**International Journal of Zoology Studies**
**www.zoologyjournals.com**
**Volume 1; Issue 1; January 2016; Page No. 35-40**

# From Production to Field Application Methodology of Generalist Predator Green Lacewing, *Chrysoperla carnea* [Stephens] (Neuroptera: Chrysopidae)

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**Abstract**
Green lacewings *Chrysoperla* species are an exceptional addition to any integrated pest management program, thus purpose of this paper is to assess mass-production and field applications for augmentative biological control of insect pests. Lacewing larvae are voracious eaters of eggs and immature stages of many soft bodied insect pests including several species of aphids, spider mites, thrips, whiteflies, leafhoppers, some beetle larvae, eggs and caterpillars of pest moths, and mealybugs. This tiny magnificence is wonderful and cost effective additions to any pest control program as each green lacewing larva can devour 200 or more pests or pest eggs in a week during their two to three weeks developmental period. Growers wanted to establish green lacewings should applicate at the beginning of plant season or while have a limited pest's infestation and choose appropriate numbers of eggs for field, garden or greenhouse releases. When there have a moderate to severe pest infestation, deliver an appropriate number of eggs or larvae weekly or biweekly preferably every 7-10 days for at least 3 times to ensure a continual supply of predators. For best results, habitats should be encouraged for adults to remain and reproduce in the released area by providing nectar, pollen and honeydew nutrition to stimulate their reproductive process.

**Keywords:** Biological control, Generalist predator, Green lacewing, *Chrysoperla*

## 1. Introduction

Green lacewings scientifically known as *Chrysoperla* species (Neuroptera: Chrysopidae) since long have been considered important naturally occurring predators in many horticultural and agricultural cropping systems, including vegetables, fruits, nuts, fiber and forage crops, ornamentals, greenhouse crops, and forests. Worldwide, these are also ranked as some of the most commonly used and commercially available natural enemies. The entomologists stated that if lacewings have been the size of dogs, all of humanity would be in trouble because of the ferocity of this predator as the larvae especially the larger ones can deliver a painful little bite to peoples and each other, wherein pollen, nectar and even honeydew are helpful to sustain the green lacewing adults. For many years, two *Chrysoperla* species, *C. carnea* and *C. rufilabris* have been mass-reared and marketed commercially in certain states and two additional species, *C. externa* and *C. nipponensis*, are used in response to a questionnaire, and ranked as unrivaled on the list of commonly applied predators. Lacewings *Chrysoperla* spp., are used in integrated pest management (IPM) systems in two principal ways, periodic release of mass-reared individuals and manipulating the habitat e.g., to attract or conserve naturally occurring field populations. So, recent work has focused on improving both these approaches [1, 2].

Green lacewings the *Chrysoperla rufilabris* are aggressive aphid predators that have an appetite for other soft-bodied pests as well. These nocturnal predators come in three major forms, eggs, larvae and adults. The eggs are useful when growers are in no great hurry to get rid of aphids and other pests. The larvae are useful for the quick cleanup and the adults being nomadic are useful in field applications. The larvae are the only predatory form of the green lacewing, but they are very opportunistic. The green lacewing can tackle a great number of aphid species, and moreover, these predators may eat outside of their aphid-preference diet to enjoy other soft-bodied pests like scale insect immature stages, including long-tailed and other mealybug species, whiteflies, and others especially certain insect eggs. The eggs of the green lacewing are shipped loose in an inert medium of rice-hulls that are a distribution carrier to facilitate the proper placement of the eggs. The larvae are very cannibalistic and must be separated in transit. This is accomplished by means of a frame or hexcell unit (though bulk-bottle forms are available which need immediate attention). The hexcell unit is comprised of little compartments which can be opened a-row-at-a-time for predator release. The green lacewing adults come in a tube screened at both ends and often-times they are already laying eggs inside their packaging [3, 4].

