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Functional response study of *Cryptolaemus Montrouzieri* Mulsant (Coleoptera: Coccinellidae) fed on Cotton mealy bug, *Phenacoccus Solenopsis* Tinsley under Laboratory Conditions

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Abstract
Functional response study of *Cryptolaemus Montrouzieri* Mulsant (Coleoptera: Coccinellidae) 4th instar and adult male and female fed on cotton mealy bug, *Phenacoccus solenopsis* Tinsley was carried out under laboratory conditions of 28±1 °C with 65±5 % % R.H and 16:8 L: D photoperiod. The prey densities used for 4th in star and adult male and female were kept uniform i.e. 30, 45, 60, 75 and 90. Results showed that increasing in the prey density the consumed prey number increased up to certain limit in the 4th instar stage as well as in the adult male and female of C. *Montrouzieri*. The recorded highest consumed prey number were 76, 75 and 71 for the highest prey densities of 90 in adult female, male and the 4th instar stage of C. *Montrouzieri*, respectively. The average potential regarding the consumptive rate adult female was found higher followed by adult male and 4th instar stage of C. *Montrouzieri*. Also results showed almost lower searching time, handling time and resting time in the 4th larval instar stage followed by the adult male and female of C. *Montrouzieri*. Results of this study showed that the C. *Montrouzieri*, especially the adult female have a good predation potential in preying of the *P. solenopsis*. Therefore, by including C. *Montrouzieri* in control programs the use of the pesticides against this pest will be minimized. However, for the detailed estimation of the bio-control potential of C. *Montrouzieri* further field studies are compulsory.

Keywords: *Cryptolaemus Montrouzieri,* Cabbage aphid, Functional response

1. Introduction
The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is an invasive polyphagous pest in Pakistan [1]. It is a small, oval, soft-bodied, sucking insect covered with white mealy wax. It attacks on fruits, vegetables, field crops and ornamental plants. Cotton mealybug has a wide host range and infests over 194 plants [2]. It damages the plants by sucking the cell sap from leaves and stems depriving plants of essential nutrients showing the retarded growth and total drying of the plant [3]. The cotton mealybug is considered the major pest of cotton [4] and yield losses due to this pest were estimated upto 50% [3]. In Pakistan it caused yield losses in cotton production equal to 1.3 million bales. The potential distribution expanded dramatically indicating that *P. solenopsis* shows a great economic threat to cotton crop [5].
Cryptolaemus Montrouzieri Mulsant (Coleoptera: Coccinellidae) is a very efficient natural enemy of the mealy bugs and has worldwide distribution [6]. Both adults and larvae of these beetles eat the mealy bug completely [6]. The success control of the mealybug species by this predator are reported in many control programs [7]. Extensive research has been conducted on *C. Montrouzieri* feeding on mealy bugs [8, 9, 10, 11, 12, 13], including demographic data on development rates and fecundity by [14, 15]. It has received much attention from researchers as well as farmers as a potential biological control agent [16, 13]. 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 have found alternatives to pesticides for managing insect pests. Since *C. Montrouzieri* is a generalist

predator, the effective and proper use of this predators is essential for a positive effect in the IPM programs.

One of the most important behavior of the predator is functional response. Functional response of a predator refers to the number of prey attacked per predator as a function of prey density [17]. It describes a way in which natural enemy responds to the changing density of its prey, by killing fewer or more individuals and it is a commonly measured natural enemies attributes to pests [18, 19].

There are three types of functional response [20]. In type I there is a linear relation between numbers of prey killed and prey density. In type II it is curvilinear and the saturation level is reached in a gradual way. Type III is described by sigmoid relation and is considered to be a regulating factor in population dynamics of natural enemy and pests. The functional response of a predator is one of the crucial factor in population dynamics of prey-predator system. This behavior can be easily determined if the predator has capacity to regulate the density of its prey [21]. The models of functional response help to calculate two vital parameters i.e. attack rate (the rate and time in which predator search its prey) and handling time i.e. the time taken by predator to consume and kill a single prey. Several studies have been conducted to carry out functional response of *Hippodamia variegata* to different densities of other aphids. The functional response types and its parameters values are influenced by different factors such as (host species, natural enemies, variety of host plants and physical conditions in the laboratory [22].

A few studies have been performed on the predation capacity of C. *Montrouzieri* fed on different hosts under different environmental conditions and some other related aspects, but not on the functional response i.e. number of prey killed as a function of prey density. The objective of this study was to study functional response of 4th instar and adult male and female of C. *Montrouzieri* fed on fed on, *P. solenopsis* under laboratory controlled conditions.

