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Feeding Potential *of Chrysoperla Cornea* (Stephens) (Neuroptera: Chrysopidae) On Natural Diet Under The Laboratory Conditions

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ABSTRACT

Highest mean number of hatching / egg survival was recorded in Artificial diet (86.50±2.90) followed by Aphids feeding (75.25±2.28). Highest mean number of larval survival/ no.of pupae was observed in Artificial diet (73.00±2.48) followed by Aphids feeding with larval survival/ no.of pupae for parent (67.00±3.93). Maximum pupal weight was observed in Artificial diet (0.07±1.79) followed by Aphids feeding with pupal weight (0.06±2.06). Highest pupal survival rate was observed in Artificial diet (75.25±1.49) followed by Aphids feeding with pual survival rate (65.50±2.39). Highest male sex ratio was recorded in Artificial diet (25.00±0.70) followed by Aphids feeding with male sex ratio (21.50±0.95). Maximum female sex ratio was observed in Artificial diet (48.50±3.17) followed by Aphids feeding with female sex ratio (37.75±0.85). Longest incubation period was noted in Aphids feeding having incubation period (4.00±0.40), while shortest incubation period was recorded in Artificial diet (3.25±0.25). Longest larval period (in days) in Aphids feeding was (8.00±0.40), although shortest larval period was recorded in Artificial diet (7.00±0.25). Longest papal period was recorded in Aphids feeding was (5.25±0.47) whereas, shortest pupal period was recorded in Artificial diet (4.25±0.25). More egg laying rate was noted for Artificial diet (2006.30±64.91) followed by Aphids feeding with egg laying rate (1830.00±32.40).

Keywords: Feeding Potential *Of Chrysoperla Cornea On Natural Diet.*

INTRODUCTION

The common Green lacewing, Chrysoperla cornea (Stephens) is an important predator; it belongs to order ‘Neuroptera’. Their agricultural significance lie in their carnivorous habits the larvae are all predators; some are terrestrial, feeding on jassids, psyllids, aphids, coccids, mites etc., and others are aquatic. It is unusual in the tropics to locate a great colony of aphids known as Aphis lion. One larva may eat as many as 500 aphids in its life and there is no uncertainty that they participate a significant part in the natural control of many small homopterous pests (Legaspi et al., 1994; Michaud, 2001). Worldwide, they also position as some of the majority frequently used and locally accessible natural enemies.

Chrysoperla carnea Stephens (Neurotera: Chrysopidae) is one of the most important generalist predators. The larval stages are active in suppressing pests, while it is free living in adult stages. Larvae of C. carnea are voracious predators of soft bodied arthropods such as aphids, whitefly, thrips, American bollworms, mites, army worms, small larvae of beetles, and eggs of lepidopetrous insects etc. (Carrillo et al., 2004). It has received much attention from researchers as well as farmers as a potential biological control agent (Gautam et al., 2007; Alasady et al., 2010; Saljoqi et al., 2013). Interest in utilizing this useful predator as one of the most important components of integrated pest management (IPM) programs for field and horticultural crops has recently increased as growers found alternatives to pesticides for managing insect pests. Since green lacewings are generalists, the effective and proper use of these predators is essential for a positive effect in the IPM programs.

Functional response studies have received much attention in the ecological literature. Functional response is the change in the number of prey consumed by each predator in response to the change in density of prey within a specific time (Holling, 1959). Functional response of predators is one of the major factors in regulating the population dynamics of the predator prey system. Functional response can be defined as an increase in the number of prey attacked by predators in per unit time as the density of prey increases. It characterizes the relationship between the predator attack rate and its prey. Insects, diseases, weeds and nutritional factors are major constraints acting against the quality and quantity of crops yield. Out of many insect pests, aphids and mites are the most important and serious insect pests of crops (E.D., 2013). The aphids are one that damages the various crops in which they habitat. They damages crops by sucking sap from plant and transferring viral diseases to healthy plants. Aphids infest wide range of several agricultural crops in horticulture, cereal crops, oilseed crops etc. Farmers are using more than one pesticide in alternating manner to suppress insect pest in their field (E.D., 2013).

The negative impacts of chemical pesticides on human health and environment, have led to realize the need for alternative method, which is environmentally friendly, economically viable and sustainable method of insect pest management. It can be reduced or minimized through the development, dissemination and promotion of alternative method such as botanical pesticides (Akter, 2015; Kafle, 2015), biological pest control (Pinstrup-Andersen and Hazell, 1985) and IPM approach (Neupane, 2010). It is important to reduce the pesticides application on crops by using or conserving the biologically derived predator in the field such as Green lacewing, Chrysoperla carnea (Stephens) (Sarwar, 2014). The common green lacewing is an important generalist predator (Sarwar, 2014) is best known as biocontrol agent (Memon et al., 2015). After knowing the importance of C. carnea in agricultural systems, it is important to develop efficient pest management strategies that are simple, economical, sustainable and bio-friendly based on biological control.

REVIEW OF LITERATURE

BIOLOGY & MASS REARING OF C. CARNEA:

Chrysoperla carnea (Stephens) is important predator, available commercially in many countries of the world for augmentative release in agro ecosystem for population management of many insect pests. Biology of C. carnea depends upon many factors biotic as well as a biotic. Biotic factors such as host species, its stage of development to be consumed as prey and the host plant on which C. carnea host is feeding. There is a huge amount of literature available on biology of C. carnea, here some of the selected references are reviewed on biology. Obrycki et al. (1989) observed that, development of C. carnea required 20.5, 21.6 and 24.9 days at 27˚C with a photoperiod of 16: 8 (L: D), when fed Ostrinia nubilalis (Hubner) eggs, Agrotis ipsilon (Hufnagel) eggs, and A. ipsilon neonates, respectively. The influence of different aphid foods on larval development, juvenile mortality, weight of cocoons and adult fecundity of C. carnea was investigated. Myzus persicae (Sulzer) and Acyrthosiphon pisum (Harris), were much more suitable than other aphid species studied. Aphis fabae (Scop.) was the most unsuitable prey type for C. carnea as high juvenile mortality occurred to larvae fed on this species. Larvae fed on this aphid 9 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). McEven (1996) studied a relationship between the quantity of larval food and the rate of larval development and survival from eclosion to pupation in C. carnea. McEwan et al., (1996) studied the influence of an artificial food supplement on larval and adult performance of C. carnea. The adult diet comprised of yeast autolysate, sugar and water in the ratio of 4: 7: 10. Different numbers of live prey eggs of Anagasta kuehniella (Zeller), on larval development and survival and on adult weight and survival of C. carnea. Given the same number of prey eggs, predator larvae receiving artificial food supplement reached the pupal stage more rapidly than those given water. Mishra et al., (1996) studied the biology and feeding potential of Chrysopa scelestes (Banks) on the eggs of the sugarcane pest Pyrilla perpusilla (Walker) in the laboratory. The egg, larval and pupal periods lasted 3.69±0.77, 10.05±1.63 and 9.55±1.23 days, respectively. Adult longevity was 24.75±3.14 days for males and 31.70±2.95 days for females. The larval diet of C. carnea exerted a significant effect on the rate of its development, survival, cocoon weight and the fecundity of the adult females (Osman and Selman, 1996). Mannan et al. (1997) studied the biology of C. carnea on Aphis gossypii (Glover) and Myzus persicae (Sulzer). The pre-oviposition, oviposition and postoviposition period were 6.55, 21.10 and 7.95 days on A. gossypii and 9.25, 21.85 and 11.20 days on M. persicae, respectively. The mean fecundity of C. carnea was about 84.70 and 103 eggs; the incubation periods were 2.25 and 3.68 days. The duration of development of 10 first, second and third instar larvae were 2.60, 2.25, 2.38 and 3.75, 2.78 and 3.35 days when reared on A. gossypii and M. persicae, respectively. The pupal period was 9.43 and11.40 days on A. gossypii and M. persicae, respectively. The females lived longer (35. 70 and 38.80 days) than males (32.20 and 35.80 days) on two respective hosts. The preoviposition, oviposition and post-oviposition recorded on two hosts were: 6.55 and 9.25, 21.10 and 21.85 and 7.95 and 11.20 days, respectively, when larvae were reared on A. gossypii and M. persicae, respectively. Saminathan et al., (1999) studied the biology and predatory potential of C. carnea on eggs of Corcyra cephalonica (Stainton), Earias vitella (Fabricius) and Helicoverpa armigera (Hubner), neonate larvae of E. vitella and H. armigera and A. gossypii (Glover) collected from cotton (Gossypium hirsutum L.), okra (Hibiscus esculentus L.) and guava (Psidium guajava L.) and Aphis carccivora (Coch.) collected from cowpea [Vigna unguiculata (L.) Walp.] and groundnut (Arachis hypogaea L.). The egg, grub and pupal period of C. carnea were minimum on A. craccivora collected from groundnut and maximum on H. armigera neonate larvae. The total developmental period of C. carnea on different insect hosts ranged from 18.59 [A. craccivora (groundnut)] to 22.74 days (H. armigera neonate larvae). C. carnea adult laid a maximum of 318.40 eggs when reared on A. craccivora. Geethalakshmi et al. (2000) studied the biology and feeding of Chrysoperla carnea on Corcyra cephalonica (Stainton) eggs. Total development period from egg to adult emergence was completed in 22.2 days. Larval and pupal period was 10.3 and 8.4 days, respectively. Progeny had a sex ratio of 1: 0.95 (female: male) an average of 640 eggs were laid per female. Males survived for 26.5 days and females for 39.0 days. A single larva fed an average of 30.3 eggs of C. cephalonica, 33.4 eggs of Helicoverpa arnigera, 0.54 egg masses of Spodoptera litura, 5.9 and 7.9 first instar larvae of H. armigera and S. litura and 33.3 and 24.6 Aphis gossypii and Planococcus citri, respectively, in a single day. Venkatesan et al., (2000) reared C. carnea for 10 successive generations on a larval semi-synthetic diet containing soybean hydrolysed powder (1.3%), egg yolk (32.3%), honey (16.1%), yeast extract (1.3%), water (38.7%), petroleum jelly (0.7%) and paraffin wax (9.6%). Larval developmental period was longer on semisynthetic diet than on Corcyra cephalonica eggs. Mean adult emergence of C. carnea reared on semi-synthetic and on C. cephalonica eggs was 56.7 and 82.5%, respectively. Food consumption increased as C. carnea developed. The first larval stage of C. carnea fed heavily on Aphis gossypii nymphs (54.05), sterilized eggs of C. cephalonica (53.90) and H. armigera (43.05). C. carnea larvae consumed more A. gossypii than Uroleucon compositae (Thomas) nymphs (Bansod et al., 2001). Liu and Chen (2001) determined the effects of three aphid species (fourth instars only), Aphis gossypii Glover; Myzus persicae (Sulzer) and Lipaphis erysimi (Kaltenbach) on immature development, survival and predation of C. carnea in the laboratory. Survival rates of C. carnea from first stadium to adult emergence were significantly different among larvae fed different aphid species. When larvae were fed A. gosypii and M. persicae, 94.4±3.3% (mean ± SE) and 87.6±5.1% of individuals developed to adults, respectively; whereas only 14.9±3.4% of individuals developed to adults when fed L. erysimi. The developmental durations of C. carnea larvae were also significantly different among larvae fed the three aphid species. The developmental duration from first stadium to adult emergence was shortest when larvae were fed A. gosypii (19.8±0.4 d), followed by M. persicae (22.8±0.2, d), and then L. erysimi (25.5±0.4, d). The total number of fourth stadium aphids consumed by C. carnea larvae differed significantly among individuals fed different aphid species. C. carnea consumed more A. gossypii (292.4) and M. persicae (272.6) than L. erysimi (146.4). Although total numbers of aphids consumed by the three C. carnea larval stadia differed significantly, the proportions of aphids consumed by each larval stadium to the total number of aphids consumed were similar, 3.9-7.1% by the first stadium, 12.0-16.8% by the second stadium and 78.1-83.0% by the third stadium.