Significant new developments in artificial larval diets, mechanized production methods, long-term storage, and quality control can reduce the cost and increase the availability and reliability of mass-reared *Chrysoperla* spp. Similarly, a re-examination of existing information on the chemical ecology and movement of lacewings reveals ways for improving the ability to attract and retain their populations in agricultural situations. Furthermore, the efficacy of procedures for both releasing and attracting *Chrysoperla* is being evaluated rigorously with quantitative methods under field conditions. Biological control is often viewed as a promising alternative or complement to pesticides in integrated pest management programs. There has been recent progress in the subsequent crucial areas of research with this important group of predators e.g., systematics, mass-production, field applications and evaluation. Factors that can influence the effectiveness of biological control agents include agent specificity (generalist or specialist), the type of agent (predator, parasitoid, or pathogen), the timing and number of releases, the method of release, synchrony of the natural enemy with the host, field conditions and release rate [5, 6].

## 2. Lifestyle of Chrysopid

Green lacewings having light green adult with large shiny eyesover winter as adult and their color change in autumn from green to brown, while in spring reverse is true. Adults feed only on nectar, pollen and aphid honeydew, but the larvae are active predators. Be sure to provide food for the adults in the habitat so they can stay and deposit their eggs there. These are a wonderful and cost effective addition to any pest control program as these actively search for the prey, and have specialized mouth parts and extra intestinal digestion. The 2 cm long green lacewing female adults actively seek out colorizations of aphids or other tiny arthropods. Mated females, when they find these groupings ay lay up to 200 of their 1 mm light green eggs perched atop on 1 cm long filaments among the aphids colony. The eggs hatch into tan-colored, alligator-like larvae that may grow to 8 mm long. They become extremely voracious feeders that can go right to work on the aphid control and even may feed each other. They can consume 100 aphids or more and the lifespan of these predators is roughly 3 weeks in their immature stages and then less than 2 months as adults depending on climatic conditions. The conditions for optimum natural aphid control performance can be between 67-89°F with a relative humidity of 30% or greater. These are optimum conditions and not necessarily essential for successful implementation. However, significantly cooler or warmer temperatures and humidity fluctuations may hamper reproduction and development of predator to a certain degree [7].

## 3. Usage Benefits and Scouting of Chrysopid

The biggest benefit of using green lacewings for aphid control has to be the cost effective. The eggs are a fairly economical method however, but with the eggs, growers have to sacrifice some effectiveness and speed. For those traits, the larvae or aphid lions as they are sometimes called are the way to go forward. The larvae are one of the fastest predators available, from release to first meal anyway. Moreover, because of their opportunistic nature, they are useful for a few pests in addition to aphids. For reliability, though use them for aphids and possibly for scale insect species control. The adults are effective when treating orchards and such as they are nomadic in nature. The eggs and larvae are useful to apply in greenhouses, field crops, intercrops, orchards and gardens. Scientists have seen the successful aphid control by implementation of these species in just about every conceivable situation. The adults should be used only in row crops, trees, orchards and possibly in tall interior plantings while the adults can lay eggs next to aphid colonies. The only problem is that this predator is short-lived, though another drawback is that the green lacewing is difficult to scoutto find actual larvae or adults by day time when they are usually well hidden. If the scouts want to locate larvae and adults, they should plan on doing so either in the evening or on an overcast day. Clean new growth is one effective sign as a scouting aid as well as looking for the eggs as they are usually on the top surfaces of the leaves. Decimated or sucked-dry-looking aphids are another scouting sign of this predator [8].

## 4. Rearing and Mass Production of Chrysopid

The commercialization of biological control depends upon the ability of insectaries to produce and market efficiently a highly reliable and relatively inexpensive supply of natural enemies. Achieving these objectives first requires efficient, standardized mass-rearing procedures like the use of inexpensive nutritious diets, mechanized and space-efficient production systems, reliable storage methods, and periodic evaluation of natural enemy's quality. In each of these areas, research has made practical and economically beneficial advances in mass-rearing of *Chrysoperla*. However, the effective marketing of natural enemies and the education of targeted customers may continue to be serious issues in need of attention. Currently, rearing of larvae constitutes the most costly aspect in *Chrysoperla* mass-production largely because all three instars are predaceous. Most insectaries depend on mass-produced insect prey as food, which is relatively expensive compared with artificial diets. The development of an artificial diet should continue to receive a high priority. Lacewing larvae can feed and develop on either liquid or solid diets. Although some automation is available for producing and encapsulating liquid diets, the cost has remained relatively high. Recent research has resulted in a fully artificial, solid or semisolid diet that apparently offers significant advantages over other diets. The new diets are relatively inexpensive, do not require encapsulation, and do not spoil quickly. When theses diets become generally available, it is projected to reduce the cost of rearing per adult lacewing [9].

Adult dietary requirements often present major practical problems for mass-rearing and marketing of predators. Early research on *C.carnea* nutrition yielded relatively inexpensive and effective artificial diets that sustain high rates of egg production. With these diets, females of all species of *Chrysoperla* tested thus far can produce 500 to 1,000 eggs in 30 days. The successful diets provide a fine example of the practical benefits derived from fundamental research in insect nutrition. Mass-rearing of such insects (especially cannibalistic predators) requires considerable space and manual labor; and currently, space-efficient, automated mass-rearing systems for *Chrysoperla* are under development. These systems include compact holding units for adults, mechanical devices for feeding adults and harvesting eggs, mechanized methods for presenting the larval diet, and automated systems for packaging larval-rearing units. When fully developed, such mechanized systems would enhance production greatly and reduce costs drastically. Progress thus far illustrates the advantages (biological and economic) that can accrue when engineers and biologists combine their expertise in solving practical problems. Medium and long-term storage of entomophagous species is a key and often-missing element in the cost-effective production and distribution of natural enemies. Recent studies indicate that long-term storage of adult *Chrysoperla* species can be accomplished simply, economically and without loss of quality. Equally important is that the post-storage adults can be brought into a reproductive state quickly, predictably and synchronously. Short-term storage of eggs, which is essential for efficient, cost-effective distribution, is more problematic for *Chrysoperla*. Several studies demonstrated that *C. carnea* eggs remain viable for up to 3 weeks when they are held at 46 ºF (8 ºC). Unfortunately, the studies offer contradictory results regarding the best age to store the eggs. Thus, it is reasonable to store young eggs because this practice would reduce hatching and cannibalism during distribution additionally necessary [10, 11].

## 5. Quality Control in Production

The standardized production of high quality natural enemies is crucial for both the practice of biological control and users' perception of biological control as a dependable pest management tactic. However, the quality of commercially marketed natural enemies can be variable because there are no strict quality control standards. For example, evaluation of shipments from insectaries, growers' ordered for *C. carnea*may not be filled consistently with the correct species, and cannibalism significantly reduced the survivorship of lacewings in transit. Such problems can be overcome through greater care in maintaining correctly identified, pure colonies and improved procedures during mass-production and packaging. In viewing the overall issue of quality control, it is believed essential for the insectary industry to develop standards that can promote the reliability and standardization of commercially produced natural enemies. In this regard, there needs to appear the greater coordinated efforts and more cooperation between the insectary industry and scientists [12].

Three aspects of release strategies used to augment green lacewings (Chrysoperla spp.), have been evaluated, the delivery system, release rate and timing, and the lacewing developmental stage released. The tests have been conducted in vineyards with either the common green lacewing *Chrysoperla carnea* (Stephens); Comanche lacewing *Chrysoperla comanche* Banks or *Chrysoperla rufilabris* (Burmeister). Lacewings have been released to suppress 2 leafhopper pests, *Erythroneura variabilis* Beamer and the western grape leafhopper, *Erythroneura elegantula* Osborn. Two commercial delivery systems have been compared. In the 1st delivery system, a mixture of lacewing eggs and com grit has been placed in paper cups, which have been distributed to every 5th vine in every other row. This delivery system resulted in poor egg hatch and larval dispersal. Egg hatch temained low (60%) in the paper cups compared with egg hatch when lacewings have been reared in individual cells (1%). The poor egg hatch is attributed primarily to cannibalism. Larval dispersal from paper cups with com grit has 25% lower than that from cups without com grit, resulting in incomplete distribution of lacewings throughout the vineyard. In a 2nd delivery system, lacewing eggs combined with com grit, have been dropped onto the vines from a moving flatbed trailer, and egg hatched 62%. Eggs have been delivered to each vine and vine row, although delivery of eggs has remained uneven. More eggs have been dropped at the beginning (11 eggs per vine) of each release batch than at the end (5 eggs per vine). Using a noncommercial delivery system, release rates between 6,175 and 1,235,000 eggs or larvae per hectare have been tested. No correlation between release rate and prey density has been found. A release timed to 50-70% leafhopper egg hatch has a greater effect on leafhopper densities than releases timed to peak leafhopper nymph densities. In the 3rd experiment, the effectiveness of egg versus larval releases has been tested. In egg release plots, there has 70% egg mortality and leafhopper densities noted not significantly different from no-release plots. In larval release plots, 50% of the larvae survived until the 3rd instar and there has a significant reduction in leafhopper densities [13].

## 6. Natural Enemies Mortality Factor

Less well-documented, but of equal importance, is the potential disruptive effect of parasitoids in augmentative release programs. Several species of parasitoids attack *Chrysoperla* eggs and larvae and rates of parasitism can be high, especially at the end of the season. Parasitoids as important mortality factor include larval parasitoids Braconidae e.g., *Chrysopophthorus chrysopimaginis*, pupae parasitoids *Hemitelesfloricolator*, egg parasites *Telenomus spec*, parasites on imagos sucking dipterans, larval predators larvae of ladybird (Coccinellidae), and on imagos the birds. In pecan orchards with season-long releases of *C. carnea* eggs, parasitization increased such that overall lacewing densities (introduced and resident populations) have been lower in experimental than control (non-release) fields. Similarly, in one of two trials, the scelionid *Telenomustridentatus* parasitized considerably more eggs in experimental plots (30%) than in control plots (2%). In some cases, release of mature (rather than newly laid or young) eggs can reduce parasitism greatly. The impact of pathogens on augmentative releases of predators is poorly understood. However, recent studies report that *C. carnea* larvae are susceptible to *Bacillus thuringiensis* toxins that are being incorporated into corn, potato, and other crop plants. Thus, the large-scale use of transgenic plants should be tested for significant negative effects on this important predaceous insect. Pesticides constitute another common disruptive component in many agroecosystems. Here, *C. carnea* may have an advantage over other introduced or resident natural enemies because it has a relatively broad tolerance to many insecticides, particularly during the larval and cocoon stages. However, tolerance can vary, for instance, *C. carnea* associated with heavy pesticide usage often are less vulnerable than those from areas with low insecticide usage. In contrast, *C. rufilabris* displays generally higher vulnerability to insecticides than does *C. carnea*. Insectary managers should consider these issues when they choose or market lacewings. Also, generalized statements regarding lacewing susceptibility to insecticide residues may not be appropriate [14, 15, 16].

## 7. Application Methodology

Development of efficient methods for commercial releases is a crucial factor in the success of augmentative biological control. In many cases, the timing and method of biological control applications were more significant factors impacting the effectiveness of biological control than the release rate. Release sites for lacewings vary greatly (they range from cotton fields in Texas and apple orchards in Washington to greenhouses in a variety of locations). Unfortunately, the innate variation among *Chrysoperla* taxa and the differences in geographic areas, agroecosystems, or environmental conditions rarely have been considered in developing release tactics; consequently, the effectiveness of releases varies greatly. The variation in seasonal responses and habitat preferences among the various *C. carnea* biotypes (species or populations) led to tentative recommendations for matching biotypes with specific pest management situations (cropping systems). For example, the dark green *C. downesi* is recommended for use in evergreen trees, whereas the light green *C. carnea* from eastern U.S.A. is recommended for annuals or deciduous perennials (e.g., field crops or vineyards). Plant structure and chemistry may influence lacewing effectiveness. For example, the smooth and hirsute leaf surfaces of certain cotton cultivars affect *C. rufilabris* larval mobility and prey consumption differentially. The effectiveness of *C. carnea* also varies in response to the surface and structure of cabbage and wheat plants. These examples illustrate the necessity of matching the predator's biological characteristics not only with the physical conditions of the environment, but to the crop as well. Currently, all *Chrysoperla* spp. are considered generalist predators of soft-bodied insects and mites, a trait that underlies their great commercial demand. However, their prey preferences appear to vary significantly. These preferences should be defined better and the differences among species and biotypes should be clarified in comparative quantitative studies [17, 18].

**7.1. Delivery Systems**

Historically, chrysopid eggs have been dispensed manually typically mixed with a solid medium such as rice hulls or vermiculite; this practice fostered uniform field distribution. New delivery systems are being developed to improve lacewing delivery to the crop. Recently, agricultural engineers tested new, much improved mechanized systems. In one test, *C. rufilabris* eggs and larvae have been mixed with vermiculite mechanically and distributed evenly over the plants without significant mortality. One disadvantage of solid carriers is poor retention of eggs on the plants and eggs fall off the leaves whereas liquid carriers help for attaching eggs to the targeted plants. Recently there have been notable advances in the development of liquid carriers and commercial sprayers. For instance, distributing of *C. carnea* eggs in an agar solution rather than sucrose-based carriers has the advantage of lowered attractiveness to ants and other predators. In prototype applicators, *C. rufilabris* eggs have been immersed in a commercial liquid carrier, pneumatically agitated to create uniform egg suspension, and discharged into the targeted crop without damage to the eggs and with good retention on the leaves [19, 20].

**7.2. Developmental Stage for Releases**

Although lacewings commonly are sold and dispensed as eggs, larval releases may sometimes be more effective. Releases of *C. carnea* larvae have superior to releases of eggs for control of the potato beetle. Although larval releases remain expensive, new advances in insectary production and dispensing systems may improve the economics of commercial releases of larvae. Meanwhile, it is crucial to evaluate the biological and economic advantages of releasing one or the other developmental stage and to begin devising efficient methods for introducing the larval stage. In experimentation, the use of 1st, 2nd and 3rd in stars of the *C. carnea* larvae against aphids pest have been investigated in *Brassica napus* L. Four releases of predator's 1st, 2nd and 3rd instar larvae were made from the time of aphid's appearance on canola crop till its maturity at fortnightly intervals. The influences on aphids due to the larvae of *C. carnea* predator have been assessed by examining pest incidence and abundance of the natural enemies at plant growth stage, and seed yield recorded at crop harvest in the test field. Results indicated that predators, irrespective of their developmental stage, reacted very positively to their preys' reduction except in untreated control. Of the different larval stages tested, the applications of 1st instar followed by 2nd and 3rd instar larvae have most effective in reducing aphids' population [21, 22].

**7.3. Release Rates**

In 64% of the cases, the release rate of the biological control agent did not significantly affect the density or mortality of the pest insect. Few studies have assessed release rates in relation to pest reduction and costs of application. In most early studies, large numbers of lacewings have been dispensed to insure a reduction in pest densities; the release rates generally have too high to be commercially practical at prevailing insectary costs. Recently, a few field studies addressed this problem by testing lacewing release rates that approximate commercially feasible rates. However, these tests yielded conflicting results, for instance, *C. rufilabris* have been dispensed on grapevines at rates varying from 6,175 to 1,235,000 larvae per hectare; in one test, there has a positive correlation between release rate and pest density, but in another, no significant correlation occurred. Clearly, more field tests using commercially feasible release rates are necessary. Weekly releases of *C. carnea* for control of *Scirtothripsperseae* have been evaluated in replicated field plots in two commercial avocado orchards. Two release techniques and rates commonly employed by commercial pest control advisors who routinely use this generalist predator for *S. perseae* control have been assessed. Release technique one utilized *C. carnea* eggs glued to paper squares that have been stapled to leaves of experimental trees at a rate of 41,000 eggs per ha. Release technique two used a motorized backpack sprayer to apply a dry mixture of lacewing eggs and larvae to trees at a rate of 514,501 per ha. Pest populations have been monitored by making biweekly population counts of *S. perseae* larvae and adults on leaves, and adult densities have been simultaneously monitored in each experimental plot with yellow sticky cards. In the laboratory, degree-day accumulation until death of immature *C. carnea* has been determined at temperatures representative of field conditions when predators have been provisioned with varying amounts of food or different food types. Preference for *S. perseae* instars by first, second and third instar *C. carnea*has been assessed in the laboratory, and intraguild predation towards larvae and adult females of a co-occurring generalist predatory thrips, *Franklinothripsorizabensis*, investigated along with intraspecific predation rates. Both release strategies failed to significantly reduce *S. perseae* populations in comparison to non-treated control plots. Approximately 35-96% of *C. carnea* eggs and larvae applied with the motorized sprayer landed on the ground, and larvae lived for approximately 1-2 days when provisioned with either no food as avocado leaf or avocado pollen. Longevity has been extended to 14-15 days when prey has been provided. Larvae showed no preference for first or second instar *S. perseae*, all predator instars attacked first instar *F. orizabensis*, but only second and third instar *C. carnea* managed attacks on second instar *F. orizabensis* larvae. No adult females*F. Orizabensis* have been attacked and no attacks by *F. orizabensis* on *C. carnea* recorded. The second instar *C. carnea* engaged in the highest levels of intraspecific predation [23, 24].