2. Materials and Methods

The research work was conducted at laboratories of Insect Pest Management Program (IPMP), Institute of Plant and Environmental Protection (IPEP), National Agricultural Research Center (NARC), Islamabad during 2012.

2.1. Rearing of host insect, *P. solenopsis*

The culture of *P. solenopsis* was reared on different vegetables (Lady Fingers, Potato sprouts and Pumpkin) under controlled conditions at a constant temperature of 28±1ºC, with 65±5% R.H and 16:8 L: D photoperiod in insect holding rooms in wooden cages of size (4′x6′) and also in plastic jars of different sizes. The mealy bug colonies were renewed by replacing the older vegetables with new fresh vegetables to ensure continuous supply of *P. solenopsis* to the predator throughout the experimental duration.

2.2. Rearing of predator, *C. Montrouzieri*

C. Montrouzieri adults were reared under controlled conditions of 28 ±1°C, with 65±5% R.H and 16:8 L: D photoperiod in insect holding rooms. Then adults were kept in plastic container of size 10˝ x 15˝ (Width x Height) and diets were provided on potato leaves, fresh okra and pumpkin infested with *P. solenopsis* crawlers every morning. The diets were replaced daily with new infested crawlers. The plastic containers were covered with fine muslin cloth at the top. Leaves of potatoes, okra and pumpkin were provided as an oviposition substrate for the collection of eggs. The *C. Montrouzieri* adults usually gave eggs singly and the eggs were collected daily early in the morning during the time of observations.

The eggs were kept in another plastic container of size, 3″x4″ and tissue paper was provided at the bottom to avoid desiccation. Upon hatching the larvae were feed mealy bug crawlers in the same container till adult emergence. The adults were shifted to stock colony to maintain the culture continuously. The rearing jars were checked every morning for the collection of eggs. Eggs were collected with camel hair brush and also on respective vegetable leaves. The stock culture of both *C. Montrouzieri* and their host *P. solenopsis* was maintained throughout the whole experimental durations for different biological parameters of predator.

2.3. Experimental Procedures

The experiment was performed to calculate the functional response of 4th instar grubs and adult male and female of *C. Montrouzieri* at the same laboratory conditions used for rearing the predator. Different densities of cotton mealy bug (crawlers) of the same ages (5-10 days), reared on potato were 30, 45, 60, 75 and 90 nymphs of (1st – 2nd) nymphal instar crawlers for 4th instar grubs and adult male and female of *C. Montrouzieri* were used in the experiments. 4th instar grubs and adult male and female of *C. Montrouzieri* were starved for 24 hours before testing. Newly emerged 4th instar grubs and adult male and female were transferred to another petri dish and were starved for 24 hours. After 24 hours starved predators were transferred to the experimental arena which was of 10 cm diameter. The observations regarding Searching time of 4th instar grubs and adult male and female *C. Montrouzieri*, handling time of prey, resting time, killing time and total number of crawlers consumed in 24 hours at each respective density were recorded with six hour interval.

After 24 hours, number of alive and dead insects was counted and the functional response of 4th instar grubs and adult male and female of *C. Montrouzieri* at different prey densities were statistically analyzed by fitting the data to Holling's disc equation [20].

$$Na= a +N (1+aT_hN)$$

Where, Na= defines the number of prey attacked by a predator per unit time, a= defines the search rate of a predator, T = is the total time of exposure (1 day), N= is the original number of prey item offered to each stage of 4th instar and adult male and female of *C. Montrouzieri* at the beginning of the experiment and T_h is the handling time for each prey caught. Search rate and handling time were calculated by using linear regression of disc equation.

3. Results

The functional responses of the 4th larval instar of *C. Montrouzieri* to *P. solenopsis* are presented in Fig. 1 & 2. The results showed that with the increase in the predator density the consumed prey density had increased up to some extent. The recorded consumed prey numbers were 20, 37, 42, 58 and 71 for the 4th larval instar of *C. Montrouzieri* at 30, 45, 60, 75 and 90 densities of *P. solenopsis*, respectively. Similarly lower searching time (0.3748 hrs), handling time (0.54298 hrs) and resting time (0.4973 hrs) were recorded for predator at density 30. These figures were increased as the density of the predator increased and finally highest figures for searching time, handling time and resting time were obtained for the predator at density 90.

The results regarding the functional response study of adult male of *C. Montrouzieri* showed higher number of consumed prey as compared with the figures recorded for 4th larval instar of *C. Montrouzieri* (Fig. 1 & 2). The recorded numbers of the consumed prey were 22, 42, 56, 64 and 75 for the predator at densities 30, 45, 60, 75 and 90 respectively. Similarly higher figures for searching time (0.7984 hrs), handling time (0.7870 hrs) and resting time (0.8768 hrs) were recorded for the highest prey density.

The greatest maximum predation rate was recorded for the adult female of *C. Montrouzieri* as compared with the adult male and 4th larval instar of *C. Montrouzieri* (Fig. 1). The recorded consumed prey numbers were 26, 41, 59, 70 and 76 for the predator at densities of 30, 45, 60, 75 and 90 respectively.

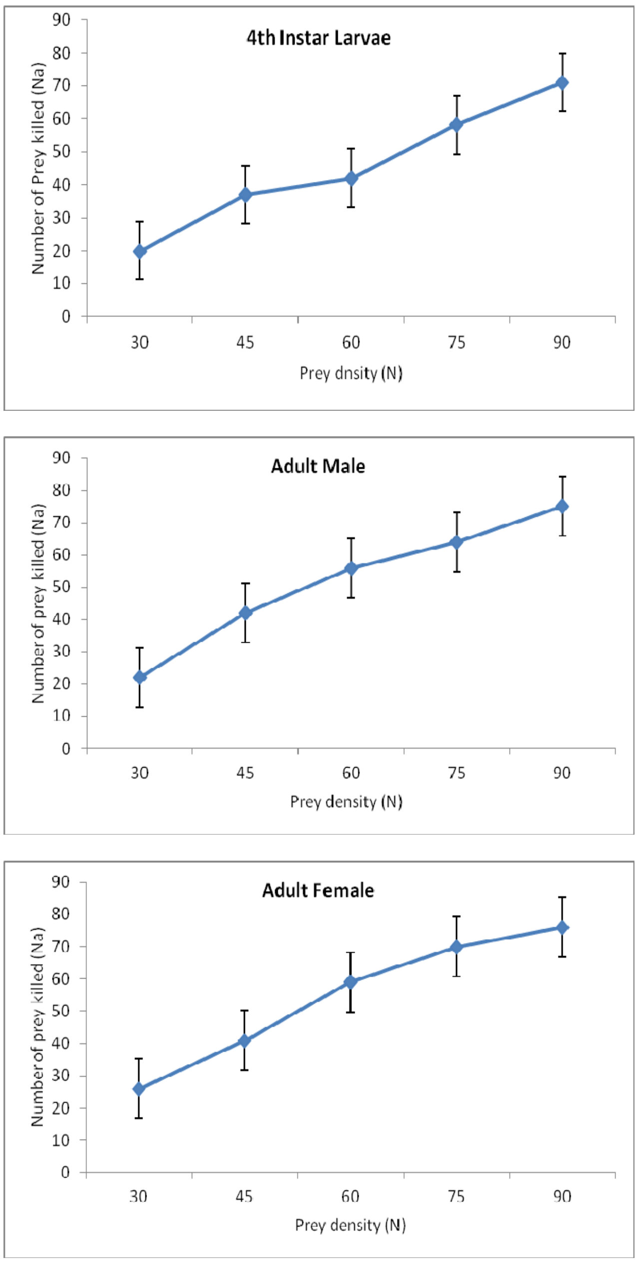

Fig. 1. Type II functional response of *C. Montrouzieri* to *P. solenopsis* in the controlled laboratory conditions

Fig. 2 shows that at lowest density (30) of the adult female of the predator, least values were recorded for searching time (0.4786 hrs), handling time (0.5974) and resting time (0.6889 hrs). Like the 4th larval instar and adult male of *C. Montrouzieri* an increasing trend up to some extent was observed in these values with the increase of the consumed host density. Highest figures were recorded for searching time (0.81362 hrs), handling time (0.8366) and resting time (0.91001 hrs) at the highest host density (90) of the predator.

