Table 4.39, fig. 4.9). In the bio-control treatment, the lowest (8.3 nos./leaf) population of *A. gossypii* was observed during the 3rd week of September, while the highest (11.4 nos./leaf), during the 2nd week of October. Whereas, the population trend during other weeks was between the lowest and highest values. When it is compared to the infestation recorded, in control (F = 3.87, df = 3, P = 0.0744), that had a non significant effect, where the lowest (13.4 no/leaf) and highest (20.4 nos./leaf) population were observed during the 3rd and 4th week of September, respectively. The percent reduction in the bio-control in comparison to control was in the range of 45.2 to 42.2%, the highest and lowest during 1st and 2nd week of October respectively. In insecticide treatment (F = 6.85, df = 3, P = 0.0230), the population ranged 2.4 to 4.8 aphids/leaf, the highest and lowest being during 3rd and 4th week of September, respectively.

The population trend of *A. gossypii* was almost similar in the year 2008 when compared to that in 2007 (Table 4.40, fig. 4.10). During year 2008, in the bio-control treatment, the highest (11.4nos/leaf), and lowest aphids (9.7nos./leaf), were seen during 1st week of October and 3rd week of September, respectively with non significant affect (F = 0.54, df = 3, P = 0.6730). In insecticide treated plots, the population of *A. gossypii* was highest (4.9 nos. /leaf) during 1st week of October and lowest (2.5 nos./leaf) during 3rd week of September having significant effect (F = 8.69, df = 3, P = 0.0133). In the control treatments the highest (20.3 nos./leaf) and lowest (16.2 nos./leaf) population of aphids population was observed during 3rd week of September (F = 0.71, df = 3, P = 0.5783). The percent reduction in the bio-control treatments in comparison to control, it was evinced to be the highest (44.6%) and lowest (40.1%), during 2nd week of October and 3rd week of September, respectively. The comparative population of *A. gossypii* for the years 2007 and 2008 are presented in figures 4.9 and 4.10, respectively.

It is concluded from the results that integration of *T. chilonis and C. carnea*, enhanced the suppression of *A. gossypii* and maintained the pest population, under sub-economic level.

Table 4.39 Mean comparative *A. gossypii* population (nos./leaf) in different treatments from September to October, 2007.

Treatments	September		October	
	Week 3	Week 4	Week1	Week2
Bio-control	8.3±0.63	11.4±1.08	10.0±1.61	10.2±0.90
Insecticide	2.4±0.29	4.8±0.86	4.1±0.47	3.6±0.26
Control	13.4±1.39 b	20.4±1.07 a	17.9±1.39 A	17.5±1.96 ab
Reduction (%) in bio-cont. vs. control	43.5	44.1	45.2	42.2

Means (±SE, n=3) sharing similar letters are statistically non significant at $P < 0.05$

Table 4.40 Mean comparative *A. gossypii* population (nos./leaf) in different treatments from September to October, 2008.

Treatments	September		October	
	Week 3	Week 4	Week 1	Week2
Bio-control	9.7±0.63	10.9±0.86	11.4±2.15	9.8±1.20
Insecticide	2.5±0.47 c	3.2±0.21 bc	4.9±0.61 a	4.2±0.72 ab
Control	16.2±1.98	19.2±1.88	20.3±2.69	17.7±1.61
Reduction (%) in bio-cont. vs. control	40.1	41.0	43.8	44.6

Means (±SE, n=3) sharing similar letters are statistically non significant at $P < 0.05$

Fig. 4.9 Mean comparative population of *A. gossypii* during the year 2007.

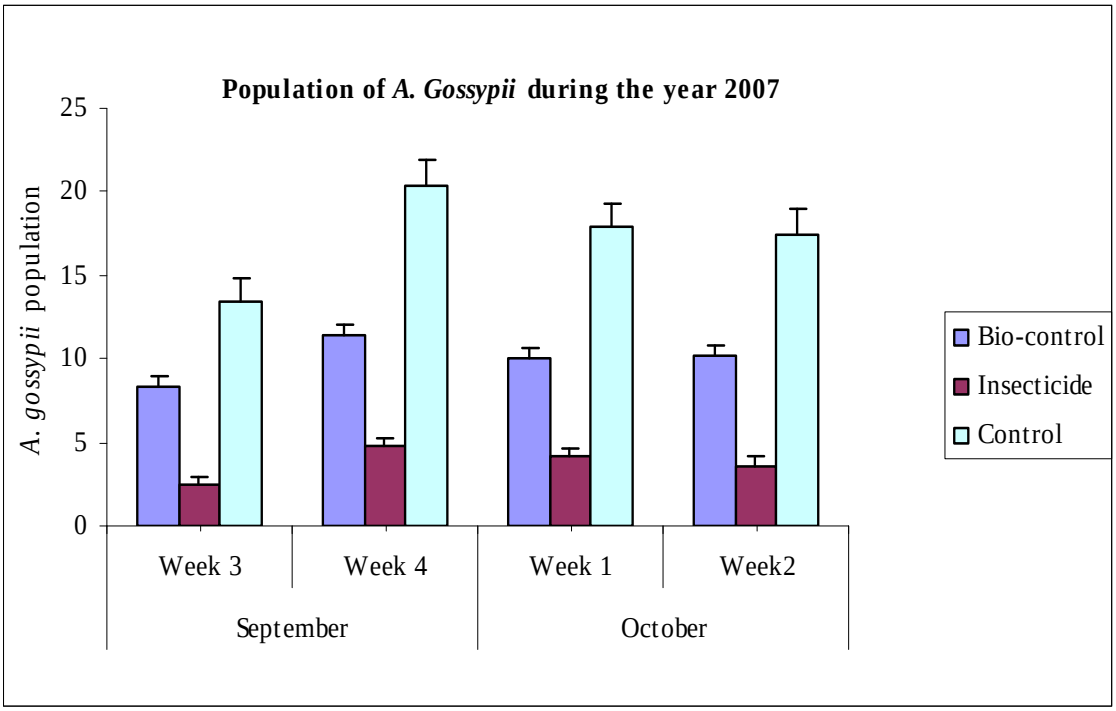
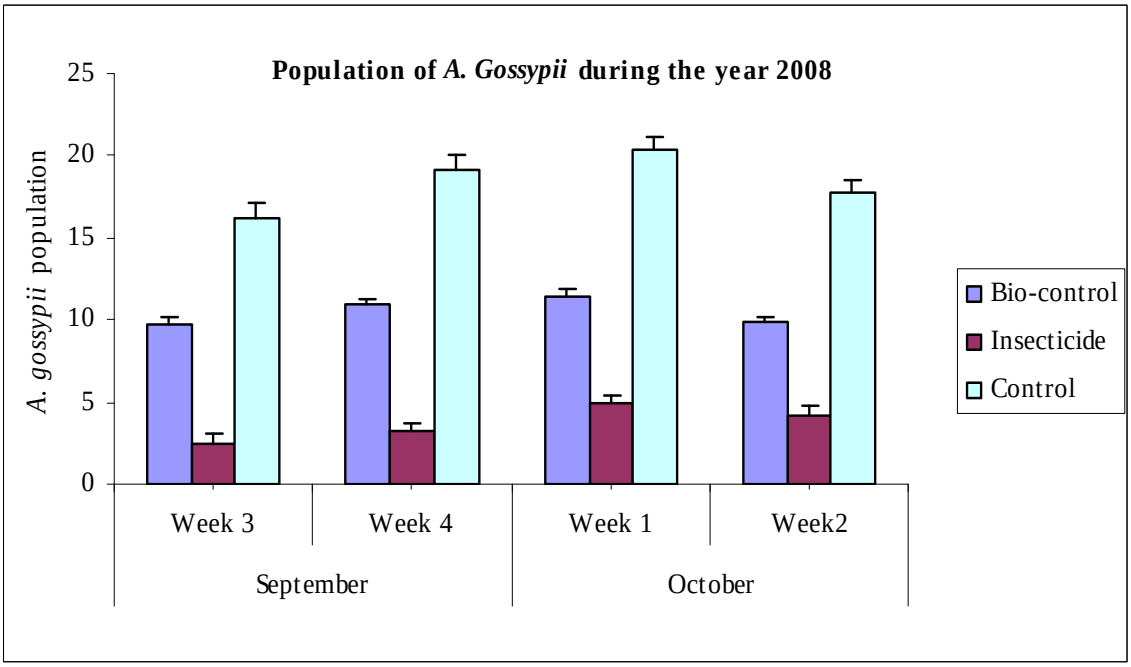


Fig. 4.10 Mean comparative population of *A. gossypii* during the year 2008.



DISCUSSION

5.1 Selection of *Trichogramma chilonis*, *Chrysoperla carnea* and *Sitotroga cerealella* strains

Fresh strains of the egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae), and a predator, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), were collected from cotton, sugarcane and lucern crops and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), collected from wheat stores and reared in mass rearing laboratories.

5.2 Rearing of *Sitotroga cerealella* on different hosts

The results of our studies showed that the trend of percent emergence of host, from the cereals was recorded; with its highest from wheat, followed by from sorghum (158.3) and barley (148.3); whereas, the lowest (125.6) was recorded from maize. Size of eggs was highest (14.2 mg/500) from adults reared from maize, followed by those from wheat (13.4) and barley (12.7); while, the lowest (9.5) from sorghum. Size of the adults was observed to be the highest (18.5 mg/10 adults) from maize, followed by those from wheat (11.8), barley (10.3) and sorghum (8.9). Fecundity was observed to be the highest (115.6 nos./female) in maize followed by that in wheat (110.0), barley (115.6) and the lowest in sorghum (98.3). So, it was concluded that the rearing of *S. cerealella* was equally good in sorghum as in wheat; where, the fecundity of adults was observed statistically at par. In rearing, when healthy and heavy sized adults required, the rearing in maize provides good results but with reduced fecundity and enlarged life span. In a

free choice rearing method, *S. cerealella* preferred wheat grains 35.4% more to followed by barley (32.3%) and sorghum (17.75), whereas; maize was preferred the least (14.6%). Our results are agreed to the results reported by Goncalves *et al*. (2005) who have elaborated improved laboratory rearing techniques for *Trichogramma* spp., by determining the emergence rate of *Trichogramma* adults, egg size of *Ephestia kuehniella* (host), fecundity of host and sex ratio of the parasitoid. *Trichogramma*, adult emergence was slightly lower as desired and was over 90%. Lewis *et al*. (1976) have reported that *T. pretiosum* reared on *H. zea* has performed better in field than that of reared on other hosts, which are disagreed with our findings. Hoffmann *et al*. (2001), have reported performance of the parasitoid *Trichogramma ostriniae* (Pang and Chen), on the eggs of four factitious host, *Ostrinia nubilalis* (Hübner), *Sitotroga cerealella* (Olivier), *Trichoplusia ni* (Hübner) and irradiated *Ephestia kuehniella* (Zeller) and found that *E. kuehniella* was proved a poor host, *T. ni* and *O. nubilalis* were good hosts and *S. cerealella* was intermediate one, this agree to our results. Nathan *et al*. (2006), have evaluated the emergence and survival of adults of *Trichogramma chilonis* (Ishii), by using host eggs of *Corcyra cephalonica* reared on the grains of millet, wheat, rice and sorghum and the nutritional indices for wheat and rice upon *C. cephalonica*, larvae were intermediate between the indices for larvae reared on millet and sorghum and results are in the line as we have, too equally good rearing of *S. cerealella* on wheat, due to its good nutritional indices.

5.3 Effect of radiation on eggs of host, *Sitotroga cerealella*

The irradiated host eggs at 05, 10, 20, 30, 40, 50, 75, 100, 125, 150, 200, 300, 400, 500, and 600 Gy, when exposed to the parasitoid, *T. chilonis* has revealed that a dose of 50 Gy had the ability to extend the host egg viability and the eggs can be used for parasitism by the parasitoids, *T. chilonis* (87.3, 82.4, 81.3, 81.1, 80.7, 58.1 and 55.8% after 1, 2, 3, 4, 5, 6 and 7 days) up to 7 days, in comparison to that of the control where, host eggs were parasitized upto 3 days prior to emergence. Our results agree to the work reported by Lianzhong *et al*. (1993), who have reported the effect of low doses of radiation on eggs of the host *Antheraea pernyis* of *Trichogramma dendrolimi* and got

80% parasitism on the host eggs without any adverse affect on the developmental parameters of *Trichogramma* spp. and their offspring. El-Mandarawy and Rizk (2002) have reported the effect of sub sterilizing doses of radiation, on the eggs of *Callasobruchus maculates* (Fabricius) and *Corcyra cephalonica* (Stainton) and offered them for parasitization to *T. evanescens* and *T. bacteriae* and recorded highest rate of emergence from irradiated eggs as compared to non irradiated ones. Similarly Fatima *et al*. (2005) have reported that parasitization was comparatively higher at 20 and 25 Gy doses of radiation, and preference by parasitoids on host eggs decreases as the age of eggs increases and eggs can be used up to the age of 4 days, are in the line with our results. The results of the study of Hamed *et al*. (2009), are also in line with our work, they reported that the impact of gamma radiation, for the improvement of mass production of *Trichogramma chilonis*, *Chrysoperla carnea* and host, *Sitotroga cerealella* whose eggs were irradiated from 5 to 55 Gy dose and used upto 7 days for parasitization by *T. chilonis* and at the highest dose (55 Gy), parasitization was recorded 45% and these results, agree to our results as we have got parasitism upto 7 days. Our results are also in the line to the findings of Fatima *et al*. (2009), who have used gamma radiations for the eggs of the host, *Sitotroga cerealella* and reported that the effect of irradiation, by using 20-25 Gy, caused delay in hatching, from 2, 3, 4, and 6 day old eggs, which were successfully parasitized by *T. chilonis* as compared to the non irradiated host eggs; while, at low doses of radiations upto 15 Gy did not affect the hatching of eggs and hatching was significantly reduced, at higher doses, with negligible hatching at 50 Gy.