A lacewing larval applicator has been designed, developed and tested for application against soft bodied insect pests in crops. The applicator is cheap and can be easily fabricated from locally available materials by village artisans. The applicator has a boom (hollow aluminium rod), on which plastic containers are screwed, as per the row spacing of the crops. The entire applicator hangs on the shoulders of the operator. The containers are filled with desired number of *Chrysoperla* larvae in an inert carrier. During application, the operator walks between the crop rows and keeps onstriking the boom with two light wooden rods to facilitate uniform release of the predatory larvae on to the crop. The larvae so released, are either trapped on whorl or leaves and those falling on soil search their way to the prey. The field tests on barley, cotton, cowpea and chilli crops revealed that the applicator performance efficiency ranged from 69.23 to 73.64 per cent, and the output from 2.59 to 3.07 h for one hectare crop area [25].

### 7.4. Habitat Manipulation

Lacewing adults are not predaceous; rather they feed on honeydew and pollen. Consequently, the behavioral responses of *Chrysoperla* adults to flowering plants and to chemical and other stimuli associated with their habitats and food can be used to augment populations in targeted areas. For instance, populations of *C. rufilabris* have been greater in the pecan canopy in orchards with a leguminous ground cover than in those with a grass cover. Similarly, food sprays that imitate honeydew can attract or retain adults and stimulate egg laying. However, the effectiveness of food sprays in manipulating field populations varies, and recent studies indicate that further basic and applied research in this area is needed. The best commercially available food sprays contain both enzymatic protein hydrolysates and sugar or honey. In most trials, protein-sprays without sugar fail to increase the number of lacewings and sugar-sprays without protein attracted lacewing adults but do not stimulate egg laying. Early work showed that by using food sprays to attract and induce chrysopids to lay eggs before natural honeydew becomes abundant and it is possible to suppress honeydew-producing or other pests before their numbers become large. However, in some cases the application of food sprays increased the densities of lacewing adults, but not the eggs or larvae. Given the above importance, it is recommended two areas of research that could be of great value, seasonal variation in reproductive responses of lacewings to food and impact of food sprays on non-target organisms that could reduce their effectiveness [26, 27].

A few studies have combined augmentative releases with the application of food sprays to induce both released and naturally occurring lacewings to remain within the crop. Augmentation of *C. externa* in soybeans and corn did not affect the resulting number of lacewing larvae or the three targeted noctuid pest species, but applying nutrients and sugar at the time of the release gave a 2- to 6-fold increase in the densities of adults and eggs of *C. externa* in corn fields. These results indicate that with some well-focused research, novel uses of food sprays have considerable potential for application in commercial agriculture. If the goal is to attract and retain *Chrysoperla* adults in the field, then there is a particular need to focus new research on their seasonal patterns of movement. Effective and reliable manipulation of *Chrysoperla*, therefore, requires knowledge of the seasonal timing of adult movement (dispersal, migration) and reproductive development, and responsiveness to the chemical, visual and other cues that attract adults, arrest their movement and promote egg laying [28].

