T.R
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PLANT PROTECTION

LIFE TABLE AND PREDATION RATE OF *Chrysoperla carnea* (STEPHEN) (NEUROPTERA: CHRYSOPIDAE) FED ON *Hyalopterus pruni* (GEOFFROY) (HEMIPTERA: APHIDIDAE)

M. Sc. THESIS

PREPARED BY: Hazhar A. ABDULRAHMAN
SUPERVISOR: Prof. Dr. Remzi ATLIHAN

VAN-2019

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ACCEPTANCE and APPROVAL PAGE

This thesis entitled **"Life table and predation rate of *Chrysoperla carnea* (Stephen) (Neuroptera: Chrysopidae) fed on *Hyalopterus pruni* (Geoffroy) (Hemiptera: Aphididae)"** presented by Hazhar A. ABDULRAHMAN under supervision of Prof. Dr. Remzi ATLIHAN in the department of Plant Protection has been accepted as a M. Sc. thesis according to Legislations of Graduate Higher Education on 02/11/2018 with unanimity / majority of votes members of jury.

Chair: Prof. Dr. Remzi ATLIHAN Signature:

Member: Prof. Dr. M. Salih ÖZGÖKÇE Signature:

Member: Assist. Prof. Dr. Cevdet KAPLAN Signature:

This thesis has been approved by the committee of The Institute of Natural and Applied Science on ..18.../..01.../..2019. with decision number .2019/4-I.

Signature

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Director of Institute

THESIS STATEMENT

All the information's presented in the thesis were obtained according to the ethical behaviors and academic rules frame. And also, all kinds of statement and source of information that does not belong to me in this work prepared in accordance with the rules of thesies were cited to the source of information absolutely.

Signature
Hazhar A. ABDULRAHMAN

ABSTRACT

LIFE TABLE AND PREDATION RATE OF *Chrysoperla carnea* (STEPHEN) (NEUROPTERA: CHRYSOPIDAE) FED ON *Hyalopterus pruni* (GEOFFROY) (HEMIPTERA: APHIDIDAE)

ABDULRAHMAN, Hazhar Abdulsalam
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The green lacewing, *Chrysoperla carnea* (Stephens), is considered to be a real natural enemy of the mealy plum aphid (MPA), *Hyalopterus pruni*, an important pest of stone fruit trees in Lake Van Basin, Turkey. In this study, the population growth rate and predation capacity of the green lacewing fed on MPA using the age-stage, two-sex life table are investigated. The life table and consumption rate studies of the green lacewing are conducted under laboratory conditions at 25 ± 1°C, 60 ± 10 % RH, and a photoperiod of 14:10 (L: D) h. The age-stage, two- sex life table are used to analyze the raw data to get an accurate population growth and predation rate in which both the stage differentiation and both sexes were taken into account. The results for the population parameters, i.e the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), mean generation time (T) and net predation rate (C_0) of green lacewings fed on MPA were 204.98 offspring, 0.1094 d^{-1}, 1.1157 d^{-1}, 48.62 d and 339.12 prey MPAs, respectively. The finite predation rate (ω) of 18.27 prey/d was calculated by combining the growth rate and predation rate. The findings obtained from the paper can be used to develop an IPM and biological control program for the MPA.

Keywords: *Chrysoperla carnea*, *Hyalopterus pruni*, Life table, Predation rate.

ÖZET

Hyalopterus pruni (GEOFFROY) (HEMIPTERA: APHIDIDAE) İLE BESLENEN *Chrysoperla carnea* (STEPHEN) (NEUROPTERA: CHRYSOPIDAE)'NIN PREDASYON ORANI VE YAŞAM ÇİZELGESİ

ABDULRAHMAN, Hazhar Abdulsalam
Yüksek Lisans Tezi, Bitki Koruma Ana Bilim Dalı
Tez Danışmanı: Prof. Dr. Remzi ATLIHAN
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Yeşil zarkanat olarak da bilinen *Chrysoperla carnea* (Stephens), Vangölü havzasında sert çekirdekli meyve ağaçlarının önemli bir zararlısı olan erik unlu afidi *Hyalopterus pruni*'nin önemli bir doğal düşmanı olarak değerlendirilmektedir. Bu çalışmada 25 ± 1 ° C sıcaklık, % 60 ± 10 orantılı nem ve 14:10 (A: K) saatlik bir ışık periyodunu sağlayan laboratuvar koşullarında erik unlu afidi ile beslenen *Chrysoperla carnea*'nın popülasyon gelişmesi ve predasyon kapasitesi araştırılmıştır. Veriler, avcının populasyon büyümesini ve predasyon oranını doğru bir şekilde tahmin edebilmek için dönem farklılaşlaması ve her iki cinsiyeti de dikkate alan yaş ve döneme özgü, iki eşeyli yaşam çizelgesi kullanılanarak analiz edilmiştir. Populasyon parametreleri; net üreme gücü (R_0), kalıtsal üreme yeteneği (r), popülasyon artış sınırı (λ) ve ortalama döl süresi (T) sırasıyla 204.98 birey, 0.1094 g^{-1}, 1.1157 g^{-1}, 48.62 gün, net predasyon oranı (C_0) ise 339.12 av/yaprakbiti olarak hesaplanmıştır. Predasyon oranı sınırı (ω), populasyon büyüme oranı ve predasyon oranının kombinasyonunla hesaplanmış ve 18.27 av/gün olarak elde edilmiştir. Bu çalışmadan elde edilen sonuçlar erik unlu afidi için hazırlanacak olan biyolojik mücadele ve entegre zararlı yönetim programlarında kullanılabilecektir.

Anahtar kelimeler *Chrysoperla carnea, Hyalopterus pruni*, Yaşam tablosu, Predasyon oranı.

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2018

Hazhar A. ABDULRAHMAN

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SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below, along with descriptions.

Symbols	Description
x	Age
j	Stage
r	Intrinsic rate of increase
λ	Finite rate of increase
$R0$	Net reproductive rate
T	Mean generation time
Qp	Transformation rate
Cxj	Age-stage specific predation rate
Sxj	Survival rate
l_x	Age-specific survival rates
mx	Age-specific fecundity
fxi	Age-stage specific fecundity
l_{xmx}	Age-specific maternity
exj	Age-stage specific life expectancy
vxj	Age-stage specific reproductive value
C_0	Net predation rate
q_x	Age-specific net predation rate
k_x	Age-specific predation rate
˚C	Centigrade

1. INTRODUCTION

Stone-fruit trees, particularly apricot and plum, are regarded as significant and a widely cultivated stone fruits in Van region in Turkey.

Mealy plum aphid *Hyalopterus pruni* (Geoffroy, 1762) (Hemiptera: Aphididae) is an important pest of several stone fruit trees such as plum, almond, apricot and peach trees. It is a serious pest which results in some kinds of reductions in yield and fruit quality in the region (Toros et al. 1996; Atlihan et al., 1999). It is cosmopolitan and widely distributed throughout the world (Blackman and eastop, 1984). The aphips are considered as an important group of insects all over the world that result in direct damage as a result of sucking plant sap and leads to inducing plant deformation and indirect damage by heavy production of honeydew. While this pest is harmful, it has been also reported as a virus vector, especially for *Plum pox virus* (Bodenheimer and Swirski 1957; Miniou, 1973) which also can be deadly. With increasing of the awareness regarding the negative side effects of chemical insecticides on the environment, biological control using natural enemies to subdue pests is currently considered as main source in integrated, ecologically sound management systems. Biological control of insect pests is a major part of integrated pest management (IPM) and can be used along with other control methods in pest management programs. There are different biocontrol agents to manage insect pests. Among them, *C. carnea* is one of the predators and can be mass reared easily in the laboratory and released in the field for the management of particular insect pests (Huang and Enkegaard, 2009). Biological control or integrated management is options for controlling this pest. According to different studies, natural enemies may be effective against aphids in integrated pest management and biological control programmes (Stary 1965; Tasan et al., 1979). Green lacewings are important predator as biological control agents that can be used in biological control programs (Gautam, 1994; Venkatsan et al., 2008).

The Green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) is a polyphagous natural enemy available in different parts of the world (McMurtry et al., 1970; Jeppson et al., 1975; Stark and Whitford, 1987; Jokar and Zarabi, 2012). Although it prefers soft bodied insects (aphid, whitefly, mealybug) (Syed et al., 2005;

Sattar et al., 2007; Jokar and Zarabi, 2012), it can feed on scale insects, thrips, leafhoppers and larvae of butterfly (Lingren et al., 1968; Ridgway and Jones, 1968; Lingren and Green, 1984; Sattar, 2010; Batool et al., 2014). *C. carnea* is a benefit predator because of its compatibility with various environmental conditions and food diversity, and ability that can hunt 80 species of pest (Jokar and Zarabi, 2012). Besides, because of its high searching, finding and consumption capacities, the predator is produced commercially (Daane et al., 1998; Tauber et al., 2000; Hodle and Robinson, 2004). It is investigated that up to one third of the programs that result in successful biological insect pest control are attributed to the introduction of *Chrysoperla carnea* (Williamson & Smith, 1994).

The Green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) is a common natural enemy of *Hyalopterus pruni* in the Van region. (Atlihan et al., 2004). It is distributed worldwide and is a predator of different pest organisms (Berker 1958; Ridgway and Jones 1969; Lopez et al. 1976; Haub et al., 1983).

C. carnea have been studied intensively due to its wide distribution, broad habitats with high relative frequency of occurrence, easy rearing in the laboratory. The larvae of lacewing feed on a wide range of pest species while adults are free living and feed only on nectar, pollen and honeydew (El-Serafi et al., 2000).

This predator has a tremendous potential and can consume many species of insect pests, such as nymph of whiteflies, aphids, thrips and eggs of bollworms and other soft bodied insects (Gurbanov, 1984; Hashami, 2001; Atlihan et al., 2004; Silva et al., 2007). Throughout the cycle of its life, one *Chrysoperla carnea* larvae might be able to devour as many as five hundred aphids and they have a big role in the natural control of many small homopterous pests (Hydrona and Whitecomb, 1979; Legaspi, 1994 and Michaud, 2001). To let a biological control program be successful, a thorough understanding of the growth, stage structure, fecundity of both predator and prey, and the predation rate of the predator should be taken into consideration (Farhadi et al. 2011; Yu et al. 2013). The life table offers a wide clarity of the survival, development, and reproduction of a species. A proper evaluation of predation potential should be based on life table. The two-sex life table has been used in the studies relation to predator–prey relationships (Yu et al. 2005; Chi and Su 2006; Farhadi et al. 2011; Huang and Chi

2012; Yu et al. 2013; Khanamani et al., 2015) to include the variation in predation rate due to stage differentiation and the effect of male predators.

The main aim of this dissertation is to obtain basic information and details on the predation potential of *C. carnea* fed on *H. pruni*, hence, the life history and predation rate of the predator fed on *H. pruni* were investigated.

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2. LITERATURE REVIEWS

2.1. Biology and Life Cycle of *Hyalopterus pruni*

Kaygin et al. (2008), investigated the economic consequences of pest-caused losses. Aphid species are among the prominent disease vectors around the world and are responsible for pest-caused diseases. Aphid species belong to the group of insects that are found to be disastrous in pest-caused losses among many developing countries. The study found that, the black citrus in Turkey is responsible for causing up to 50% loss, on average, annually. There are many pest-control techniques that are aimed to protect from aphid species and the pest-caused losses. However, little improvements have been made so far. The results of the study concluded that the pest-cause losses are growing despite the development in technology and these growing losses have severe economic consequences for many developing and underdeveloped countries that mainly rely on agriculture and crops.

Sattar (2010), explored the consequences of aphid foods on the larval development, juvenile mortality, and changes in body weight of cocoons and adult fecundity of *C.carnea*. The results of the study found that the most suitable prey types for aphid species are *Myzus persicae* (Sulzer) and *Acyrthosiphon pisum* (Harris) whereas, *Aphis fabae*, known as (Scop.) is the most unsuitable prey type. The study concluded that high juvenile mortality was associated with larvae fed on aphid species.

Cranshaw (2009), examined the impact of extended sucking by aphid species on the plants. The study found that as the number of aphid sucking increases, the sagging among the plants also increases. There are so many changes including curling of the leaves. Further, changes include wilting and sometimes deleterious effects shoots and buds of the plant. Honeydew (excreted by aphids and other phloem-sucking insects) may appear to be covering the plant leaves, branches, and anything located underneath an infested plant. The study concluded that the plants may further be affected by other species attracted by the honeydew excreted by aphid species on the leaves.

Özgökçe and Atlihan (2005), conducted an experiment in the Van region of Turkey to study the population growth parameters of mealy plum aphid *Hyalopterus pruni* (Geoffroy) among four distinguishing apricot cultivars named as Tyrinte, Sakit, Colomer, and Bebeco. The study aimed to observe the vulnerability of the apricot cultivars. The results of the study outlined that the Tyrinte apricot cultivar was one of the most vulnerable cultivars to be affected by the mealy plum aphids.

Rakauskas et al. (2015), compared the guild structure of plum aphid (Hemiptera: Aphididae) in two different time frames. The study was conducted in Lithuania and the data was collected for two time periods as, before 1975 and after 2012. The formation of aggressive aphid species *Brachycaudus divaricatae* Shaposhnikov in 1956 was executed to examine the impact of this aggressive species on the native species. The results of the study found that there is no or least significant relationship between the native plum aphid species structure, host plant associations and seasonal dynamics frequency.