5.4 Development of *Trichogramma chilonis* on stored eggs of host, *Sitotroga cerealella*

Our results showed that the cold storage of host eggs, *Sitotroga cerealella* at 6 and 8^{o}C, has resulted in an effective and highest preference by the parasitoid *T. chilonis* for 5 to 50 days, and a comparatively more suitable temperature, was 6^{o}C for both short and long term storages of the host eggs. However, the storage of eggs, at 10, 12, 14 and 16^{o}C of temperature proved useful only for a short tem storage of host eggs and is discussed as under.

5.4.1 Emergence of *T. chilonis*

Among the tested temperatures, 6^{o}C evaluated as least suitable temperature in the present studies corroborated with the results of Kilincer *et al*. 1990; Uzun, 1994 and Greco and Stilinovic, 1998. In our study the emergence of parasitoids, achieved from the stores declined as storage period increased, and this agree with the work reported by Özder, 2004 who have also got comparatively better emergence from stored eggs, at temperatures between 0 and 8^{o}C as we have.

5.4.2 Parasitism by *T. chilonis*

Parasitism was increased with a decrease in the storage period as compared to the control in the present study are agreed with the reported results of Özder, 2004, who have found that at 8^{o}C temperature, 71.20% parasitism was observed, after 10 days of storage; whereas, we have got 77.60% parasitism, after 20 days of storage. Our results are also in the line to the work of El-Mandarawy (2003) who has reported in his investigations on the preference by *T. evanescens* and *T. cacoeciae* of different aged group egg after stored at low temperatures.

5.4.3 Longevity of *T. chilonis* adults

From the above results, it is obvious that the longevity of *T. chilonis*, after being fed, on stored host eggs decreased as the storage duration increased. The results reported by Özder, 2004, who have got 8.8 and 6.2 days of longevity after 14 and 31 days of storage at 8^{o}C temperature conditions are agreed to our results as we have got 8.7 and 7.3 days of longevity after 15 and 30 days of storage respectively.

5.5 Effect of radiation and low temperatures on eggs of host, *Sitotroga cerealella*

The collaborative effect of radiation and low temperature on the egg storage of host, *Sitotroga cerealella* at 6, 8, 10, 12, 14 and 16^{o}C for 5-90 days, have shown almost similar affect as that of the individual affect of storage obtained on the fitness parameters of parasitoids, *Trichogramma chilonis, i.e*., percent emergence, percent parasitism and adult longevity (days) in comparison to the control. Our results are agreed to the findings reported by Tuncbilek *et al*. (2005), who have investigated the effects of 3 months of storage of irradiated eggs of *Ephestia kuehniella* and *Sitotroga ceraelella* on the wasp's quality. No significant differences on parasitization, female and male emergence between irradiated and unirradiated eggs upto 60 and 30 days for *E. kuehniella* and *S. cerealella* eggs were reported, respectively.

5.6 Effect of adult food nutrition on development of *Trichogramma chilonis*

Results of the present study on evaluation of the affect of adult food on the biological parameters of *Trichogramma chilonis i.e*., parasitism, male and female adult in comparison to the control, concluded that the biological parameters like parasitism, male and female adult longevity of *T. chilonis* survived the best after being fed on 10% honey solution, which is equally at par to that fed at 5% honey solution. Over all a decreasing trend of biological parameters was attained with the concentration of honey solution. So in order to get good development of parasitoids 10% honey solution gave best results.

5.6.1 Parasitism by *T. chilonis* adults

The highest parasitism (93.0%) on the host eggs, recorded as of the parasitoids fed upon 10% honey solution and there was 22.1% increase over the control; whereas, the lowest parasitism (76.4%) was observed when parasitoids were fed on 25% honey

solution, with only 5.3% increase over the check. Parasitism at par to with that to 10% was observed in parasitoids, fed on 5% honey solution and there was recorded, an increase of 22.1% over check. Parasitism was observed in decreasing trend (86.9, 82.1 and 76.5% after fed 15, 20 and 25% respectively as the honey solution concentration increases towards 25%. Ashley and Gonzalez (1974), have reported an increase in parasitism, after feeding the parasitoid on honey, due to the survival of parasitoids for a long duration, when compared to that in case of the unfed parasitoids.

5.6.2 Male adult longevity of *T. chilonis*

Male longevity of *T. chilonis* adults was extended to 6.0 days in the parasitoids after being fed on 10% honey solution with 70.0% increase over the check, which was at pat with that of 5.8 days longevity after their feeding on 5% honey solution, with 68.9% rise over the check. The lowest adult longevity was experienced to be 2.8 days, subsequent when feeding on 25% honey solution with an increase of 35.7% over the check. Male longevity, after fed on 15, 20 and 25% honey solutions was recorded to 4.5, 3.7 and 2.8 days, respectively. Our results concerning over male longevity are agree to the work reported by McDougall and Mills (1997) who have reported that more than 10% honey solution, improved the longevity of parasitoids 10-13 folds with 15-20 days in comparison to that of the unfed parasitoids.

5.6.3 Female adult longevity of *T. chilonis*

Longevity of *T. chilonis* female adults was prolonged to 7.3 days in parasitoids fed on 10% honey solution with an increase of 66.6% longevity over the control. An increase of female adult longevity of 65.7% recorded after fed on 5% honey solution was at par to longevity at 10%. Increased female adult longevity over control as of 58.3, 50.0 and 37.5% with decreasing trend were obtained after fed upon increased honey solution concentrations as 15, 20 and 25%. From our findings, the female adult longevity decreased as the adult feed (honey) concentration increased are agreed to the results

reported by the previous investigators as the results reported by Lundgren and Heimpel (2002), who have got mean longevity of honey fed individuals as 7.16 days for *T. pretiosum*, and 6.71 days for *T. minutum* whereas, mean longevity of unfed individuals was 2.68 and 1.96 days, respectively.

5.7 Optimization of short and long term storage duration for *Trichogramma chilonis* at low temperatures*

Storage of the parasitoid, *Trichogramma chilonis*, after held at low temperatures (6^{o}C to 16^{o}C), for different durations (5-90 days), upon the fitness parameters of the parasitoids i.e., percent emergence, percent parasitism and adult longevity in comparison to that of the control concluded that 10^{o}C was evaluated to be an effective temperature for the storage of *T. chilonis*, where the highest percent emergence, percent parasitism and adult longevity were recorded, at this temperature, which suited both for a long and short term storage, that ensures the availability of parasitoids, in insectaries for research and field releases are discussed as under.

5.7.1 Percent emergence of *T. chilonis*

The emergence of *T. chilonis*, from 88.5 to 85.9% obtained after 5 to 25 days of storage in present investigation are also similar to the results reported by Harrison *et al*. (1985), who observed 88.0% emergence at 15^{o}C for *T. exiguum.* Our results are agreed to the findings of Zhu *et al*. (1992), who reported that *T. evanescens* was not viable for very long time after being stored at a low temperature. Our results are in line with the study, concluded by Garcia *et al*. (2002), who have investigated the role of temperature in causing diapause in *T. cordubensis*, under laboratory conditions, after a long storage, at a low temperature of 10^{o}C, for 30 or 40 days, as we have in present case. The results by Pitcher *et al*. (2002), are agree to our findings and here, the adult emergence of *T. chilonis*, at 12^{o}C was 84.8% after 15 days of storage, was similar to that reported by them who have got 90.7% emergence of *T. ostriniae* parasitoids at same temperature and days.

At 6°C storage, the parasitoid did not survive, after 25 days; whereas, at 16°C the parasitoid completed development and emerged. Our findings disagreed to the results reported by Pitcher *et al*. (2002), that at 15°C, parasitoid (*T. ostriniae*) did not survive more than 2 weeks. Tezze and Botto (2004), reported that *T. nerudai*, stored at 4ºC, were greatly affected from 50 days onward in storage, but in our work, *T. chilonis*, emergence, was completed in 25 days at 6°C, indicating that duration in storage varies among the different *Trichogramma* species.

5.7.2 Percent parasitism by *T. chilonis*

The parasitoids gave best parasitism for 25 days, at 10°C, which was suitable for short term storage, and the parasitoids can remain viable for field releases. However, prolonged storage decreased the parasitism gradually after 90 days of storage, with 38.7 and 42.2% parasitism at 8 and 10°C, respectively. Our findings agree with results reported by Harrison *et al*. (1985), who got 83.6% parasitism, at 15°C, for *T. exiguum vs*. 89.9% at 14°C in the present work. Our results, on *T. chilonis* parasitism, agree with investigations of Pitcher *et al*. (2002) who have reported that parasitism by stored *T. ostriniae* was not affected adversely, at 9°C for 30 days of storage but declined at 12°C, for 30 days.

5.7.3 Longevity of *T. chilonis* adults

Adult longevity decreased gradually as the storage duration increased from 5-90 days for 6-16°C. Prolonged storage gradually decreased the adult longevity and after 90 days of storage, the parasitoids survived only for 3 days, at 10°C. Our findings, on decreased adult longevity, at 8°C for a long term storage are agree to those reported by Özder (2004), where adult longevity of the egg parasitoid, *T. cacoeciae* was also decreased, after 31 days of storage at 8°C.

**Research article has been published as per appendix 32 at page 187.*

5.8 Comparative rearing of *Trichogramma chilonis* at different temperature conditions**

Rearing temperature for the parasitoid, *Trichogramma chilonis* in the present study, showed that the biological parameters of *T. chilonis* were very favorable at 28^{o}C, to provide highest parasitism and emergence from host eggs as compared to the parasitoids reared on other temperatures.

5.8.1 Developmental period of *T. chilonis*

The development time of *T. chilonis*, in our findings decreased with an increase in temperature and it is supported by the work, reported by Gross, 1988; Harrison *et al*. (1985), who have observed the development time of *T. exiguum* faster, at 25 and 30^{o}C; while slow at 20^{o}C. Our results also agree to the work reported by Ramesh and Baskaran (1996), who have observed that rearing at 40^{o}C was highly lethal for the development parameters of the adult parasitoids of *Trichogramma.*

5.8.2 Parasitism by *T. chilonis* adults

Our results are in the line to the investigations of Scott *et al*. (1997), who reported that the parasitism rate was influenced after rearing at 14, 25 and 30^{o}C and suggested that the developmental acclimation could help to increase parasitism, under low to high temperature conditions. Prasad (2002), have evaluated that rearing temperature, had a significant effect on the potential fecundity and parasitism rate of *Trichogramma sibericum*, on host eggs (*Ephestia kuehniella* Zeeler), and it was more on 21^{o}C. This did not agree to our results as we have got highest parasitism at 28^{o}C, followed by that at 25^{o}C temperature condition. Our results also agree with the investigations of Nadeem and Hamed (2008), who reported that parasitism by *T. chilonis* was affected adversely at 35^{o}C and parasitoids at this temperature gave 57.7% parasitism; whereas, in the present study we have got 60.1% parasitism on the same temperature conditions.

5.8.3 Emergence of *T. chilonis* adults

Rearing provision, at 40^{o}C did not support the emergence of parasitoids due to mortality. At 20, 25 and 31^{o}C, the emergence of the parasitoids was observed to be 90.4, 96.2 and 89.3%, respectively. Here in our findings, at 25^{o}C, the adult emergence of *T. chilonis* was recorded as 92.8%, which agreed with the work reported by Nadeem and Hamed (2008), who have got 90.6% emergence, at the same temperature conditions.

5.8.4 Longevity of *T. chilonis* adults

At 25, 28 and 31^{o}C the parasitoids longevity, was recorded to be 10.0, 9.0 and 5.6 days, respectively which provides the parasitoids with sufficient opportunity, to give more parasitism, which is the main quality criteria of parasitoids among the others. Results reported by Harrison *et al*. (1985) that the adult longevity was decreased, as the temperature increased, agrees to our results. Contradictory results were reported by Malik (2000) who have studied the life table of *T. bactrae*, which is an effective biological agent against the pink bollworm, *P. gossypiella* in cotton and evaluated that the immature mortality was recorded to be highest (32.01%) at 28^{o}C, and lowest (16.79%) at the rearing temperature of 18^{o}C and also observed that the females tend to live longer as compared to the males on all rearing temperatures, with the net reproductive rate being observed at 23^{o}C, while minimum at 13^{o}C temperature conditions. Results reported by Schöller and Hassan (2001), who has observed no emergence of the parasitoids at 35^{o}C, disagreed to our results. Doyon and Boivin (2005) have observed a significant relationship between the size, adult longevity and lifetime fecundity on the fitness of female, *Trichogramma evanescens* and reported that early emerging females have a higher fitness than the emerging females upon fecundity. The adult longevity decreased, as the temperature increased in present study are agrees to the previous investigations by Shirazi (2006) who have reported that the longevity of the parasitoid adults decreased as the temperature increased from 20 to 30^{o}C.

***Research article has been published as per appendix 31 at page 186.*

5.9 Effect of storage duration and low temperatures on developmental parameters of eggs of *Chrysoperla carnea*

The developmental parameters of the predator, *Chrysoperla carnea*, after its eggs, were held at low temperatures (6, 8, 10, 12, 14 and 16^{o}C) for a delayed embryonic development, without causing higher rates of mortality to the embryo inside the eggs, in incubators, for different intervals (5, 10, 15, 20, 25, 30 and 40 days) in comparison to a control, accomplished that the storage of predator, *C. carnea*, eggs at 10^{o}C can give a storage for 20 days, with minimum detrimental effect upon the emergent embryo inside the egg, for a short term storage and 40 days for a long term storage at this temperature. So, the storage temperatures 12, 14 and 16^{o}C can only be held when short term storage of eggs is desired in insectaries while 8^{o}C temperature is also suited at par to that at 10^{o}C for storage of predator eggs. Arroyo *et al*. (2000) have evaluated that 10^{o}C is well suited for the egg storage of *C. carnea*; where all reproductive traits were favorably towards the insect development as we have observed. Thes results of our study are in the line with the results reported by Silva *et al*. (2007), who have observed a prevented development of eggs at a temperature bellow 15^{o}C and reported 9 eggs per day per female with a total of 200 eggs per female.

