# SEARCHING EFFICIENCY AND FUNCTIONAL RESPONSE OF AUSTRALIAN LADY BIRD BEETLE (*CRYPTOLAEMUS MONTROUZIERI*) ON GUAVA MEALYBUG (*PLANOCOCCUS CITRI*), A PREY-PREDATOR INTERACTION IN A HORTICULTURAL ECOSYSTEM OF COIMBATORE, TAMIL NADU, INDIA

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**Abstract.** Under laboratory conditions the searching efficiency and functional response of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* were evaluated on guava mealybug, *Planoccus citri*. The prey consumption per predator was calculated by taking the ratio of number of prey consumed and predator density. The per cent prey consumption was calculated by taking the ratio of prey consumed and initial prey density. The searching efficiency and rate of consumption by fourth instar larvae of *C. montrouzieri* increased significantly from $40.3 \pm 1.6$ to $90.7 \pm 1.8$ individuals of *P. citri* at constant density of 200 when predator density increased from one to eight. However, prey consumption per predator decreased from 33.7 to 11.6 with increase in predator density. The prey consumed by the larvae did not double when the prey density doubled and remained less than the double. However, Functional response reveals that prey consumption by *C. montrouzieri* increased with increase in prey density, whereas per cent prey consumption decreased. Prey consumption by a fourth instar larva of *C. montrouzieri* increased significantly from $49.5 \pm 1.8$ to $302.0 \pm 4.9$ individuals of *P. citri*, whilst per cent prey consumption decreased from 99.0 to 37.7 with increase in prey density from 50 to 800. Area of discovery of the fourth instar larva decreased from 3.912 to 0.474 when the prey density increased from 50 to 800. Prey consumption by *C. montrouzieri* increased with increase in prey density. These findings

support the potential of *C. montrouzieri* in controlling the guava mealybug, however, additional field investigations are needed to utilize the *C. montrouzieri* in biocontrol programs.

## Introduction

Guava trees are attacked by about 80 species of insects, of which fruit flies (*Bactrocera dorsalis* Hend), coccoids (*Chloropulvinaria psidii* Mask) and castor capsule borer (*Conogethes punctiferalis* Guen) are of major importance. In recent years, the mealybug, *Planococcus citri* Risso and Ferrisia virgata Ckll. has become one of the serious pests of guava by attacking the foliage and fruits. As this crop is perennial in nature it harbors persistent insect pests like mealybugs (Chattopadhyay, 2003). Leaves of mealybug infested trees turn yellow as if affected by drought and its honey dew secretion causes the sooty mold growth on the leaves. The affected guava trees are with reduced vigor and produce less market valued fruits which lead to severe economic loss to the growers. Among the various groups of insect predators, coccinellids are well known for their predation on pests like aphids, scales, mealybugs and phytophagous mites. Hence, exploitation of indigenous coccinellids as biocontrol agent of guava mealybug are worthwhile. To be an effective biocontrol agent, the success of a predator depends upon its foraging ability. The searching and predation response of a predator can be traditionally and analytically studied as: (i) Functional response, which involves the prey consumption by a predator at different prey densities, and (ii) Numerical response, which is the response to changes in predator density (Solomon, 1949).

Functional response of the predator was earlier promulgated in three disc equations (Holling, 1959a). Most of the previous studies on functional response, using predaceous coccinellids as models revealed Holling's Type II response with a curvilinear relationship between prey consumption and prey density (Omkar and James, 2001; Omkar and Srivastava, 2001; Kundo and Khan, 2017 and Saljoqi et al., 2015). However, a few exhibited type III response, which is sigmoidal in shape (Haji-Zadeh et al., 1994).

Nicholson and Bailey (1935) proposed a model to explain such interactions for parasitoids. However, it can also be applicable for predators, as it introduced the term "area of discovery," a measure for searching efficiency, which was initially proposed to be independent of prey and predator – densities. The later inductive model explains that area of discovery decreases exponentially with predator population and is not a constant (Hassell and Varley, 1969a).

One important factor that influences the role of insect predators in biological control in crops is the number of prey attacked per predator in biological control in crops is the number of prey attacked per predator as a function of prey density, i.e., a functional response (Solomon, 1949; Holling, 1959b). The number of prey attacked and consumed largely determines predator development, survival, and reproduction (Oaten and Murdoch, 1975). Functional response curves can be used to infer basic mechanisms underlying predator–prey interactions, clarify co-evolutionary relationships, and enhance biological control (Houck and Strauss, 1985).