2.2. Biology of *Chrysoperla carnea*

Sattar (2010), studied the biological (biotic and abiotic) factors that impact *C. carnea.* The study observed the biotic factors including, host species and development stage. Similarly, Sattar *et al*. (2011), distinguished the effects of host on the biotic of *Chrysoperla carnea* (Stephens) through laboratory testing. The experiment was conducted at 26 ± 2 $^{\mathbf{0}}$C temperature, 65 ± 5% RH. The results of the study highlighted that, incubation time of eggs of *C. carnea* females feeding with distinguished hosts as larvae was observed to be significantly different with a value of (P<0.001). Thus, the study concluded that, maximum of 100% and a minimum of 50% survival to adult stage as hosts was *S. cerealella* and *P. gossypiella.* The maximum fertility per female recorded was (503.3±9.17).

Nadeem et al. (2014), conducted a study under the laboratory conditions to explore the reproductive features of the *C. carnea*. The study observed the effects of low temperature and considered the storage conditions for determining the reproductive system. The results of the study outlined that, the reproductive parameters including, pre-oviposition period, oviposition and adult life span were improved upon short and long period storage. The study concluded that the survival of the adult was possible at 6°C and 8°C, however; 10°C was identified as more effective for the survival.

Kasap et al. (2003), examined the *Chrysoperla carnea* (Stephens). The study conducted the test with two different preys, *Tetranychus urticae* Koch, and *Aphis pomi* (De Geer). The study tested the preys under fixed settings like 25 ± 2 °C temperature, 60 ± 10% relative humidity and for16 hours light period. The results showed that the development time for egg to hatch and grow as an adult of *C. carnea* fed on *A. pomi* was 25.68 days, and the highest mortality rate for first instar larva was observed to be 13.3% and for egg was 11%. *C. carnea* could not reach the adult stage when fed on *T. urticae.*

Letardi and Caffarelli (1990), Reared *C. Carnea* for five generations. *C. carnea* was fed on a semi-artificial liquid diet and studied the effects on development, mortality, and fertility. The results of the study outlined that the rate of development was same for all five generations however, the rate of mortality changed from 2.5% to 29.4% in 1st and 5th generations, respectively. The pre-imaginal mortality in the 5th generation was 58.82%. Similarly, no changed in the female fecundity was observed. The study did not observe changes in the rates of development or mortality between the offspring in each generation as they were reared on the natural prey (eggs of *Ephestia kuehniella*).

McEwen et al. (1993), examined the effect of providing artificial honeydew consisting of yeast autolysate, sugar and water in the ratio of 4:7: 10, live prey (eggs of *Ephestia kuehniella* (Zeller) and water and live prey on the larval development and survival of green lacewing *Chrysoperla carnea*.

Khan et al. (2013), studied the biological parameters of *Chrysoperla carnea* (Stephens) on *Schizaphis graminym* (Rondani) aphid. The research was carried out in an insectary bio control laboratory. The results of the study outlined that; incubation period was 3.8±0.08 days and 87.0% hatchability. The developmental duration of first instar larvae was observed to be 3.2 ± 0.13, second instar larvae was observed to be 4.0±0.21 and third instar larvae recorded was 4.8±0.25 days. However, the total larval developmental duration was 12.0 ±0.67 days with 85.05% survival rate. The predatory potential of larval was observed to be 414.6±0.05 aphid per larvae. The female and male longevity was observed to be 51.2 ± 2.18 and 32.4±2.04 days, respectively. The pre-oviposition, oviposition and post oviposition periods were 9.2±1.25, 34.6±1.72 and 7.4±1.02 days respectively. The total duration and survival rate from egg to adult was 24.6± 0.06 days with 73% rate of survival. The female fecundity was 384.2±21.20 eggs per female with 11.16±1.31 eggs per day per female.

Sultan et al. (2017), explored biological and life parameters of the green lacewing, *Chrysoperla carnea* (Stephens, 1836) (Neuroptera: Chrysopidae). The sample of the study was the sugarcane whitefly *Aleurolobus barodensis* (Maskell, 1896) (Homoptera: Aleyrodidae), the sugarcane stem borer, *Chilo infuscatellus* (Snellen, 1890) (Lepidoptera: Pyralidae) and the *Angoumois grain* moth, *Sitotroga cerealella* (Olivier, 1789) (Lepidoptera: Gelechiidae). Laboratory conditions used were set to be 26 ± 2^{o}C temperature and 65±5% R.H. The incubation period was 2.25 to 2.75 and 3.50 days on *S. cerealella*, the stem borer and the whitefly, respectively. *S. cerealella*'s larval period was 8.25 days for 10.00 days for the stem borer and 12.00 days for the whitefly. The highest larval survival rate (90.50%) was recorded on *S. cerealella*, followed by the whitefly (80.00%) and then the stem borer (61.75%). The adult survival rate was observed to be 70% for the stem borer was 80.75% for the whitefly and 95.50% for *S. cerealella*. Male and female longevity was *S. cerealella* less than whitefly that was less than stem borer. The *C. carnea* female laid 18 eggs per day with 91% fertility on *S. cerealella*, 13 eggs per day with 78% fertility on the stem borer and 12 eggs per day with 75% fertility on the whitefly. The highest values of *C. carnea* *Lx* (0.91), R_0 (106.45), *T* (50 days), *Mx* (263) and *rm* (0.1082) were recorded on *S. cerealella*. Whereas, doubling time (*DT*) (8.03007) and death rate D(x) 0.196 were found on sugarcane borer. Thus, the study concluded that Sugarcane whitefly and sugarcane stem borer could be alternate prey for *C. carnea.*

2.3. Life Table and Predation Rate of *Chrysoperla carnea*

Polat Akköprü and Atlihan (2016), examined both the growth potential and predation capacity of *C. carnea* fed *on M. persicae.* The study aimed to develop effective pest management programs. Intrinsic rate of increase (*r*), finite rate of increase (*λ*), net reproductive rate (R_0), and mean generation time (*T*) of the predator were 0.114 d^{-1}, 1.119 d^{-1}, 122.5 offspring and 40.48 d, respectively. The evaluation of predation potential, net predation rate and finite predation rate obtained are helpful in managing the pest control programs for high efficiency.

Yu et al. (2013), investigated the life table of green lacewing *Chrysopa pallens* (Rambur). The team observed the behavior at a specific temperature of 22 °C and with a photoperiod of 15:9 (L: D) h, whereas the relative humidity was 80% within the laboratory. The data was analyzed through age-stage, two-sex life table of intrinsic rate of increase (*r*), the finite rate of increase (*λ*), the net reproduction rate (R_0), and the mean generation time (*T*) of *Chrysopa pallens* were 0.1258 d^{-1}, 1.1340 d^{-1}, 241.4 offspring and 43.6 d, respectively.

Similarly, Sattar et al. (2007), investigated the generalist benefits of the important predator *Chrysoperla carnea* (Stephens). The study used a standardized artificial diet to enhance the larval efficiency for massive rearing of this predator. The study observed three different larval survival, pupation, and emergence percentage. The study concluded that there are variations among adults' longevity and egg lying potential.

Kayahan et al. (2014), studied survival and development period of *Chrysoperla carnea* larvae fed on *Aphis fabae* and *Aspidiotus nerii.* The study investigated development period and survival in a climate cabinet with temperature 26±0.0 °C and humidity as 60±1%. The room was in a light-dark period condition for 16: 8 hours. The results of the statistical analysis outlined that there are significant differences among all biological periods. However, the study also observed that developmental periods except egg period of *C. carnea* also had significant differences. Weibull distribution was adjusted to survival rate of development periods of *C. carnea* populations from two preys. Survival curves were adjusted to Holling's type III life curves because of the high mortality at the development periods.

Nadeem et al. (2012), studied the significance of temperatures in the development and production of insects and predators. The author investigated how temperature can be significant in development and production of insects and predators like *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). The study was determined under laboratory conditions in a completely randomized design to sort out the comparatively effective nurturing temperature by identifying developmental and reproductive parameters at different temperatures conditions.

Geethalakshmi et al. (2000), investigated the *Chrysoperla carnea* on *Corcyra cephalonica* (Stainton) eggs' biology and feeding. The study observed that the total days to be an adult from an egg were 22.2 with larval period of 10.3 and pupal period of 8.4 days. Progeny had a sex ratio of 1: 0.95 (male: female). Each female laid about 640 eggs, approximately. However, the results showed that the survival rate for females were higher than that of males as 39 and 26.5 days, respectively. In a single day, each larvaefed approximately 30.3 eggs of *C. cephalonica*, 33.4 eggs of *Helicoverpa arnigera*, 5.9 and *S. litura*, 33.3 and 24.6 *Aphis gossypii*, and *Planococcus citri*, 7.9 first instar larvae of *H. armigera*, 0.54 egg masses of *Spodoptera litura*, respectively.

Polat Akköprü and Atlihan (2014), explored the dusky-veined walnut aphid *Panaphis juglandis* (Goeze) (Hemiptera: Callaphididae) for intrinsic rate of increase, finite rate of increase and mean generation time. The results showed that intrinsic rate of increase was 0.103 d^{-1}, finite rate of increase was 59.91, and mean generation time was 39.72 d for an offspring. The study also observed that the predation rate was 143.94 aphids. *P. juglandis* can effectively be used to develop an efficient pest management program for *P. juglandis.*

Obrycki et al. (1989), studied the development of *C. carnea.* The study concluded that the development requires 20.5, 21.6 and 24.9 days at 27°C with a photoperiod of 16: 8 (L: D), when fed with *Ostrinia nubilalis* (Hubner) eggs, and *A. ipsilon* neonates, *Agrotis ipsilon* (Hufnagel) eggs respectively. It was observed that different aphid foods have different impact on larval development, weight of cocoons, juvenile mortality and adult fertility of *C. carnea. Myzus persicae* (Sulzer) and *Acyrthosiphon pisum* (Harris), were much more suitable than other aphid species studied. *Aphis fabae* (Scop.) was the most unfitting prey type for *C. carnea* as high juvenile mortality occurred to larvae fed on this species. Larvae fed on this aphid produced small cocoons and fecundity was much reduced compared to *M. persicae*. *Macrosiphum albifrons* (Essig) delayed development and affected the fecundity of adult females but caused less juvenile mortality (Osman and Selman, 1993).

Pari et al. (1993), used *Chrysoperla carnea* against infestations of the aphids, *Chaetosiphon fragaefolii* (Cockerell) and *Macrosiphum euphorbiae* (Thomas) with at least 20-larvae / linear rows in a paired form. The results of the study were satisfactory for pest management.

Similarly, Sengonca et al. (1995), analyzed the effect of *C. carnea* egg releases on the development of *Aphis fabae* population on sugar beet with several different predator- prey ratios such as 1: 15, 1: 10, and 1: 5. The research was conducted under both laboratory and field conditions. The results showed that under field conditions, a predator-prey ratio of 1: 5 provided a suitable protection for a period of approximately two weeks with less than 10.0 average numbers of aphids per plant.

Quentin et al. (1995), studied the efficiency of *Aphidius matricariae* (Haliday), *Aphidoletes aphidimyza* (Rondani) and *Chrysoperla carnea* in controlling aphid species, *Aulacorthum solani* (Kaltenbach), *Macrosiphum euphorbiae* (Thomas), *Nasonovia ribisinigri* (Mosley) and *Myzus persicae* (Sulzer) in green house. All predators and parasitoids did not give satisfactory control to aphids but the *C. carnea* was effective in controlling.

Daane et al. (1996), examined the effectiveness of inundate release of *C. carnea* to suppress vineyard pests *Erythroneura variabilis* (Beamer) and E. *elegantula* (Osborn). The results of the study observed reduction in Leafhopper densities by 23.5 and 30.3% in plots that received 29652 and 88956 *C. carnea* larvae/ ha, respectively, as compared with no-release plots. Similarly, significant position correlation was observed between release rate and effectiveness.

Batool et al. (2014), investigated the prey density impact on the biological and functional response of green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). It was observed that the prey density had a significant effect on positive consumption rate, fertility, and development of *C. carnea*. Maximum consumption within minimum time of fertility, longevity was also observed. Thus, the study observed that improved prey density reduce fertility and developmental time.

Rashid et al. (2012), observed that feeding of *Chrysoperla carnea* larvae and adults of *Cryptolaemus montrouzieri* on different nymphal instars of cotton mealy bug, *Phenacoccus solenopsis* plays an effective role in pest control program. The research was conducted in ambient laboratory conditions. The results confirmed that the proposed model has significant implications for the pest control program. The pest control program was found to be effective and efficient for the mealy bugs. The combination of these instars was found to be effective for the mealy bugs and to control their population. The results of the study outlined that the predators were effective in reducing nymphal instars occurrence.

Jokar and Zarabi (2012), outlined that *Chrysoperla carnea* (Steph.) is the prominent predator of whitefly and aphids. The study investigated the relative consumption and the effects of three different diets and kinds on prey development. Furthermore, the study also examined longevity, fertility, and ratio of male and female for *C.carnea.* The study tested larvae with different diets at different stages. The results of the study were aligned to the main aim and objective of the study. The results showed that there were close relations between different diet levels and the development of the whitefly and aphids. The study found that three nymphal stages including, *Shizaphis graminum*, and *Bemisia tabaci* (Biotype B), or a semi artificial diet that includes products that contain essential amino acids like honey, yeast, and Distilled water were evaluated. The study concluded that there is a significant relation between the level of diet and the development, longevity, fertility, and sex ratio among the cosmopolitan whitefly and the aphids.