5.10 Effect of storage duration and temperature on reproductive parameters of the adult of *Chrysoperla carnea* at different temperature conditions

The tested storage temperatures and durations have caused significant variations in the reproductive parameters of *C. carnea* adults. Reproductive parameters, including; adult survival, pre oviposition period, fecundity/female/day, total eggs/female and adult female longevity were close to the control (unsorted) and each other after a storage at 6, 8 and 10^{o}C from 5 to 30 days. From the results, it is inferred that although the adults survived, after storage at 6, and 8^{o}C temperature conditions but the reproductive traits were comparatively better at 10^{o}C conditions for upto 90 days, whenever needed to

preserve susceptible or resistant strains in laboratories for experimentation or field releases either in controlled or natural conditions. The results reported by Tauber *et al*. (1997b), who have got storage of *C. carnea* adults at 5^{o}C temperature conditions and got 24.4 eggs, after 30 days of the adult storage. Our results are in the line with the work reported by Tauber *et al.* (1997a) who have got oviposition by *C. externa* at 10^{o}C upto 15 eggs per day for 60 days of adult storage and 10.1 eggs per day at 120 days storage.

5.11 Effect of different rearing temperatures on developmental and reproductive parameters of *Chrysoperla carnea*

5.11.1 Developmental parameters of *C. carnea*

Our findings lead towards the conclusions that rearing at a temperature of 31 and 35^{o}C did not positively favor the developmental parameters. However, when a rapid development is desired then, 31^{o}C may be useful. Among the tested rearing temperatures, of 28, 31 and 35^{o}C, 100% egg hatching, within 4.5, 4.0 and 4.0 days respectively, was observed; whereas, at 20 and 25^{o}C, 92 and 96% egg hatching with a prolonged hatching period of 10.3 and 5.9 days, respectively as compared to that on other rearing temperatures was observed. Cumulative larval duration of all three instars was prolonged (20.4 days) at 20^{o}C and reduced to 12.9, 11.0, 10.2 and 10.0 days, at 25, 28, 31 and 35^{o}C respectively. So, from these results, it was concluded that rearing at 28^{o}C, gave good rearing results. A temperature of 25^{o}C was also closer to the favored rearing; whereas, 20^{o}C gave prolonged rearing which does not reflect upon the sound effects upon the developmental traits. However, whenever needed prolonged development, at this temperature can be effective for rearing. Our results agreed to the work reported by Albuquerque *et al*. (1994), who have observed that rearing at 40^{o}C, was highly lethal for the developmental parameters of the adult parasitoids of *Trichogramma.* The developmental traits of *C. carnea*, in our findings decreased with the increase in temperature and it supports the work reported by Silva *et al*. (2007) who have observed the developmental time of *C. carnea* to be faster at 25 and 30^{o}C, while slow at 20^{o}C.

5.11.2 Reproductive parameters of *C. carnea*

Present findings demonstrated that rearing of *C. carnea*, could be carried with a range of temperature from 20 to 31^{o}C and that 25^{o}C proved to be the best, where reproductive parameters were comparatively better than those at other temperatures. Total life span of female and male were observed to be highest (51.6 and 18.2 days), at 20^{o}C and lowest (13.3 and 7.0 days) at 31^{o}C respectively, which were not intended to increase the egg laying potential. Almost a similar trend of female and male life spans was recorded at 25 and 28^{o}C, respectively. Our results also agreed to the work reported by Albuquerque *et al*. (1994) who have observed that rearing at, 35^{o}C was highly lethal for the development parameters of the predator *C. carnea*. Chang *et al*. (2003) have determined that the adults of three populations showed a high survival after 35 weeks of storage and six or more weeks of storage produced an average fecundity ranging from 400-900 eggs/female. The developmental parameters of *C. carnea*, in our findings decreased with the increase in temperature and it supports the work reported by Silva *et al*. (2007), who have observed the developmental time of *C. carnea* to be faster at 25 and 30^{o}C whereas slow at 20^{o}C.

5.12 Effect of different host eggs on quality of developmental parameters of *Trichogramma chilonis*

The parasitism by *T. chilonis* was observed as 93.2 and 92.1%, from the eggs of *S. cerealella* and *P. interpunctella*, respectively. The adult emergence was 95.3 and 96.4% after being fed the eggs of two hosts, respectively. The male adult longevity was observed to be 4.2 and 4.5 days; whereas, that of the female 10.3 and 11.1 days, after rearing on two host eggs respectively. The female emerged from *P. interpunctella* eggs tend to live longer as compared to the female emerged from the *S. cerealella* eggs. Overall results manifest that there are no significant differences, among the biological parameters, that were observed in individuals reared upon two host eggs, respectively. Hoffmann *et al*. (2001), have evaluated the performance of parasitoid, *Trichogramma ostriniae* on the eggs of four factitious host, *Ostrinia nubilalis*, *Sitotroga cerealella*,

Trichoplusia ni and evaluated *S. cerealella* as an intermediate host for rearing of the parasitoid as compared to the other hosts and in our results, are nearly equal after rearing on both *S. cerealella* and *P. interpunctella*. Similarly Nathan *et al*. (2006) have evaluated the emergence and survival of adults of *Trichogramma chilonis*, by using host eggs *Corcyra cephalonica* and showed that besides *S. cerealella* rearing on other hosts can give desired results, as we have evaluated *S. cerealella* and *P. interpunctella* to be equally good for the rearing of *T. chilonis*.

5.13 Effect of different host eggs on quality of developmental parameters of *Chrysoperla carnea*

The average larval food consumption by *C. carnea* larvae in its all larval instars was observed as 811 and 792 eggs of *S. cerealella* and *P. interpunctella* respectively. Out of 25 larvae, 24 were survived after feeding upon the two host eggs. The larval life span was recorded to be 12.3 and 11.2 days, from the two host eggs, respectively. Pre-pupal period lasted for 4.2 and 4.1 days upon the two host eggs, respectively. Work related to our studies was carried by Nasreen *et al.*, 2004 and their reported results are in the line to present studies.

5.14 Evaluation of different releases methods of *Trichogramma chilonis* under field conditions

Field releases of parasitoids were comparatively evaluated by three methods.

5.14.1 Evaluation of releases of *Trichogramma chilonis* through micro-cages in cotton under field conditions

The results revealed that the parasitoids, *T. chilonis* confined in small micro-cages when released in cotton after 24 hours of the released time, parasitoid released from the cages was 62.3% from the total and gave 87.2% parasitism on the host eggs. After 48 and

72 hours, the releases were followed by 20.8 and 14.6% with a parasitism of 60.5 and 45.2%. However, a total of 94.7% releases, were completed from the micro-cages into the field gave 64.3% parasitism. Besides providing for the high rate of survival of parasitoids it protected the parasitoids from adverse environmental conditions. Present findings, on the parasitoids pupae in micro-cages are agree to the results reported by Chihrane and Lauge (1995) who have simulate high temperatures, 35 and 44^{o}C conditions in the field, when *Trichogramma brassicae* parasitoid were released in the form of white pupae (WP) and imago, ready to leave (IRL) against the European corn borer, *Ostrinia nubilalis* and evaluated that WP and IRL stages of *T. brassica* were susceptible to the heat shocks at 44^{o}C with a WP exposure, the loss of parasitization was 85.8%. Accordingly, it was concluded that IRLs methods, of releases proved most susceptible at high temperature as compared to the WPs.

5.14.2 Evaluation of releases *Trichogramma chilonis* through paper cards in cotton under field conditions

The parasitoids, *T. chilonis* releases in cotton field through the parasitoids pasted on paper cards, showed that after 24 hour of the release time, parasitoids emerged out from the eggs as 45.4% from the total and got 61.3% parasitism of the host eggs. After 48 and 72 hours, the releases were followed by 12.8 and 9.6% from the paper cards, having a parasitism of 43.9 and 27.1%, respectively and total of 67.9%, releases were accomplished. Our results agreed to the findings of Rejendran (1999) who have reported that emergence of *T. chilonis*, was influenced by the variation in temperature.

5.14.3 Evaluation of releases of *Trichogramma chilonis* through broad casting in cotton under field conditions

Releases of *T. chilonis* into the cotton field, with saw dust, showed 70.3% parasitism after 24 hours of the released time. After 48 and 72 hours of the releases, parasitism of 40.7 and 12.9% respectively. Whereas, a total of 51.9% parasitism was accomplished on host eggs into the field. Similar results, were also reported by Nordlund

et al. (1974) who have evaluated field application methods of *Heliothis zea* eggs and kairomones for *T. evanescens* and applied eggs to the plants having a pneumatic sprayer by using adhesive plantgard and reported that the pneumatic spray system, is very acceptable for the use of kairomones and releases/dispersal of parasitoid, eggs for experimental studies, in field conditions.

5.15 Evaluation of *Chrysoperla carnea* releases under natural field condition

Survival of field releases of predator was evaluated at egg and larval stage.

5.15.1 Evaluation of *Chrysoperla carnea* releases at egg stage

The results on the hatching of three days, eggs of *C. carnea*, from the single cage, installed on the leaves of plant, showed that out of 25 separately caged eggs, 16 were hatched inside the cages, with 64% hatching attained under natural field environment. Virtually no published data is available on such type of releases of *C. carnea* in field conditions.

5.15.2 Evaluation of 2nd instar larval releases of *Chrysoperla carnea*

Survival of *C. carnea* in the 2nd larval instar from the micro-cage installed on the leaves of plant, showed that out of 25 separate larvae, 23 survived and completed the 2nd instar and entered into the 3rd instar inside the cages with 92% larval survival, under natural field environments. It was evinced that the releases during larval instar, have more survival potential as compared to the releases in the egg form. The results reported by Butler and Hennebery (1988), who have observed the predation of *Chrysoperla carnea*, upon *Bemisia tabaci*, in the field conditions, and reported that the first instar larvae of *C. carnea*, consumed both eggs and larvae of *B. tabaci* at the same time; while, the second instar larvae consumed more eggs rapidly than the first instar larvae. So, the

presence of *C. carnea* larvae on cotton leaves inhibited the visit and oviposition, by *B. tabaci*, which supports our findings that the 2nd instar larvae, better survive in the field as compared to the egg releases are agreed to our results.

5.16 Parasitism and searching ability of *Trichogramma chilonis* on host eggs at different distances

The parasitism by the parasitoid, *T. chilonis* on host (*S. cerealella*) eggs, at 5, 10, 15, 20 and 25 m distances from the fixed distance of releases, from three plant portions *i.e*., upper, middle and lower have revealed, that parasitism gradually decreased as the distance increased. At 5 m distance from a fixed release point, parasitism was observed, after 24, 48 and 72 hours and was seen to be 63.6, 77.7 and 78.7%, respectively and this ranked to be the highest parasitism, as compared to other treatment, at various distances. Whereas, at 10 m distance, the parasitism on the host eggs was 54.0, 58.1 and 58.0; at 15 m distance, parasitism was recorded as 23.4, 28.7 and 29.1%. At a distance of 20 m, the parasitism was recorded as 20.4, 23.2 and 23.0% and at 25 m distance it was 14.3, 16.7 and 17.1% for 24, 48 and 72 hours respectively. It was inferred that parasitism significantly differed at various distances, as well as on temperatures, plant height and leaf area. The results reported by Stinner *et al*. (1974a) on longevity, fecundity and searching ability of *Trichogramma pretiosum* by rearing on eggs of different hosts, *Heliothis* and *Sitotroga cerealella* in fed cadged studies where the parasitoid survived for 54 hours, and 100% mortality was observed in all the parasitoids regardless of the rearing host are in the line with our studies.

Similarly, Stinner *et al*. (1974b) have reported that average parasitism on *Heliothis* eggs was in the range of 33-81% with 400 feet movement of the parasitoids in 2 days and here in our experiment the percent parasitism was also highest for 48 hrs (2 days) and the movement was, successfully up to 25 m in cotton crop. Saavedra *et al.* (1997) have carried out field experiments in the dispersal and parasitism of *Heliothis verescens* eggs, by the parasitoid, *Trichogramma pretiosum* and their result revealed that the parasitoids, released as pupae attained low parasitism as compared to one day old adult releases. Wang *et al.* (1997) have reported that releases of *T. ostriniae* in the sweet

corn, for the control of European corn borer to study the effects plant size, on leaves in upper, middle and lower portion of plants, within 5 to 35 meters from the point of parasitoid releases and observed that the percent egg parasitization decreased as the leaf area and distance increased; while, the eggs that were stapled on the middle and lower portion of plant, got higher parasitization in comparison to egg stapled on the upper portion, and more parasitism after 48 hrs (2 days) are agree to our results. Ahmad *et al*. (1998), reported the efficacy to parasitize the eggs of different cotton bollworms by *Trichogramma chilonis*, and evaluated that the parasitizing potential decreased as the age of host eggs increased under field conditions. QingWen *et al.* (1998) have reported effective dispersal distance, by *T. chilonis*, was in between 10 to 25 m in cotton field is agree to our results. Fournier and Boivin (2000); Ballal and Singh (2003) have reported the comparative dispersal of *Trichogramma evanescens* and *T. pretiosum*, in relation to the environmental conditions and results are in line to our studies. Hamed *et al*. (2004), have reported the percent parasitization at distances of 1-5 metre from fixed releasing sites and intensity of parasitization was more after 24 h as compared to the 48 h post release of parasitoids while we have got contradictory results, as more parasitism has seen after 48 hours; while, parasitism also differed at 5 metre distance. Gingras *et al*. (2008) have reported the effect of plant structure on the searching efficiency of *T. turkestanica* and his findings demonstrated that the structure of plants can modulate searching activities and oviposting behavior of the parasitoid for the host finding success and are agree to our results. Singh and Shenhmar (2008) have reported 8 and 10 m distance, after searching by two *Trichogramma chilonis* strains are also agree with present study.