Functional response has received much attention in the entomological and ecological literature. Several types of functional responses in relation to prey density have been described, including a linear increase (type I functional response), an increase

decelerating to a plateau (type II functional response), a sigmoid increase (type III functional response), and a dome-shaped response (type IV functional response). Many arthropod predators exhibit a type II functional response, which is characterized by a predation rate that is limited only by handling time, i.e., the time it takes a predator to subdue, consume, and digest its prey. The type II functional response has been described by the disk equation of Holling (1959b). Though, searching efficiency is an important component of prey-predator interactions, not much attention has been paid using predacious coccinellids.

## Materials and methods

### Mass culturing of citrus mealybug, Planococcus citri Risso

Citrus mealybug was mass cultured separately on red pumpkin (*Cucurbita moschata* Duchesne) as suggested by Chacko et al. (1978) (*Plate 1*). Fully matured unripened pumpkin fruit (weighing about 2 to 3 kg) with well-defined ridges and grooves were selected. Fruit with stalk was selected for easy handling during culture work. The pumpkin was washed with water to remove unwanted dusts and was treated with 0.1% formalin to avoid mold attack before introduction of ovisacs (Srinivasan, 1987). Then the pumpkin was treated with Dithane M-45 (1 g/L) and wounds on the fruit if any, were plugged with wax. The stalk of the fruit was smeared with molten wax to avoid contact with the mealybug while handling or transporting. To initiate culture, ovisacs of *P. citri* were taken from mulberry and were placed over pumpkin and was kept in a wooden cage of 1 × 1 × 1' size and maintained under dark condition for uniform settlement of crawlers. After five to seven days, crawlers emerged from ovisacs settled on all sides of pumpkin and later on developed into fully matured mealybugs in 30-40 days. One fully infested pumpkin was sufficient to infest 3-4 fresh pumpkins and the crawlers were transferred with the help of tender Glyricidia leaves (*Glyricidia masculata* Steud.) whenever the infested pumpkin produced crawlers. Thus, the cycle was repeated. The culture thus obtained was utilized for the various experimental studies.



A. With rope    B. Without rope

*Plate 1. Mass culturing of P citri on ripe pumpkin fruits*

### Mass culturing of Cryptolaemus montrouzieri Mulsant

As *Cryptolaemus montrouzieri* is the dominant coccidophagous species, it was multiplied on pumpkin infested with *Planococcus citri*, separately. One fully infested pumpkin of mealybug was taken separately in a wooden cage of 1 × 1 × 1' size and 50 adults of *C. montrouzieri* (15 days old) comprising both sexes (1:1) were introduced on the infested pumpkin. As supplementary food for the adults vials containing 50% honey

solution was kept inside the cage. The cages were kept under dark for mating and oviposition of beetles (Mani and Krishnamoorthy, 1997). During this period, beetles deposited their eggs either singly or in groups in the ovisacs of female mealybugs. The grubs were visible in such cages within a week after the introduction of the beetles (*Plate 2*). Grubs of *C. montrouzieri* pupated on the pumpkin or anywhere inside the breeding cage after a period of 20 days. To facilitate easy removal of pupa, dried guava leaves were kept at the base of the pumpkin in the cages. Emerged adults were collected and introduced into pumpkin with 15 days old mealybugs for further multiplication. Thus, the cycle was repeated. Various life stages of *C. montrouzieri* were taken from this laboratory cultures as and when they were required for conducting laboratory experiments. The cultures of mealybug species, *P. citri* and the predator, *C. montrouzieri* were maintained in the laboratory with $25.5 \pm 2.1°C$ and $69.9 \pm 5.5\%$ RH at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.



***Plate 2.*** *Grubs of C. montrouzieri feeding on P. citri crawlers and adults*

## *Evaluation of searching efficiency and functional response of C. montrouzieri on P. citri*

The first set of experiments was designed to evaluate the searching efficiency and second set for the functional response of the fourth instar of *C. montrouzieri*.

### *Searching efficiency*

For the first set of experiments, 12 h prestarved fourth instar grubs of *C. montrouzieri* were introduced @ 1, 2, 4 and 8 grubs into four plastic containers containing two hundred individuals of mealybug *P. citri* infested on a twig of guava. Open ends of the plastic containers were covered with muslin cloths fastened with rubber bands and placed in room temperature at $27.5 \pm 2.3°C$ and $72.3 \pm 3.1\%$ RH. After 3 h of exposure, larvae were taken out and unconsumed mealybugs were counted to find out the number of mealybugs consumed. The prey consumption per predator was calculated by taking the ratio of number of prey consumed and predator density.

### *Functional response*

Second set of experiments was designed to study the effect of varying prey densities on searching efficiency of the predator. For this purpose, 50, 100, 200, 400, 600 and 800 individuals of *P. citri* were kept in separate plastic containers along with host plant twigs. One fourth instar larva of *C. montrouzieri* prestarved for 12 h was introduced in each plastic container and open end was covered with muslin cloth fastened with a

rubber band. After 24 h of exposure at $27.5 \pm 2.3°C$ and $72.3 \pm 3.1\%$ RH., the larvae were taken out from the containers to record the number of unconsumed mealybugs to find out the number of mealybugs consumed. The per cent prey consumption was calculated by taking the ratio of prey consumed and initial prey density.

Both the experiments were replicated ten times. Area of discovery was calculated following Nicholson and Bailey (1935).

$$a = 1/P \log_e N/S$$

where, a = area of discovery, N = prey density exposed for predation, P = predator density released for predation, and S = number of prey surviving predation.

As per the new inductive model of searching efficiency proposed by Hassell and Varley (1969b), which incorporate mutual interference constant (m), derived as:

$$a = Q/P^m$$

where, Q = quest constant, a = area of discovery, when only one predator is searching, m = mutual interference constant (the slope of regression of log a on log P) and P = predator density released for predation.

The log values of initial number of prey and predators were evaluated and data obtained were analyzed by linear regression to determine the relationship between, (1) area of discovery and log initial number of predators, and (2) area of discovery and log initial number of prey. The log values, i.e. log prey consumption and log prey density obtained from the data of second experiment were subjected to regression analysis following a statistical package "Statistix 4.1" on PC. The disc equation proposed by Holling (1959) was transformed to nullify the assumption of constant prey density and to obtain a linear equation. This transformation was made following Livdhal and Stiven (1983) and Veeravel and Baskaran (1997).

## Results and discussion

### *Searching efficiency*

Prey consumption by the fourth instar larvae of *C. montrouzieri* increased significantly from $40.3 \pm 1.6$ to $90.7 \pm 1.8$ individuals of *P. citri* at constant density of 200 when predator density increased from one to eight (*Table 1*). However, prey consumption per predator decreased from 33.7 to 11.6 with increase in predator density. Also, the area of discovery decreased from 0.184 to 0.077 when one, two, four and eight predators were searching (*Figs.1* and *2*).

*Table 1. Prey consumption and area of discovery of C. montrouzieri with its different densities*

| Predator density | Total prey consumed* | Prey consumption per predator | Area of discovery |
|---|---|---|---|
| 1 | $40.3 \pm 1.6^a$ | 40.3 | 0.223 |
| 2 | $54.4 \pm 1.8^b$ | 7.2 | 0.157 |
| 4 | $69.8 \pm 2.3^c$ | 17.4 | 0.107 |
| 8 | $90.7 \pm 1.8^d$ | 11.3 | 0.076 |

*Values are mean ± SEM. Different letters denote that data are statically significant by DMRT
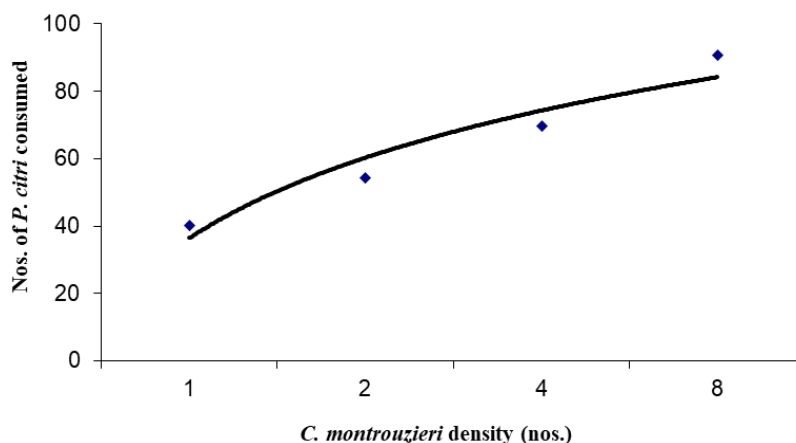
***Figure 1.*** *Relationship between P. citri population Vs C. montrouzieri densities*
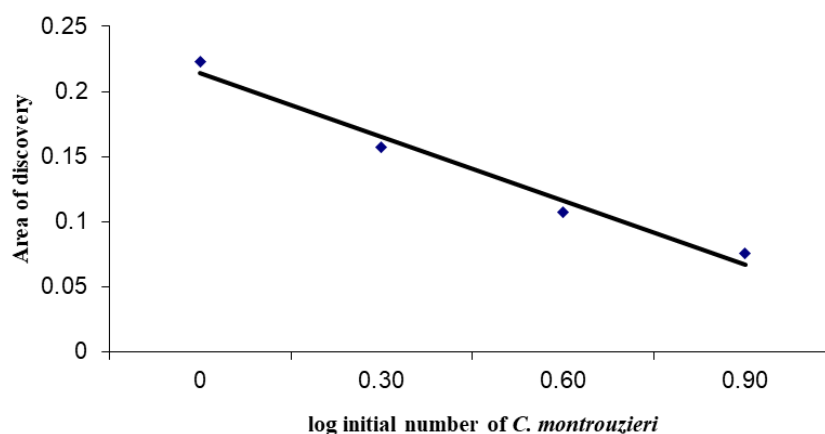


***Figure 2.*** *Relationship between log area of discovery of C. montrouzieri and log initial numbers of C. montrouzieri*

## Functional response

Prey consumption by the fourth instar larva of *C. montrouzieri* increased significantly from $49.5 \pm 1.8$ to $302.0 \pm 4.9$ individuals of *P. citri*, whilst per cent prey consumption decreased from 99.0 to 37.7 with increase in prey density from 50 to 800 (*Table 2*). Area of discovery of the fourth instar larva decreased from 3.912 to 0.474 when the prey density increased from 50 to 800 (*Figs. 3* and *4*).

***Table 2.*** *Functional response of C. montrouzieri at different prey densities*

| Predator density | Prey density | Total prey consumed* | Prey consumption (%) | Area of discovery |
|---|---|---|---|---|
| 1 | 50 | 49.50 ± 1.80a | 99.00 | 3.912 |
| 1 | 100 | 80.30 ± 1.80b | 80.30 | 1.609 |
| 1 | 200 | 143.40 ± 3.39c | 71.70 | 1.255 |
| 1 | 400 | 224.80 ± 4.47d | 56.20 | 0.826 |
| 1 | 600 | 250.80 ± 3.73e | 41.80 | 0.541 |
| 1 | 800 | 302.00 ± 4.94f | 37.75 | 0.474 |

*Values are mean ± SEM. Different letters denote that data are statically significant by DMRT

Allwin et al.: Searching efficiency and functional response of Australian lady bird beetle (*Cryptolaemus montrouzieri*) on guava
mealybug (*Planococcus citri*), a prey-predator interaction in a horticultural ecosystem of Coimbatore, Tamil Nadu, India
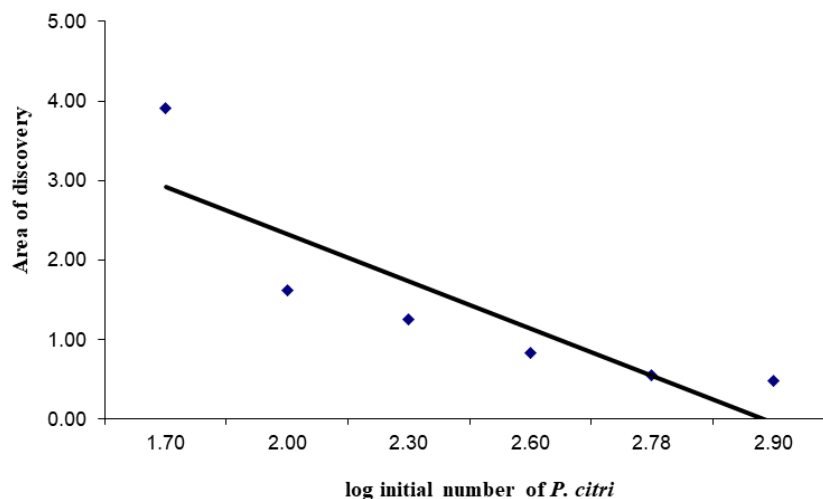- 1459 -

*Figure 3. Relationship between the log area of discovery of C. montrouzieri and its log initial numbers of P. citri*



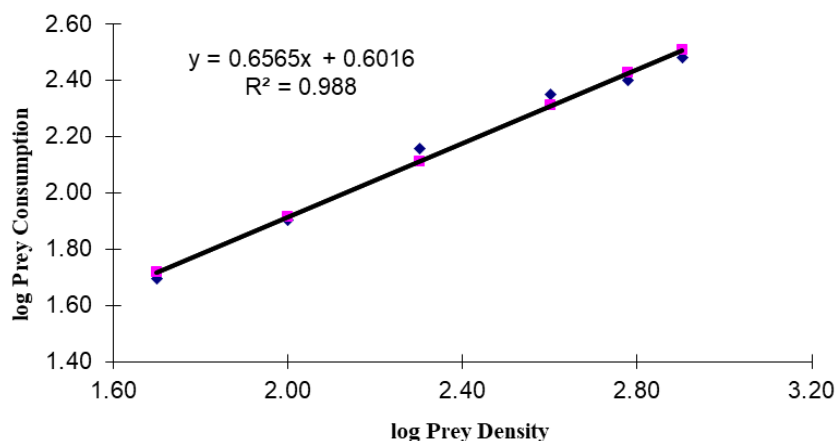*Figure 4. Relationship between the log density of P. citri and log consumption by fourth instar of C. montrouzieri*

When one larva was searching, the prey consumption rapidly increased and thereafter gradually decelerated, resulting in a plateau, at which consumption rate remained almost constant irrespective of further increase in prey density. Area of discovery decreased at high prey density, possibly as an outcome of more area restricted (i.e., intensive) search, enabling more exposure of predator to prey individuals. Clumping of prey at high prey density results in increased prey capture as also opined by Munyaneza and Obrycki (1998) for *Coleomegilla maculata* de Geer larvae. Higher prey density also results in reduction of unsuccessful attacks of predator on a prey, as there are less chances of escape irrespective to those in scarce prey density, where there are more chances for the prey to escape from predator (O'Neil, 1988). Assemblage of prey also affected the searching. Since mealybugs were widely spaced out at lower prey density, more time and energy were expended in searching because of the dispersed prey pattern, whereas, at higher prey density, there was a ready supply of prey. In field conditions the lady beetle might spend more time to find the patch where the prey was

present (Tamaki and Long, 1978). Satiation is a possible reason for decreased per cent prey consumption at high prey density, since satiated beetles spent more time in prey handling due to which rate of prey capture decreased (Mora et al., 1995; Dreyer et al., 1997; Veeravel and Baskaran, 1997; Hamid et al., 2021). Searching rate, mutual interference, and killing power of Coccinella undecimpunctata L. and Hippodamia tredecimpunctata L. (Coleoptera: Coccinellidae) varied when provided with two prey species, Aphis gossypii (Glover) and Aphis punicae (Shinji) (Hemiptera:Aphididae), under laboratory conditions of $27 \pm 2°C$ and $70 \pm 5\%$ RH. The searching rate of larvae and adult female C. undecimpunctata was higher than that of H. tredecimpunctata showed the host preference by the predator (Al-Deghairi et al.,2014). Studies suggest that the efficient predator *C. montrouzieri* feed on more prey of preferred host and the predator's searching efficiency is increased (Ghafoor et al., 2011; Rostami et al., 2024).

## Conclusion

Hence, the searching efficiency and rate of consumption was maximum when one predator was searching at prey density of 50 mealybugs. Thus, the predator-prey ratio of 1:50 may be considered suitable for the release of the predator at the infested prey site and it might be used for predicting the dynamics of prey populations under field conditions.:

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