Similarly, a study conducted by Shrestha and Enkegaard (2013), investigated the preference of prey between green lacewing called as *Chrysoperla carnea* (Neuroptera: Chrysopidae), and lettuce aphids, *Nasonovia ribisnigri* (Mosley) (Hemiptera: Aphididae) and western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). The study was conducted in the laboratory setting of temperature of 25 ± 1º C. the relative humidity during the experiment was observed to be 70 ± 5%. The experiment prepared five prey ratios. Furthermore, the study prepared third instar *C. carnea* larvae. *C. carnea* larvae were later prepared to prey on thrips and aphids. The findings of the study and the discussion of the results outlined that these can play an effective role in preparing pest controllers. *N. ribisnigri* and *F. occidentalis* by *C. carnea* are discussed were identified as potential targets.

Furthermore, a study conducted by Sattar et al. (2007), examined the predatory potential of *Chrysoperla carnea* (Stephens). The study sampled the predatory potential against mealy bugs. The experiment was conducted under laboratory conditions. The results revealed that *C. carnea* larvae were effective for controlling mealy bugs. Hence, the results of the study concluded that the *C. carnea* is among the potential predators against mealy bugs. This means that *C. carnea* could be effectively used against mealy bugs to control their development and/or reproduction.

McEven (1996), also studied the relationship between the level of food and the development of the larvae and survival from eclosion to pupation of *C. carnea*. The results of the study found that the larval development depends significantly on the level of food given to the species. McEwan et al. (1996), study tested the effect of artificial food supplement on larval development. The study also found the relationship between the level of food and the performance of *C. carnea*. The results of the study found that the relationship between the level of the food and the performance of the C. *carnea* is found to be significant. Similarly, Mishra et al. (1996), investigated the biological properties of the *Chrysopa scelestes* (Banks) on the eggs. The sample of the study was taken as the sugarcane pest *Pyrilla perpusilla* (Walker). The study was conducted in the laboratory and the results obtained showed insignificant relationship between the two.

Nasreen et al. (2004), investigated the effect of different quantities of host, *Sitotroga cerealella* eggs with different numbers of predators, *Chrysoperla carnea* eggs on the larval life of *C. carnea*. The study was conducted in laboratory conditions. The study found that larval length is insignificant in different treatments. Also, the study found that the quantities of the host impact significantly on the development of the larvae. Maximum larval length was recorded in treatments with high food levels (48 and 60mg) and vice versa. The effect of treatments was significant on larval weight. High food levels (48mg and 60mg) with two and three eggs of predators had highest larval weight as compared to less quantity of host eggs per capsule. The larval period was found in the range of 10.17-12.67 days in different treatments. Prepupae of alfalfa leafcutting bee, *Megachile rotundata* (F.), were evaluated as a larval diet of the lacewings, *C. carnea* and *Chrysopa oculata* Say. Leafcutting bee pre pupae were suitable for rearing lacewings: 90% of *C. carnea* eggs hatched and the larvae reached adulthood (Uddin et al., 2005).

Similarly, Saminathan et al. (2003), studied effect of prey density on the development period and predatory potential of *C. carnea.* The study included two pre densities of 100 and 200 per day. The study used *C. cephalonica* eggs, *A. gossypii* on cotton, bhindi / okra and guava, A. *craccivora* as prey insects on cowpea and groundnut, eggs and neonate larvae of *E. vitella* and *H. armigera*. The results of the study found that the density of the prey is closely related to the development and the predatory properties of the aphids. The experiment was conducted in the field under natural conditions and the results were aligned to the aim of the study. The study concluded that the density of prey was observed to influence the development period and vice versa.

Liu and Chen (2001), determined the effect of three aphid species *Aphis gossypii* Glover, *Myzus persicae* (Sulzer) and *Lipaphis erysimi* (Kaltenbach) (fourth instars only) on immature development, survival and predation of *C. carnea.* The study observed the effect of aphid species under laboratory conditions. The results of the study found that the survival rates of *C. carnea* during the first stage to adult age were significantly different among larvae fed on different aphids. When larvae were fed on *A. gosypii* and *M. persicae*, 94.4±3.3% (mean ± SE) and 87.6±5.1% species developed to adults, respectively; whereas only 14.9±3.4% of species developed with *L. erysimi* feeding. The study concluded that, although there is a significant difference between the total number of aphids consumed by the three *C. carnea* larval stadium, the proportions of aphids consumed by each larval stadium to the total number of aphids consumed were same as 3.9-7.1%, 12.0-16.8%, 78.1-83.0% respectively.

Gautam et al. (2009), conducted an experiment for a life table of two chrysopid predators *Chrysoperla sp.* (*carnea*-group) and *Mallada desjardinsi* (Navas) on the invasive mealybug named as *Phenacoccus solenopsis* (also reported as *P. solani*). The experiment was conducted under laboratory conditions. The aim of the experiment was to analyze the effectiveness of predators in pest control. The study observed and compared the rate of mortality and age intervals. *Chrysoperla sp.* (*carnea*-group) (0.28) was found to have greater age interval as compared to *M. desjardinsi* (0.22) while it was contrary during 70-77 days age interval at the time it was reared on *P. solenopsis.* The rate of multiplication per day was observed to be 0.1159 for female and 0.1414 females for *Chrysoperla sp*. (*carnea*-group) and *M. desjardinsi*. The intrinsic rate of increase (*rm*) was observed to be 0.11 for both *Chrysoperla sp*. (*carnea*-group) and *Mallada desjardinsi* (Navas). *Chrysoperla sp*. (*carnea*-group) population multiplied 62.80 times in a generation time of 35.72 days on the mealy bug. Furthermore, the results of the study showed that, *M. desjardinsi* multiplied 67.12 times in 29.75 days.

Bar et al. (1979), studied the efficiency of *Chrysoperla carnea* as an important predator of *Heliothis armigera*. The experiment was conducted in cotton fields. Observations concluded that the predators exist throughout the occurrence time period for H. *armigera*. Gurbanov (1984) conducted an experiment included three releases of 3-4 days old eggs and 1st and 2nd instar larvae of *C. carnea*. The aim of the study was to control the sucking pests and *Heliothis armigera* in cotton field. The results for three releases outlined that, prey ratio 1:1 observed to be weak after the 1st release, the abundance of *Aphis gossypii*, the thrips and spider mites, eggs and larvae of *Heliothis* sp. reduced by 98.5%, 95%; 100% and 50% in the 25. The results of the study concluded even more reduction with the second and third release.

Furthermore, a study conducted by Atakan (2000), explored the distribution of *Chrysoperla carnea* in cotton fields. The results showed that the early cotton growing season has the highest density of *D. pallens* and *C. carnea* is specifically related with *Aphis gossypii.*

Badgujaret et al. (2000), and Hemagirish et al. (2001), conducted an experiment to analyze *Chrysoperla carnea*'s effective stage and rate of releases against safflower aphid, *Dactynotus carthami* (HRL.). The study concluded that, larval discharges of *C. carnea* reduced the density of aphids by 40 to 50% when 2nd or 3rd larvae of *C. carnea* were released at the population level of 10 or 20 aphids per shoot. However, the release of eggs did not impact the density of aphids.

3. MATERIALS AND METHODS

3.1. Insect Rearing

A stock colony of *Chrysoperla carnea* was collected from apricot orchards around Van province in the eastern region of Turkey and was reared by depending on a method modified from Hassan (1975). At the same time, *Hyalopterus pruni* was collected on its secondary host plant, *Phragmites australis* (Cav.) (Figure 3.1). The colony was kept in a cage in a growth chamber at 25 ± 1 ^{o}C temperature, 60 ± 10% RH, and a photoperiod of 14:10 (L:D) h. (Figure 3.2).

Figure 3.1. *Hyalopterus pruni* on *Phragmites australis*.

Figure 3.2. Growth chamber.

3.2. Life Table of *Chrysoperla carnea*

To start the investigation, the eggs that were taken from stock culture were shifted to Petri dishes (one egg per dish). According to preliminary tests, various numbers of aphids were provided to different stages of *C. carnea*: 30 aphids for 1st instar larva, 60 aphids for 2nd instar larva and 90 aphids for 3rd instar larva, respectively (Table 3.1). Duration of the developmental stages and the survival rate of the predator were recorded by daily observations.

Table.3.1. Number of aphids provided.

Stages of *C. carnea*	Number of aphids
First instar larva	30
Second instar larva	60
Third instar larva	90

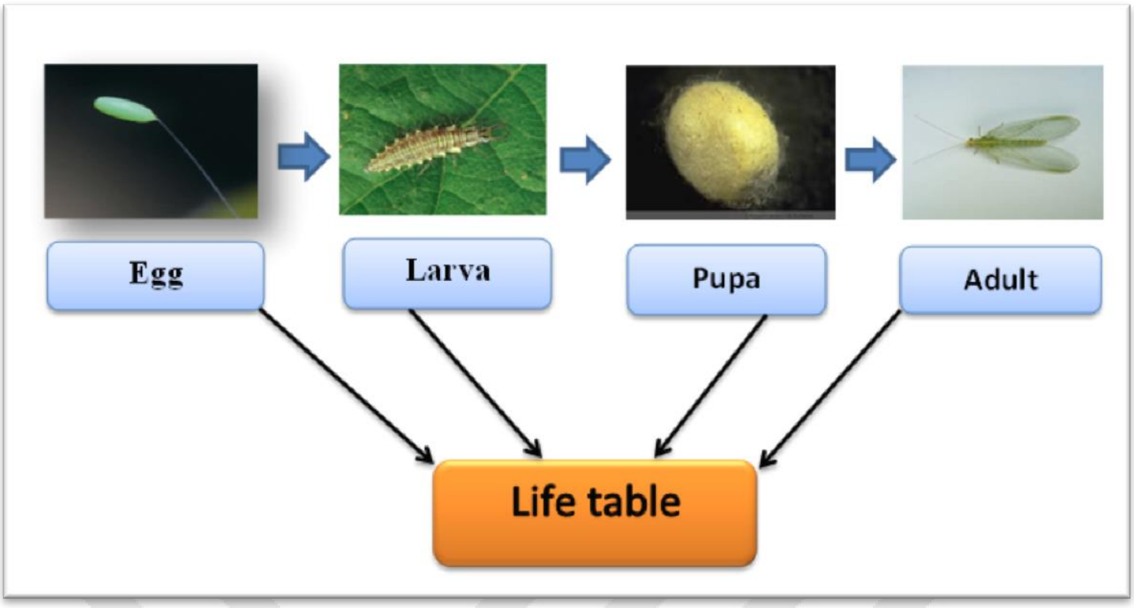

Figure 3.3. Developmental stages of *Chrysoperla carnea.*

After adult emergence, male/female pairs were transferd to glass jars (200*120 mm) with a solution (water + hony + yeast) described by Hassan (1975). The survival rate and the number of eggs laid were also recorded daily until the female died (n=10-16) (Figure 3.4, 3.5). The experiments were conducted at 25 ± 1 ^{o}C temperature, 60 ± 5% RH, and a photoperiod of 16:8 (L: D) h. in a temperature-controlled cabinet.

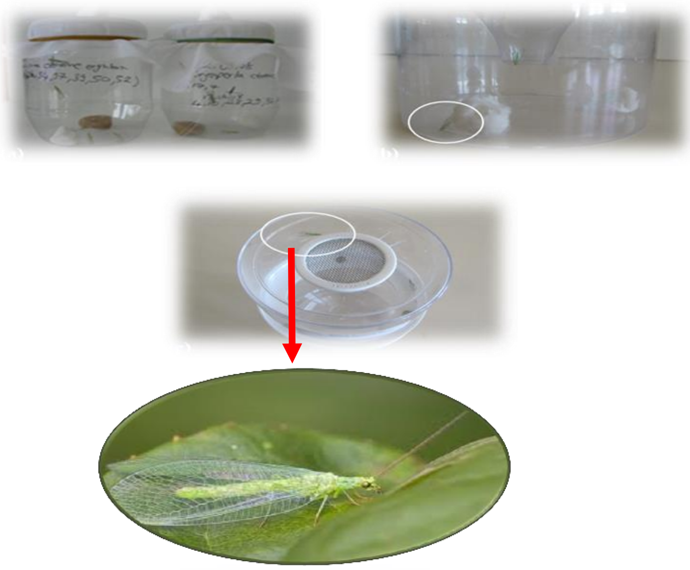

Figure 3.4. Combined adults of *Chrysoperla carnea* for mating.

Figure 3.5. Solution food for adult of *Chrysoperla carnea.*

3.3. Predation Rate of *Chrysoperla carnea*

The predation rate of the predator was investigated at same time with life table studies. In the life table studies of *C. carnea*, when prey was given as food, the number of prey consumed was counted every day, and the larvae of *C. carnea* were transferred to a new petri dish and new aphids were provided as food every day. Hence, the number of aphids consumed by every stage and the total (from 1st instar larvae to adult) was calculated.

3.4. Data Analysis

3.4.1. Life table analysis

To get the accurate life table results, daily raw data of developmental time, survival and fecundity were analyzed using the computer program TWOSEX-MSChart (Chi 2017a) based on the age-stage, two-sex life table theory (Chi and Liu 1985, Chi 1988) which takes the stage differentiation of the immature stage, real survival, and the male population into account

The age-stage specific survival (s_{xj}) (where x = age of insect in days and j = stage), age specific survival rate (l_x), age specific fecundity (m_x), age-stage specific fecundity (f_{xj}), age-stage specific life expectancy (e_{xj}), age-stage specific reproductive rate (v_{xj}) and population parameters (intrinsic rate of increase (r); finite rate of increase (λ); net reproductive rate, (R_o) and mean generation time, (T) were calculated accordingly.