## 8. Conclusion

The commercialization of natural enemies and increasing their use in pest management have presented to applied entomologists and ecologists with formidable challenges. A response to these challenges requires reducing the cost of mass-rearing and manipulating of natural enemies, improving the success rate and predictability of biological control procedures, and demonstrating the effectiveness, ecological benefits and safety of biological control under commercial conditions. Lacewingor aphid lions larvae voraciously attack almost any prey using pincer-like jaws, after injecting paralyzing venom these suck the body fluids from victim. During 2-3 weeks larval stage, they can eat up to 200 aphids or other insect eggs, larvae and adults a week, then they spin a silky cocoon, pupate a few days, and hatch into a fragile adults. Adult female lacewings live for approximately three or four weeks and lay up to 600 eggs on the end of a slender stalk to decrease the chances of predation by ants to hatch in four days. Lacewing eggs are mixed with rice hulls to give them space, if some eggs are turning grey, it means they are starting to hatch, and should be released immediately. If there is no activity yet, leave the containers at room temperature until microscopic movement is seen. Lacewing larvae are grey-brown in color and for best results, release the lacewing eggs and larvae in field soon after hatching. Lacewing eggs come with a quantity of previously frozen moth eggs as a food source for the hatching larvae, but if this runs out before they are released, larvae turn to cannibalism. Eggs and larvae can be hand sprinkled or with a pill bottle with a small hole in the cap wherever desired and even if placed in the wrong place, they can search upto 100 feet for their first meal. If it is inconvenient to release lacewing eggs immediately, these may be refrigerated for a few days at 38-45ºF to delay hatching, but be careful not to freeze them. Typical lacewing release rates range from 5000- 50,000 eggs per acre depending on infestation levels. It is best to start early in the season with a relatively low number of lacewings, then make repeat releases every 2-3 weeks, and increase quantities as more pests appear. Once the peak pest infestation period has passed, releases can be decreased and eventually stopped, but should be reintroduced in spring, as they overwinter with difficulty. Nectar, pollen and honeydew sources such as an assortment of flowering plants or beneficial insect food are helpful to stimulate adult lacewings to lay eggs.

## 9. References


1. Henry CS, Brooks SJ, Thierry D, Duelli P, Johnson JB. The common green lacewing (*Chrysoperla carnea*) and the sibling species problem. In: P. McEwen, T. R. New, and A. E. Whittington (eds.), Lacewings in the Crop Environment. Cambridge University Press, Cambridge, United Kingdom. 2001, 29-42.
2. Kareim AI. Searching rate and potential of some natural enemies as bio-control agent against the *Bemisiatabaci* (Homoptera: Aleyrodidae). J Appl Entomol. 1998; 122:487-492.
3. Senior LJ, McEwen PK. The use of lacewings in biological control. In: P. McEwen, T. R. New, and A. E. Whittington (eds.), Lacewings in the Crop Environment. Cambridge University Press Cambridge, United Kingdom. 2001, 296-302.
4. Stelzl M, Devetak D. Neuroptera in agricultural ecosystems.Agric. Ecosystems Environ., 1999; 74:305-321.
5. Kral K, Stelzl M. Daily visual sensitivity pattern in the green lacewing *Chrysoperla carnea* (Neuroptera: Chrysopidae). European Journal of Entomology, 1998; 95:327-333.
6. Hoffmann MP, Frodsham AC. Natural Enemies of Vegetable Insect Pests. Cooperative Extension, Cornell University, Ithaca, NY. 1993, 63.
7. Amarasekare KG, Shearer PW. Life history comparison of two green lacewing species *Chrysoperla johnsoni* and *Chrysoperla carnea* (Neuroptera: Chrysopidae). Environ Entomol., 2013; 42(5):1079-1084.
8. Amarasekare KG, Shearer PW. Life history comparison of two green lacewing species *Chrysoperla johnsoni* and *Chrysoperla carnea* (Neuroptera: Chrysopidae). Environ Entomol., 2013; 42(5):1079-1084.