EFFECTS OF DIFFERENT DIETS ON FECUNDITY:

Ulhaq *et al* (2006) conducted the experiment at the Entomology Division of Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan. Experiment was designed in Randomized Complete Block Design (RCBD) with three replications each having five pairs of adult C. Carnea. The results showed that the mean number of eggs laid by female C. carnea fed on diets containing egg yolk, egg white and mixed egg were 168.30±0.98, 114.40±0.44 and 99.40±0.36 respectively, as compared to the standard diet where the mean number of eggs were 131.10±0.59. It is obvious that fecundity was not significantly higher for the females fed on diet containing egg yolk (168.30±0.98) from standard diet (131.10±0.59) but it was significantly higher than the other diets containing egg white (99.40±0.36) and mixed egg (114.40±0.44). Whereas fecundity was not significantly different for the diets containing egg white, mixed egg and standard diet. So in the present experiment the diet containing egg yolk, milk and honey in the ratio of 5ml: 10ml: 5ml proved to be the best resulting in significantly higher egg laying by the female C. carnea as compared to the other diets under the same laboratory conditions. This diet consists of three components and each component has the promoting effect on egg production. As reported by Hill (1989), sugar is a very important component in adult diet for the insects that has pronounced effect on the egg production. Similarly McEwen and Kidd (1995) had recommended yeast and sugar for maximum egg production. Honey is also a very important component regarding fecundity, McEven and Kidd (1995) and Kubota and Shiga (1995) analyzed that a mixture of honey and yeast autolysate is a suitable adult diet for production of fertile eggs. Last but not the least component is yolk that is the most important one. Milevoj (1999) reared adults of C. carnea on adult diet consisting of milk, eggs, fruits sugars and yeast and found a favourable effect on fecundity. Higher fecundity observed in diet containing egg yolk is because as egg yolk is rich in protein (amino acids). There are 15.5% amino acids as compared to egg white and mixed egg which contain 9.8% and 11.95% respectively (Norioka et al., 1984). Vitamin A, niacin, riboflavin B12, pantothenic acid, thiamin, pyridoxine, folic acid, Vitamin E and D are present in greater quantity in egg yolk than in egg white and mixed egg. Similarly folic acid, which is particularly more important for egg productions is much higher (117 µ g) in egg yolk than in mixed egg (73 µ g) and an egg white (3 µ g). Egg yolk also has higher amount of saturated, mono unsaturated, polyunsaturated oils and lipids than mixed eggs, whereas egg white has no lipids at all. Also the egg yolk has greater caloric value (303 calories per 100 g) than mixed egg (148 calories per 100 g) and egg white (117 calories per 100 g). The cholesterol level is particularly very high (1075 mg) in egg yolk as against (432 mg) in mixed egg and no cholesterol in egg white (Rolfes et al., 1978).

Geethalakshmi et al. (2000) studied the biology and feeding of Chrysoperla carnea on Corcyra cephalonica (Stainton) eggs. Total development period from egg to adult emergence was completed in 22.2 days. Larval and pupal period was 10.3 and 8.4 days, respectively. Progeny had a sex ratio of 1: 0.95 (female: male) an average of 640 eggs were laid per female. Males survived for 26.5 days and females for 39.0 days. A single larva fed an average of 30.3 eggs of C. cephalonica, 33.4 eggs of Helicoverpa arnigera, 0.54 egg masses of Spodoptera litura, 5.9 and 7.9 first instar larvae of H. armigera and S. litura and 33.3 and 24.6 Aphis gossypii and Planococcus citri, respectively, in a single day. Venkatesan et al., (2000) reared C. carnea for 10 successive generations on a larval semi-synthetic diet containing soybean hydrolysed powder (1.3%), egg yolk (32.3%), honey (16.1%), yeast extract (1.3%), water (38.7%), petroleum jelly (0.7%) and paraffin wax (9.6%). Larval developmental period was longer on semisynthetic diet than on Corcyra cephalonica eggs. Mean adult emergence of C. carnea reared on semi-synthetic and on C. cephalonica eggs was 56.7 and 82.5%, respectively. Food consumption increased as C. carnea developed. The first larval stage of C. carnea fed heavily on Aphis gossypii nymphs (54.05), sterilized eggs of C. cephalonica (53.90) and H. armigera (43.05). C. carnea larvae consumed more A. gossypii than Uroleucon compositae (Thomas) nymphs (Bansod et al., 2001).

Larval Period:

The mean total larval period of lacewing derived from adults fed on diets containing egg yolk, egg white and mixed egg was 13.84±0.20, 15.42±0.32 and 15.09±0.29 days respectively, as compared to standard diet where the total larval period was 14.84±0.41days. Analysis of the data revealed that total larval period of adults fed on diet containing egg yolk was significantly shorter (13.84±0.20 days) as compared to standard (14.84±0.41days) and other diets, where as the larval period was not significantly different for the diet containing mixed egg (15.09±0.29 days) when compared with standard diet. The larval period of the adults fed on diet containing egg white (15.42±0.32 days) was significantly longer than standard diet. Different scientists had reported that adult and larval diet has reared effect on the larval period of green lacewing. Stelzl et al. (1992), Mishra et al. (1996), Sarode and Sonalkar, (1998) and Saminathan et al., (1999) tried different adult and larval diets and concluded that the larval period can be greatly effected by these diets. Diet containing egg yolk is quite rich in proteins, minerals, vitamins and lipids as compared to the diets containing egg white and mixed egg (Rolfes et al., 1978 and Norioka et al., 1984), which promoted quick growth and quick completion of the larval period. The shorter larval period is because of the better chemical composition of the diet containing egg yolk.

Pupal Period:

Mean pupal period of C. carnea offspring developed from the adults fed on different adult diets. It can be seen that pupal period of C. carnea was 6.33±0.40, 7.11±0.34 and 7.22±0.38 days when adults were fed on diet containing egg yolk, mixed egg and egg white respectively as compared to standard diet where pupal period was 6.97±0.34 days. Statistical analysis of the data showed that mean pupal period developed from the adults fed on diet containing egg yolk was significantly shorter than standard and all other diets. Whereas diets containing mixed egg and egg white were not significantly different from standard diet. The shorter pupal period of C. carnea in the case of feeding on a diet containing egg yolk was due to the rich nutritive value of egg yolk (Norioka et al., 1984), which promoted the quick growth, and complateion of pupal period. Mishra et al., (1996), Mannan et al., (1998), Cohen and Smith, (1998), Sarode and Sonakar, (1998), Saminathan et al., (1999) and Choi et al., (2000) have also reported the same results when larvae and adults of C. carnea were fed on different types of diets.

Longevity (adult life):

The data showed that the mean longevity of male C. carnea which were fed on a diet containing egg yolk was 28.22±0.28 days followed by 27.72±0.60, 26.62±0.43 and 25.82±0.43 days in standard diet, diet containing mixed egg and diet containing egg white, respectively. The mean longevity of adult females fed on diet containing egg yolk, egg white, and mixed egg was 29.52±0.35, 26.02±0.51 and 26.22±0.42 days respectively, whereas it was 26.92±0.39 days in females fed on standard diet). Statistical analysis showed that adults who were fed on diet containing egg yolk lived significantly longer compared to the adults that were fed on egg white. When the means life span of female fed on these four different diets were compared, there was also no significant difference. The studies showed that different adult diets have significant effects on the longevity of the both male and female C. carnea. McEwen and Kidd (1995) reported that adult life of C. carnea is affected directly by the adult diet and found that the adults receiving only sugar as adult diet lived longer than those receiving sugar and yeast (yeast was added to the adult diet for more eggs production). Adult life including pre oviposition, oviposition and post oviposition periods can be prolonged directly by the use of suitable adult diet (Ribeiro et al., 1997). Adult nutrition is a very important factor for egg production and longevity in the case of insects (Morales et al., 1996). The adult diet containing egg yolk in addition to milk and honey used in this experiment prolonged adult life probably because of good nutritive value, as egg yolk contains plenty of essential and non-essential amino acids, carbohydrates, oils, vitamins, and minerals.

Effect of Artificial Diets on the Development of Immature Stages of Chrysoperla Carnea:

The findings of present research conducted by Umair *et al*,(2017) indicated that 1st instar larval instar rearing on artificial diets displayed that the longest development was recorded in the artificial diet D4 followed by D1, D2 and D3, respectively. Whereas, the lowest development was observed on diet D5 (Control). The larval instar lived longer in the plastic tube and shortest in the glass tube on all diets, whereas, pupa lived longer in glass tube as compare to plastic tube reared on D5 (Control). The results further revealed that in the 2nd instar larval survival was displayed the maximum development period on the artificial diet D2 followed by D4, D1 and D3, respectively. However, the lowest development was recorded on diet D5 (Control). The maximum development was seen in the plastic tube and minimum in the glass tube fed on all artificial diets. Therefore, pupal stage survived longest in glass tube and lowest in plastic tube on diet D5 (Control). The findings of present result indicated the 3rd instar larval lived longer when fed with artificial diet D2 followed by D1, D3 and D4, respectively. Therefore, the lowest development time was observed on diet D5 (Control). Furthermore, it was also defined that plastic tube reared larvae passed maximum time in development as compare to glass tube on all artificial diets. The result further depicted that the highest survivor % was recorded in the first, second, third instar and pupa reared in plastic and glass tube on diet D5 (control). The maximum survivor % of larvae of C. carnea was obtained in first instar followed by second and third instar, respectively reared on artificial diets, while third instar not survivor more and found unable to transform in the subsequent stage. Furthermore, it was observed that the maximum survivor % of third instar larvae of C. carnea was found when reared on artificial diets. However, maximum survival % of pupa was recorded on diet D1 followed by D3 and D4, respectively. Therefore third instar reared on diet D2 was not to transform into next stage. The findings of present study have more or less conformity with those of (Zhang *et al*, 2004) reared 10 generations on larval semi-synthetic diets containing egg yolk (32.3%), honey (16.1%), soybeans hydrolyzed powder (1.3%), water (38.7%), yeast extract (1.3%), petroleum jelly (0.7%) and paraffin wax (9.6%). Larval developmental period was recorded longer on semi-synthetic diet than on C. cephalonica eggs. There were two different means of C. carnea reared on semi-synthetic diet and C. cephalonica eggs were 56.7 and 82.5%, respectively. As C. carnea was developed, food consumption was also increased. First larval stage of C. carnea fed more on Aphis gossypii nymph, sterilized eggs of C. cephalonica than on H. armigera 54.05, 53.90 and 43.05, respectively. Salwa and Samad (2011) evaluated the different biological parameters on adult diet of C. carnea. (A) pollen grains + honey distilled water, (B) honey distilled water, (C) royal jelly and pollen grains + honey distilled water and (D) royal jelly + honey distilled water. The overall results of egg hatching, larval survival rate, pupal survival rate, adult emergence and overall developmental period from egg to adult (89.3%, 92.6%, 95.1%, 98.1% and 77%) were observed in treatment (D), respectively. Pre-ovipositional period, longovipositional period and shortest total development duration (3.6, 14, and 19.3 days) were recorded on treatment (D), respectively. Highest values of net reproductive rate, intrinsic rate of natural increase, and finite rate of increase were also recorded on treatment (D). Shafique *et al* (2015) reported that Crysoperla is predator of soft bodied insect pests. Therefore, C. carnea was reared on artificial diets to compare with natural diets. Aphis craccivora and eggs of Corcyra cephalonica were used as artificial diet. Artificial diets having some composition were used, in diet 1 (eggs and ginger) and in diet 2 (chemical antimicrobials and egg yolk). The predator population was significantly higher in diet 1, as compare to diet 2. On diet 2 higher pupal period was observed. In the head capsule and in body length there were no significant. IN the third instar body length was higher with diet of C. cephalonica eggs. Whereas, the emergence % of adult no difference were found in both diets. Therefore, diet 1 is suggested for rearing due to significantly higher population.

Effect of Cabbage Aphid, Brevicoryne brassicae (Linnaeus) on the Functional Response of Chrysoperla carnea):

Result showed that almost all larval instars of C. carnea showed a good predation potential to the B. brassicae, but third instar larvae of C. carnea were found more effective on this prey. The potential regarding the consumptive rate of the 3rd instar larvae of the C. carnea was found higher than that of the 1st and 2nd ones. Yüksel and Göçmen (1992), Atlihan et al. (2004), Hassanpour et al. (2009) and Hany et al. (2010) reported higher predation figures on the last instar of C. carnea stage as compared with the younger ones. The higher predation of the last instar is a logical reflection of its larger size and thus an ensuing higher voracity. Before experimentation starvation for a fixed time period may have a significantly influenced the three larval stages of the C. carnea. Also increase in the movement speed with C. carnea larval age may likewise play a role (Houck and Strauses, 1985).

Results showed lower searching time, handling time and resting time in the first instar larvae followed by an increase in the 2nd and 3rd instar larval stage of C. carnea. It should be noted that search rate and handling time values from the functional response curves represent the mean values of these parameters for 24 h exposure time which the predator was starved before lead to decreasing of starvation levels throughout the duration of the experiment at different rate of prey density. This change in the starvation level carries on secondary components affects the values of the searching rate, handling and resting time (Holling, 1963). Stark and Witford (1987) referred to similar type of fuctional response of C. carnea feeding on Heliothis virescens eggs. Hassel (1978) described that for the type II response, consumed prey is not density dependent i.e. consumed prey intensity does not increase with prey density. The parameters estimated for functional response are not accurate measurement by laboratory testing and could not be linked to the field conditions (O'Neil, 1989). Wiedenmann and O'Neil (1991) described that under simple laboratory conditions the attack rate is limited mostly by consumptive behavior (e.g. handling time), where as in the field conditions the attack is limited by searching behavior. However, even though several factors e.g. host plans, weather conditions, interference from competing beneficial and presence of alternative prey, may influence the effectiveness of the predators (Ding-Xu et al., 2007). The laboratory studies are only useful in comparing the effectiveness of natural enemies required as a bio-control agent (Lee and Kang, 2004).

Field Releases:

Chrysoperla carnea are commonest species of Chrysoperla, adults are predacious, but prefer pollen, honey-dew and secretions of plants and trees. C. carnea attacks 80 species of insects and 12 species of tetranychid mites. It has 3-4 generations annually and over winters as an adult, in buildings or under bark or leaves. Cannibalism is common among larvae of C. carnea. The egg and pupal stages of Chrysopidae are less susceptible to the effect of insecticides than are the early larval and adult stages (Kaitazov and Kharizanov, 1976). Bar et al., (1979) studied the effectiveness of Chrysoperla carnea as an important predator of Heliothis armigera in cotton fields. The predator existed throughout the occurrence period of H. armigera. C. carnea fed on the eggs and very young larvae of the H. armigera. Gurbanov (1984) attempted three releases of 3-4 days old eggs and 1st and 2nd instar larvae of C. carnea for controlling the sucking pests and Heliothis armigera in cotton field. The three releases were made at predator: prey ratio of 1:1. A week after the 1st release, the abundance of Aphis gossypii, the thrips and spider mites, eggs and larvae of Heliothis sp. had fallen by 98.5%, 95%; 100% and 50% in the same sequence. The second and third release caused even greater reduction in the pest population. Pari et al. (1993), released Chrysoperla carnea against infestations of the aphids, Macrosiphum euphorbiae (Thomas) and Chaetosiphon fragaefolii (Cockerell) at a density of at least 20-larvae/ linear m of each paired row. The biological control techniques gave satisfactory results. Sengonca et al. (1995) analyzed the influence of egg releases of C. carnea on the population development of Aphis fabae on sugar beet at various predatorprey ratios (1: 15, 1: 10 and 1: 5) under both laboratory and field conditions. Under field conditions, a predator-prey ratio of 1: 5 provided satisfactory 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. Only application of C. carnea resulted in reasonable aphid control.

MATERIALS AND METHODS

The rearing of the host insect and predator was started under the room temperature for knowing the feeding potential of predator on different species of aphids. The initial culture was obtained from Lasbela University of Agriculture, Water and Marine Science, Uthal, Balochistan which was further multiplied on the standard laboratory host, the *eggs* of *Sitrotoga cerealella.*The aphids viz:, *Aphis craccivora, Aphis gossypii*and *Rhopalosiphum maidis, Aphis Fabae* and *Myzus persicae* was collected from the surrounding orchards of Quetta.

The lacewing adults were confined in a glass chimney (6 cm dia. X 8 cm dia). Adults were supplied with standard artificial diet consisting of yeast, sucrose, honey, casein and water. The mixture forms slurry was provided to adults and cotton soaked in distilled water was also supplied to maintain moisture. The plexi glass strips were drilled at three points to make pits for holding drops of diet slurry. The upper portion of glass chimney was covered with black muslin cloth as a substrate of egg deposition. The adult diet was changed each after 2 days. Eggs laid by female on muslin cloth will be harvested with sharp razor.

Second instars of all aphid species were provided with the help of camel hair brush as adlibitum of 50, 100 and 150 to the first, second and third instars of green lacewing larvae, respectively. Total 05 larvae of each instar was used for the experiment and newly moulted (less than 2 hours old) larval stages were studied on each host for the developmental parameters of *C. carnear*. Different parameters such as egg hatching, larval duration (days), larval survival, pre-pupation period (days), pupation period days) total developmental period (days, from egg hatching to adult formation) and total survival was recorded on daily basis. For the study of reproductive traits of *C. carnea,* 10 pairs of adults were obtained to observe the reproductive parameters such as pre-oviposition period (days), oviposition period (days), total eggs laid per female, life span of female and male (days).

Each larval instar of *Chrysoperla carnea* was fed separately in the 9cm Petri dish. Each treatment was replicated three times. In each Petri dish, a single egg of *C. carne* with known age was transferred. After hatching, the individual larva was provided with known number o feach freh host every day. The number of prey consumed and non-cnsumed was recorded as daily feeding potential.

Statistical analysis:

The data was then subjected to one way analysis of varinance (ANOVA) under Completely Randomized Design (CRD) and Least Significant Difference (LSD) test at 5% probability level was used to test the difference among treatment means.

RESULTS

1. Hatching / egg survival:

The analysis of variance (Appendix-I) demonstrated significant (P<0.05) difference for mean number of hatching / egg survival. The data (Table-1) indicates that highest mean number of hatching / egg survival was recorded in Artificial diet (86.50±2.90) followed by Aphids feeding (75.25±2.28). This indicates that *Chrysoperla carnea* produced more hatching when fed on artificial diet compared to aphid feeding.

Table-1. Effect of different feeding regimes on the hatching / egg survival of *Chrysoperla carnea*

Treatments	Hatching / egg survival
Aphids feeding	75.25±2.28 b
Artificial diet	86.50±2.90 a
SE±	3.7561
LSD @ 0.05	8.0060

2. Larval survival / no of pupae.

The analysis of variance (Appendix-II) demonstrated significant (P<0.05) difference for larval survival/ no.of pupae. The data (Table-2) indicates that the highest mean number of larval survival/ no.of pupae was observed in Artificial diet (73.00±2.48) followed by Aphids feeding with larval survival/ no.of pupae for parent (67.00±3.93).

Table-2. Effect of different feeding regimes on the number of larval survival / no. of pupae of *Chrysoperla carnea*

Treatments	Number larval survival / no. of pupae
Aphids feeding	67.00±3.93 a

Artificial diet	73.00±2.48 a
SE±	5.3603
LSD @ 0.05	11.425

3. Pupal weight

The analysis of variance (Appendix-III) demonstrated significant (P<0.05) difference for pupal. The data (Table-3) indicates that maximum pupal weight was observed in Artificial diet (0.07±1.79) followed by Aphids feeding with pupal weight (0.06±2.06).

Table-3. Effect of different feeding regimes on the pupal weight of *Chrysoperla carnea*

Treatments	Pupal weight (grams)
Aphids feeding	0.06±2.06 b
Artificial diet	0.07±1.79 a
SE±	1.4803
LSD @ 0.05	3.1563

4. Pupal survival/no.of adult emergence

The analysis of variance (Appendix-IV) demonstrated significant (P<0.05) difference for pupal survival/ no.of adult emergence among the treatments. The data (Table-4) resulted that highest pupal survival rate was observed in Artificial diet (75.25±1.49) followed by Aphids feeding with pual survival rate (65.50±2.39).

Table-4. Effect of different feeding regimes on the pupal survival / no. of adult emergence of *Chrysoperla carnea*

Treatments	Pupal survival / no. of adult emergence
Aphids feeding	65.50±2.39 b
Artificial diet	75.75±1.49 a
SE±	2.7218
LSD @ 0.05	5.8014

5. Male sex ratio

The analysis of variance (Appendix-V) demonstrated significant (P<0.05) difference for male sex ratio among the feeding regimes. The data (Table-5) indicates that highest male sex ratio was recorded in Artificial diet (25.00±0.70) followed by Aphids feeding with male sex ratio (21.50±0.95).

Table-5. Effect of different feeding regimes on the male sex ratio of *Chrysoperla carnea*

Treatments	Male sex ratio
Aphids feeding	21.50±0.95 b
Artificial diet	25.00±0.70 a
SE±	0.9747
LSD @ 0.05	2.0775

6. Female sex ratio

The analysis of variance (Appendix-VI) determined the significant (P<0.05) difference in female sex ratio among the treatments. The data (Table-6) indicates that maximum female sex ratio was observed in Artificial diet (48.50±3.17) followed by Aphids feeding with female sex ratio (37.75±0.85).

Table-6. Effect of different feeding regimes on the female sex ratio of *Chrysoperla carnea*

Treatments	Female sex ratio
Aphids feeding	37.75±0.85 b
Artificial diet	48.50±3.17 a
SE±	2.6724
LSD @ 0.05	5.6961

7. Incubation period (in days)

The analysis of variance (Appendix-VII) showed non-significant (P>0.05) difference of incubation period in days between the treatments. The results in (Table-7) revealed that longest incubation period was noted in Aphids feeding having incubation period (4.00±0.40), while shortest incubation period was recorded in Artificial diet (3.25±0.25).

Table-7. Effect of different feeding regimes on the incubation period of *Chrysoperla carnea*

Treatments	Incubation period in days
Aphids feeding	4.00±0.40 ab
Artificial diet	3.25±0.25 b

SE±	0.6708
LSD @ 0.05	1.4298

8. Larval period in days

The analysis of variance (Appendix-VIII) demonstrated significant (P<0.05) difference for larval period (in days) between treatments. The results of (Table-8) showed the longest larval period (in days) in Aphids feeding was (8.00±0.40), although shortest larval period was recorded in Artificial diet (7.00±0.25).

Table-8. Effect of different feeding regimes on the larval period of *Chrysoperla carnea*

Treatments	Larval period (in days)
Aphids feeding	8.00±0.40 b
Artificial diet	7.00±0.25 b
SE±	0.7246
LSD @ 0.05	1.5444

9. Pupal period in days

The analysis of variance (Appendix-IX) showed significant (P<0.05) difference for pupal period in days between the treatments. The results of (Table-9) revealed that longest papal period was recorded in Aphids feeding was (5.25±0.47) whereas; shortest pupal period was recorded in Artificial diet (4.25±0.25).

Table-9. Effect of different feeding regimes on the pupal period of *Chrysoperla carnea*

Treatments	Pupal period (in days)
Aphids feeding	5.25±0.47 bc
Artificial diet	4.25±0.25 c
SE±	0.4916
LSD @ 0.05	1.0478

10. Egg laying

The analysis of variance (Appendix-IX) significant (P<0.05) difference for egg laying rate between the treatments. The data (Table-10) indicates that more egg laying rate was noted for Artificial diet (2006.30±64.91) followed by Aphids feeding with egg laying rate (1830.00±32.40).

Table-10. Effect of different feeding regimes on the egg laying (no. of adults emerged) of *Chrysoperla carnea*

Treatments	Egg laying
Aphids feeding	1830.00±32.40 b
Artificial diet	2006.30±64.91 a
SE±	63.174
LSD @ 0.05	134.65

DISCUSSION

In the current study average mean number of hatching / egg survival , larval survival / no. of pupae, pupal weight, pupal survival/ no. of adult emergence, male sex ratio, female sex ratio and egg laying percentage were higher in Artificial diet followed by Aphids feeding. While, incubation period, larval period and pupal period were equally longer in Aphids feeding and shortest values for these traits were examined in Artificial diet. The results are in accordance with the findings of Sattar *et al.*, (2011) they reported that larval food significantly affected the length of larval period. The shortest larval period was recorded on *S. cerealella* eggs, while longest on *H. armigera* eggs. Balasubramani and Swamiappan (1994) studied development of *C. carnea* on different hosts in laboratory and found that larval development was rapid on eggs of *Corcyra cephalonica* (8.20 days) and longest on neonates of *H. armigera* (11.10 days). Mannan *et al.* (1997) studied biology of *C. carnea* on *A. gossypii* and *M. persicae* and observed that larval duration was long when fed on *M. persicae*. Saminathan *et al.* (1999) and Bansod and Sarode (2000) studied biology and feeding potential of *C. carnea* on different hosts and noted developmental period of *C. carnea* ranged from 18.6 days on *Aphis cracivora* to 22.7 days on *H. armigera* neonate larvae. Giles *et al.* (2000) studied nutritional interactions among alfalfa, *Medicago sativa* and faba bean, *Vicia faba*, as host plants, pea aphid, *Acyrthosipnon pisum* an herbivore and *C. carnea* a predator. *C. carnea* larvae developed faster on pea aphid reared on alfalfa than on pea aphid raised on faba bean. Chemical analysis showed that aphids reared on faba bean had 6.3 times more levels of myristic acid. The duration of development of *C. carnea* was significantly different on three aphid species. It was shortest when larvae were fed *A. gossypii* followed by *M. persicae* and *Lipaphis erysimi* (Liu and Chen, 2001). Ballal and Singh (1999) and Bartlett (1984) studied the host plant-mediated orientational and ovipositional behaviour of three species of chrysopids and found that *C. carnea* females had significantly higher preference for sunflower and cotton, while pigeon pea was less preferred. On cotton, *C. carnea* preferred to lay more eggs on underside of leaves than on buds. Flint *et al.* (1979) reported that damaged cotton plants release the terpenoid β caryophyllene which attracts *C. carnea*. Selman (1993) investigated the influence of different aphid species on larval development and fecundity of *C. carnea*. *M. persicae* and *A. pisum* were suitable, while *A. fabae* was most unsuitable prey causing high juvenile mortality. *C. carnea* larvae fed on this aphid and *Macrosiphum albifrons* had reduced fecundity. The survival of larvae of *C. carnea* feeding on *A. cracivora*, *Drosophila melanogaster* and *C. cephalonica* were 51.8, 80.9 and 86.7%, respectively. While *C. carnea* laid 1079, 582 and 172.8 eggs/female when reared on *C. cephalonica*, *D. melanogaster* and *A. cracivora*, respectively (Tesfaye and Gautam, 2002). When Obrycki *et al.* (1989) fed *C. carnea* larvae on *Ostrinia nubilalis* and *Agrotis ipsilon* eggs, 26-40% larvae died and when reared on *A. ipsilon* neonates, 65%, while all larvae died when fed *O. nubilalis* neonates, which was due to entanglement in silk produced by these larvae. Liu and Chen (2001) determined the development, survival and predation of *C. carnea* on three aphid species, *A. gossypii*, *M. persicae* and *L. erysimi*. Survival was significantly different on aphid species; when larvae were fed on *A. gossypii* and *M. persicae*, 94.4 and 87.6% individuals developed to adult stage, respectively; whereas, only 14.9% when fed *L. erysimi*. Duration of development was significantly short (19.8 d) when fed *A. gossypii* followed by *M. persicae* (22.8 d) and *L. erysimi* (25.5 d). Similarly, *C. carnea* consumed more *A. gossypii* (292.4) and *M. persicae* (272.6) than *L. erysimi* (166.4). Zheng *et al.* (1993) found a highly significant positive correlation between prey consumed during larval stage and adult body weight of *C. carnea*.

CONCLUSIONS

On the basis of this study findings it could be concluded that average mean number of hatching/egg survival, larval survival/ no.of pupae, pupal weight, pupal survival/no. of adult emergence, male sex ratio, female sex ratio and egg laying percentage was higher in Artificial diet followed by Aphids feeding. Similarly longer, incubation period, larval period and pupal period was recorded in Aphids feeding although, shortest incubation period, larval period and pupal period were examined in Artificial diet.

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APPENDICES

Appendix-I. Completely Randomized of Analysis of variance (ANOVA) for Hatching /egg survival.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	4510.50	1127.63	40.0	0.0000
Error	15	423.25	28.22	-	-
Total	17	4933.75	-	-	-

Appendix-II. Completely Randomized of Analysis of variance (ANOVA) for larval survival /no. of pupae recorded.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	7051.20	1762.80	30.7	0.0000
Error	15	862.00	57.47		
Total	17	7913.20			

Appendix-III. Completely Randomized of Analysis of variance (ANOVA) for pupal weight.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	4.39904	1.09904	25.1	0.0000
Error	15	6.57605	4.38406	-	-
Total	17	5.05604	-	-	-

Appendix-IV. Completely Randomized of Analysis of variance (ANOVA) for pupal survival / no. of adult emergence.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	9874.3	2468.58	167	0.0000
Error	15	222.2	14.82		
Total	17	10096.5			

Appendix-V. Completely Randomized of Analysis of variance (ANOVA) for male sex ratio.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	992.50	248.125	131	0.0000
Error	15	28.50	1.900		
Total	17	1021.00			

Appendix-VI. Completely Randomized of Analysis of variance (ANOVA) forfemale sex ratio.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	3824.30	956.075	66.9	0.0000
Error	15	214.25	14.283		
Total	17	4038.55			

Appendix-VII. Completely Randomized of Analysis of variance (ANOVA) for incubation period.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	9.7000	2.42500	2.69	0.0713
Error	15	13.5000	0.90000		
Total	17	23.2000			

Appendix-VIII. Completely Randomized of Analysis of variance (ANOVA) for larval period.

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	34.0000	8.50000	8.10	0.0011
Error	15	15.7500	1.05000		
Total	17	49.7500			

Appendix-IX. Completely Randomized of Analysis of variance (ANOVA) for pupal period

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	31.7000	7.92500	16.4	0.0000
Error	15	7.2500	0.48333		
Total	17	38.9500			

Appendix-X Completely Randomized of Analysis of variance (ANOVA) for number egg laying

Source	DF	SS	MS	F-vale	Prob.
Treatment	2	4646311	1161578	146	0.0000
Error	15	119727	7982		
Total	17	4766038			

Lasbela University of Agriculture, Water and Marine Science, Uthal, District Lasbela Balochistan

(Department of Entomology)

Synopsis for, M.Phil

Title: Feeding potential *of Chrysoperla cornea* (Stephens) (Neuroptera: Chrysopidae) on natural diet under the laboratory conditions

Name of the Student	:	Abdul Jabbar
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INTRODUCTION:

Most vegetable and cereal crops are attacked by lepidopterous and homopterous insects causing quality destroying and yield loss. This reduces farmer's income drastically and farmers resort to using insecticides, which increases the cost of production. The Pesticides which are currently used are mostly non selective and are affecting the biotic and abiotic components of the environment. The indiscriminate use of pesticides created a number of problems such as environmental pollutin, resistance in insect pests, upsurge of the secondary pests due to elimination of their natural enemies, increased cost of crop production and hazards for human beings and animals. According to an estimate, pesticides adversely affected the health of about 400,000 to 2,000,000 people every year. Out of these 1,000 to 40,000 die mostly in the developing countries. (Robert et al.,1985)

During the last two decades or so, the role of green lacewings as a predator of different crops has been appreciated all over the world. Server chrysopid species are included among the most important aphidophagous predators. The most of adult chrysopids are non predatory, but their larval instars are predatory in nature. The influence of prey on the development of insect predator has been evaluated for several predatory species (Tauber and Tauber, 1987). They attack and consume a wide variety of pests including aphids, chinch bugs, mealy bugs, scales, 1989; Sujatha and Singh, 2003; Syed et al., 2008; Alasady et al., 2010). Among these, *Chrysoperla Carnea* have been recorded as important natural enemies in suppressing especially soft bodies insects and lepidopterous pest (Canard et al., 1984). The *C. carnea* have emerged as strong and potent bio-control agents and the result oriented researches are further needed to conclusively ascertain their efficiency in the integrated pest management program. The natural population of this biological control agent in the field is not adequate to suppress the pest population of their own.

Moverovr, biological control would be best achieved by mass rearing and seasonal colonization of the aphied lion. It is a prerequisite to evaluate the feeding potential of *Chrysoperla carnea* as a biological control agent in Quetta, Balochistan, Hence, the present investigations will be taken up to know the feeding potential *Chrysoperla carnea* on second instars of five different aphid species for the better pest management. The present investigation will be carried out at the directorate of Vegetable, Seed ARI Sariab Quetta. Balochistan during the year 2017.

Material and Methods:

The rearing of the host insect and predator will be started under the room temperatur for knowing the feeding potential of predator on different species of aphids. The initial culture will be obtained from Lasbela University of Agriculture, Water and Marine Science, Uthal, Balochistan which will be further multiplied on the standard laboratory host, the *eggs* of *Sitrotoga cerealella.*The aphids viz:, *Aphis craccivora, Aphis gossypii*and *Rhopalosiphum maidis, Aphis Fabae* and *Myzus persicae* will be collected from the surrounding orchards of Quetta.

The lacewing adults will be confined in a glass chimney (6 cm dia. X 8 cm dia). Adults will be supplied with standard artificial diet consisting of yeast, sucrose, honey, casein and water. The mixture forms slurry will be provided to adults and cotton soaked in distilled water will also be supplied to maintain moisture. The plexi glass strips will be drilled at three points to make pits for holding drops of diet slurry. The upper portion of glass chimney will be covered with black muslin cloth as a substrate of egg deposition. The adult diet will be changed each after 2 days. Eggs laid by female on muslin cloth will be harvested with sharp razor.

Second instars of all aphid species will be provided with the help of camel hair brush as adlibitum of 50, 100 and 150 to the first, second and third instars of green lacewing larvae, respectively. Total 05 larvae of each instar will be used for the experiment and newly moulted (less than 2 hours old) larval stages will be studied on each host for the developmental paramenters of *C. carnear.* Different paprameters such as egg hatching, larval duration (days), laryal survival, pre-pupation period (days), pupation period days) total developmental period (days, from egg hatching to adult formation) and total survival will be recorded on daily basis. For the study of reproductive trits of *C. carnea*, 10 pairs of adults will be obtained to observe the reproductive parameters such as pre-oviposition period (days), oviposition perio d(days), total eggs laid per female, life span of female and male (days).

Each larval instar of *Chrysoperla carnea* will be fed separately in the 9cm Petri dish. Each treatment will be replicated three times. In each Petri dish, a single egg of *C. carne* with known age will be transferred. After hatching, the individual larva was provided with known number o feach freh host every day. The number of prey consumed and non-cnsumed will be recorded as daily feeding potential.

Statistical analysis:

The data will be then subjected to one way analysis of varinance (ANOVA) under Completely Randomized Design (CRD) and Least Significant Difference (LSD) test at 5% probability level will be used to test the difference among treatment means.

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