In the age stage, two-sex life table the l_x, m_x and R_0 values are calculated as:

$$l_x = \sum_{j=1}^{k} s_{xj} \tag{1}$$

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}} \tag{2}$$

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \tag{3}$$

Where k is the number of stages. The intrinsic rate of increase (r) and finite rate of increase (λ) was estimated using the iterative bisection method from the Euler-Lotka formula with age indexed from 0 (Goodman 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1 \tag{4}$$

The finite rate (λ) and the mean generation time (T) were then calculated as follows:

$$\lambda = e^r \tag{5}$$

$$T = \frac{\ln R_0}{r} \tag{6}$$

The life expectancy (e_{xj}) is the length of time that an individual of age x and stage j is expected to live and it is calculated according to (Chi and Su 2006) as:

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{k} s'_{iy} \qquad (7)$$

Where s'_{iy} is the probability that individuals of age *x* and stage *j* will survive to age *i* and stage *y* and, is calculated by assuming s'_{xj} = 1. The reproductive value (v_{xj}) was calculated according to (Tuan et al. 2014a, Tuan et al. 2014b) as:

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{k} s'_{iy} f_{iy} \qquad (8)$$

The standard errors of the development time, reproduction time, fecundity and population parameters were analyzed via a bootstrap approach with 100,000 replicates (Efron and Tibshirani 1993, Johnson 2001, Polat-Akköprü et al. 2015) in order to avoid problems that can be caused by simplified methods as pointed out by Carter et al. (1978) and Hesterberg (2008). The differences among treatments were analyzed with paired bootstrap test at 5% significance level. The bootstrap method and paired bootstrap test are embedded in the computer program TWOSEX-MSChart.

The standard errors of the population parameters were estimated using the bootstrap method with 200,000 resampling.

3.4.2. Predation rate analysis based on age-stage, two-sex life table

Predation rate data were analyzed by using the computer program CONSUME-MSChart (Chi, 2017b).

k_x: The age-specific predation rate is the mean number of aphids consumed by *C. carnea* at age x

$$k_x = \frac{\sum_{j=1}^{\delta} s_{xj} c_{xj}}{\sum_{j=1}^{\delta} s_{xj}}$$

q_x: The age-specific net predation rate. This rate represents the mean number of aphids a predator needs to consume to produce an offspring.

$$q_x = k_x l_x$$

C_0 : The net predation rate is the total number of prey killed by an average individual during its life span.

$$C_0 = \sum_{x=0}^{\infty} l_x \, k_x$$

Q_p: The transformation rate from prey population to predator offspring.

$$Q_p = \frac{C_0}{R_0}$$

4. RESULTS AND DISCUSSION

4.1. Life Table of *Chrysoperla carnea* Fed on *Hyalopterus pruni*

In our study, we examined feeding of *Chrysoperla carnea* on *Hyalopterus pruni* which resulted in 3.67 days of egg incubation period, the period of first, second, and third instar larvae were 3.87, 3.07 and3.89 days, recpectively. The 2nd larvae period was days and the 3rd larvae period was days. Pupa life span was 9.48 days and the developmental time of pre adult stages was recorded a as 23.96 days, respectively (Table 4.1). However, Khan et al. (2013) investigated the developmental duration of the 1st, 2nd and 3rd instar larva as 3.2 ± 0.13, 4.0±0.21 and 4.8±0.25 days, respectively. The total larval developmental duration was 12.0 ±0.67 days with 85.05% survival rate.

The rates of mortality of *C. carnea* (Stephens) in pre-adult development periods are shown in Table 4.1. According to the results, the rate of the egg mortality was 14% and the rate reached its highest level in the first larval period which was 12%, The total mortality rate was 25% in pre-adult duration, and there was no mortality in the third larval and pupal periods.

The highest mortality rate of *C. carnea* fed on *P. juglandis* at 23 ° C was observed in the third larval stage and total immatıue mortality as 21.66%, while the highest mortality rate at 28 ° C was in the pupal stage and total mortality was 29.82%. (Yarımbatman and Atlıhan 2008). Results obtained by are Yarımbatman and Atlıhan (2008) are different than our results, the difference may be attributed to the temperatures, and preys used.The developmental time from egg to adult of *C. carnea* fed on *Aphis pomi* took 25.68 days and the mortality rate of the predator was 11% in egg period and 13.3% in first larval period, respectively. Mentioned results are similar to results we obtained.

Table 4.1. Preadult developmental time (Mean ± SE) and mortality of *C. carnea* reared on *H. pruni*.

Stages	*N*	Mean (day)	Mortality (%)
Egg	36	3.67 ± 0.11	14
L1	31	3.87 ± 0.129	12
L2	27	3.07 ± 0.106	10
L3	27	3.89 ± 0.134	0
Pupa	27	9.48 ± 0.098	0
Total preadult	27	23.96 ± 0.223	25

The age-stage-specific survival rate (s_{xj}) indicates the probability that a newly laid egg of *C. canea* will survive to each age-stage unit The probability that a newly laid egg would survive to the adult stage was 0.33 for female and 0.30 for the male. (Figure. 4.1). The figure also represents stage differentiation of all individuals of *C. carnea*. The female's and male's survival curves were constant horizontally, so that the periods when no deaths occurred were between the 26th- 65th d for female and the 26th -52th d for male, respectively. However, Yu et al. (2013) examined the probability of a newly laid egg of *Ch. pallens* surviving to the adult stage was 0.38 and 0.35 for females and males, respectively. Their results are slightly higher than our findings, the difference in preys used may explain the difference mentioned.

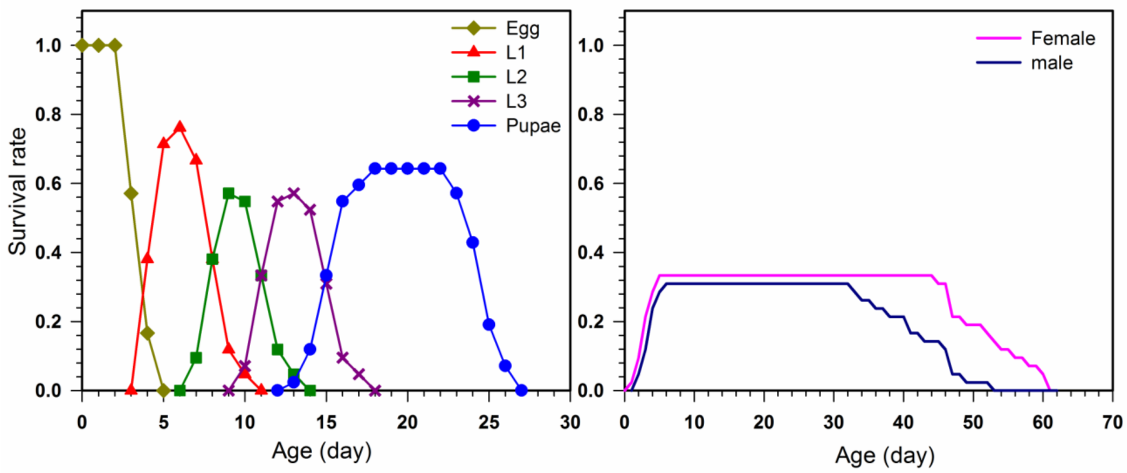

Figure 4.1. Survival rate (s_{xj}) of *C. carnea* fed on *H. pruni*.

4.2. Fecundity

The length of adult preoviposition period (APOP), total preoviposition period (TPOP), longevity and fecundity of *C. carnea* fed on *H. pruni* were shown in Table 4.2.

In this study, the first mating appeared within 24 hours after adults emerged and was repeated several times throughout the adult life span. The results showed that the adult pre-oviposition (APOP) periods and the total pre-oviposition periods (TPOP) were 12.71 ± 0.77 and 36.86 ± 0.78 days, respectively (Table 4.2). The total longevity of male and female were 62.69 ± 1.71 and 73.64 ± 1.55 days, respectively (Table 4.2). On the other hand, the female lived longer than the male. The fecundity rate was 614.93 ± 65.12 eggs per female. Yu et al (2013) reported similar results for TPOP (34.3 d) and fecundity rate was (660.7 eggs per female). Atlıhan et al. (2001) indicated that duration of adult preoviposition, oviposition and postoviposition days of C. carnea fed on H. pruni at 25^{0}C were 6, 41.9 and 2.4 days, respectively. However, Serafi et al. (2000) showed pre-oviposition period of *C. carnea* as 9.46, 7.29, 8.9 and 10.72, and oviposition periodsas 24.6, 18.6, 20.50 and 26.15, and 8.40, 6.9, 7.20 and 5.73 days respectively when fed *A. gossiypii*, *S. avenae*, *R. maidia* and *A. nerii leaves*, respectively. On the other hand, Sattar et al. (2011) determined the pre-oviposition, oviposition, postoviposition periods and oviposition days of *C. carnea* feeding on *Aphis gossypii* as 3.37, 27.62, 6.87 as15.21 days. Khan et al. (2013), indicated that durations of adult preoviposition, oviposition, post-oviposition, female and male longevity of *C.carnea* fed on *Schizaphis graminum* were 9.2, 34.6, 7.4, 51.2 and 32.4 days respectively. Kasap et al. (2003) concluded the female and male longevity of *C. carnea* fed on *Aphis pomi* to be 54.30 and 49.33 days respectively, and the fecundity to be 641.28 eggs per female. In general, results in the literature mentinoned were different than our findings. Differences with results in literature might be due to different preys and temperatures used.

Table 4.2. Longevity and fecundity of *C. carnea* reared on *H. pruni*.

Statistics	*n*	Mean ± SE
Adult pre-oviposition period (APOP)	14	12.71 ± 0.77
Total pre-oviposition period (TPOP)	14	36.86 ± 0.78
Fecundity (eggs/female)	14	614.93 ± 65.12
Female longevity	14	73.64 ± 1.55
Male longevity	13	62.69 ± 1.71

The age specific survival rate (l_x), the age-specific fecundity (m_x), and the age-specific maternity ($l_x m_x$) of *C. carnea* were displayed in figure 4.2. The curves of age-specific maternity ($l_x m_x$) and age-specific fecundity (m_x) show severely periodic peaks in reproduction. A maximal daily mean fecundity (m_x) of *C. carnea* (13,37 offsprings per per female) was obtained at age 56 days. The maximum maternity value ($l_x m_x$) was 7.8 eggs per day. However, Yu et al. (2013) determined the maximum maternity value of the female (m_x) of *Chrysopa pallens* fed with *Aphis craccivora* as 1.3, which is considerably lower than our result.

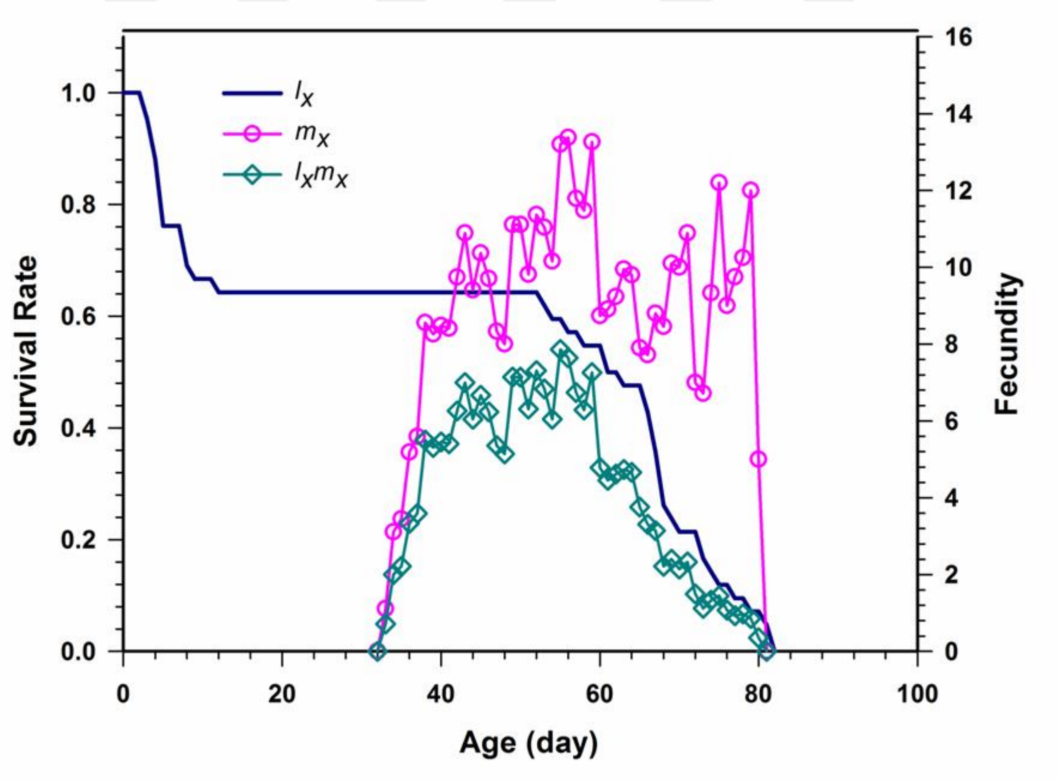

Figure 4.2. Age-specific survival rate (l_x), age-specific fecundity (m_x) and age- specific maternity ($l_x m_x$) of *Chrysoperla carnea* reared on *Hyalopterus pruni*.

