Indian Journal of Scientific Research and Technology (INDJSRT) ISSN: 2321-9262 (Online)
Volume 5 Year 2017 Available at: www.indjsrt.com
Research Article

FUNCTIONAL RESPONSE OF *CYRTORHINUS LIVIDIPENNIS* (REUTER) ON EGGS OF BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (STAL.)

***K. Vasanta Bhanu, P. Satyanarayana Reddy and J. Satyanarayana**
Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru. A.P., India
**Author for Correspondence*

ABSTRACT
Functional response of female green mirid bug on the varying egg densities of BPH was assessed in the greenhouse. The varying egg densities of BPH was obtained by releasing three days old gravid BPH females onto the caged plants at densities of 1, 2, 3, 4, 5, 6, 7, 8, and 9 per pot for 24 hours. The results indicated that the logistic regression showed a type II functional response for female green mirid bug. The number of eggs attacked per day per predator increased from 1.0 at a prey density of 12 to a maximum of 23.0 at a prey density of 71.0 and thereafter the number of eggs attacked per day was decreased gradually with increase in prey density. The parameters (using Rogers' model), the search rate (a) and the handling time (T_h) were estimated to be 0.318 and 0.0679 (days) respectively. Based on the estimates of handling time the mean number of eggs that one female *C. lividipennis* able to consume per day was 14.73.

Key Words: *Cyrtorhinus lividipennis,* Functional response, *Nilaparvata lugens,* Eggs

INTRODUCTION
The brown planthopper (BPH), *Nilaparvata lugens* (Stal.) (Homoptera: Delphacidae) is one of the most destructive monophagous insect pests of rice. In tropical rice, it is well established that BPH is a secondary pest problem caused by ecological disruptions, particularly due to use of insecticides that reduce natural biological control. The activity of indigenous parasitoids, predators and pathogens form the major component of biological control and their conservation is an essential part of integrated BPH management. Naturally occurring predators and parasites were sufficient for economic control of BPH in most rice ecosystems. Among the natural enemies of BPH, green mirid bug, *Cyrtorhinus lividipennis* (Hemiptera: Miridae) is one of the important insect predators, predaceous on nymphs as well as on eggs of BPH (Bae and Pathak, 1966; Pawar, 1975). Stapley (1976) reported that the ratio of BPH and mirid bug in 20:1 is necessary to achieve BPH control. Pophaly et al., (1978) reported that the prey-predator ratio of 4:1 per hill checked the buildup of BPH population and 20.00 to 99.70 per cent mortality of early nymphal instars of planthoppers. Functional response is an important behavioral response to reveal different aspects of prey-predator interactions. The term "functional response" shows the response of individual natural enemy to varying prey density (Solomon, 1949). When the number of prey killed is plotted against the number of prey available, a continuum of patterns may emerge from which ecologists delimit three types of functional responses (Holling, 1959). Functional response curves may represent linear increase (type I); an increase decelerating to a plateau (type II); and a sigmoid increase (type III). The functional response curves can be differentiated by evaluating the parameters, viz**.,** coefficient of attack rate 'a' (the proportion of prey killed per unit time by a predator) and handling time 'T_h' (time spent by predator in attacking, killing, subduing, and digesting the prey). The values of a' and T_h vary with the relative size of the predator and prey and the efficiency of the predator. The functional response of the *C.lividipennis* to brown planthopper under laboratory conditions was reported to be Holling's type II (Sivapragasam and Asma, 1985; Heong et al., 1990 and Laba and Heong, 1996). Hence, the present investigation on the functional response of female green mirid bug on the varying egg densities of BPH was carried out in greenhouse to assess the type of functional response.

MATERIALS AND METHODS
Mass culturing of *C. lividipennis*
Mirid predator, *C. lividipennis* was mass reared on BPH eggs, using TN1 rice plants. Adult mirids collected in the field are introduced into Mylar cages containing 30 day old TN1 rice plants infested with five gravid BPH females. Plants, mirids and BPH females are transferred into oviposition cage after 24 h. When the mirid eggs hatch, some gravid BPH females are added to provide food for the mirids. Each cage will produce mirids of known age, those can be used for experiment (Manti, 1990).
Mass culturing of BPH
To obtain different instar nymphs and adults of BPH required for the various studies, the insect was mass reared in the greenhouse and iron framed rearing cages covered with fine mesh wire net. Four to six weeks old potted plants

of susceptible rice variety, Taichung Native1 (TN1) were used for culturing the BPH. To start the culture of BPH, the potted TN1 plants were cleaned and the dried outer leaf sheaths were removed. They were then placed in an oviposition cage. Gravid females of BPH obtained from the maintenance cage were released on to the potted TN1 plants for oviposition and exposed for 3 days. Then the oviposited plants were placed in maintenance cage for hatching of the eggs. The host plants in culture maintenance cage were changed twice a week and replaced them with fresh potted plants (Heinrichs et al., 1985).