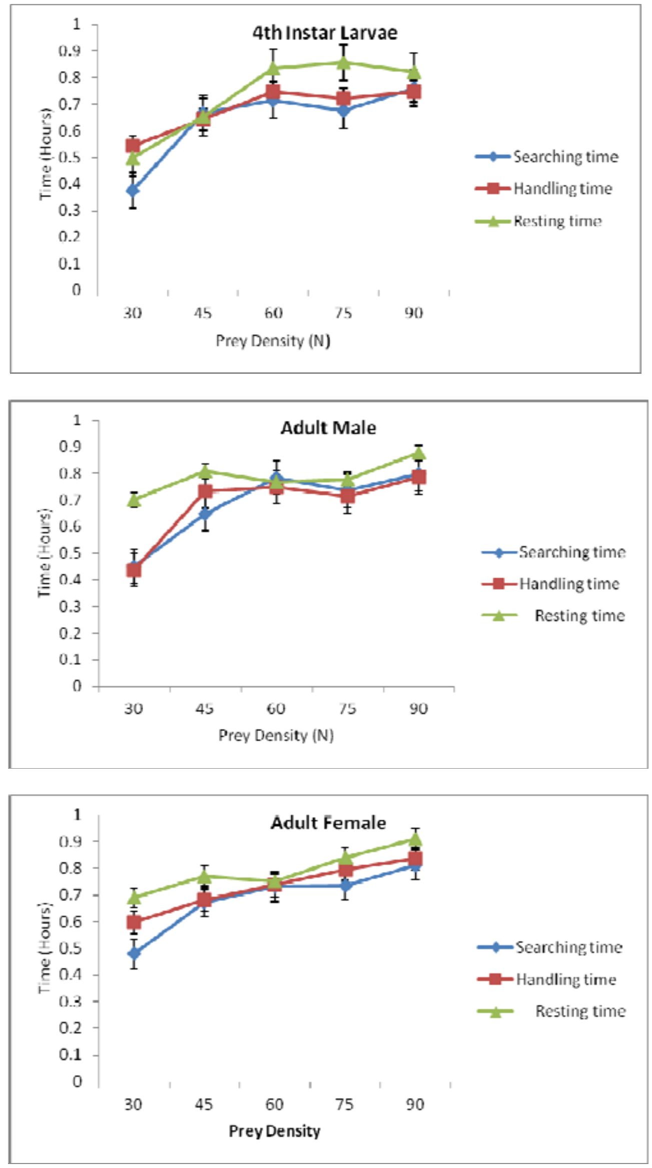

Fig. 2. Functional response of *C. Montrouzieri* to *P. solenopsis* in the controlled laboratory conditions

4. Discussion

The present findings showed that *C. Montrouzieri* is an efficient predator of *P. solenopsis*, which corroborates the findings of Gautam *et al.* [23] and Kairo *et al.* [24], who reported that *C. Montrouzieri* is the best biological control agent for hibiscus mealy bug, *M. hirsutus*. Result showed that the 4th larval instar and adult male and female of *C. Montrouzieri* showed a good predation potential to the *P. solenopsis*, but adult female of *C. Montrouzieri* were found more effective on this prey. The potential regarding the consumptive rate of the adult female of *C. Montrouzieri* was found higher than that of the adult male and 4th larval instar of *C. Montrouzieri*. Similar results were reported by Kaur & Virk [25] and Rosas-Garcia *et al.* [26] that the adult stage of *C. Montrouzieri* was the most efficient predatory stage as compared with the other development stages of the predator. The higher predation of the adult stage 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 on the 4th larval instar and adult male and female of *C. Montrouzieri*. Also increase in the movement speed with *C. Montrouzieri* in the adult stage may likewise play a role [27].

Our results showed lower searching time, handling time and resting time in the 4th larval instar followed by an increase in the adult male and female of *C. Montrouzieri*. It should be noted that search rate and handling time values from the fictional response curves represent the mean values of these parameters for 24 hour 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 [20]. Stark and Witford [28] referred to similar type of functional response of *C. carnea* feeding on *H. virescens* eggs.

Hassel [18] 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 [29]. Wiedenmann and O'Neil [30] 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 conspecifies and from competing beneficial and presence of alternative prey, may influence the effectiveness of the predators [20, 31, 32]. The laboratory studies are only useful in comparing the effectiveness of natural enemies required as a bio-control agent [19, 33].

5. Conclusion

The present findings showed that *C. Montrouzieri* is an efficient predator of *P. solenopsis*, and thus can play an important role for the development of pest management strategies based on the biological control. Also by including *C. Montrouzieri* the use of pesticides will be minimized. However before drawing firm conclusions, further research work under field conditions are required for better understanding of these predator-prey interactions.

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