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FUNCTIONAL AND NUMERICAL RESPONSES OF *EXOCHOMUS FLAVIPES* THUNBERG (COLEOPTERA: COCCINELLIDAE), A LOCAL PREDATOR OF THE CASSAVA MEALYBUG, *PHENACOCCUS MANIHOTI* MATILE-FERRORE (HOMOPTERA: PSEUDOCOCCIDAE)

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A B S T R A C T

Laboratory studies were conducted to assess the functional and numerical responses of adult females of *Exochomus flavipes,* as a predator of *Phenacoccus manihoti* the cassava mealybug (CMB). Day old eggs of CMB at densities of 100, 200, 300, 400, 500, 600 and 700 were fed to young adult females of *E. flavipes.* Each density was replicated 6 times. Number of eggs consumed (Functional response) and number of eggs laid (Numerical response) daily were recorded. Generally, eggs consumption per day increased significantly with increase in prey density and a significant correlation (P<0.05) between mean number of CMB eggs consumed per predator and prey density (r=0.956) was observed. No significant (P>0.05) difference was observed in prey consumption between prey densities of 500 and 700. There was increased prey consumption from 44% at prey density 200 to 67% at prey density 400 per day, while percentage prey consumption decreased from 65.4% at prey density 500 to 48% at prey density of 700. Number of eggs laid by adult *E .flavipes* increased with increase in prey density. The correlation coefficient between number of CMB eggs consumed and the number of eggs laid by *E. flavipes* was highly significant (r=0.9908) (P< 0.05).With increase in prey density, the pre oviposition period reduced from 9 days at 100 prey density to 4 days at 700 prey density. Also, oviposition period and longevity of adult *E.flavipes* were observed to increase significantly (P<.05: r=0.9524) (P<0.05:0.9481) respectively, with increase in prey density. From the result of this study, it may be said that *E. flavipes* has potentials to be exploited as a biocontrol agent of mealybugs.

Keywords: predator, prey density, functional and numerical responses, *Exochomus flavipe*, *Phenacoccus manihoti*.

INTRODUCTION

The genus *Exochomus* belongs to the family Coccinellidae, which comprises of two sub-families, Epilachninae, members of which are mostly phytophagous, and Coccinellidae which are carnivorous in habits (Sweetman, 1958). The insect eating coccinellids are known to attack sedentary preys such as scale insects, mealybug and aphids (Christopher, 2007). The black lady bird beetle *E. flavipes* is an Ethiopian species, apparently occurring throughout Africa and has a very wide distribution in South Africa (Gayer, 1947a). Like other entomophagous coccinellids, it feeds on soft bodied insects such as aphids and mealybugs (Hemchandra *et al*., 2010). *E.flavipes* is an important species used as biological control agent, In California it was introduced against the scale insect, *Ulvinaria mesembryanthemis* Vall (Tassan *et al*., 1982). In Egypt *E. flavipes* is said to be a potential natural enemy of the green shield scale, *Pulvinaria psidii* (Abd- Rabou Shaaban, 2011).

The life cycle of *E. flavipes* is holometabolous *and* the incubation period is influenced by temperature (Kiyindou, 1987). Mailu *et al.* (1980), working under laboratory conditions of constant temperature of 30^oC in Kenya, recorded larval to adult period to last between 21-53 days, while adult life span was 50 days when fen on aphids. Among may factors that determine the

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efficiency of a predator is its ability to synchronise with its prey especially at a high prey density (Murdoch, 1973). According to Everson (1980), many factors such as functional and numerical responses, reproductive rate, search capacity, the predator's life history in relation to that of the prey interact and ultimately determine the success of a predator in controlling its prey (Murdoch, 1973).

In a field survey in Ibadan,Nigeria, *E. flavipes* was noted as the most predominant local predator collected from cassava fields in the area (personal observation). Both nymphs and adults fed on all stages of the *P. manihoti.* Thus this study was designed to investigate the functional and numerical responses of *E. flavipes* as a measure of its efficiency as a biological control agent of mealybugs.

MATERIALS AND METHODS

***Phenacoccus manihoti* culture**: A culture of *P.manihoti* was established and maintained on cassava plants of the local 'Odongbo' variety. Every two weeks until the experiment was terminated, 30 fresh cuttings of cassava plants were each planted in plastic pots containing field soil. Two weeks after sprouting, the potted cassava plants were artificially infested with egg masses of *P. manihoti* collected from the fields. The potted plants were kept in the Green House of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria and watered regularly. To maintain a continuous supply of the population of *P. manihoti*, new clean potted plants were placed close to the already infested ones for continuous infestation.

***Exochomus flavipes* culture**:The initial stock of *E. flavipes* used to establish the mass culture was collected from cassava plots in Ibadan, Nigeria. They were placed in cages containing *P. manihoti* infested potted cassava plants described above. The *P. manihoti* infested plants were replaced regularly to ensure that *E. flavipes* did not outstrip the amount of available food. *P. manihoti* egg masses were collected daily, observed under the microscope for *E. flavipes* eggs, which were removed and incubated, and reared to adults.