4.3. Population Parameters

The intrinsic rate of increase (*r*) and the finite rate of increase (*λ*) of *C. carnea* fed on *H. pruni* was 0.1094 d^{-1} and 1.1157 d^{-1}, respectively. The net reproductive rate (R_0) of the predator was 204.98 offspring, and the mean generation time (*T*) was 48.62 days. (Table 4.3). However, Atlıhan et al. (2001) concluded that the net reproductive rate of *C. carnea* fed with *H. pruni* at 25 ° C was 235.43 female / female, and the mean generation time was 34.35 days. Polat Akköprü and Atlihan (2014) worked on predation rate and two-sex life table of *C. carnea* fed on *Panaphis juglandis,* and they determined that the intrinsic rate of increase (*r*), the finite rate of increase (λ), the net reproductive rate (R_0), and the mean generation time (*T*) of were 0.103 d^{-1}, 1.108 d^{-1}, 59.91 offsprings and 39.72 days respectively. In another study by Polat Akköprü and Atlihan (2016) the predation rate of the *.carnea* fed on *Myzus persicae* was evaluted, and they found out that the intrinsic rate of increase (*r*), the finite rate of increase (*λ*), the net reproductive rate (R_0), and the mean generation time (*T*) of the predator were 0.114 d^{-1}, 1.119 d^{-1}, 122.5 offsprings and 40.48 d. respectively.

Morever, Kasapet al. (2003) concluded that the intrinsic rate of increase (*r*), was 0.138 female /female/days, and the net reorpductive rate (*Ro*) of *the* predator fed on *Aphis pomi* at 25 ± 2 ° C was 155.7 female/female, and the mean generation period was 36.7 days.

Table 4.3. Population parameters (Means ± SE) of *C. carnea* reared on *H. pruni.*

Population Parameters	Mean ± SE
Intrinsic rate of increase, *r* (d^{-1})	0.1094 ± 0.00615
Net reproduction rate, R_0 (offspring)	204.98 ± 49.39057
Finite rate of increase, λ (d^{-1})	1.1157 ± 0.006848
Mean generation time, T (d)	48.62 ± 0.998

The age-stage specific life expectancy (e_{xj}) of *C. carnea* was shown in Figure 4.3. The life expectancy relates to the period that an individual of age *x* and stage *j* is expected to survive. As this study was carried out in the laboratory without the adverse effects of field conditions, the life expectancy reduced step by step with aging.The average life expectancy of a newly hatched *C. carnea* egg was 46 days and the expected life span of the female was 51 days which is considered to be higher than that of the male expected life span (40 days). Yu et al. (2013) reported that the average life expectancy of *Chrysopa pallens* fed on *Apha craccivora* was 49 days and the expected life span of *C. pallens* female was 78 days. Thus, the expected life span of *C. carnea* is parallel to the expected life span of the study mentioned, but the expected life span of the female is shorter.

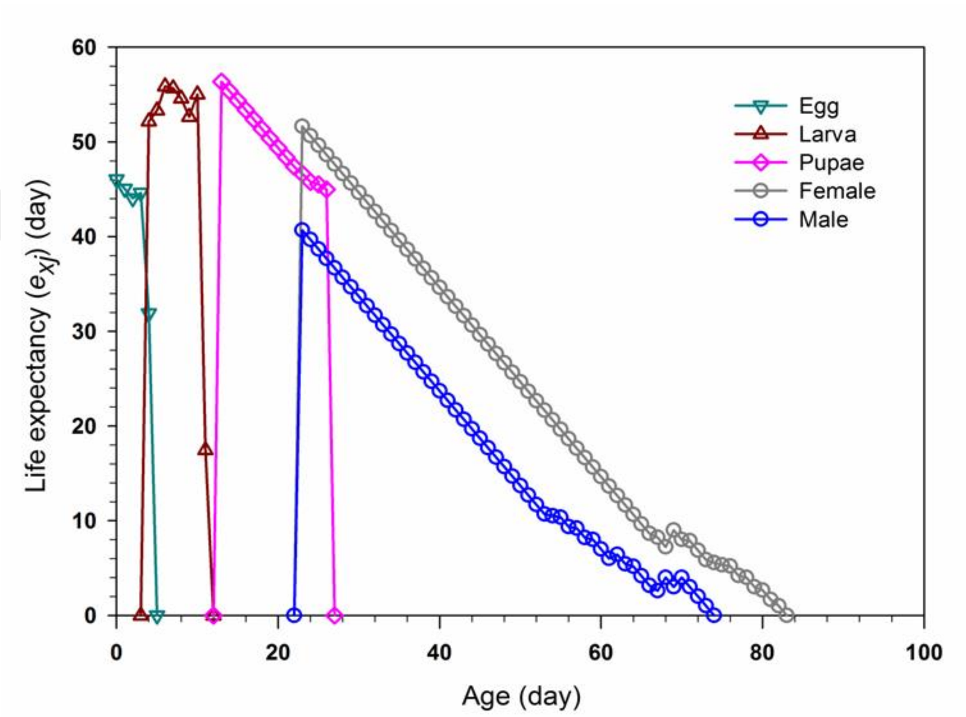

Figure 4.3. Age-stage specific life expectancy (e_{xj}) of *C. carnea* fed on *H. pruni*.

Age-stage specific reproductive value (v_{xj}) indicates the contribution of a *C. carnea* individual at age x and stage j to the future population (Figure 4.4). Once the pre-adult period finished, the females reproductive value increased significantly with the onset of fecundity. The highest point in the reproduction curve shows an individual's ability to have the highest contribution to the population. For example, a female at the age of 21 days has a reproductive value of 37.2. On the other hand, a 42-d-old female has a significantly lower reproductive value, 173.7. In a study by Yu et al (2013), the females of *Chrysopa pallens* fed with *Aphis craccivora* were mature on the 26th day and the highest v_{xj} value (267.1) was obtained at the 37th day.

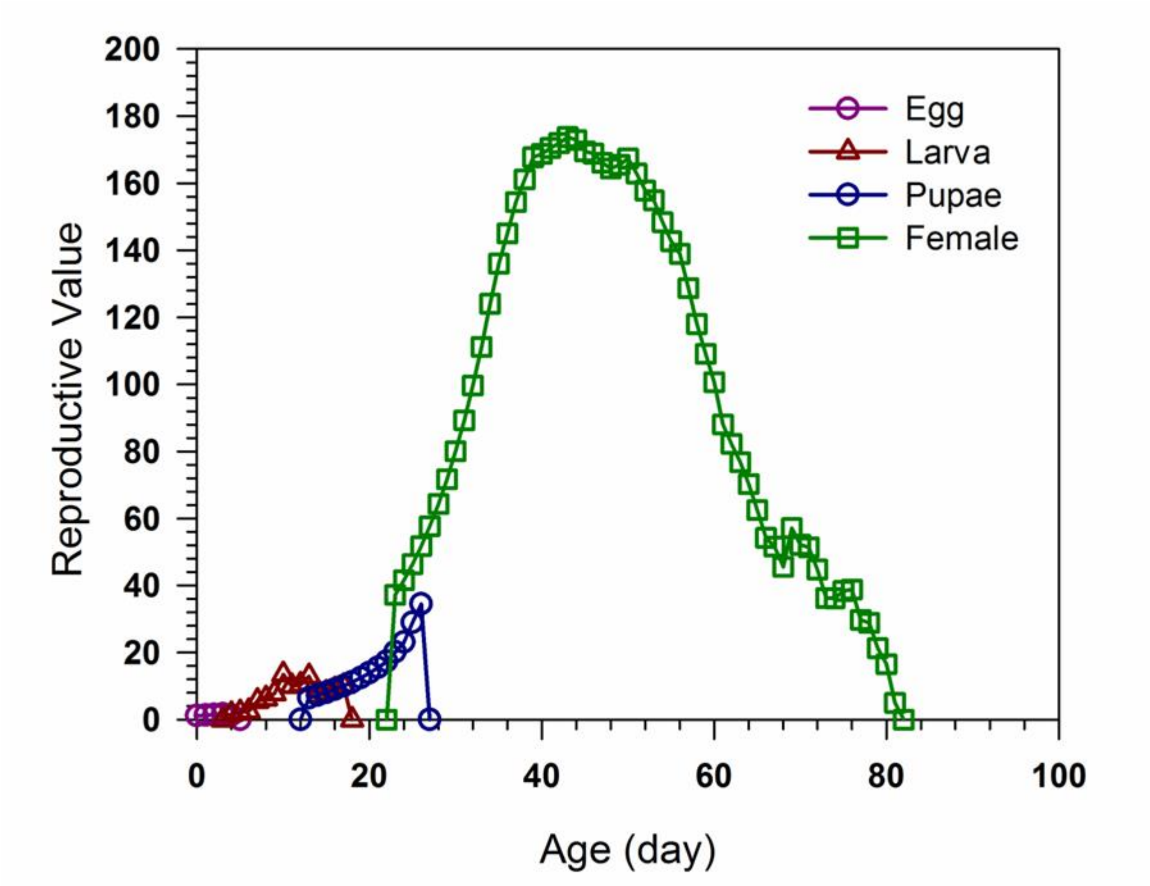

Figure 4.4. Age-stage specific reproductive value (v_{xj}) of *C. carnea* fed on *H. pruni.*

4.4. Predation Rate

The results of the study shows that the predation rate of the 1st , 2nd and 3rd instar larva were 88 ± 4.0, 125.93 ± 4.56 and 287.74 ± 9.24 aphids, respectively (Table 4.4). Moreover, all larval stages of *C. carnea* are voracious predator of *H. pruni* aphid and maximum aphid was consumed by the third instar larvae. The predation rates of third larval stages of *C. carnea* were higher than those of first and second larval instars. The total predation rates of the larval stages increased in an exponential way. The overall numbers of aphids consumed through the larval stage was 501.67 ± 17.8 aphids (Table 4.4).The net predation rate was 339.12 aphids, the transformation rate was 1.65, the stable predation rate was 15.75 aphids and the finite predation rate was17.56, respectively (Table 4.4).

Polat Akköprü and Atlihan (2016) conducted a study on predation rate of *C. carnea* fed on *Myzus persicae* (Sulzer), their results showed that the net predation rate

(C_0) and the finite predation rate (λ), of the predator were 324.67 and 14.25 aphids, respectively. Polat Akköprü and Atlihan (2014) also reported the net predation rate (C_0) of *C. carnea* fed on *Panaphis juglandis* as 143.941 aphids. The results obtained with *M.persicae* were similar to our findings, but a results obtained with *P. juglandis* was different. However, Khan et al. (2013) studied predatory potential of *C. carnea fed* on *Schizaphis graminu* and the results showed that the larvae consumed 414.6 ± 0.05 aphids. The result mentioned is lower than that of our, the discrepancy with literature may be attributed to the different prey used in the experiments.

Table 4.4. Predation rates (mean ± SE) of *C. carnea* fed on *H. pruni.*

Stage and statistics		Predation rate (aphid/predator)	
		N	Mean ± SE
Larval stage	First instar	31	88±4.0
	Second instar	27	125.93±4.56
	Third instar	27	287.74±9.24
Total Preadult	First to Third instar	42	501.67 ± 17.8
C_0			339.12±10.48
Q_p			1.65
Stable predation rate (Psi)			15.75
Finite predation rate			17.56

Age-specific survival rate (l_x), age-specific predation rate (k_x) and age-specific net predation rate (q_x) of *C. carnea* fed on *H. pruni* are plotted in Figure 4.5. The summation of all *qx* indicates the net predation rate (C_0). The three arrows show the gaps in curves of k_x and q_x because the eggs, pupa and adults of *C. carnea* don’t consume prey.

The age-specific net predation rate (q_x) is the weighted number of prey consumed by a predator of age *x*, (Figure 4.5). The age-specific predation rate (k_x) is the mean number of aphids consumed per *C. carnea* of age x (Figure 4.5). Both q_x and k_x were calculated and it was calculated by incorporating the age-specifc survival rate. The stages of non-predatory including the eggs, pupae and adult stages resulted in three gaps in the predation rate.

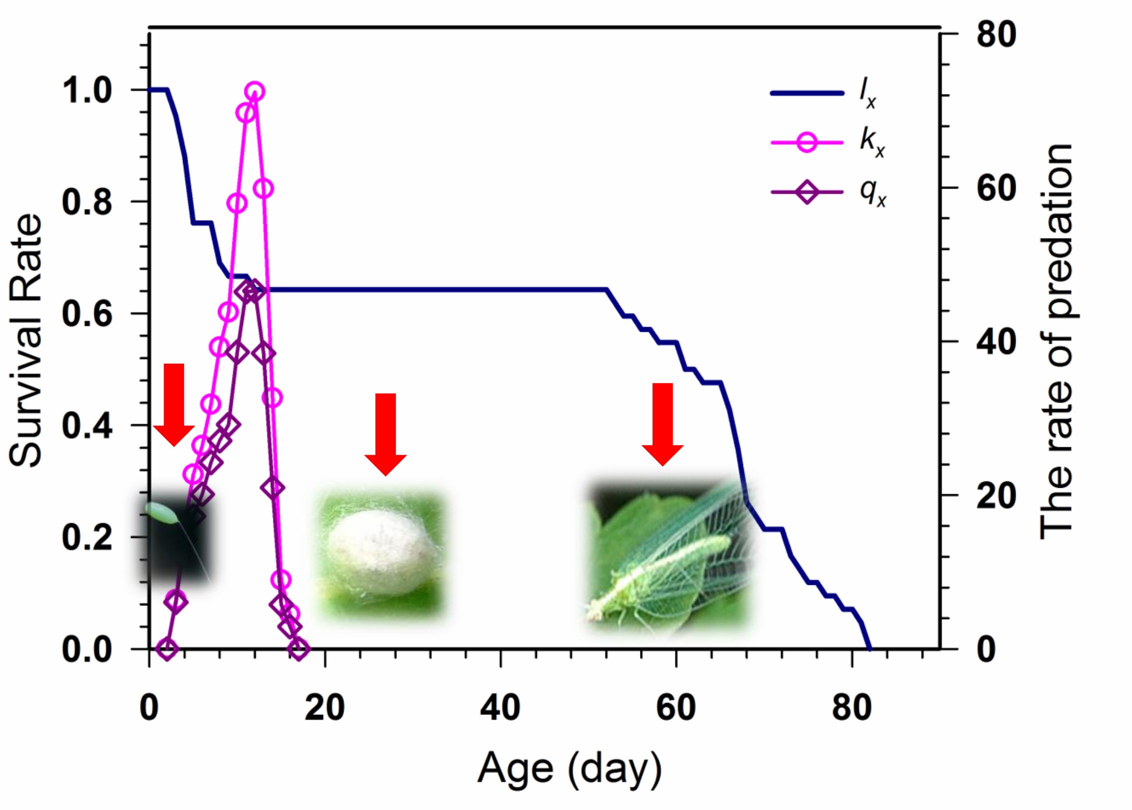

Figure 4.5. Age-specific survival rate (l_x), age-specific predation rate (k_x) and age-specific net predation rate (q_x) of *C. carnea* on *H. pruni*.

The age-stage specific predation rates (c_{xj}) of *C. carnea* fed on *H. pruni* is plotted in Figure 4.6. It shows the mean predation rate consumed by *C. carnea* larva at age *x* and stage *j*. As there is an overlap of predation rates at different stages, thus, the variability in the consumption rate between individuals can be observed. As it the expected, the daily predation rate of third instar larva is higher than thats of the other instars (Figure 4.6). The 3rd instar larva is generally described as a much more successful and economically essential predator on *H. pruni*. It is worth to mention that the egg and pupa periods and adult periods are not shown in the graphical curves as they are not consumed in these periods. Similar to our results, Liu and Chen (2001) obtained that the *C. carnea* had higher rates of predation in the third larval period in comparison to other larval instarts. On the other hand, Khan et al. (2013) indicated that the predatory potential of first, second and third instar larvae of *C. carnea* fed on *Schizaphis graminum* were 61.8 ± 1.973, 113.6 ± 2.426 and 239.2 ± 6.870 aphids, respectively.

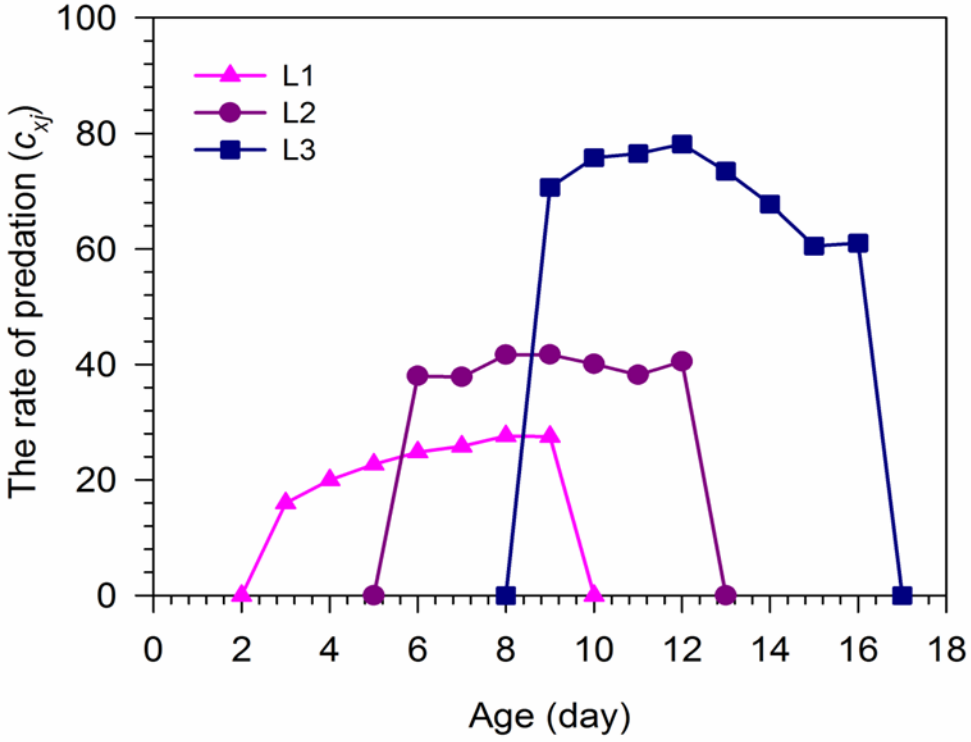

Figure 4.6. The age-stage specific predation rate (c_{xj}) of *C. carnea* fed with the third larval stage of *H. pruni*.

5. CONCLUSION

By the current study, the significance of using age-stage, two-sex life table and predation rate for mass-rearing studies is examined. The use of the age-stage, two-sex life table is highly recommended for studies that concern integrated pest management and biological control, and in all related research areas.

In our study, data on the development, survival, reproduction, life table and predation rate of *Chrysoperla carnea*, which is known as a common natural enemy of Hyalopterus pruni, were obtained. These results obtained may be useful in the management program prepared or developed for H. pruni. The field investigations on release density and effects of climate on the effectiveness of the predator should be carried out to drive the firm conclusion.

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REFERENCES

Atakan, E., 2000. Within plant distribution of predators *Chrysoperla carnea, Deraeocoris pallens* and *Orius niger* on cotton. ***Turkiye Entomology Dergisi,* 4**: 267-277.

Atlihan, R., Denizhan, E., Yasar, B., 1999. Effects of different prey on the development and fecundity of *Scymnus subvillo sus* Goeze (Coleoptera: Coccinellidae). ***Turkish National Congress of Biological Control***: 379-406.

Atlıhan, R., Kaydan, B. M., Özgökçe, M. S., 2001. *Hyalopterus pruni* (Geoffer) (Hom.: Aphididae) ile beslenen avcı böcek *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)'nın bazı biyolojik özellikleri üzerine araştırmalar. ***Türkiye Entomoloji Dergisi****,* **25**(3): 223-230.

Atlihan, R., Kaydan, B., Özgökçe, M. S., 2004. Feeding activity and life history characteristics of the generalist predator, *Chrysoperla carnea* (Neuroptera: Chrysopidae) at different prey densities***. Journal of Pest Science,* 77**: 17-21.

Badgujaret, M. P., Deotale, V. Y., Sharnagat, B. K., Nandanwar, V. N., 2000. Performance of *Chrysoperla carnea* against safflower aphid, *Dactynotus carthami* (HRL.). ***Journal of Soils and Crop,* 10**: 125-127.

Bar, D., Gerling, D., Y. Rossler, Y., 1979. Bionomics of the principal natural enemies attacking *Heliothis armigera* in cotton fields in Israel. ***Environmental Entomolgy,* 8**: 468-474.

Batool, A., Abdullah, K., Rashid, M. M. U., Khattak, M., Abbas, S. S., 2014. Effect of prey density on biology and functional response of *Chrysoperla carnea* (stephens) (neuroptera: chrysopidae). ***Pakistan Journal of Zoology,* 46**(1): 129-137.

Berker, J., 1985. Dienatu rlichen feinde der tetranychiden. ***Zeitschrift für Angewandte Entomologie,* 43**:115-142.

Blackman, R. L., Eastop,V. E.,1984. ***Aphids on the World's Crops: An Identification Guide.*** John Wiley and Sons, New York***:*** 466.

Bodenheimer, F.S. and Swirski, E., 1957. ***The Aphidoidea of The Middle East.*** The Weizmann Science Press of Israel, Jerusalem, Israel.

Carter, N., Aikman, D. P., Dixon, A. F. G., 1978. An appraisal of hughes' time specific life table analysis for determining aphid reproductive and mortality rates. ***journal of Animal Ecology***, **47**: 677-687.

Chi, H., Liu, H., 1985**.** Two new methods for the study of ınsect populatıon ecology. ***Bulletin of the Instituteof Zoology, Academia Sinica,* 24**(2): 225-240.

Chi, H., 1988. Life-table analysis ıncorporating both sexes and variable development rates among ındividuals. ***Environmental Entomology***, **17**(1):26-34.

Chi, H., 2017a. TWOSEX-MSChart: a computer program for the age-stage, two-sex life table analysis.***http://140.120.197.173/Ecology/Download/TWOSEX-MSChart.zip*.**

Chi, H., 2017b. CONSUME-MSChart: a computer program for the predation rate analysis based onage-stage, two-sex life table ***http://140.120.197.173/Ecology/ Download/Consume-MSChart.zip*.**

Chi, H., Su, H., 2006. Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead) (Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer) (Homoptera: Aphididae) with mathematical proffof the relationship between famale fecundity and the net reproductive rate***. Environmental Entomology*, 35**(1):10-21.

Cranshaw, W. S., 2009. ***Aphids on Shade Trees and Ornamentals***. Colorado state university, U.S. department of agriculture and colorado counties cooperatin. **5**:511

Daane, K. M., Hagen, K. S., Mills, N. J., 1998. ***Predaceous Insects for Insects and Mite Control***. In Mass-Reared Natural Enemies: Application, Regulation and Needs: 61–115.

Daane, K. M., Yokota, G.Y., Zheng, Y., Hagen, K. S., 1996. Inundative release of common green lacewings (Neuroptera: Chrysopidae) to suppress *Erythroneura variabilis* and *E. elegantula* (Homoptera: Cicadellidae) in vineyards. ***Environmental Entomology,*** **25**: 1224-1234.

Efron, B., Tibshirani, R. J., 1993. ***An Introduction to The Bootstrap***. Chapman and Hall , New York, NY.

El Serafi, H. A. K., Salam, A., Bakey, N. F., 2000. Effect of four aphid species on certain biological characteristics and life table parameters of *C. carnea* (Stephens) and *Chrysoperla septempunctata* Wesmael (Neuroptera: Chrysopidae) under laboratory conditions. ***Pakistan Journal of Biological Sciences,*** **3**: 232-245.

Farhadi, R., Allahyari, H., Chi, H., 2011. Life table and predation capacity of *Hippodamia variegata* (Coleoptera: Coccinellidae) feeding on *Aphis fabae* (Hemiptera: Aphididae). ***Biological Control,*** **59**: 83-89.

Gautam, R. D., 1994. Present status of rearing of chrysopids in India. ***Bull Entomology,*** **35**: 31-39.

Gautam, S., Singh, A. K., Gautam, R. D., 2009. Comparative life table analysis of chrysopids reared on *Phenacoccus solenopsis* tinsley in laboratory. ***Journal of Biological Control,*** **23**(4): 393-402.

Geethalakshmi, L., Muthukrishnan, N., Chandrasekaran, M., Raghuraman, M., 2000. Chrysopids biology on *Corcyra cephalonica* and feeding potential on different host insects. ***Annals of Plant Protection Sciences,*** **8**: 132-135.

Goodman, D., 1982. Optimal life histories, optimal notation, and the value of reproductive value. ***The American Naturalist***. **119:** 803-823.

Gurbanov, G. G., 1984. Effectiveness of the use of the common lacewing *Chrysoperla carnea* (Steph.) in the control of sucking pests and cotton moth on cotton. ***Biology Nauk,*** **2**: 92-96.

Hashami, A. A., 2001. ***Insect Pest Management in the 21st Century.*** PARC, Islamabad, Pakistan: 27

Hassan, S. A., 1975. The mass rearing of *Chrysopa carnea* Steph. (Neuroptera, Chrysopidae). ***Zeitschrift fur Angewandte Entomologie,*** **79**: 310-315.

Haub, G., Stellwaag-Kittler, F., Hassan, S. A., 1983. Zum Auftreten der Florfliege *Chrysopa carnea* (Steph.) als Spinnmilbenrauber in Rebanlagen. ***Weinwissenschaft,*** **38**:195-201.

Hemagirish, M. B., Goud, K. B., Mallapure, C. P., 2001. Utilization of *Chrysoperla carnea* (Stephens) in the management of safflower aphid, *Uroleucon compositae* (Theobald). ***Karntaka Journal of Agriculture Sciences,*** **14**: 806-808.

Hesterberg, T. C., 2008. ***It's Time To Retire The "N >= 30" Rule***. Proceedings of the American Statistical Association, Statistical Computing Section (CD-ROM)

Hodle, M. S., Robinson, L., 2004. Evaluation of factors influencing augmentative releases of *Chrysoperla carnea* for control of scirtothrips perseae in california avocado orchards. ***Biological Control,*** **31:** 268–275.

Huang, N., Enkegaard , A., 2009. Predation capacity and prey preference of *Chrysoperla carnea* on *Pieris brassicae*. ***Journal of Biological Control***, **55**: 379-385.

Huang, Y. B., Chi, H., 2012. Age-stage, two-sex life tables of bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae) with a discussion on the problem of applying female age-specific life tables to insect populations. ***Insect Science,*** **19**: 263-273.

Hydron, S. B., Whitecomb, W. H., 1979. Effects of larval diet on *Chrysoperla rufilabris*. ***Florida Entomologist,*** **62**: 293-298.

Jeppson, L. R., Keifer, H. H., Baker, E. W., 1975. ***Mites Injurious to Economic Plants,*** University of California Press, California: 615.

Jokar, M., Zarabi, M., 2012. Investigation effect three diets on life table parameters *Chrysoperla carnea* (Steph.) (Neuroptera: Chrysopidae) under laboratory conditions. ***Journal of Biological Sciences,*** **5**(1): 107-114.

Johnson, W. R., 2001. An introduction to bootstrap. ***Teaching Statistics***, **23**: 49-53.

Kasap, I., Aktuğ, Y., Atlıhan, R., 2003. Avcı böcek *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)'nın bazı biyolojik özellikleri üzerine araştırmalar. ***Journal of Agricultural Science,*** **13**(1): 49-53.

Kayahan, A., Sımsek, B., Özgökçe, M. S., Karaca, I., 2014. Development and survival of *Chrysoperla carnea* on two different preys. ***Turkish Journal of Agricultural and Natural Sciences,*** (2):1944-1948.

Kaygin, A. T., Görür, G., Çota, F., 2008. Contribution to the aphid (Homoptera: Aphididae) Species damaging on woody plants in Bartın, Türkiye. ***International Journal of Natural and Engineering Sciences,*** **2**(1): 83-86.

Khan, j., ul-Haq, E., Javed. H. I., Mahmood, T., Rasool, A., Akhtar, N., Abid, S., 2013. Biological parameters and predatory potential of *Chrysoperla carnea* (neuroptera: chrysopidae) feeding on wheat aphid *schizaphis graminum* (hemiptera: aphididae) under laboratory conditions**.** ***Pakistan Journal of Agricultural Research,*** **26**(4): 328-334.

Khanamani, M., Fathipour, Y., Hajiqanbar, H., 2015. Assessing compatibility of the predatory mite *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) and resistant eggplant cultivar in a tritrophic system. ***Annals of the Entomological Society of America,*** **108**: 501-512.

Legaspi, J. C., Carruthers, R. I., Nordlund, D. A., 1994. Life history of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) provided sweet potato whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) and other food. ***Southwestern Entomologist,*** **4**: 178-184.

Letardi, A., Caffarelli, V., 1990. Effect of using liquid semi-artificial larval diet on the rearing of *Chrysoperla carnea* (Steph.) (Planipennia: Chrysopidae). ***Redia,*** **73**: 79-88.

Lingren, P. D., Green, G. L., 1984. Suppression and management of cabbage looper populations. ***U.S. Department of Agriculture, Technical Bulletin***, **1684**: 152.

Lingren, P. D., Ridgway, R. L., Jones, S. L., 1968. Consumption by several common arthropod predators of eggs and larvae of two *Heliothis* species that attack cotton. ***Annals Entomological Society of America,*** **61**(3): 613-618.

Liu, T., Chen, T., 2001. Effects of three aphid species (Homoptera: Aphididae) on development, survival and predation of *Chrysoperla carnea* (Neuroptera: Chrysopidae). ***Applied Entomology Zoology,*** **36**: 361-366.

Lopez, J. D., Ridgway, R. L., Pinnelli, P. E., 1976. Comparative efficacy of four insect predators of the bollworm and tobacco budworm. ***Environmental Entomology,*** **5**:1160-1164.

McEven, K. P., 1996. ***Possible Effects of Artificial Food on The Development and Survival of Chrysoperla carnea (Stephens) Larvae in The Laboratory and in The Field (Insecta: Neuroptera: Chrysopidae).*** Pure and Applied Research in Neuropterology. Procedings of fifth International Symposium on Neuropterology. Cairo, Egypt: In: Canard, M., H. Aspock and M.W. Mansell (eds.) Toullouse, France. 181-186.

McEwan, P. K., Canard, M., Aspock, H., Mansell, M. W., 1996. The influence of an artificial food supplement on larval and adult development and survival of *Chrysoperla carnea* (Stephens) in laboratory and field. (Insecta: Neuroptera: Chrysopidae). ***International Journal of Pest Management,*** **42**: 25-27.

McEwen, P. K., Jervis, M. A., Kidd, N. A. C., 1993. Influence of artificial honeydew on larval development and survival in *Chrysoperla carnea* (Neuropter: Chrysopidae). ***Entomophaga,*** **38**: 241-244.

McMurtry, J., Huffaker, C., Van de Vrie, M., 1970. Ecology of tetranychid mites and their natural enemies: A review: I. Tetranychid enemies: Their biological characters and the impact of spray practices. ***California Agriculture,*** **40**(11): 331-390.

Michaud, J. P., 2001. Evaluation of green lacewings, *Chrysoperla plorabunda* (Fitch) (Neuroptera) augmentative release against *Toxoptera citricida* (Homoptera: Aphididae) in citrus. ***Journal of Applied Entomology,*** **122**: 383-388.

Miniou, N., 1973. The vectors transmitting plum pox virus (Prunus virus 7 Christ.) to plum. ***Analele Institutului de Cercetari pentru Protectia Plantelor***, **9**: 49-56.

Mishra, B. K., Jena, B. C., Mishra, P. R., 1996. Biology and feeding potential of *Chrysopa scelestes* (Banks) feeding on the eggs of *Pyrilla perpusilla* (Walker.). ***Indian Sugar,*** **45**: 757-759.

Nadeem, S., Hamed, M., Nadeem, M. K., Hasnain, M., Atta, B. M., Saeed, N. A., Ashfaq, M., 2012. Comparative study of developmental and reproductive characteristics of *Chrysoperla carnea* (stephens) (neuroptera: chrysopidae) at different rearing temperatures. ***The Journal of Animal and Plant Sciences,*** **22**(2):399-402.

Nadeem, S., Hamed, M., Nadeem, M. K., Hasnain, M., Atta, B. M., Saeed, N. A., Ashfaq, M., 2014. Effect of storage duration and low temperatures on reproductive characteristics of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). ***Pakistan Journal of Zoology,*** **46**(1): 31-35.

Nasreen, A., Iqbal, M., Mustafa, G., Ashfaq, M., 2004. Effect of different combinations of host (*Sitotroga cerealella*) and predator eggs on larval life of *Chrysoperla carnea*. ***Pakistan Entomologist,*** **26**: 101-108.

Obrycki, J. J., Hamid, M. N., Sajap, S. A., 1989. Suitability of corn insect pests for development and survival of *Chrysoperla carnea* and *Chrysopa oculata* (Neuroptera: Chrysopidae). ***Environmental Entomology,*** **18**: 1126-1130.

Osman, M. Z., Selman, B. J., 1993. Suitability of different aphid species to the predator *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). ***University Journal of Zoology, Rajshahi University,*** **12**: 101-105.

Özgökçe, M. S., Atlihan, R., 2005. Some biological features and life table parameters of the mealy plum aphid *Hyalopterus pruni* on different apricot cultivars. ***Phytoparasitica,*** **33**(1):7-14.

Pari, P., Lucchi, C., Brigliadori, M., 1993. Application of biological control techniques to strawberries in protected cultivation. ***Informature Agrario,*** **49**: 49-54.

Polat Akköprü, E., Atlihan, R., 2014. Two-sex life table and predation rate of *Chrysoperla carnea* (Stephen) (Neuroptera: Chrysopidae) fed on *Panaphis juglandis*(Goeze)(Hemiptera:Callaphididae).1-3. ***http://esa.confex.com/esa/2014/symp/papers/confirmation.cgi?username=83322&EntryTable=Paper***.

Polat Akköprü, E., Atlihan, R., 2016. Combining insect life table and predation rate for IPM and biological control: A study of *Chrysoperla carnea* (Stephen) (Neuroptera: Chrysopidae) fed on *Myzus persicae* (Sulzer) (Homoptera: Aphididae). ***International Congress of Entomology***.

Polat Akköprü, E., Atlihan, H., Okut., Chi, H., 2015. Demographic assessment of plant cultivar resistance to insect pests: a case study of the dusky-veined walnut aphid (Hemiptera: Callaphididae) on five walnut cultivars. ***Journal of Economic Entomology,*** **108**: 378-387.

Quentin, U., Hommmes, M., Basedow, T., 1995. Studies on the biological control of aphids (Homoptera: Aphididae) on lettuce in greenhouses. ***Journal of Applied Entomology,*** **119**: 227-232.

Rakauskas, R., Havelka, J., Zaremba, A., 2015. Plum (*Prunus* spp.) aphid guild (Hemiptera: Sternorrhyncha, Aphididae) Structure in Lithuania: any impact of an alien aphid species? ***Zemdirbyste-Agriculture,*** **102**(1):81-86.

Rashid, M. M. U., Khattak, M. K., Abdullah, K., Amir, M., Tariq, M., Nawaz. S., 2012. Feeding potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* on cotton mealybug, phenacoccus solenopsis.***The Journal of Animal and Plant Sciences,*** **22**(3): 639-643.

Ridgway, R. L., Jones, S. L., 1968. Field cage releases of *Chrysopa carnea* for supression of population of bollworm and the tobacco budworm on cotton. ***Journal of Economic Entomology ,*** **61** (4): 892-897.

Ridgway, R. L., Jones, S. L., 1969. Field-cage releases of *Chrysopacarnea* for suppression of population of the bollworm and thetobacco budworm on cotton. ***Journal of Economic Entomology,*** **61**:892-897.

Saminathan, V. R., Mahadevan, N. R., Muthukrishnan, N., 2003. Influence of preydensity on the predatory potential and development of *Chrysoperla carnea*. ***Indian Journal of Entomology,*** **65**: 1-6.

Sattar, M., 2010. ***Investigations on Chrysoperla Carnea (Stephens) (Neuroptera: Chrysopidae) As A Biological Control Agent Against Cotton Pests In Pakistan.*** Department of Entomology Faculty of Crop Protection Sindh Agriculture University, PhD. Thesis, 193.

Sattar, M., Abro, G. H., Syed, T. S., 2011. Effect of different hosts on biology of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) in laboratory conditions. ***Pakistan Journal of Zoology,*** **43**(6): 1049-1054.

Sattar, M., Hamed, M., Nadeem, S., 2007. Predatory potential of *Chrysoperla carnea* (stephens) (neuroptera: chrysopidae) against cotton mealy bug. ***Pakistan Entomologist.,*** **29**(2): 103-106.

Sengonca, C., Griesbach, M., Lochte, C., 1995. Suitable predator-prey ratios for the use of *Chrysoperla carnea* (Stephens) eggs against aphids on sugar beet under laboratory and field conditions. ***Zeitschrift furPflanzenkrankheiten and Pflanzenchutz,*** **102**: 113-120.

Shrestha, G., Enkegaard, A., 2013. The green lacewing, *Chrysoperla carnea*: preference between lettuce aphids, *Nasonovia ribisnigri*, and western flower thrips, *Frankliniella occidentalis*, ***Journal of Insect Science,*** **13**(94): 1-10.

Silva, P. S., Albuquerque, G. S., Tauber, C. A., Tauber, M. J., 2007. Life history of a widespread Neotropical predator, *Chrysoperla lineafrons* (Neuroptera: Chrysopidae). ***Biological Control,*** **41**: 33-41.

Stark, S. B., Whitford, F., 1987. Functional response of *Chrysopa carnea* (Neuroptera: Chrysopidae) larvae feeding on *Heliothis virescens* (Lep: Noctuidae) eggs on cotton in field cages. ***Entomophaga,*** **12**(5): 521-527.

Stary, P., 1965. Aphidid parasites of aphids in the USSR (Hym:Aphididae). Sb Faun prac entomol.***Oddelni Narodniho Mus Praze,*** **1**: 187-223.

Sultan, A., Khan, M. F., Siddique, S., Akbar , M. F., Manzoor, A., 2017. Biology and life table parameters of the predator, *Chrysoperla carnea* (stephens, 1836) (neuroptera: chrysopidae) on sugarcane whitefly, sugarcane stem borer and angoumois grain moth. ***Egyptian Journal of Biological Pest Control,*** **27**(1): 7-10.

Syed, A. N., Ashfaq, M., Khan, S., 2005. Comparison of development and predation of *Chrysoperla carnea* (Neuroptera: Chrysopidae) on different densities of two hosts (Bemisia tabaci, and Amrasca devastans). ***Pakistan Entomologist,*** **27**(1): 231-234.

Tassan, R. L., Hagen, K. S., Sawall, E. F., 1979. The ınfluence of field food sprays on the egg production rate of *Chrysopa carnea*. ***Environmental Entomology,*** **8**(1): 81-85.

Tauber, M. J., Tauber, C. A., Daane, K. M., Hagen, K. S., 2000. Commercialization of predators: recent lessons from green lacewings (neuroptera: chrysopidae: chrysoperla). ***Amrican Entomologist,*** **46**: 26–38.

Toros, S., Yasar, B., Özgökçe, M. S., Kasap, I., 1996. Studies on determination of aphidoidea species in Van province. ***Turkish National Entomological Congress***: 549-556.

Tuan, S. J., Lee, C. C., Chi, H., 2014a. Population and damage projection of *Spodoptera litura*(F.) on peanuts (*Arachis hypogaea* L.) under different conditions using the age-stage, two-sex life table. ***Pest Management Science,*** **70**: 805-813

Tuan, S. J., Li, N. J., Yeh, C. C., Tang, L. C., Chi, H., 2014b. Effects of green manure cover crops on *Spodoptera litura* (Lepidoptera: Noctuidae) populations. ***Journal of Economic Entomology,*** **107**: 897-905.

Uddin, J., Holliday, N. J., Mackay, P. A., 2005. Rearing lacewings, *Chrysoperla carnea* and *Chrysopa oculata* (Neuroptera: Chrysopidae), on prepuae of alfalfa leafcutting bee, *Megachile rotundata* (Hymenoptera: Megachilidae). ***Proceedings of the Entomological Society of Manitoba,*** **61:** 11-19.

Venkatsan, T., Poorani, J., Jalali, S. K., Srinivasamurthy, K., Ashok Kumar G., Lalitha, Y., Rajeshwari, R., 2008. Confirmation of the occurrence of *Chrysoperla zastrowi Arabica* Henry et al. (Neuroptera: Chrysopidae) in India. ***Journal of Biological Control,*** **22**: 143–147.

Williamson, F. A., Smith, A., 1994. ***Biopesticides in Crop Protection.*** Agrow report (DS 95), PJB publications, 120.

Yarımbatman, A., Atlıhan, R., 2008. ***Farklı Sıcaklık Koşullarında "Chrysoperla carnea" nın Gelişme ve Üremesinin İncelenmesi*** (yüksek lisans tezi, basılmamış) YYÜ, Fen Bilimleri Enstitüsü, Van.

Yu, J. Z., Chi, H., Chen, B. H., 2005. Life table and predation of *Lemnia biplagiata* (Coleoptera: Coccinellidae) fed on *Aphis gossypii* (Homoptera: Aphididae) with a proof on relationship among gross reproduction rate, net reproduction rate, and preadult survivorship. ***Annals of the Entomological Society of America***, **98**: 475-482.

Yu, J. Z., Chi. H., Chen, B. H., 2013. Comparsion of the life table and predation rates of *Harmonia dimidiate* (F.) (Coleptera: Coccinellidae) fed on *Aphis gossypii* Glover (Hemiptera: Aphididae) at different temperatures. ***Biological Control,*** **64**: 1-9.

Yu, L. Y., Chen, Z. Z., Zheng, F. Q., Shi, A. J., Guo, T. T., Yeh, B. H., Chi, H., Xu, Y. Y., 2013. Demographic analysis, a comparison of the jackknife and bootstrap methods, and predation projection: a case study of *Chrysopa pallens* (Neuroptera: Chrysopidae). ***Journal of Economic Entomology,*** **106**: 1-9.

APPENDIX

EXTENDED TURKISH SUMMARY
(GENİŞLETİLMİŞ TÜRKÇE ÖZET)

Hyalopterus pruni (GEOFFROY) (HEMIPTERA: APHIDIDAE) İLE BESLENEN *Chrysoperla carnea* (STEPHEN) (NEUROPTERA: CHRYSOPIDAE)'NIN PREDASYON ORANI VE YAŞAM ÇİZELGESİ

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ÖZET

Yeşil zarkanat olarak da bilinen *Chrysoperla carnea* (Stephens), Vangölü havzasında sert çekirdekli meyve ağaçlarının önemli bir zararlısı olan erik unlu afidi *Hyalopterus pruni*'nin önemli bir doğal düşmanı olarak değerlendirilmektedir. Bu çalışmada 25 ± 1 ° C sıcaklık, % 60 ± 10 orantılı nem ve 14:10 (A: K) saatlik bir ışık periyodunu sağlayan laboratuvar koşullarında erik unlu afidi ile beslenen *Chrysoperla carnea*'nın popülasyon gelişmesi ve predasyon kapasitesi araştırılmıştır. Veriler, avcının populasyon büyümesini ve predasyon oranını doğru bir şekilde tahmin edebilmek için dönem farklılaşlaması ve her iki cinsiyeti de dikkate alan yaş ve döneme özgü, iki eşeyli yaşam çizelgesi kullanılanarak analiz edilmiştir. Populasyon parametreleri; net üreme gücü (R_0), kalıtsal üreme yeteneği (r), popülasyon artış sınırı (λ) ve ortalama döl süresi (T) sırasıyla 204.98 birey, 0.1094 g^{-1}, 1.1157 g^{-1}, 48.62 gün, net predasyon oranı (C_0) ise 339.12 av/yaprakbiti olarak hesaplanmıştır. Predasyon oranı sınırı (ω), populasyon büyüme oranı ve predasyon oranının kombinasyonunla hesaplanmış ve 18.27 av/gün olarak elde edilmiştir. Bu çalışmadan elde edilen sonuçlar erik unlu afidi için hazırlanacak olan biyolojik mücadele ve entegre zararlı yönetim programlarında kullanılabilecektir.

Anahtar kelimeler: *Chrysoperla carnea*, *Hyalopterus pruni*, Yaşam tablosu, Predasyon oranı.

GİRİŞ

Ser çekirdekli meyve ağaçları, özellikle de kayısı ve erik, Türkiye'nin Van yöresinde yaygın şekilde yetiştirilen ve bölgenin ekonomisine önemli katkıları olan ürünlerdir. Erik unlu afidi olarak bilinen *Hyalopterus pruni* (Geoffroy, 1762; Hemiptera: Aphididae) erik, badem, kayısı ve şeftali ağaçları için önem arz eden bir zararlı türüdür. Bu zararlının bölgede meyve kalite ve verimine zarar verdiği bilinmektedir (Toros ve ark., 1996; Atlıhan ve ark., 1999). *H. pruni* tüm dünyada yaygın şekilde görülmektedir (Blackman ve Eastop, 1984). Bitki özsuyunu emerek bitkilerde şekil bozukluklarına sebep olmak suretiyle doğrudan zararlara, çok miktarlarda fumajin üretilmesine sebep olarak da dolaylı zararlara yol açan, ciddi etkileri olan bir zararlı türüdür. *H. pruni*'nin bütün bu zararlarının yanı sıra, çeşitli virüslere vektörlül ettiği de bildirilmiştir (Bodenheimer ve Swirski 1957; Miniou 1973). Zararlılarla mücadelede kullanılan kimyasalların doğa üzerindeki olumsuz etkileri konusundaki farkındalık arttıkça, zararlılarla mücadelede doğal düşmanların kullanılmasına dayanan ekolojik açıdan uygun teknikler geliştirilmiştir. "Biyolojik mücadele, entegre zararlı yönetim programlarının en önemli bileşenlerindendir. Avcılar, biyolojik mücadele programlarında en çok yer verilen etmenlerin başında gelmektedir. *C. carnea* geniş av yelpazesine sahip olması, oldukça yaygın görülmesi, tüketim gücü ve arama kabiliyetinin yüksek olması, kitle üretiminin kolaylığı, kimyasal ilaçların kullanımından sonra bölgede erken görülmesi nedeniyle entegre zararlı yönetimi ve biyolojik mücadele çalışmalarında dikkate alınan önemli bir avcı türüdür (Jeppson et al., 1975; Obrycki et al., 1989; Bozsik, 1995; Huang ve Enkegaard, 2009). Ele alınan bu çalışmada *H. pruni* ile beslenen *C. carnea*'nın bazı biyolojik özelllikleri ile predasyon oranı araştırılmıştır.

1. KAYNAK BİLDİRİŞLERİ

2.1. *H. Pruni*'nin Biyolojisi ve Yaşam Döngüsü

Yaprakbitlerinin çeşitli konukçu bitkilerde beslenmeleri sonucunda yolaçtıkları zararın yanı sıra yoğun fumajin oluşumu ile bitkilerin özümleme kabiliyetini azalttıkları ve çeşitli virüslere vektörlük yapmaları sonucunda hastalıklı bitkilerden sağlıklı olanlara çeşitli virüs hastalıklarını bulaştırdıkları çok sayıda çalışmada bildirilmiştir (Kaygin et al. 2008; Sattar 2010; Cranshaw 2009; Özgökçe veAtlıhan 2005; Rakauskas ve ark. 2015).

Yaprakbitlerinin önemli bir avcısı olarak bilinen *C. carnea*'nın çeşitli yaprakbiti türleri üzerinde biyolojik mücadele etmeni olarak kullanılmasına yönelik bilgilerin elde edildiği çok sayıda çalışma bulunmaktadır (Kasap ve ark. 2003; Sattar ve ark. 2011;Shrestha ve Enkegaard 2013; Nadeem ve ark. 2014;Batool ve ark. 2014; Sultan ve ark 2017).

2. MATERYAL ve YÖNTEM

Denemelerde kullanılacak *C. carnea* bireylerini elde etmek için Van ilindeki kayısı bahçelerinden toplanan bireyler Hassan (1975) tarafından önerilen yöntemin biraz değiştirilmesi ile çoğaltılmıştır. Av olarak kullanılan *H. pruni* bireyleri ise ara konukçusu olan *Phragmites australis* (Cav.; Şekil 3.1) üzerinden toplanmıştır. Her iki türün de kitle üretimleri 25 °C sıcaklık, % 60±5 orantılı nem ve 16:8 saatlik aydınlık-karanlık koşullarını sağlayan iklim kabinlerinde yürütülmüştür. Denemelere, avcının bir dölü üretildikten, böylece önceki konukçuların etkisi elemine edildikten sonra başlanmıştır.

Denemeler *C. carnea*'nın kitle üretiminden alınan henüz bırakılmış yumurtalar ile başlatılmıştır. Avcının larvalarına besin olarak verilen H. pruni'nin farklı yoğunlukları verilmiştir (1., 2. ve 3. dönem için sırasıyla, 30, 60 ve 90 yaprakbiti). Günlük gözlemlerle gelişme süresi ve canlılık oranları kaydedilmiştir. Erginler, Hassan (1975) tarafından önerilen bira mayası + bal + su karışımı ile beslenmiş, günlük gözlemlerle bıraktıkları yumurta sayısı ve canlılık oranları kaydedilmiştir. Denemeler 25 °C sıcaklık, % 60±5 orantılı nem ve 16:8 saatlik aydınlık-karanlık koşullarını sağlayan iklim kabinlerinde yürütülmüştür. Elde edilen veriler yaş ve döneme özgü – iki eşeyli yaşam çizelgesi teorisine göre analiz edilmiştir. Yaşam çizelgesi analizinde TWOSEX-MSChart programı (Chi, 2017A), predasyon analizinde ise CONSUME-MSChart programı (Chi, 2017A) kullanılmıştır.

3. BULGULAR ve TARTIŞMA

Çalışma sonucunda *Hyalopterus pruni* ile beslenen *Chrysoperla carnea*'nın yumurtadan ergine gelişme süresi 23.96 gün, toplam ölüm oranı ise %25 olarak saptanmıştır. Avcının rrgin pre-oviposizyon süresi, toplam pre-oviposizyon süresi, dişi başına bırakılan toplam yumurta sayısı ile dişi ve erkek ömür uzunlukları sırasıyla 12.71 gün, 36.86 gün, 614.93 yumurta, 73.64 gün ve 62.69 gün olarak bulunmuştur. Avcının gelişme canlılık ve üreme verileri kullanılarak yaşam çizelgesi parametreleri elde edilmiştir. Avcının gelişme canlılık ve üreme verileri kullanılarak populasyon parametreleri elde edilmiştir. Populasyon parametreleri; net üreme gücü (R_0), kalıtsal üreme yeteneği (r), popülasyon artış sınırı (λ) ve ortalama döl süresi (T) sırasıyla 204.98 birey, 0.1094 g^{-1}, 1.1157 g^{-1}, 48.62 gün olarak belirlenmiştir.

Çalışmada *H. pruni* ile beslenen *C. carnea*'nın avcılık/predasyon kapasitesi de belirlenmiştir. Avcının 1., 2., ve 3. larva dönemleri süresince sırasıyla 88, 125.93 ve 287.74 yaprakbiti tükettikleri belirlenmiş, predasyon oranı hesaplamalarında temel parametreler olan net predasyon oranı (C_0) 339.12 av/yaprakbiti predasyon oranı sınırı (ω), ise 18.27 av/gün olarak elde edilmiştir.

4. SONUÇ

Bu çalışmada, çeşitli sert çekirdekli meyve ağaçlarının önemli bir zararlısı olan *Hyalopterus pruni*'nin yaygın bir doğal düşmanı olarak bilinen *Chrysoperla carnea*'nın gelişme, canlılık üreme ve bunlara bağlı olarak populasyon parametreleri ile *H. pruni* üzerinde predasyon kapasitesi araştırılmıştır. Sonuçlar, konu ile ilgili literatür ile karşılaştırmalı olarak değerlendirildiğinde, *C. carnea*'nın *H. pruni* ile mücadelede yararlanılması gereken bir doğal düşman olduğu kansına varılmıştır. Ancak avcının iklim etkenleri başta olmak üzere doğa koşullarında çeşitli fakörlerle ilişkisine dair çalışmalar ile daha kesin ve güvenilir sonuçlar elde edilebilecektir. Elde edilen sonuçlardan *H. pruni* için hazırlanacak olan zararlı yönetim programlarında yararlanılabilecekir, ayrıca elde edilen bulgular konu ile ilgili olarak yürütülecek çalışmalar için bilgi atyapısı sağlayabilecektir.

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He was born in Erbil - Iraq, 1983. He completed the primary and secondary education in Erbil., During the years of 2003-2007, He had studied in Salahaddin University, the College of Agriculture, Department of Plant Protection. In 2007 He had graduated from here. At the September of 2014, He started his master study in Van Yuzuncu Yıl University.

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