9. Bellows TS. Fisher TW. Handbook of biological control: principles and applications of biological control. Academic Press. 1999, 418.
10. Henry CS, Brooks SJ, Duelli P, Johnson JB. Discovering the True *Chrysoperla carnea* (Insecta: Neuroptera: Chrysopidae) Using Song Analysis, Morphology and Ecology. Annals of the Entomological Society of America. 2002; 95(2):172.
11. Daanel KM, Glenn Y. Yokota. Release Strategies Affect Survival and Distribution of Green Lacewings (Neuroptera: Chrysopidae) in Augmentation Programs. Environmental Entomology, 1997; 26(2):455-464.
12. Rojht H, Budija F, Trdan S. Effect of temperature on cannibalism rate between green lacewings larvae *Chrysoperla carnea* (Stephens), (Neuroptera, Chrysopidae). Acta Agric. Slov., 2009; 93:5-9.
13. Hagler JR, Naranjo SE. Using gut content immunoassays to evaluate predaceous biological control agents: A case study. In: The Ecology of Agricultural Pests, W.O.C. Symondson and J.E. Liddell (Eds.) Published in 1996 by Chapman & Hall, London. 1996, 383-399.
14. Amarasekare KG, Shearer PW. Comparing effects of insecticides on two green lacewings species, *Chrysoperla johnsoni* and *Chrysoperla carnea* (Neuroptera: Chrysopidae). J Econ. Entomol. 2013; 106(3):1126-1133.
15. Fernandes OA, Wright RJ, Mayo ZB. Parasitism of greenbugs (Homoptera: Aphididae) by *Lysiphlebustestaceipes* (Hymenoptera: Braconidae) in grain sorghum: Implications for augmentative biological control. Journal of Economic Entomology. 1998; 91:1315-1319.
16. Gabarra R, Castane C, Albajes R. The mirid bug *Dicyphustamaninii* as a greenhouse whitefly and western flower thrips predator on cucumber. Biocontrol Science and Technology, 1995; 4:475-488.
17. Bellows TSJ, Paine TD, Bezark LG, Ball J. Optimizing natural enemy release rates, and associated pest population decline rates, for *Encarsia*inaron walker (Hymenoptera: Aphelinidae) and *Siphoninusphillyreae* (Haliday) (Homoptera: Aleyrodidae). Biological Control. 2007; 37:25-31.
18. Campbell CAM, Lilley R. The effects of timing and rates of release of *Phytoseiulus persimilis* against two-spotted spider mite *Tetranychusurticae* on dwarf hops. Biocontrol Science and Technology, 1999; 9:453-465.
19. Collier T, Van Steenwyk R. A critical evaluation of augmentative biological control. Biological Control, 2004; 31:245-256.
20. Daane KM, Yokota GY. Release strategies affect survival and distribution of green lacewings (Neuroptera: Chrysopidae) in augmentation programs. Environmental Entomology, 1997; 26:455-464.
21. Liu T, Stansly PA. Timing and release rates for control of *Bemisiatabaci* (Homoptera: Aleyrodidae) by *Nephaspisoculatus* (Coleoptera: Coccinellidae) under confined conditions. Journal of Entomological Science, 2005; 40:74-79.
22. Sarwar M. The propensity of different larval stages of lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) to control aphid *Myzuspersicae* (Sulzer) (Homoptera: Aphididae) evaluated on Canola *Brassica napus*L. Songklanakarin Journal of Science and Technology, 2014; 36 (2):143-148.
23. Crowder DW. Impact of Release Rates on the Effectiveness of Augmentative Biological Control Agents. J Insect Sci. 2007; 7:15.
24. Hoddle MS, Robinson L. Evaluation of factors influencing augmentative releases of *Chrysoperla carnea* for control of *Scirtothripsperseae* in California avocado orchards. Biological Control, 2004; 31(3):268-275.
25. Srivastava RC, Qureshi QG, Mathur NM. A new field application technology for *Chrysoperla larvae*. Journal of Biological Control, 1996; 10(1/2):53-59.
26. Sarwar M, Ahmad N, Tofique M, Salam A. Efficacy of some natural hosts on the development of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)- A laboratory investigation. The Nucleus, 2011; 48(2):169-173.
27. McEwen P, New TR, Whittington AE. Lacewings in the Crop Environment (Cambridge University Press, Cambridge. 2001.
28. Stiling P, Cornelissen T. What makes a successful biological control agent? A meta-analysis of biological control agent performance. Biological Control, 2005; 34:236-246.