Functional response study

To prepare the experimental arenas, the seedlings of TN1 rice variety were transplanted in clay pots at five seedlings per pot. At 60 days after transplanting, the rice plants were thinned to have four tillers per pot. These plants were then enclosed in a cylindrical Mylar film cage with its top and a cut-out window covered with muslin cloth. Three days old gravid BPH female were released into the caged plants at densities of 1, 2, 3, 4, 5, 6, 7, 8, and 9 per pot for 24 hours to obtain varying densities of BPH eggs. Then these arenas were caged with one freshly emerged *C. lividipennis* female and allowed to predate for 24 hours. Then the predators were taken out of the arenas and the total number of BPH eggs, and the eggs consumed were counted and recorded with the help of microscope (Heong et al., 1990). Consumed eggs were distinguished based on the shrunken egg shell without internal contents.

Statistical analysis

To model the relationship between the numbers of prey consumed (N_a) and initial prey density (N_0) the data was fitted to Holling's disc equation (Holling, 1959) and to the Random predator equation (Rogers, 1972).

Holling's disc equation

$$N_a = \frac{aN_0}{1 + aT_hN_0}$$

Random predator equation

$$N_a = N_0\,(1 - \exp(aT_hN_a - a))$$

Where '*a'* is the instantaneous searching rate and 'T_h' is the handling time per prey item. The parameters '*a'* and 'T_h' were estimated through a nonlinear least-square regression (NLR) in statistical software R (version 2.15.0) and the response curve was fitted to understand the type of functional response. The Rogers random-predator equation contains N_a on both the left- and right-hand sides of the equation; traditionally, one has to use iterative numerical methods to compute the function (Vonesh and Bolker, 2005). However, the Lambert W function (Corless et al., 1996), which gives the solution to the equation W(x)eW(x) = x, can be used to compute the Rogers equation efficiently.

In terms of the Lambert W the Rogers equation is:

$$N_a = N_0 - [W\,(ahN_0e^{-a\,(1-hN0)})/ah]$$

The starting values of '*a'* and 'T_h' required by the NLR procedure were found by linearly regressing $1/N_a$ against $1/N_0$. The resultant *y*-intercept is the initial estimate of 'T_h 'and the reciprocal of the regression coefficient (slope) is an estimate of '*a'* (Watson et al., 2000). These initial estimates of 'a' and 'T_h' were refined by NLR.

RESULTS AND DISCUSSION

The results pertaining to the functional response studies of *C. lividipennis* on BPH eggs were presented in table 1, fig. 1 and fig 2. The figure 1 illustrated the relationship between the number of eggs attacked and the initial BPH egg density. As the initial egg density increased, the number of eggs attacked by the predator changed in a manner of negatively accelerating increase to a plateau indicated that *C. lividipennis* exerts Hollings' Type II functional response. The number of eggs attacked per day per predator increased from 1.0 at a prey density of 12 to a maximum of 23.0 at a prey density of 71.0 and thereafter the number of eggs attacked per day was decreased gradually with increase in prey density.

The results from the functional response study of *C. lividipennis* female to different densities of BPH eggs satisfactorily fitted to modified Rogers' random predator equation and Hollings disc equation (Table 1). Using the Rogers' random predator equation, the search rate (a) and the handling time (T_h) were estimated to be 0.318 and 0.0679 (days) respectively at 95% confidence limits. The attack rate was higher than the handling time. Whereas, using Hollings disc equation the search rate (a) and the handling time (T_h) were estimated to be 0.283 and 0.0659 (days) respectively which were slightly lower compared to the values of Rogers' random predator equation. Between the two models the best fit model was Rogers' random predator equation with lower values of Root mean square error (4.11319); