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# RESEARCH ARTICLE

**Effect of prey density on biology and foraging potential** **of *Mallada boninensis* (Okamato) (Neuroptera: Chrysopidae)**

## **ABSTRACT**

 Effect of prey density on biology and functional response of green lacewing, *Mallada boninensis* (Okamato)(Neuroptera: Chrysopidae) was studied in the laboratory. Newly emerged larvae of *M. boninensis* were fed 20, 30, 40, 50, 60, 70, 80, 90 and 100 fresh eggs of *Corcyra cephalonica* (Lepidoptera: Gelechiidae) in plastic vials. It was observed that the prey density had a significant effect on positive consumption rate, development and fecundity of *M. boninensis.* In general, maximum consumption with shortest developmental time, maximum fecundity and longest adult longevity were observed as prey density increased. In all the treatments, predatory potential was high when the prey density was raised. Daily predation rate of *M. boninensis* increased slowly during the first two instars and reached to its peak in the third larval instar. The results indicated that *M. boninensis* feeding potential and developmental period may vary from 6.00±0.01 to 11.33±0.02 days based on food density and having difference in per day consumption also. Maximum consumption of 87.88±0.01 eggs/ day was observed in 100 Corcyra eggs/day treatment followed by 90 eggs/day (79.33±0.05 eggs) and 80 egg day-1 (69.75 ±0.03 eggs).

**Keywords:** *Corcyra cephalonica*, Chrysopidae, Prey density, Lacewing, *Mallada boninensis*

## **INTRODUCTION**

##  There are a number of natural enemies of insect pests which co-exist with them in the different ecosystem. Amongst a very complex network of bio agents, the Chrysopid is known to be the most effective predator. Chrysopids commonly termed as green lacewings. Chrysopids have a tremendous potential to consume pests of crops. Among the three species of chrysopids, *C. zastrowi sillemi* and *Mallada Boninensis* (Okamoto) are the most intensively studied species of Chrysopids because of its wide geographical distribution, broad habitats with a high relative frequency of occurrence, good searching ability and easy rearing in the laboratory. Green lacewings are considered to be one of the most effective generalist predators used in biological control (McEwen et al., 2001). Adults are generally not predatory and feed on nectar, pollen or honeydew while a few of them are predatory (Coppel and Mertins, 1977). Amongst the *Mallada* spp., *M. boninensis*, *M. basalis*, *M. aster* and *M. desjardinsi* are important as these are found to be potential predators of aphids, leaf miners, psylla, blackfly and whitefly (Syed *et al.*, 2008; Riddick, 2009). In recent years use of green lacewing species have been recommended for the IPM programme (Nehare et al., 2004). They can be successfully reared on eggs of *Corcyra* *cephalonica* Stainton in the laboratory.

##  The predation phenomena of the *M. boninensis*, are sometime not as simple as mentioned above but change with varying prey densities. It has been observed with many insect and small animal predators that when prey population increased, prey consumption also increased and consumption rate is the function of food density. Such a changing behaviour ultimately affect the predator's release pattern in a bio- control program and needs to be studied for better understanding under different ecosystems. Therefore, a study was designed to evaluate the predation rate of laboratory reared *M. boninensis*, on Corcyra eggs with the following objectives: (i) to determine predation rate of all larval instars under nine prey density levels and (ii) to study effect of prey density on the biology of *M. boninensis*.

## **MATERIAL AND METHODS**

**Culture of Rice moth, *Corcyra cephalonica* (Stainton)**

 Rice moth, *C. cephalonica* has been widely used as an efficient alternative host for the mass rearing of many biocontrol agents. Bajra grains were coarsely milled and broken into 2-3 pieces in a milling machine. The broken grains are heat sterilized at 1000C for 1 hour to eliminate the residual population of stored product insects *viz., Rhizopertha dominica*, *Sitotroga cerealella*, *Tribolium castaneum* and fungal contaminants. Upon sterilization the grains weare cooled under fan in a clean area. The grains were then transferred to plastic basins @ 2.5 kg/basin. Groundnut kernel in required quantity is broken using a pounding machine or a mechanical blender (domestic mixer). Then 100 g of the broken kernel is transferred to each basin and the contents are hand mixed thoroughly. Dry yeast (Bakers) and wettable sulfur is added @ 5g/ basin and the contents are mixed thoroughly. A spray of 10 ml of 0.01-0.05% streptomycin sulfate and mixing of the contents follows this. This bajra medium is used for rearing Corcyra larvae. The eggs used for building up the colony of *Corcyra* have to be free from contaminants like the moth scales and broken limbs and not exposed to UV light. The collections of overnight laid eggs are measured volumetrically to ascertain the number of trays that can be infested with eggs. A cc of eggs is known to contain approximately 16000 – 18000 eggs. The cumbu medium with Corcyra eggs in desired quantities. Per basin 0.5 cc eggs of Corcyra is infested. The basins are then covered with clean khada cloth and held tightly with rubber fasteners. The adults begin to emerge in 28-30 days after infestation of the eggs. The adults can be seen on the inner side of the *khada* cloth. They are either aspirated with mechanical moth collector or collected with specimen tubes. The whole operation is carried out in a tent of mosquito net. This prevents the large-scale escape of the moths, which if uncontrolled can migrate to the storage area and spoil the grains stored by laying eggs. The moths collected are transferred to the oviposition drum @ 1000 pairs per drum at a time. The oviposition drums of size 30 x 20 cm are made of galvanized iron. The drums rest on tripod frames with legs of height 5cm. The bottoms of the drums are provided with wire meshes that enable collection of eggs. The adults are provided feed containing honey solution. The adult feed is prepared by mixing 50 ml honey with 50 ml water and 5 capsules of vitamin E (Evion). The moths lay the eggs in large numbers loosely. The scales and broken limbs are also found in larger quantities along with the eggs. The collections are cleaned by gently rolling the eggs on filter paper to another container. Then they are passed to sieves in series and finally clean eggs are collected. The eggs are quantified in measuring cylinders and used for building up the stocks and natural enemy production.

**Mass culturing of *Mallada boninensis***

Grubs were reared in GI round basins (28 cm dia) @250 larvae/basin covered with khada cloth. The eggs of *Corcyra cephalonica* were given as feeding material for the larvae in the laboratory. The *M. boninensis* larvae pupate into round white colored silken cocoons in ten days. The cocoons were collected with fine brush and transferred into 1 litre plastic container with wire mesh window for emergence of adults. The adults are collected daily and transferred to pneumatic glass troughs or G.I. round troughs (30 cm × 12 cm). Before allowing the adults, the rearing troughs were wrapped inside with brown sheet which act as egg receiving card. About 250 adults (60 % females) were allowed into each trough and covered with white nylon or georgette cloth secured by rubber band. Three bits of foam sponge (2 sq.in) dripped in water were kept above the nylon cloth cover. Besides an artificial protein rich diet (yeast, fructose, honey, ProteinexR and water in the ratio 1:1:1:1) was provided in semisolid paste form in three spots on the cloth outside. The adults were collected daily and allowed into fresh rearing troughs with fresh food. From the old troughs, the brown paper sheets along with *M. boninensis* eggs were removed and used for maintaining culture of green lacewing.

**Prey density on biology of *M. boninensis***

 The experiment was designed in a completely randomized (CRD) design. There were nine (food densities) treatments, *viz*., 20, 30, 40, 50, 60, 70, 80, 90, 100 *Corcyra* eggs/grub/day. Each treatment was replicated three times. Each replication has three samples (Mallada grubs). Freshly harvested *M. boninensis* eggs were placed in 9cm petri dish sealed with parafilm to avoid desiccation and were observed daily. Newly emerged larvae of *M. boninensis* were transferred into plastic vials with counted number of fresh *Corcyra* eggs for each food density/ replication. The larvae of *M. boninensis* were transferred very carefully to the capsules with the help of fine camel hair brush. Vials contents were observed under stereo microscope every day to find out the number of unconsumed eggs and any change in larval biology. The numbers of unconsumed eggs were subtracted from the total number of offered eggs (prey density) and data were recorded on daily basis. Biological parameters like, the duration of development of each larval instar, pupation, adult emergence and mortality occurring in each treatment was recorded daily in all prey densities. After pupation, each pupa was observed for adult emergence and recorded. The emerging adults were transferred to G.I. round troughs (30 cm × 12 cm). The adults were fed daily on thick viscous solution of water + honey + yeast. The adult’s basins were observed every 24 h for egg laying

**Statistical analysis**

 The data collected under laboratory experiments in completely randomized design were analyzed using analysis of variance (ANOVA) using AGRES 3.01 and AGDATA software. Data in the form of numbers were transformed to square root values and those in numbers were transformed to $\sqrt{x}+0.5 $and analyzed. The mean values of the treatments were compared using DMRT at 5 per cent level of significance

## **RESULTS AND DISCUSSION**

**Effect of food density on *Mallada boninensis* consumption**

 The larvae of *M. boninensis* responded to increasing prey densities with increasing food consumption and older larval stages displayed a higher rate of predation than younger ones (Fig 1). The consumption rate increased progressively during each day. Maximum the *M. boninensis* fed 703.00±0.18 *Corcyra* eggs with in minimum developmental period of 6.00±0.01 days in the 100 eggs/day treatment, respectively. When consumption rate was decreased (173.67±0.07*Corcyra* eggs) in the low number of eggs per treatment (20 eggs/day) with the increased developmental period 11.33±0.02 days( Table. 1). The results indicated that *M. boninensis* feeding potential and developmental period may vary (6.00±0.01 to 11.33±0.02 days) based on food density and having difference in per day consumption also. Maximum consumption 87.88±0.01 eggs/ day were observed in 100 *Corcyra* eggs/day treatment followed by 90 eggs/day (79.33±0.05 eggs) and 80 egg day-1 (69.75 ±0.03 eggs). Hassanpour *et al.* (2009) who studied functional response of three larval instars of *C. carnea* on adult females of *T. urticae*. Results of the present studies revealed that the larvae of *M. boninensis,* especially the last instar, have a good predation potential and probably its larger size facilitated its increased dietary requirement resulted in more prey consumption than second and first instars. These results are in accordance with Klingen *et al.* (2009) who studied the predation rate of *M. boninensis* on eggs and first instar larvae of the lepidopterous species *Mamestra brassicae* (L.) including the prey's influence on survival and development. In both cases the daily predation rate of *C. carnea* increased slowly during the first two instars and reached a peak in the third larval instar. During the third instar 87% and 85% of the total numbers of *M. brassicae* eggs and larvae were consumed.

**Biological parameters**

 Food density had pronounced effects on the biological parameters of *M. boninensis*. The *M. boninensis* having three instar in a grub period and developmental periods also changing based on the food density. The First instar grub having duration from 2.33 days (100 eggs /day) to 3.67 days (20 eggs /day). The first instar duration was same in the treatment 60, 70 and 80 eggs/day with 3.00 days. Similar results was also found in duration of first instar grub was maximum on *A. gossypii* with 3.54 days and minimum on *C. cephalonica* with2.48 days(Guntupalli and Kalyanasundram, 2016). The duration wise there is not that much wide variance in high and low density pray in the first instar. The second instar *M. boninensis* having duration from 1.67 days to 3.00 days. Averagely in all treatments other than 90 and 100 eggs/day, the duration of second instar was 2.33 days. The third instar duration range from 2.00 days (100 eggs /day) to 4.67 days(20 eggs /day)(Table.1)( In third instar *M. boninensis* was voraciously feeding in *Corcyra* eggs and there may be variance in the third instar duration of *M. boninensis.* Earlier research indicated the larval duration of a related species *Mallada astur* (Banks) as 11.6 days (Venkatesan et al., 2002) and *Mallada basalis,* 11.8 days (Chang, 2000) which are closes to our observations. In the present trials, it was noticed that although, *M. boninensis* larvae completed development in each of the nine prey densities, increase in prey density reduced development time and mortality rate.

**Duration of developmental stages**

 Food density directly affected the 3rd instar larval duration, pupal period and adult longevity of *M. boninensis*. Increased prey densities reduced developmental time and mortality rate of *M. boninensis*. (Fig. 2). Maximum duration 20.67 days of grub period was recorded in 20 eggs/day treatment whereas; minimum duration 10.67 days was recorded in 100 eggs/day treatment. In case of pupal period, it was shortest in 70 and 80 eggs/day treatment (6.63 and 6.00 days) whereas, longest pupation period (9.33 days) was recorded in 20 eggs/day treatment. Longest adult longevity was observed in 80, 90 and 100 eggs/day treatments while shortest adult longevity was noticed in 20, 30 and 40 eggs/day treatments. The results were on par with the results of Nagamallikadevi *et al.* (2013). They observed that eggs of *C. cephalonica* were superior over all treatments followed by sucking pests for all biological parameters.Larvae survived comparatively more on grubs fed with *C. cephalonica* with 92.8 per cent and Larvae survived comparatively more on grubs fed with *C. cephalonica* followed by *A. gossypii*, *A. dispersus* and *A*. *craccivora.* Pupation and adult emergence per cent was more on *C. cephalonica* (Guntupalli and Kalyanasundram, 2016).This was strengthens our present findings. It is widely reported that unsuitable food can extend the pre-imaginal development of chrysopids and decrease the survival, fecundity and longevity of the adults (Zheng *et al*., 1993). Results of the present studies indicated that prey density had remarkable effect on consumption rate, development and mortality of *M. boninensis*. Larvae of *M. boninensis* responded to increasing prey densities with increasing food consumption rate. Older larval stages displayed a higher rate of predation than younger ones. The above findings were in conformity with Zheng *et al.* (1993) who reported that individual lacewing larvae provided with higher number of Mediterranean flour moth (*Anagasta kuehniella)* eggs had a significantly higher feeding potential*.* Hence, *Corcyra cephalonica*  was an suitable host for the mass culturing and development of *Mallada boninensis*

**Table 1. Effect of food density on duration of grub, pupal and adult periods of *Mallada boninensis***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments****(Eggs)** | **First instar (Days)** | **Second instar****(Days)** | **Third instar****(Days)** | **Pupal period****(Days)** | **Developmental period (Days)** | **adult longevity****( Days)** |
| 20 | 3.67(1.92) | 3.00(1.73) | 4.67(2.16) | 9.33(3.05) | 20.67(4.55) | 2.33(1.53) |
| 30 | 3.67(1.92) | 3.00(1.73) | 4.33(2.08) | 8.33(2.89) | 19.33(4.40) | 4.67(2.16) |
| 40 | 3.33(1.82) | 2.33(1.53) | 4.00(2.00) | 8.67(2.94) | 18.33(4.28) | 5.67(2.38) |
| 50 | 3.33(1.82) | 2.33(1.53) | 3.67(1.92) | 8.00(2.83) | 17.33(4.16) | 7.67(2.77) |
| 60 | 3.00(1.73) | 2.33(1.53) | 3.33(1.82) | 7.67(2.77) | 16.33(4.04) | 8.00(2.83) |
| 70 | 3.00(1.73) | 2.33(1.53) | 3.33(1.82) | 6.33(2.52) | 15.00(3.87) | 8.33(2.89) |
| 80 | 3.00(1.73) | 2.33(1.53) | 2.67(1.63) | 6.00(2.45) | 14.00(3.74) | 9.00(3.00) |
| 90 | 2.67(1.63) | 2.00(1.41) | 2.33(1.53) | 5.00(2.24) | 12.00(3.46) | 9.67(3.11) |
| 100 | 2.33(1.53) | 1.67(1.29) | 2.00(1.41) | 4.67(2.16) | 10.67(3.27) | 10.67(3.27) |
| **SE d** | **0.018** | **0.015** | **0.018** | **0.028** | **0.034** | **0.020** |
| **CD** | **0.038** | **0.032** | **0.037** | **0.058** | **0.072** | **0.041** |

**\***Mean of three replications. Values in the parentheses are square root transformed values. In a column, means followed by the common letter(s) are not significant in DMRT @ 5% level of significance

**Fig 1. Effect of prey density on the growth of *Mallada boninensis***

**Fig 2. Effect of various food densities on the food consumption of *Mallada boninensis* at various intervals (days)**

**CONCLUSION**

 It was noticed from the data that younger *M. boninensis* grub consumed less food in all prey densities than older grub, probably due to smaller in size larvae has less mobility and prey handling efficiency than a larger sized grub or older grub.

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**Ethics statement**

No specific permits were required for the described field studies because no human or animal subjects
were involved in this research.

**Originality and plagiarism**

Authors should ensure that they have written and submit only entirely original works, and if they have used the work and/or words of others, that this has been appropriately cited.

**Consent for publication**

All the authors agreed to publish the content. **Competing interests**

There was no conflict of interest in the publication of this content

**Data availability**

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail; *elaento@gmail.com*

**Author contributions**

|  |  |  |
| --- | --- | --- |
| Research grant | - | - |
| Idea conceptualization | - | SJN & SS |
| Experiments | - | KE |
| Guidance | - | SJN |
| Writing-original draft | - | KE |
| Writing- reviewing &editing | - | KE&SJN |

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