5.17 Survival of *Trichogramma chilonis* under field conditions

Parasitism by the parasitoid, *T. chilonis* on host eggs under field conditions, during June, July, August, and September have much influenced by the prevailing field temperature as the mild temperature in September, have favored more parasitism of host eggs as compared to that in other months. Parasitism by the parasitoid, *T. chilonis* on host eggs under field conditions during June was recorded to be highest (73.9%) during the 3rd

week of June, when average maximum temperature was 33.7^{o}C. In this month, the lowest parasitism (56.5%) was observed during 2nd week when average temperature was 44.7^{o}C; while, 64.0 and 66.6% parasitism, was observed during the 1st and 4th weeks, respectively and which was between highest and lowest. During the month of July, the average cumulative parasitism was recorded to be 65.2%. Average parasitism, on the host eggs in the month of July, was recorded as 67.7% a bit more than that observed in June (68.6%). In August, the average cumulative parasitism was recorded as 66.7%. In September, the average parasitism, on host eggs was recorded to be highest (82.3%), during 1st week of September when average maximum temperature was 35.3^{o}C with mild minimum temperature of 25.5^{o}C that favored parasitism.

In our study the parasitism by the parasitoids decreased as the temperature increased is agree with the results reported by Biever (1972) that the rate of searching by female species of *Trichogramma* increased as the temperature increased from 20-35^{o}C and decreased at 40^{o}C and it also effected on the searching activity and thus the potential effectiveness of *Trichogramma*, in the field. Similarly, López and Morrison (1980) have also reported the effects of high temperature on the *Trichogramma pretiosum* released in cotton field at high temperature, and reported that the parasites inside the host eggs were susceptible at 37^{o}C, for a short period of time and reduced the mortality of parasites, which agrees to our results. The results reported by Thomson *et al*. (2001); Mansfield and Mills (2002) on the effect of heat hardening upon the egg parasitoid, *Trichogramma* and their acclimation in the field conditions survival time are in line to our results. Ahmad *et al.* (2003) conducted, field study in cotton crop for management of insect pests with, parasitoid as well as the predator and recorded low as 2.5% parasitism in early crop growing month increased gradually and attained its highest position of 70% in the month of October; whereas, we have observed 82.3% parasitism, in the month of September and hence, these results are in close contest to our results. Kalyebi *et al*. (2005) reported that the optimum temperature for parasitization was around 30^{o}C. Wang *et al.* (1997), have released *T. ostriniae*, from 5 to 35 meters distance, and observed that the percent egg parasitization was decreased as the leaf area and distance increased; while, eggs that were stapled on the middle and lower portion of the plant have got higher parasitization, and

high parasitization was also observed when more exposure was given to the host eggs for 2 days (48 hours) are agreed to our results as we have got more parasitism after 24 hours at 5 metre distance.

5.18 Survival of *Chrysoperla carnea* under field conditions

C. carnea survived under field conditions during the month of June, July, August and September, and shown a wide range of adaptability, in diversified temperatures in field environment. Throughout June, the collaborative survival was observed like 77.7%. In July, the highest (88.8%) survival was observed, during the 2nd and 3rd week of July, when the average maximum temperature was 36.7 and 35.6^{o}C, respectively. In this month, the lowest survival (83.3%) was recorded in 4th week when average temperature was 37.0^{o}C. In August, the highest (88.8%) survival was observed, during 3rd week, when average maximum temperature was 37.9^{o}C. In this month the lowest survival (83.3%) was recorded in the 1st week, when average temperature was 36.70^{o}C. Whereas, in September, the highest (97.2%), survival was observed during the 1st week when average maximum temperature was 35.3^{o}C. In this month the lowest survival (88.8%) was recorded in the 4th week when average temperature was 34.2^{o}C. Afzal and Khan (1978) studied the life history and feeding behavior of green lacewing, *Chrysoperla carnea*, in the laboratory conditions and evaluated its bio-control potential, against the pests. Our results are in the line to the results reported by Farkade *et al*. (1999), who measured 15-65% bio-control and among them *Chrysoperla* spp., shared about 7% for the control of sucking pest complex of crops and vegetables on the experimental sites. Michaud (2001); Ahmad *et al.* (2003) have evaluated green lacewing, *Chrysoperla* and observed 37.5% and 230 number of larvae of the predator respectively, that are in the line of our work.

5.19 Comparative evaluation of bio-control agents in management of cotton pests under field conditions

The comparative field evaluation of bio-control agents *i.e*., *T. chilonis* and *C. carnea* in different treatments are discussed as under.

5.19.1 Comparative evaluation of bio-control agents in management of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in cotton under field conditions

Infestation (%) of *H. armigera*, during the year 2007 was the lowest (4.5) during the 1st weeks of August and the highest (11.3) during the 1st week of September in bio-control treatment. In control the lowest (6.1) and highest (18.7) infestation, was observed during the 1st week of August and September, respectively. The percent reduction in the bio-control, in comparison to the control was in the range of 26.2 to 44.0%, the highest and lowest, during 1st week of August and 4th week of September, respectively. A bit lower infestation of *H. armigera* was recorded during the year 2008 in bio-control treatment, as compared to year the 2007. Due to high infestation, the percent reduction in bio-control, as compared to the control, was in the range of 16.6 to 42.6%, the lowest and highest during 4th week of July and 2nd week of September respectively. Here, it is clear that weekly releases of *T. chilonis* and *C. carnea*, suppressed the *H. armigera* infestation near to the economic threshold level in biological control treatments. Treacy *et al*. (1985) have reported the effectiveness of *C. rufilabris* and *T. Pretiosum* against *H. zea* in cotton and recorded that association of predator and parasitoid complex influences significantly the expression of host plant resistance in cotton to reduce plant damage. Our results are agrees to the results reported by Mclaren and Rye, (1983) by the release of *T. ivelae* for the control of *Heliothis*.

Similar results were attained by Verma and Shenhmar, 1988. Kabissa *et al.* (1995), who have studied the biology of *C. congrua* on *H. armigera* and *A. gossypii*, in laboratory conditions and reported the feeding potential of *C. congrua*, to consume *H. armigera* better to *M. desjardinsi* and it appeared to be a promising control measure against *H. armigera.* Romeis *et al.* (1999) have evaluate the parasitism ability of *Trichogramma* on egg of *H. armigera* in pigenopea and sorghum, in intercropped plants and reported that on pigeonpea plants and the parasitism level from 79 to 100% was recorded, on *H. armigera* eggs on plants of sorghum that agreed to our findings. Suh *et al*. (2000), have conducted field studies in two years of trial and got 67 to 83% and 25 to 55% parasitism on heliothine eggs in the experimental and control plots respectively in

year 1996; whereas, during 1997, parasitism level by *T. exiguum* ranged from 74 to 89% in treated plots; whereas, 18 to 69% in control plots, which is almost the similar to our results. Our results also are agree with the work reported by Rasool *et al*., 2002 who got 36.6% suppression of *H. armigera* by using *T. chilonis* as we have got 47.1%. Ahmad *et al*., 2003, reported that, augmentative releases of *T. chilonis* and *C. carnea*, suppressed the infestation of bollworm pests to sub-economic levels, as we have got in our results. Ballal and Singh (2003) have evaluated the effectiveness of three *Trichogramma* species, and reported 50.1% parasitism on eggs of *H. armigera* on sunflower plants was 47.1% as in our case.

5.19.2 Comparative evaluation of bio-control agents in management of *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in cotton under field conditions

The infestation (%) of *Earias vittella* during different weeks of July, August, September and October, 2007, the lowest (2.1) during the 3rd week of July and the highest (18.0%) during the 2nd week of September. When it was compared with the infestation recorded in the control, the lowest (2.7) and highest (31.4) infestation was observed during the 3rd week of July and 2nd week of September respectively. Percent reduction in the bio-control treatment in comparison to the control and it seems to be in the range of 22.2 and 45.5 which was the highest and lowest during 3rd week of July and 1st week of October, respectively. Trend of *E. vittella* infestation was recorded during year 2008 was higher as compared to year 2007. In the bio-control treatment, the lowest (6.9) infestation of *E. vittella* was observed during the 3rd week of July and the highest (16.2) during the 2nd week of July. In the control, the lowest (9.0) and highest (28.9) infestations was observed during 3rd week of July and 2nd week of September, respectively. From our results, it was clear that the integration of *T. chilonis and C. carnea*, enhanced the suppression of *E. vittella* and maintained the pest population under sub-economic levels, which are in the line with the work reported by Pawar (1991) who concluded experiments on the control of insect pests of cotton, by the use of the predator *Chrysoperla* spp. releases in fields and reported an effective control of the pests, when the rate of releases were one lakh per hectare, at fortnight intervals. Similarly, Ahmad *et al*. (1998), reported

effectiveness of *Trichogramma chilonis* upon the eggs of different cotton bollworms and evaluated that the parasitizing potential and gradually decreased as the age of host eggs increased under field conditions agreed to our results. Ahmad *et al.* (2003), have reported that the population of parasitoid was recorded to be 2.5% in the early crop growing month and it increased gradually to its highest place of 70.0% in the month of October. Similarly our observations 46.9% reduction in September also supports the effectiveness of bio-control agents.

5.19.3 Comparative evaluation of bio-control agents in management of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton under field conditions

The population (nos./leaf) of *Bemisia tabaci*, in bio-treatments was the lowest (7.3) during the 1st week of July and the highest (10.2) during 4th week of July. In the control treatment, the lowest (9.1) and highest (14.3) population were observed during the 1st week of July and 3rd week of August, respectively. The percent reduction in the bio-control treatment, in comparison to the control was in the range of 17.6 to 39.8% during the 1st week of July and 3rd week of September respectively. During the year 2008, in bio-control treatment, population was recorded as the highest (12.3) and the lowest (6.3 nos./leaf) during 3rd week of July and 4th week of September respectively. The percent reduction in bio-control treatment in comparison to control it was evinced that highest (36.2) and lowest (25.8) during 1st and 2nd week of July respectively.

From the above results, it was inferred that the integration of *T. chilonis* and *C. carnea* enhanced the suppression of *B. tabaci* and maintained the pest population under a sub-economic level and this agreed to the results reported by Butler and Hennebery (1988), who have got predation of *Chrysoperla carnea* upon *B. tabaci* in the field conditions and observed that larvae of *C. carnea* has consumed both eggs and larvae of *B. tabaci* at the same time to give an effective control of cotton pests. Similarly Pawar (1991); Breene *et al*. (1992) concluded experiments on control of insect pests of cotton by the use of predator *Chrysoperla* spp. releases in field and found that the effective

controls of pests were attained at the fortnightly intervals. The results reported by Zia *et al.* (2008), on the effectiveness of *C. carnea*, against *B. tabaci* in six advance genotypes of cotton have obtained the highest reduction of whitefly population (57.35%), during the 4th week of August; while the lowest population (22.56%) was recorded during the 2nd week of July in MNH-552 and these are agree with our results.

5.19.4 Comparative evaluation of bio-control agents in management of *Thrips tabaci* (Linderman) (Thysanoptera: Thripidae) in cotton under field conditions

The population (nos./leaf) of *Thrips tabaci* in the year 2007, in the bio-treatments was recorded, as the lowest (7.1 insects/leaf) during the 1st week of July and the highest (13.4) in the 3rd week of August; whereas, in control, where the lowest (9.4) and highest (18.2) population was observed during the 1st and 2nd week of July respectively. The percent reduction in the bio-control treatments in comparison to those of the control was in the range of 24.4 to 32.7, as being the highest and lowest, during 1st week of July and August respectively. In the insecticide treated plots, it ranged from 3.7 to 4.3 as being the highest and lowest during different weeks of observed months respectively. The population of *T. tabaci* was lower in year 2008 in bio-control treatments and the highest (12.7) and lowest (5.4) during the different weeks of observations. Percent reduction in the bio-control treatments in comparison to the control, it was evinced to be the highest (35.6) and lowest (16.1) during 2nd week of July and 3rd week of August respectively. It was concluded from the present study that integration of *T. chilonis and C. carnea* enhanced the suppression of *T. tabaci* and maintained the pest population under sub-economic level are agree to the work by Chang, 1998 who has reported the feeding potential of *Chrysoperla* upon thrips.

5.19.5 Comparative evaluation of bio-control agents in management of *Aphis gossypii* Glover (Homoptera: Aphididae) in cotton under field conditions

Population (nos./leaf) of *A. gossypii*, during the year 2007, in bio-control treatment was recorded to be the lowest (8.3) during the 3rd week of September, while the highest (11.1), during the 4th week of September. In the control treatment, the lowest (13.4) and highest (20.4) population was observed during the 3rd and 4th week of September respectively. The percent reduction in bio-control treatment in comparison to the control was in the range of 45.2 to 42.2% as being the highest and lowest, during the 1st and 2nd week of October, respectively. Population trend of *A. gossypii* year 2008, in bio-control treatment, the population was the highest (11.4) and lowest (9.7) during the 1st week of October and 3rd week of September respectively. In control treatment the highest (20.3) and lowest (16.2) populations were observed during 3rd week of September. The percent reduction in the bio-control treatments in comparison to control, the highest (44.6%) and the lowest (40.1%) was observed during 2nd week of October and 3rd week of September respectively.

Kabissa *et al.* (1995) and Kabissa *et al.* (1996) have studied the biology *C. congrua* on *H. armigera* and *A. gossypii* and reported the feeding potential of *C. congrua*, to consume *H. armigera*, better than that of *M. desjardinsi* and appeared to give a promising control against *H. armigera*. Zaki *et al.* (1999) who have released two predators, *C. carnea* and *Coccinella undecimpunctata* both, in the natural field and in green house conditions, against *A. gossypii* and *B. tabaci* and reported 99.97% reduction by using the double doses, in *A. gossypii* in okra vegetation, in a span of two weeks are in the line to our findings.Chen and Liu (2001) have studied the relative consumption of three aphid species, by the lacewing, *Chrysoperla rufilabris* and reported the ability of lacewing feeding and development processes, on aphid preys to be critical to sustained existence in vegetable ecosystem are in the in present study. Work of the previous investigators as, Su, *et al.* (2004); Gao *et al.* (2007) who have reported the consumption of *A. gossypii* by *C. carnea* are in the confirmatory of present work.

SUMMARY

The summarized results of the present study, on the rearing of factitious hosts, *Sitotroga cerealella* (Olivier), the impact of radiation on the prolongation of the shelf life of host eggs, storage of parasitoid, *Trichogramma chilonis* (Ishii) and predator, *Chrysoperla carnea* (Stephens) at low temperatures, the searching ability of parasitoids in field, evaluation of the field releases methods, field adaptations of the predator and parasitoid as well as on the effectiveness of predator and parasitoid against their target pests in the cotton field are presented in this chapter.

Work on development and evaluation of *S. cerealella* on its naturally available cereal foods, like maize, barley, sorghum and wheat showed that the rearing of this host was as equally good on sorghum as on wheat grains; where, the fecundity of adults was observed statistically at par. Whenever the rearing of healthy and heavy sized adults is required, the rearing in maize provides good results but with reduced fecundity and an enlarged life span. Whereas, in free choice rearing situation, *S. cerealella* preferred wheat grains more followed by barley and sorghum as against maize which was preferred least.

The parasitism by *T. chilonis* on the gamma irradiated eggs of *S. cerealella* has shown significant differences among different doses of egg exposure, a dose of 50 Gy prolonged the shelf life of host eggs for 7 days. The combine effect of radiation and low temperatures on the storage of host eggs at 6, 8, 10, 12, 14 and 16^{o}C for 5-90 days have showed non-significant differences and their combined effect was similar to that of the individual effect on storage, after the results were obtained on the fitness parameters of the parasitoids *i.e.*, percent emergence, percent parasitism and adult longevity in comparison to the control.

Storage of host eggs, *S. cerealella* at 6^{o} and 8^{o}C resulted in an effective and highest preference by the parasitoids *T. chilonis* for 5 to 50 days and a relatively more suitable temperature was 6^{o}C for both short and long term storage of the host eggs. However, eggs stored at 10, 12, 14, and 16^{o}C temperature proved good only for short term storage duration. Storage of the parasitoid, *T. chilonis* at low temperatures showed that 10^{o}C proved to be an effective storage temperature, where highest percent emergence, percent parasitism and adult longevity were recorded. This temperature suited both for a long and short term storage that ensures the availability of parasitoids in insectaries for research and field releases.

The effect of different adult food concentrations, showed that the male and female adult longevity were best after being fed on 10% honey solution which is on one hand at par with that fed at 5% honey solution. In general, a decreasing trend of the biological parameters was attained as the concentration of honey solution increased. The favorable rearing temperature for *T. chilonis* was found to be 28^{o}C. This rearing temperature not only gave a better emergence but also the better developmental period, parasitism and adult longevity of *T. chilonis* emerged from host eggs as compared to those reared at other temperatures.

The consequence of storage duration and low temperatures, on the developmental traits of the eggs of predator, *C. carnea* accomplished that the storage of eggs at 8^{o}C can give storage for 20 days, with minimum detrimental effects to developing embryo inside the egg for short term storage and for 40 days for long term storage. While the studies on the effect of storage duration and temperature on the reproductive traits at the adult stage of *C. carnea*, at different temperature conditions have shown that although the adults survived, after storage at 6 and 8^{o}C temperature conditions yet the reproductive traits were comparatively better at 10^{o}C, for up to 90 days; whenever, needed to conserve susceptible or resistant strains in laboratories for experimentation or field releases either in controlled or natural conditions. The impact of different rearing temperatures on the developmental and reproductive parameters of *C. carnea* in our studies showed that the rearing at 31 and 35^{o}C had no positive effect on the developmental parameters of *C.*

carnea. However, when rapid development is desired then 31^{o}C may be useful. In view of reproductive parameters of *C. carnea* a range of temperature from 20 to 31^{o}C is quite suitable and 25^{o}C proved to be the best.

Consequences of different host eggs on the quality of developmental traits of the parasitoid, *T. chilonis*, have shown that there were no significant differences among the biological parameters that were observed after rearing *T. chilonis* on eggs of *Plodia interpunctella* and *S. cerealella*. Effect of different host eggs on the quality of developmental traits of *C. carnea* inferred that rearing on *S. cerealella*, in comparison to *P. interpunctella*, have no differences and both are equally suitable having good results, for rearing.

Out of the three methods evaluated for releases of the parasitoids, *T. chilonis* in the field, the one that confined to small cages exhibited 94.7% releases completion and produced 64.3% parasitism that was considerably higher that the other two methods in use *i.e.*, through paper cards and broadcast. This method has the further advantage to not only increase the releases and parasitism but also protected the parasitoids from adverse environmental conditions. Assessment of *Chrysoperla carnea*, releases when compared, showed that the releases of larvae were having more survival as compared to the releases in egg form. Subsequently, in order to get more reliable field releases predator should be released in the larval form.

Parasitism by *T. chilonis* of host eggs at different distances, had shown that the searching ability and parasitism were gradually decreased as the distance increased and in the field conditions, *T. chilonis* had traveled a distance upto 25 m. Survival of *T. chilonis*, in field conditions showed that parasitism by parasitoids on host eggs under field conditions during June, July, August, and September was much influenced by the prevailing field temperature and the mild temperature in September had favored the parasitism of host eggs more as compared to the other months. Survival of *C. carneaI* in the field conditions during the month of June, July, August, and September had shown a wide range of adaptability of this predator in diversified field temperature conditions.

Comparative evaluation of the bio-control agents for two years studies in the management of *Helicoverpa armigera*, *Earias vittella*, *Bemisia tabaci*, *Thrips tabaci* and *Aphis gossypii* in cotton under natural field conditions have shown that integration of *T. chilonis* and *C. carnea* enhanced the suppression of these pests as compared to the control treatment.

From the results of the present studies, it is concluded that the improved rearing of factitious host, parasitoid (*T. chilonis*) and predator (*C. carnea*), their storage, field releases techniques, field adaptations of these parasitoid and predator have the potential to combat effectively against the pests of cotton under field conditions.

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APPENDICES

Appendix 1a. Life span (days) of *S. cerealella* adults.

Cereals	R_1	R_2	R_3	Mean
Maize	34	27	29	30.0
Barley	27	25	28	26.7
Sorghum	29	27	32	29.3
Wheat	27	29	28	28.0

Appendix 1b. Emergence (%) of *S. cerealella*, adults.

Cereals	R_1	R_2	R_3	Mean
Maize	132	127	118	125.7
Barley	152	143	150	148.3
Sorghum	160	164	151	158.3
Wheat	151	160	169	160.0

Appendix 1c. Size (mg/500) of *eggs* of *S. cerealella*.

Cereals	R_1	R_2	R_3	Mean
Maize	12.3	15.4	14.9	14.2
Barley	12.4	14.4	11.3	12.7
Sorghum	9.7	10.2	8.6	9.5
Wheat	13.0	14.7	12.5	13.4

Appendix 1d. Size of adults (mg/10) of *S. cerealella*.

Cereals	R_1	R_2	R_3	Mean
Maize	20.2	19.2	16.1	18.5
Barley	10.5	9.0	11.4	10.3
Sorghum	8.6	7.9	10.2	8.9
Wheat	11.3	10.9	13.2	11.8

Appendix 1e. Fecundity (eggs/♀) of female of *S. cerealella*.

Cereals	R_1	R_2	R_3	Mean
Maize	90	82	84	85.3
Barley	117	112	118	115.7
Sorghum	103	92	100	98.3
Wheat	107	108	115	110.0

Appendix 2a. Parasitism (%) by *T. chilonis* on the 1 day old irradiated, host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
Control	98.5	99.0	97.4	98.3
5	88.3	91.4	94.2	91.3
10	91.6	95.7	91.1	92.8
20	97.2	95.3	94.3	95.6
30	87.4	91.3	89.5	89.4
40	82.7	89.5	90.4	87.5
50	86.7	83.9	91.3	87.3
75	85.5	86.4	88.1	86.7
100	84.1	86.4	82.5	84.3
125	82.0	84.7	85.9	84.2
150	85.5	84.5	82.1	84.0
200	75.7	77.9	79.5	77.7
300	70.9	75.8	69.4	72.0
400	65.4	72.9	73.5	70.6
500	70.6	72.4	68.1	70.4
600	66.0	62.4	59.9	62.8

Appendix 2b. Parasitism (%) by *T. chilonis* on the 2 day, old irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
Control	94.9	87.6	88.1	90.2
5	85.8	90.3	91.4	89.2
10	88.3	86.1	89.7	88.0
20	86.4	89.4	84.7	86.8
30	82.3	85.9	89.5	85.9
40	80.3	78.9	83.6	80.9
50	81.3	87.0	78.9	82.4
75	79.7	78.8	80.5	79.7
100	77.8	79.8	76.8	78.1
125	76.8	75.4	74.2	75.5
150	72.5	76.8	75.3	74.9
200	57.8	55.7	52.7	55.4
300	44.5	42.7	48.6	45.3
400	41.8	42.6	45.1	43.2
500	40.7	43.8	45.7	43.4
600	42.8	43.7	38.9	41.8

Appendix 2c. Parasitism (%) by *T. chilonis* on the 3 day old irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
Control	74.5	80.5	71.8	75.6
5	45.3	40.9	42.8	43.0
10	45.8	40.9	42.7	43.1
20	38.9	40.7	41.7	40.4
30	81.5	80.9	82.4	81.1
40	82.5	78.8	81.9	80.9
50	82.3	79.9	81.3	81.3
75	71.9	70.5	69.8	70.7
100	65.3	68.7	69.1	67.7
125	45.2	40.3	45.8	43.8
150	36.9	45.8	44.6	42.4
200	0	0	0	0.0
300	0	0	0	0.0
400	0	0	0	0.0
500	0	0	0	0.0
600	0	0	0	0.0

Appendix 2d. Parasitism (%) by *T. chilonis* on the 4 day old irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
5	43.0	42.8	44.9	43.0
10	42.6	39.6	41.8	41.1
20	39.1	41.6	40.2	40.4
30	79.8	82.4	81.3	80.0
40	81.7	79.8	80.4	80.9
50	79.6	80.9	82.4	81.1
75	50.8	52.4	51.6	51.6
100	47.9	46.8	45.8	46.8
125	0	0	0	0.0
150	0	0	0	0.0
200	0	0	0	0.0
300	0	0	0	0.0
400	0	0	0	0.0
500	0	0	0	0.0
600	0	0	0	0.0

Appendix 2e. Parasitism (%) by *T. chilonis* on the 5 day old, irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
5	39.3	40.9	42.8	41.4
10	41.8	40.9	42.7	41.3
20	38.9	40.7	41.7	40.3
30	80.5	81.9	78.4	79.6
40	81.5	78.8	81.9	80.6
50	80.3	79.9	82.4	80.7
75	0	0	0	0.0
100	0	0	0	0.0
125	0	0	0	0.0
150	0	0	0	0.0
200	0	0	0	0.0
300	0	0	0	0.0
400	0	0	0	0.0
500	0	0	0	0.0
600	0	0	0	0.0

Appendix 2f. Parasitism (%) by *T. chilonis* on the 6 day old, irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
5	39.8	38.2	40.2	39.4
10	36.8	38.6	39.7	38.4
20	42.3	38.4	41.2	40.6
30	59.2	58.4	55.8	57.5
40	52.7	53.8	50.9	52.5
50	57.4	56.3	59.8	58.1
75	0	0	0	0.0
100	0	0	0	0.0
125	0	0	0	0.0
150	0	0	0	0.0
200	0	0	0	0.0
300	0	0	0	0.0
400	0	0	0	0.0
500	0	0	0	0.0
600	0	0	0	0.0

Appendix 2g. Parasitism (%) by *T. chilonis* on the 7 day old, irradiated host eggs.

Dose (Gy)	R_1	R_2	R_3	Mean
5	0	0	0	0.0
10	0	0	0	0.0
20	38.5	36.7	35.9	37.0
30	50.4	48.7	46.9	48.7
40	46.8	45.5	44.1	45.5
50	58.3	56.4	52.7	55.8
75	0	0	0	0.0
100	0	0	0	0.0
125	0	0	0	0.0
150	0	0	0	0.0
200	0	0	0	0.0
300	0	0	0	0.0
400	0	0	0	0.0
500	0	0	0	0.0
600	0	0	0	0.0

Appendix 3a. Emergence (%) of *T. chilonis* from host eggs, stored for 5 days.

Temp.	R_1	R_2	R_3	Mean
6	93.8	85.4	92.0	90.4
8	90.1	86.3	80.7	85.7
10	81.2	84.3	81.4	82.3
12	63.9	74.4	72.3	70.2
14	75.9	69.9	65.4	70.4
16	55.8	63.7	61.4	60.3
Control	98.2	99.0	94.4	97.2

Appendix 3b. Emergence (%) of *T. chilonis* from host eggs, stored for 10 days.

Temp.	R_1	R_2	R_3	Mean
6	93.7	88.0	86.2	89.3
8	80.1	82.7	78.4	80.4
10	69.3	75.9	71.4	72.2
12	60.0	58.5	62.7	60.4
14	47.1	53.8	49.1	50.0
16	35.6	41.2	43.8	40.2

Appendix 3c. Emergence (%) of *T. chilonis* from host eggs, stored for 15 days.

Temp.	R_1	R_2	R_3	Mean
6	80.9	77.1	82.9	80.3
8	74.3	78.9	75.4	76.2
10	51.9	53.5	44.6	50.0
12	40.4	45.2	41.6	42.4
14	46.1	38.4	36.1	40.2
16	34.3	33.7	38.2	35.4

Appendix 3d. Emergence (%) of *T. chilonis* from host eggs, stored for 20 days.

Temp.	R_1	R_2	R_3	Mean
6	80.8	78.8	75.0	78.2
8	71.8	73.1	66.3	70.4
10	51.4	44.9	51.3	49.2
12	51.2	43.2	45.1	46.5
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 3e. Emergence (%) of *T. chilonis* from host eggs, stored for 25 days.

Temp.	R_1	R_2	R_3	Mean
6	74.6	78.9	72.1	75.2
8	55.7	52.4	56.9	55.0
10	31.2	38.8	36.2	35.4
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 3f. Emergence (%) of *T. chilonis* from host eggs, stored for 30 days.

Temp.	R_1	R_2	R_3	Mean
6	66.9	61.7	58.6	62.4
8	52.6	51.6	48.2	50.8
10	41.6	43.9	38.4	41.3
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0

Appendix 3g. Emergence (%) of *T. chilonis* from host eggs, stored for 40 days.

Temp.	R_1	R_2	R_3	Mean
6	49.3	51.9	46.7	49.3
8	42.0	47.8	45.2	45.0
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 3h. Emergence (%) of *T. chilonis* from host eggs, stored for 50 days.

Temp.	R_1	R_2	R_3	Mean
6	28.0	31.6	33.1	30.9
8	23.6	28.9	24.6	25.7
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 4a. Parasitism (%) by *T. chilonis* on host eggs, stored for 5 days.

Temp.	R_1	R_2	R_3	Mean
6	90.8	94.7	91.4	92.3
8	80.3	85.6	81.3	82.4
10	82.4	78.9	79.6	80.3
12	74.2	78.3	73.1	75.2
14	70.7	65.4	72.1	69.4
16	66.8	65.2	63.9	65.3
Control	97.6	94.2	98.7	96.8

Appendix 4b. Parasitism (%) by *T. chilonis* on host eggs, stored for 10 days.

Temp.	R_1	R_2	R_3	Mean
6	88.4	92.4	89.9	90.2
8	75.3	78.2	79.4	77.6
10	55.3	54.9	58.4	56.2
12	42.3	40.2	49.8	44.1
14	25.3	32.6	24.4	27.4
16	18.4	15.3	17.0	16.9

Appendix 4c. Parasitism (%) by *T. chilonis* on host eggs, stored for 15 days.

Temp.	R_1	R_2	R_3	Mean
6	84.8	86.9	89.4	87.0
8	70.9	71.8	65.7	69.5
10	45.4	48.9	44.3	46.2
12	35.3	39.4	34.5	36.4
14	20.4	18.9	24.6	21.3
16	16.3	15.1	12.7	14.7

Appendix 4d. Parasitism (%) by *T. chilonis* on host eggs, stored for 20 days.

Temp.	R_1	R_2	R_3	Mean
6	77.3	76.2	79.5	77.7
8	66.3	68.1	69.0	67.8
10	35.4	38.2	38.0	37.2
12	22.4	24.7	23.4	23.5
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 4e. Parasitism (%) by *T. chilonis* on host eggs, stored for 25 days.

Temp.	R_1	R_2	R_3	Mean
6	69.9	75.9	65.7	70.5
8	60.4	58.9	69.4	62.9
10	31.4	32.7	33.1	32.4
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 4f. Parasitism (%) by *T. chilonis* on host eggs, stored for 30 days.

Temp.	R_1	R_2	R_3	Mean
6	52.4	49.7	50.6	50.9
8	38.9	33.2	33.8	35.3
10	14.3	10.0	12.9	12.4
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 4g. Parasitism (%) by *T. chilonis* on host eggs, stored for 40 days.

Temp.	R_1	R_2	R_3	Mean
6	40.4	38.0	39.5	39.3
8	31.7	25.8	33.7	30.4
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 4h. Parasitism (%) by *T. chilonis* on host eggs, stored for 50 days.

Temp.	R_1	R_2	R_3	Mean
6	25.7	23.8	25.2	24.9
8	16.5	15.7	20.0	17.4
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 5a. Adult longevity (days) of *T. chilonis* from 5 day, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	12	12	13	12.3
8	11	10	11	10.7
10	11	10	11	10.7
12	12	13	13	12.7
14	12	14	13	13.0
16	13	14	14	13.7
Control	15	16	15	15.3

Appendix 5b. Adult longevity (days) of *T. chilonis* from 10 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	12	12	11	11.7
8	11	11	12	11.3
10	11	10	10	10.3
12	10	11	11	10.7
14	11	11	11	11.0
16	10	11	11	10.7

Appendix 5c. Adult longevity (days) of *T. chilonis* from 15 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	7	8	8	7.7
8	8	9	9	8.7
10	9	8	8	8.3
12	10	10	9	9.7
14	10	11	10	10.3
16	7	6	8	7.0

Appendix 5d. Adult longevity (days) of *T. chilonis* from 20 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	7	8	8	7.7
8	7	7	8	7.3
10	7	6	7	6.7
12	8	9	9	8.7
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 5e. Adult longevity (days) of *T. chilonis* from 25 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	8	7	7	7.3
8	9	8	8	8.3
10	9	8	7	8.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 5f. Adult longevity (days), of *T. chilonis* from 30 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	8	6	6	6.7
8	7	8	7	7.3
10	6	7	6	6.3
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 5g. Adult longevity (days), of *T. chilonis* from 40 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	7	6	6	6.3
8	7	7	6	6.7
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 5h. Adult longevity (days), of *T. chilonis* from 50 days, stored host eggs.

Temp.	R_1	R_2	R_3	Mean
6	6	6	5	5.7
8	4	5	4	4.3
10	0	0	0	0.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 6a. Parasitism (%), by *T. chilonis* after feed on different concentrations of honey.

Conc. (%)	R_1	R_2	R_3	Mean
5	90.6	94.3	94.1	93.0
10	95.7	92.2	95.9	94.6
15	87.6	85.5	87.3	86.8
20	80.8	84.3	81.2	82.1
25	76.3	77.4	75.4	76.4
Control	74.8	73	69.4	72.4

Appendix 6b. Male adult longevity (days), of *T. chilonis* at different concentration of honey.

Conc. (%)	R_1	R_2	R_3	Mean
5	5.7	5.1	6.6	5.8
10	6.3	5.9	5.8	6.0
15	4.0	3.7	5.8	4.5
20	3.6	3.2	4.3	3.7
25	2.5	2.9	3.0	2.8
Control	1.6	1.5	2.3	1.8

Appendix 6c. Female adult longevity (days), of *T. chilonis* at different concentration of honey.

Conc. (%)	R_1	R_2	R_3	Mean
5	8.0	6.8	7.3	7.4
10	8.5	7.1	7.5	7.7
15	6.3	5.9	6.0	6.1
20	6.2	4.0	5.0	5.1
25	4.7	3.8	4.0	4.2
Control	2.5	2.7	2.5	2.6

Appendix 7a. Emergence (%) of *T. chilonis*, at different temperatures after 5 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	65.3	66.7	62.3	64.8
8	92.4	94.6	95.3	94.1
10	95.3	96.4	98.2	96.6
12	90.3	93.5	88.5	90.8
14	87.4	89.8	92.5	89.9
16	88.3	87.3	90.1	88.6
Control	96.2	93.8	93.2	94.4

Appendix 7b. Emergence (%) of *T. chilonis*, at different temperatures after 10 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	50.1	44.7	52.9	49.2
8	93.5	94.0	87.5	91.7
10	94.3	92.4	96.3	94.3
12	89.6	85.3	90.4	88.4
14	88.5	91.0	86.4	88.6
16	86.2	90.3	83.9	86.8

Appendix 7c. Emergence (%) of *T. chilonis*, at different temperatures after 15 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	44.2	48.6	42.8	45.2
8	90.3	91.3	87.6	89.7
10	93.8	90.3	91.3	91.8
12	85.7	88.6	80.3	84.9
14	87.6	79.3	85.3	84.1
16	88.9	91.3	85.6	88.6

Appendix 7d. Emergence (%) of *T. chilonis*, at different temperatures after 20 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	25.6	24.3	20.6	23.5
8	89.3	91.2	84.3	88.2
10	90.7	91.3	84.2	88.7
12	84.9	85.3	87.8	86.0
14	86.3	88.8	82.4	85.5
16	87.5	90.1	86	87.8

Appendix 7e. Emergence (%) of *T. chilonis*, at different temperatures after 25 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	5.3	8.9	10.0	8.1
8	87.2	85.0	90.3	87.5
10	88.3	82.4	83.9	84.9
12	80.2	76.3	84.2	80.2
14	84.9	82.3	84.0	83.7
16	85.3	82.1	87.7	85.9

Appendix 7f. Emergence (%) of *T. chilonis*, at different temperatures after 30 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	82.3	84.1	81.3	82.6
10	84.4	86.2	86.0	85.5
12	78.3	79.4	80.3	79.3
14	80.2	81.6	79.2	80.3
16	0	0	0	0.0

Appendix 7g. Emergence (%) of *T. chilonis*, at different temperatures after 40 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	79.1	76.2	80.7	78.7
10	80.2	81.3	79.9	80.5
12	76.8	78.2	76.1	77.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 7h. Emergence (%) of *T. chilonis*, at different temperatures after 50 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	76.3	75.2	81.4	77.6
10	78.4	80.3	77.9	78.8
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 7i. Emergence (%) of *T. chilonis*, at different temperatures after 60 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	75.2	72.9	70.8	72.9
10	76.4	75.9	77.6	76.6
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 7j. Emergence (%) of *T. chilonis*, at different temperatures after 70 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	65.2	60.3	61.9	62.5
10	71.3	70.9	69.7	70.6
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 7k. Emergence (%) of *T. chilonis*, at different temperatures after 80 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	45.4	49.3	48.2	47.6
10	49.2	44.3	42.2	45.2
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 7l. Emergence (%) of *T. chilonis*, at different temperatures after 90 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	20.3	20.1	22.6	21.0
10	25.6	22.9	20.1	22.8
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8a. Parasitism (%), by *T. chilonis* at different temperatures after 5 days of storage

Temp.	R_1	R_2	R_3	Mean
6	92.4	90.1	94.7	92.2
8	96.4	97.2	95.3	96.3
10	97.3	96.1	98.9	97.4
12	95.3	94.2	96.0	95.1
14	95.2	96.1	94.4	95.2
16	93.1	92.6	91.9	92.5
Control	98.1	96.9	98.4	97.8

Appendix 8b. Parasitism (%), by *T. chilonis* at different temperatures after 10 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	91.8	90.2	92.4	91.5
8	95.7	96.3	95.2	95.7
10	96.3	97.4	95.3	96.3
12	94.2	93.7	95.0	94.3
14	93.4	94.2	90.3	92.6
16	92.9	91.3	88.1	90.7

Appendix 8c. Parasitism (%), by *T. chilonis* at different temperatures after 15 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	82.3	82	83.1	82.4
8	93.2	90.6	94.2	92.6
10	94.5	90.0	91.4	91.9
12	90.3	92.8	91.3	91.4
14	88.8	90.2	91.0	90.0
16	85.3	87.3	80.3	84.1

Appendix 8d. Parasitism (%), by *T. chilonis* at different temperatures after 20 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	80.3	81.4	79.3	80.3
8	91.8	90.0	92.3	91.4
10	92.3	94.4	90.3	92.3
12	90.4	91.7	88.4	90.2
14	85.9	84.3	86.1	85.4
16	80.6	86.0	82.1	82.9

Appendix 8e. Parasitism (%), by *T. chilonis* at different temperatures after 25 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	50.0	49.3	46.2	48.5
8	89.3	90.4	86.3	88.6
10	90.7	91.7	92.3	91.5
12	87.9	86.3	85.0	86.4
14	83.4	82.2	81.3	82.3
16	80.3	81.4	79	80.2

Appendix 8f. Parasitism (%), by *T. chilonis* at different temperatures after 30 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	80.3	81.0	79.3	80.2
10	88.4	89.6	87.1	88.4
12	82.4	81.2	79.7	81.1
14	80.6	79.3	81.8	80.6
16	0	0	0	0.0

Appendix 8g. Parasitism (%), by *T. chilonis* at different temperatures after 40 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	78.3	79.1	76.9	78.1
10	84.0	82.7	85.6	84.1
12	71.2	70.0	72.6	71.2
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8h. Parasitism (%), by *T. chilonis* at different temperatures after 50 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	75.3	74.6	72.1	74.0
10	74.2	72.9	70.6	72.5
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8i. Parasitism (%), by *T. chilonis* at different temperatures after 60 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	74.3	72.0	71.9	72.7
10	72.8	76.6	74.3	74.5
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8j. Parasitism (%), by *T. chilonis* at different temperatures after 70 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	70.6	70.0	67.3	69.3
10	71.5	72.7	73.6	72.6
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8k. Parasitism (%), by *T. chilonis* at different temperatures after 80 days of storage.

Temp.	R1	R2	R3	Mean
6	0	0	0	0.0
8	60.4	61.3	57.3	59.7
10	65.3	64.2	60.9	63.4
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 8l. Parasitism (%), by *T. chilonis* at different temperatures after 90 days of storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	35.6	39.3	41.4	38.8
10	50.3	40.3	36.2	42.3
12		0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9a. Adult longevity (days) of *T. chilonis* at different temperatures after 5 days storage.

Temp.	R_1	R_2	R_3	Mean
6	6	6	5	5.7
8	6	7	6	5.7
10	5	57	6	5.3
12	5	4	5	4.7
14	5	5	4	4.7
16	4	3	5	4.0
Control	6	5	5	5.0

Appendix 9b. Adult longevity (days) of *T. chilonis* at different temperatures, after 10 days storage.

Temp.	R_1	R_2	R_3	Mean
6	5	5	6	5.3
8	7	6	6	6.3
10	6	6	6	6.3
12	5	4	4	4.3
14	4	5	5	4.6
16	5	4	5	4.6

Appendix 9c. Adult longevity (days) of *T. chilonis* at different temperatures, after 15 days storage.

Temp.	R_1	R_2	R_3	Mean
6	6	6	6	6.0
8	6	7	6	6.3
10	6	6	6	6.0
12	5	6	4	5.0
14	6	6	6	6.0
16	5	5	4	5.0

Appendix 9d. Adult longevity (days) of *T. chilonis* at different temperatures, after 20 days storage.

Temp.	R_1	R_2	R_3	Mean
6	6	6	5	5.6
8	5	6	6	5.6
10	6	5	5	5.3
12	5	4	4	4.3
14	5	4	5	4.6
16	4	4	5	4.3

Appendix 9e. Adult longevity (days) of *T. chilonis* at different temperatures, after 25 days storage.

Temp.	R_1	R_2	R_3	Mean
6	5	6	5	5.3
8	6	7	6	6.3
10	6	5	6	5.6
12	6	5	6	5.6
14	6	5	5	5.3
16	5	5	4	4.6

Appendix 9f. Adult longevity (days) of *T. chilonis* at different temperatures, after 30 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	5	5	6	5.3
10	5	6	6	5.6
12	4	5	5	4.6
14	4	5	4	4.3
16	0	0	0	0.0

Appendix 9g. Adult longevity (days) of *T. chilonis* at different temperatures, after 40 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	5	5	4	4.6
10	4	4	3	3.6
12	4	4	3	3.6
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9h. Adult longevity (days) of *T. chilonis* at different temperatures, after 50 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	4	3	3	3.3
10	4	4	3	3.6
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9i. Adult longevity (days) of *T. chilonis* at different temperatures, after 60 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	4	4	3	3.6
10	4	3	3	3.3
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9j. Adult longevity (days) of *T. chilonis* at different temperatures, after 70 days storage.

. Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	3	4	4	3.7
10	3	4	3	3.3
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9k. Adult longevity (days) of *T. chilonis* at different temperatures, after 80 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	3	3	2	2.6
10	3	2	2	2.3
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 9l. Adult longevity (days) of *T. chilonis* at different temperatures, after 90 days storage.

Temp.	R_1	R_2	R_3	Mean
6	0	0	0	0.0
8	2	3	3	2.6
10	3	3	3	3.0
12	0	0	0	0.0
14	0	0	0	0.0
16	0	0	0	0.0

Appendix 10a. Parasitism (%), by *T. chilonis* at different rearing temperatures.

Temp.	R_1	R_2	R_3	Mean
20	85.8	90.3	91.4	89.1
25	91.6	95.7	91.1	92.8
28	97.2	95.3	94.3	95.6
31	82.3	85.9	89.5	85.9
35	58.0	62.4	59.9	60.1

Appendix 10b. Emergence (%) of *T. chilonis* at different rearing temperatures.

Temp.	R_1	R_2	R_3	Mean
20	93.4	90.0	87.8	90.4
25	94.9	96.3	97.4	96.2
28	97.8	98.8	97.4	98.0
31	85.1	89.9	92.9	89.3
35	32.4	36.3	32.4	33.7

Appendix 10c. Developmental period (days) of *T. chilonis* at different rearing temperatures.

Temp.	R_1	R_2	R_3	Mean
20	18	18	16	17.3
25	8	9	8	8.3
28	8	7	7	7.3
31	8	8	7	7.6
35	7	7	7	7.0

Appendix 10d. Adult longevity (days), of *T. chilonis* at different rearing temperatures.

Temp.	R_1	R_2	R_3	Mean
20	12	11	12	11.6
25	11	9	10	10.0
28	9	10	8	9.0
31	5	6	6	5.6
35	2	3	2	2.3

Appendix 11a. Releases, parasitism and survival of *T. c.* after 24 h field releases through micro-cages.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	60.4	60.4	66.2	62.3
Parasitism (%)	87.9	84.4	89.3	87.2

Appendix 11b. Releases, parasitism and survival of *T. c.* after 48 h field releases through micro-cages.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	20.3	24.0	18.2	20.8
Parasitism (%)	57.5	68.1	55.9	60.5

Appendix 11c. Releases, parasitism and survival of *T. c.* after 72 h field releases through micro-cages.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	15.2	18.0	10.7	14.6
Parasitism (%)	50.9	41.3	43.4	45.2

Appendix 12a. Releases, parasitism and survival of *T. c.* after 24 h field releases through paper cards.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	45.9	40.3	50.2	45.5
Parasitism (%)	58.6	68.2	57.3	61.4

Appendix 12b. Releases, parasitism and survival of *T. c.* after 48 h field releases through paper cards.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	12.6	15.7	10.1	12.8
Parasitism (%)	37.3	52.9	41.5	43.9

Appendix 12c. Releases, parasitism and survival of *T. c.* after 72 h field releases through paper cards.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	8.2	9.9	10.8	9.6
Parasitism (%)	37.6	18.3	25.4	27.1

Appendix 13a. Releases, parasitism and survival of *T. c.* after 24 h field releases through broadcasting.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	100	100	100	100.0
Parasitism (%)	67.9	65.2	77.8	70.3

Appendix 13b. Releases, parasitism and survival of *T. c.* after 48 h field releases through broadcasting.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	100	100	100	100.0
Parasitism (%)	44.5	46.2	31.4	40.7

Appendix 13c. Releases, parasitism and survival of *T. c.* after 72 h field releases through broadcasting.

Parameters	R_1	R_2	R_3	Mean
Releases (%)	100	100	100	100.0
Parasitism (%)	26.8	20.3	8.4	12.9

Appendix 14a. Parasitism (%) by *T. c.* from 5 metre distance, on different plant parts, 24 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	70.2	65.4	53.0	62.9
Middle	58.9	77.2	67.4	67.8
Lower	66.2	55.3	59.1	60.2
Total	65.1	66.0	59.8	63.6

Appendix 14b. Parasitism (%) by *T. c.* from 5 metre distance, on different plant parts, 48 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	65.7	81.9	79.2	75.6
Middle	78.3	75.3	87.6	80.4
Lower	82.5	84.0	64.8	77.2
Total	75.6	80.4	77.2	77.7

Appendix 14c. Parasitism (%) by *T. c.* from 5 metre distance, on different plant parts, 72 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	77.4	70.3	82.4	76.7
Middle	71.9	82.4	90.5	81.6
Lower	81.4	70.6	81.5	77.8
Total	76.9	74.4	84.8	78.7

Appendix 15a. Parasitism (%) by *T. c.* from 10 metre distance, on different plant parts, 24 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	52.6	48.3	61.4	54.1
Middle	46.5	66.9	51.2	54.9
Lower	49.2	60.0	49.5	52.9
Total	49.4	58.4	54.0	54.0

Appendix 15b. Parasitism (%) by *T. c.* from 10 metre distance, on different plant parts, 48 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	57.3	44.6	69.4	57.1
Middle	59.0	55.0	67.2	60.4
Lower	55.9	62.3	52.2	56.8
Total	57.4	54.0	62.9	58.1

Appendix 15c. Parasitism (%) by *T. c.* from 10 metre distance, on different plant parts, 72 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	51.0	61.3	62.9	58.4
Middle	51.9	60.1	65.9	59.3
Lower	63.1	55.1	50.9	56.4
Total	55.3	58.8	59.9	58.0

Appendix 16a. Parasitism (%) by *T. c.* from 15 metre distance, on different plant parts, 24 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	14.8	27.3	22.4	21.5
Middle	18.6	28.4	30.7	25.9
Lower	20.4	27.2	20.5	22.7
Total	17.9	27.6	24.5	23.4

Appendix 16b. Parasitism (%) by *T. c.* from 15 metre distance, on different plant parts, 48 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	20.9	24.4	30.3	25.2
Middle	38.6	30.2	25.1	31.3
Lower	26.9	28.0	33.9	29.6
Total	28.8	27.5	29.8	28.7

Appendix 16c. Parasitism (%) by *T. c.* from 15 metre distance, on different plant parts, 72 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	35.1	25.7	21.4	27.4
Middle	39.3	33.3	25.5	32.7
Lower	21.5	29.4	30.7	27.2
Total parasitism	32.0	29.5	25.9	29.1

Appendix 17a. Parasitism (%) by *T. c.* from 20 metre distance, on different plant parts, 24 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	22.7	20.2	18.9	20.6
Middle	27.9	17.6	18.7	21.4
Lower	22.7	15.2	20.0	19.3
Total parasitism	24.4	17.7	19.2	20.4

Appendix 17b. Parasitism (%) by *T. c.* from 20 metre distance, on different plant parts, 48 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	19.7	23.1	24.7	22.5
Middle	23.7	25.3	28.7	25.9
Lower	18.0	20.7	24.9	21.2
Total parasitism	20.5	23.0	26.1	23.2

Appendix 17c. Parasitism (%) by *T. c.* from 20 metre distance, on different plant parts, 72 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	17.2	27.6	20.3	21.7
Middle	26.3	22.7	23.7	24.2
Lower	25.7	18.6	25.3	23.2
Total parasitism	23.1	23.0	23.1	23.0

Appendix 18a. Parasitism (%) by *T. c.* from 25 metre distance, on different plant parts, 24 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	9.8	20.6	11.3	13.9
Middle	15.3	18.7	11.6	15.2
Lower	15.9	20.1	5.8	13.9
Total parasitism	13.7	19.8	9.6	14.3

Appendix 18b. Parasitism (%) by *T. c.* from 25 metre distance, on different plant parts, 48 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	20.1	15.3	10.2	15.2
Middle	12.3	15.2	25.7	17.7
Lower	15.1	16.2	20.6	17.3
Total parasitism	15.8	15.6	18.8	16.7

Appendix 18c. Parasitism (%) by *T. c.* from 25 metre distance, on different plant parts, 72 h post field releases.

Plant parts	R_1	R_2	R_3	Mean
Upper	11.4	15.8	15.4	14.2
Middle	10.8	21.3	25.5	19.2
Lower	21.4	15.2	17.4	18.0
Total parasitism	14.5	17.4	19.4	17.1

Appendix 19a. Parasitism (%) by *T. chilonis* on host eggs, during different weeks of June, 2007.

Weeks	R_1	R_2	R_3	Mean
1^{st}	70.8	55.7	65.6	64.0
2^{nd}	63.2	48.0	58.2	56.5
3^{rd}	79.1	66.3	76.2	73.9
4^{th}	73.4	57.9	68.4	66.6

Appendix 19b. Parasitism (%) by *T. chilonis* on host eggs, during different weeks of July, 2007.

Weeks	R_1	R_2	R_3	Mean
1^{st}	65.1	69.5	73.0	69.2
2^{nd}	60.7	70.2	75.2	68.7
3^{rd}	64.2	72.1	67.4	67.9
4^{th}	60.7	69.2	65.4	65.1

Appendix 19c. Parasitism (%) by *T. chilonis* on host eggs during different weeks of August, 2007.

Weeks	R_1	R_2	R_3	Mean
1^{st}	65.2	63.4	81.1	69.9
2^{nd}	59.4	62.4	70.8	64.2
3^{rd}	65.2	60.2	73.5	66.3
4^{th}	60.2	68.7	66.7	65.2

Appendix 19d. Parasitism (%) by *T. chilonis* on host eggs during different weeks of September, 2007.

Weeks	R_1	R_2	R_3	Mean
1^{st}	88.1	85.2	73.6	82.3
2^{nd}	79.4	80.2	73.8	77.8
3^{rd}	70.8	78.7	80.3	76.6
4^{th}	76.2	83.6	85.0	81.6

Appendix 20a. Survival (%) of *C. carnea* under field conditions during different weeks of June, 2007.

Weeks	R_1	R_2	R_3	Mean
1st	66.6	75.0	83.3	75.0
2nd	58.3	66.6	75.0	66.6
3rd	75.0	91.6	91.6	86.1
4th	91.6	83.3	75.0	83.3

Appendix 20b. Survival (%) of *C. carnea* under field conditions during different weeks of July, 2007.

Weeks	R_1	R_2	R_3	Mean
1st	83.3	91.6	83.3	80.0
2nd	91.6	91.6	83.3	88.8
3rd	91.6	91.6	83.3	88.8
4th	91.6	83.3	75.0	83.3

Appendix 20c. Survival (%) of *C. carnea* under field conditions during different weeks of August, 2007.

Weeks	R_1	R_2	R_3	Mean
1st	75.0	91.6	83.3	83.3
2nd	75.0	83.3	91.6	83.3
3rd	91.6	83.3	91.6	88.8
4th	91.6	83.3	83.3	86.1

Appendix 20d. Survival (%) of *C. carnea* under field conditions during different weeks of September, 2007.

Weeks	R_1	R_2	R_3	Mean
1st	100	100	91.6	97.2
2nd	91.6	91.6	100	94.4
3rd	100	100	91.6	97.2
4th	91.6	91.6	83.3	88.8

Appendix 21a. Infestation (%) of *H. armigera* in the bio-control treatment from July to October, 2007.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0	2.7	6.2	6.9	8.7	12.1	12.8	8.0	9.8	10.1	6.2
R_2	0	5.9	5.7	7.2	10.4	8.7	6.4	9.6	8.4	6.3	3.4
R_3	0	4.9	4.2	6.0	9.1	13.1	8.1	5.8	8.5	8.8	6.6
Mean	0.0	4.5	5.7	6.7	9.4	11.3	9.1	7.8	8.9	8.4	5.4

Appendix 21b. Infestation (%) of *H. armigera* in the control treatment from July to October, 2007.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0	6.1	9.6	12.4	17.2	19.3	16.7	12.1	16.3	15.2	8.6
R_2	0	7.5	7.4	10.7	14.9	16.4	13.4	14.2	12.4	14.3	5.7
R_3	0	4.7	7.9	7.2	15.9	40.4	15.8	13.9	19.0	13.3	12.4
Mean	0.0	6.1	8.3	10.1	16.0	18.7	15.3	13.4	15.9	14.3	8.9

Appendix 21c. Infestation (%) of *H. armigera* in the insecticide treatment from July to October, 2007.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0	0.5	5.6	5.9	10.7	12.4	4.9	4.1	4.7	5.9	3.5
R_2	0	1.2	3.7	3.1	8.2	11.2	5.6	4.7	1.6	4.1	3
R_3	0	0.7	3.0	7.2	5.1	7.3	3.6	2.0	5.4	2.6	4.9
Mean	0.0	0.8	4.1	5.4	8.0	10.3	4.7	3.6	3.9	4.2	3.8

Appendix 22a. Infestation (%) of *H. armigera* in the bio-control treatment from July to October, 2008.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0.8	1.8	14.3	13.2	8.7	8.8	6.0	7.9	7.4	6.9	5.3
R_2	0.5	0.3	10.4	8.7	7.6	7.4	8.3	10.2	5.9	7.3	2.2
R_3	1.7	0.9	11.6	9.0	11.3	5.1	5.2	8.3	5.0	4.9	4.8
Mean	1.0	1.0	12.1	10.3	9.2	7.1	6.5	8.8	6.1	6.1	4.1

Appendix 22b. Infestation (%) of *H. armigera* in the control treatment from July to October, 2008.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	1.0	1.7	15.2	14.2	13.4	11.4	10.2	16.3	11.5	9.7	7.3
R_2	0.9	1.3	17.1	18.7	16.8	15.2	12.5	18.4	9.4	7.6	5.9
R_3	1.7	1.2	19.3	13.3	12.4	10.0	11.8	15.7	9.7	10.9	8.4
Mean	1.2	1.4	17.2	15.4	14.2	12.2	11.5	15.1	10.2	9.4	7.2

Appendix 22c. Infestation (%) of *H. armigera* in the insecticide treatment from July to October, 2008.

	July	August				September				October	
Rep.	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0.1	0.6	0.9	7.9	8.9	6.0	3.5	3.7	4.8	5.7	3.9
R_2	0.1	0.5	1.4	5.0	6.6	4.4	2.6	5.0	3.1	4.0	4.1
R_3	0.4	1.0	0.7	7.2	10.6	4.9	4.7	3.0	6.2	5.0	3.1
Mean	0.2	0.7	1.0	6.7	8.7	5.1	3.6	3.9	4.7	4.9	3.7

Appendix 23a. Infestation (%) of *E. vittella* in the bio-control treatment from July to October, 2007.

	July		August				September				October	
Rep.	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	1.8	3.0	5.3	16.9	12.7	15.0	12.4	20.0	12.7	12.3	12.2	9.8
R_2	1.5	8.3	4.9	19.3	14.6	14.2	14.5	17.3	18.2	14.2	11.9	11.2
R_3	3.0	6.7	10.5	15.1	15.3	11.9	12.7	16.7	14.1	16.1	9.2	9.9
Mean	2.1	6.0	6.9	17.1	14.2	13.7	13.2	18.0	15.0	14.2	11.1	10.3

Appendix 23b. Infestation (%) of *E. vittella* in the control treatment from July to October, 2007.

	July		August				September				October	
Rep.	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	4.2	8.2	8.9	32.1	26.8	20.1	21.3	32.8	22.1	23.4	20.2	21.4
R_2	2.6	9.2	10.2	28.5	22.4	23.9	15.5	29.6	30.1	20.1	22.8	16.2
R_3	1.3	11.1	11.2	31.5	23.1	23.2	24.4	31.8	27.6	22.8	18.2	18.5
Mean	2.7	9.5	10.1	30.7	24.1	22.4	20.4	31.4	26.6	22.1	20.4	18.7

Appendix 23c. Infestation (%) of *E. vittella* in the insecticide treatment from July to October, 2007.

	July		August				September				October	
Rep.	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0.1	1.5	1.8	2.9	8.1	8.7	11.3	8.4	9.3	6.1	6.1	2.8
R_2	0.9	1.1	1.9	2.1	5.5	7.2	12.4	10.6	10.4	7.9	4.9	5.7
R_3	2.0	1.3	1.4	3.4	5.3	9.3	6.6	8.9	5.5	4.6	4.6	2.6
Mean	1.0	1.3	1.7	2.8	6.3	8.4	10.1	9.3	8.4	6.2	5.2	3.7

Appendix 24a. Infestation (%) of *E. vittella in* the bio control treatment from July to October, 2008.

	July		August				September				October	
Rep	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	5.9	18.3	13.7	11.2	8.3	14.3	13.4	17.0	17.6	10.5	6.1	7.2
R_2	7.2	13.5	7.8	9.5	8.0	12.7	14.5	14.9	15.1	8.4	8.4	5.8
R_3	7.6	16.8	11.2	16.2	7.4	10.2	12	16.4	12.9	10.5	11.6	7.7
Mean	6.9	16.2	10.9	12.3	7.9	12.4	13.3	16.1	15.2	9.8	8.7	6.9

Appendix 24b. Infestation (%) of *E. vittella* in the control treatment from July to October, 2008.

	July		August				September				October	
Rep.	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	7.3	26.7	21.3	19.6	14.7	22.5	24.4	29.3	25.4	16.5	12.6	10.2
R_2	8.4	29.4	17.5	17.1	15.2	16.1	25.5	26.4	18.5	15.4	16.5	9.5
R_3	11.3	21.6	15.5	18.5	10.9	24.7	20.3	31.0	21.8	10.4	17.1	14.5
Mean	9.0	25.9	18.1	18.4	13.6	21.1	23.4	28.9	21.9	14.1	15.4	11.4

Appendix 24c. Infestation (%) of *E. vittella* in the insecticide treatment from July to October, 2008.

	July		August				September				October	
Rep.	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2
R_1	0.2	0.8	1.5	1.8	5.7	7.3	9.3	10.4	11.3	7.4	8.4	4.7
R_2	0.8	0.6	1.7	1.9	4.3	6.2	7.1	6.0	8.9	6.5	6.0	3.2
R_3	1.0	1.6	0.7	2.0	5.6	4.8	8.8	11.5	6.8	10.7	6.9	7.4
Mean	0.7	1.0	1.3	1.9	5.2	6.1	8.4	9.3	9.0	8.2	7.1	5.1

Appendix 25a. Population of *B. tabaci* per leaf in the bio-control treatment from July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	6.3	9.2	7.4	12.5	9.2	8.3	10.2	7.2	5.9	8.1	4.3	6.4
R_2	8.4	5.3	9.2	8.2	7.2	9.4	8.4	5.9	7.3	8.4	6.9	8.2
R_3	7.2	9.2	8.3	9.9	7.9	9.3	9.0	5.8	8.4	7.2	7.4	6.1
Mean	7.3	7.9	8.3	10.2	8.1	9.0	9.2	6.3	7.2	7.9	6.2	6.9

Appendix 25b. Population of *B. tabaci* per leaf in the control treatment from July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	7.9	11.2	12.5	13.5	9.7	12.5	15.2	10.4	11.4	12.4	10	8.8
R_2	10.1	9.5	10.2	15.8	13.2	14.4	16.3	11.2	10.3	11.6	12.4	9.7
R_3	9.3	11.4	12.1	17.8	10.7	13.2	11.4	6.0	9.2	9.6	8.5	12.1
Mean	9.1	10.7	11.6	15.7	11.2	13.4	14.3	9.2	10.3	11.2	10.3	10.2

Appendix 25c. Population of *B. tabaci* per leaf in the insecticide treatment during July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	2.4	2.9	2.0	1.5	2.6	3.1	5.0	2.0	2.5	2.1	6.0	3.1
R_2	2.0	3.2	3.1	1.0	2.9	3.7	5.4	1.5	4.2	1.5	3.2	3.7
R_3	2.2	5.0	2.1	2.6	1.7	4.0	5.2	3.1	3.9	3.3	3.4	2.5
Mean	2.2	3.7	2.4	1.7	2.4	3.6	5.2	2.2	3.5	2.3	4.2	3.1

Appendix 26a. Population of *B. tabaci* per leaf in the bio-control treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	8.3	8.7	10.1	10.8	8.5	10.2	11.5	12.5	8.9	7.5	7.1	7.4
R_2	7.1	9.4	11.7	11.8	10.6	11.4	12.3	10.0	11.1	6.6	8.5	6.0
R_3	6.2	9.5	12.4	4.4	6.7	5.1	6.8	11.1	4.9	5.4	5.1	5.5
Mean	7.2	9.2	12.3	11.4	8.6	8.9	10.2	11.2	8.3	6.5	6.9	6.3

Appendix 26b. Population of *B. tabaci* per leaf in the control treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	10.5	13.6	19.8	18.3	12.3	12.7	13.9	15.5	13.6	10.5	10.5	10.1
R_2	11.0	12.2	16.5	16.0	13.5	12.6	13.4	13.7	14.8	8.7	9.3	9.0
R_3	12.4	11.4	18.2	15.5	14.4	10.4	15.0	11.0	9.4	9.0	11.1	8.5
Mean	11.3	12.4	18.2	16.6	13.4	11.9	14.1	13.4	12.6	9.4	10.3	9.2

Appendix 26c. Population of *B. tabaci* per leaf in the insecticide treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	3.6	2.1	3	2.6	3.1	2.5	3	2.5	2.7	2.4	1.3	2.4
R_2	3.9	1.9	3.2	2.1	3.9	3	1.6	1.7	2.1	2.9	2.6	1.7
R_3	3	3.8	4.0	2.2	3.2	3.8	6.2	3.0	3.0	2.2	2.1	2.2
Mean	3.5	2.6	3.4	2.3	3.4	3.1	3.6	2.4	2.6	2.5	2.0	2.1

Appendix 27a. Population of *T. tabaci* per leaf in the bio-control treatment from July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	8.7	10.3	14.4	10.5	14.2	13.9	14.1	8.7	11.9	14.2	13.2	8.3
R_2	7.4	17.5	10.2	12.7	8.4	10.4	11.3	9.0	12.4	12.5	14.6	10.3
R_3	5.2	9.4	9.0	7.1	9.5	12.6	14.8	14.4	12.3	12.0	12.4	8.1
Mean	7.1	12.4	11.2	10.1	10.7	12.3	13.4	10.7	12.2	12.9	13.4	8.9

Appendix 27b. Population of *T. tabaci* per leaf in the control treatment from July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	8.3	15.1	17.4	15.1	16.4	17.4	18.4	16.1	18.2	16.8	19.6	13.2
R_2	10.1	22.0	16.2	12.3	13.3	15.7	17.0	17.1	17.4	15.2	17.2	12.7
R_3	9.8	17.5	15.3	15.5	18.0	15.2	16.2	12.1	15.1	19.6	17.5	11.5
Mean	9.4	18.2	16.3	14.3	15.9	16.1	17.1	15.1	16.9	17.2	18.1	12.5

Appendix 27c. Population of *T. tabaci* per leaf in the insecticide treatment from July to October, 2007.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	2.6	2.5	3.1	2.5	4.2	4.7	3.1	3	4.9	2.7	2.6	3.6
R_2	5.4	2	2.9	2	3.6	4.1	2.7	5.0	3.5	1.7	4.4	5.6
R_3	3.1	1.8	2.7	1.8	5.1	3.5	5.3	2.8	3.6	1.9	1.8	2.5
Mean	3.7	2.1	2.9	2.1	4.3	4.1	3.7	3.6	4.0	2.1	2.9	3.9

Appendix 28a. Population of *T. tabaci* per leaf in the bio-control treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	4.4	7.8	11.2	13.4	12.4	10.3	11.0	14.9	11.6	10.4	13.5	10.6
R_2	5.2	4.9	9.3	14.2	16.8	12.5	10.4	12.8	12.3	8.6	10.3	11.4
R_3	6.6	7.7	11.3	10.5	17.6	11.4	12.5	11.9	7.3	8.9	6.8	7.4
Mean	5.4	6.8	10.6	12.7	15.6	11.4	11.3	13.2	10.4	9.3	10.2	9.8

Appendix 28b. Population of *T. tabaci* per leaf in the control treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	6.5	11.3	15.6	16.0	24.5	19.0	15.2	19.8	15.5	15.2	12.3	14.6
R_2	8.3	12.4	12.3	14.4	22.5	21.4	13.7	22.5	17.3	16.4	15.8	16.2
R_3	8.3	15.0	14.4	18.2	19.3	12.1	17.0	12.9	13.1	10.7	16.5	9.4
Mean	7.7	12.9	14.1	16.2	22.1	17.5	15.3	18.4	15.3	14.1	14.9	13.4

Appendix 28c. Population of *T. tabaci* per leaf in the insecticide treatment from July to October, 2008.

	July				August				September			
Rep.	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
R_1	1.9	3.6	2.8	3.2	5.1	6.4	6.0	4.2	5.8	3.6	4.0	6.0
R_2	3.6	2.5	1.9	2.2	6.3	5.9	5.1	5.3	4.3	3.1	4.7	3.8
R_3	2.9	4.1	3.4	2.4	7.2	2.1	4.8	3.7	6.4	1.4	2.7	4.3
Mean	2.8	3.4	2.7	2.6	6.2	4.8	5.3	4.4	5.5	2.7	3.8	4.7

Appendix 29a. Population of *A. gossypi* per leaf in the bio-control treatment from September to October, 2007.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	9.5	11.7	13.2	11.7
R_2	7.4	9.4	8.1	8.6
R_3	8.0	13.1	8.7	10.4
Mean	8.3	11.4	10.0	10.2

Appendix 29b. Population of *A. gossypi* per leaf in the control treatment from September to October, 2007.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	15.9	22.3	18.7	18.1
R_2	13.1	18.6	15.2	20.5
R_3	11.1	20.3	19.8	13.8
Mean	13.4	20.4	17.9	17.5

Appendix 29c. Population of *A. gossypi* per leaf in the insecticide treatment from September to October, 2007.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	2.5	5.9	4.5	4.1
R_2	1.9	3.1	3.2	3.5
R_3	2.9	5.4	4.7	3.2
Mean	2.4	4.8	4.1	3.6

Appendix 30a. Population of *A. gossypi* per leaf in the bio-control treatment from September to October, 2008.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	10.6	11.9	14.3	12.2
R_2	8.5	9.2	12.7	8.7
R_3	10.0	11.6	7.2	8.5
Mean	9.7	10.9	11.4	9.8

Appendix 30b. Population of *A. gossypi* per leaf in the control treatment from September to October, 2008.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	12.3	15.9	21.4	18.5
R_2	18.7	22.4	15.2	14.6
R_3	17.6	19.2	24.3	20.0
Mean	16.2	19.2	20.3	17.7

Appendix 30c. Population of *A. gossypi* per leaf in the insecticide treatment from September to October, 2008.

	September		October	
Rep.	W_3	W_4	W_1	W_2
R_1	2.3	3.6	5.9	4.6
R_2	1.8	2.9	3.8	2.8
R_3	3.4	3.1	5.0	5.2
Mean	2.5	3.2	4.9	4.2

Appendix 31. Research article: Nadeem *et al*., 2009. Comparative rearing of *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammitaidae) at different temperature conditions.

Appendix 32. Research article: Nadeem *et al*., 2010. Optimization of short and long term storage duration for *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) at low temperatures.