Rearing unit: The rearing unit consisted of a petri dish, 8.5cm in diameter and a lid with an opening of about 3cm in diameter on it. This opening was covered with fine nylon mesh for aeration. The floor of the petri dish was covered with Whatmann filter paper, 8.5cm in diameter.

Functional and Numerical Responses of ovipositing female *E. flavipes*: Young adult *E. flavipes* females collected from the stock described above were confined on mealybugs in petri-dishes and mated with three day old males to ensure successful mating. Each female was then transferred with a male into the rearing unit, previously described, and observed daily until the onset of reproduction, when the males were removed, because according to Gayer (1947a), one mating is enough for female *E. flavipes* to oviposit throughout thier lifetime. There were seven feeding regimes from 100-700 mealybug eggs.

Each regime was replicated six times. Each replicate consisted of a female *E.flavipes* provided daily with the appropriate number of mealy bug eggs under its own feeding regime. The mealy bug eggs (prey) were counted and scattered over the filter paper in the rearing unit. Empty mealybug eggs sacs were added to the unit to serve as ovipostion site (Nsiama She 1985). The number of prey consumed (functional response) and the number of eggs laid (numerical response) were recorded daily, The remaining prey eggs were discarded daily, and replaced with freshly laid eggs to maintain a constant number of prey eggs of appropriate age. The experiment was terminated at the death of the female. Data were subjected to an Analysis of Variance (ANOVA) and the means separated by Duncan's New Multiple Range Test. The number of prey eggs consumed and the number of eggs laid by the predator were correlated separately with the prey densities used.

RESULTS AND DISCUSSION

The mean number of *P. manihoti* eggs consumed by *E flavipes* female ranged from 52 at prey density 100 to 340 at density of 700 per day (Table 1).Prey consumption by the predator was significant between prey densities of 100 to 400, while there were no significant differences in prey consumption between prey densities of 500 to 700(Table 1). The number of eggs consumed per day, increased significantly with increase in prey density. The relationship between prey consumption and prey densities gave a sigmoid or S-shaped curve (Fig. 1), which is Holling's type 111 response curves. There was an initial steep rise of the curve, followed by a gradual curve to a plateau.

The correlation between the mean number of CMB eggs consumed per predator and the prey density was significant ($P < 0.05$) with an r- value of 0.956.

Table 1. Functional and Numerical responses of predator, Exochomus flavipe female *at* different densities of prey, *Phenacoccus manihoti* eggs.

Functional Responses		Numerical Responses	
Prey density	Mean prey egg consumed	% consumption per day	Mean eggs laid per day
100	52e	52	3d
200	88d	44	5d
300	148c	49	9c
400	268b	67	12bc
500	327a	65.4	16ab
600	339a	56.5	17a
700	340a	48.5	18a

Means followed by the same letter(s) are not significantly different at P< 0.5. (Duncan's New Multiple Range Test).

Table 2. Effect of prey, *P. manihoti* density on the time related oviposition Parameters of the predator, *E. flavipes*.

Host density	No. of prey Consumed/ female Per day	No. of eggs laid/ female Per day	Preoviposition Period (days)	Oviposition Period (days)	Longevity (days)
100	52 ± 7. 78e	3.37 ± 1.67b	8.83 ± 0.6a	27.0 ± 2.32b	35.83±2.75b
200	88. 25 ± 12. 26d	5.42 ± 2.89d	7.17 ± 0.79a	27.83±2. 12b	35.00±2.38bc
300	147. ± 24. 66c	8.71± 3.57cd	5.33 ± 0.62c	37.5± 2.60a	42.83±2.77bc
400	267.79 ±24.35b	12.05±4.69bc	5.17 ± 0.48c	39.67± 3.03a	44.83±3.00ab
500	327.03 ± 31. 91a	16.17±6.11ab	4.50 ± 0.43c	39.83 ±3.44a	44.33±3.44ab
600	338.81 ± 39.06a	17.38 ± 6.27a	4.30 ± 0.42c	43.33± 3.08a	47.83±3.18a
700	340.02 ± 77.92a	17.64 ±6.65a	4.17 ± 0.31c	45.67± 3.70a	50.00±3.75a

Means followed by the same letter (s) in the column are not significantly different at 5% level. [Duncan's New Multiple Range Test].

Percentage prey consumption increased from 44% at prey density of 200 to 67% at a prey density of 400 per day. Thereafter, percentage prey consumed decreased from 65.4% at a prey density of 500 to 48.5% at a prey density of 700 (Table 1). Egg production by *E. flavipes* female (Numerical response) increased with increase in the availability of prey. This result agrees with the findings of Sohrabi and Shishehbor (2007), who did a similar work on the functional and Numerical responses of *Stethorus gilvifrons* a predator of strawberry spidermite, *Tetranychus turkestani*.

The number of eggs laid per day increased from 3 at a prey density of 100 to 18 at a prey density of 700 (Table 1). There were no significant differences in the number of eggs laid between prey densities of 100 and 200 and also between 500 to 700. A plot of the rate of egg production against prey densities also gave a sigmoid or S- shape curve (Fig. 1). There was a high degree of correlation between the number of *P. manihoti* eggs consumed and the number of eggs laid by the predator. The correlation coefficient, 0.991 was significant P<; 0.05). Generally, the functional and numerical responses of *E. Flavipes* adult females showed a consistent rise from the prey density of 100 and reached a plateau at the prey densities of 500 to 700 (Fig.1).

The effect of prey density and other reproduction parameters is shown in Table 2; pre- oviposition period was reduced with increase in prey density and ranged between 9 days at a prey density of 100 to 4 days at a prey density of 700. Increase in prey density increased the oviposition period and longevity of *E flavipes* females increased from 36 to 50 days. The relationship between prey densities on one hand, the oviposition period and the longevity of the predator on the other were significant (p < 0.05) with r- values of 0.952 and 0.948 respectively.

The density of prey is one of the factors influencing the searching efficiency of a predator (Holling, 1959a). In the functional and numerical responses, the female *E. flavipes* provided with different densities of prey eggs, consumed more prey and laid more eggs at higher prey densities. In order for a predator to control its prey, the predator has to exert an increasing percentage effect as the prey density rises (Sohrabi and Shishehbor, 2007).One of the ways by which a predator can vary its effect on the prey population is by change in number, (Numerical Response) (Solomon, 1949).

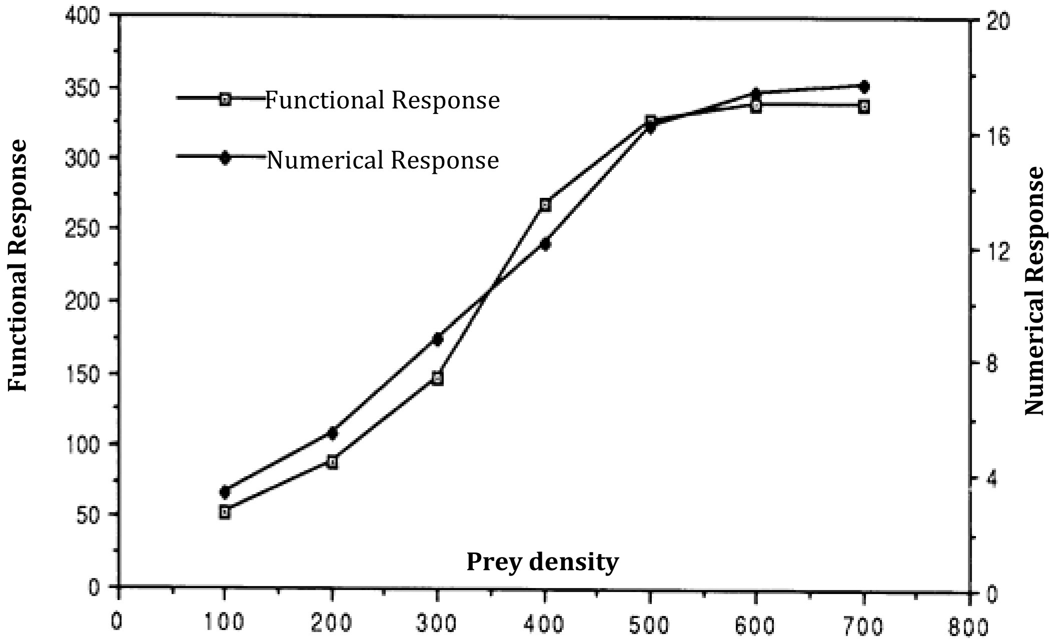

Figure 1. Functional and Numerical Responses of ovipositing females of E. Flavipes at different densities of P. manihoti eggs.

The increase in numerical response with increase in prey density could be attributed to the availability and increase food consumption hence the insect having enough food reserve and thus more energy was channeled into reproduction (Price, 1975.,Eveleign and Chant,1981).The reproductive rate increases leading to increase in the population (numerical response). Apparently, between prey densities of 500 to 700 there was no significant difference in the functional and numerical response of *E.flavipes* females. This is in line with the observation made by Holling (Holling, 1959a; 1961) that any realistic functional response must level up at a point, which in this study of *E flavipes* is at the prey density of 500 to 700.

The ovipositing adult *E.flavipes* feeding on *P.manihoti* eggs showed a density dependent mortality or sigmoid curve. Hollings (1959b), Huffaker and Kenneth (1969) reported that only the sigmoid functional response represent the possibility of prey population control or regulation. Increase in prey density reduced the pre-oviposition period with no significant difference at 300 to 700 prey densities. It is apparent that as food availability increased, oviposition began earlier and *E. flavipes* female lived longer than when food was in short supply. There was a positive and significant correlation ($P < 0.05$) ($r = 0.9480$) between longevity of *E. flavipes* female and prey densities.

The result of this study implies that *E. flavipes* has the potential to be exploited as a biocontrol agent for the management of *P. manihoti* population.

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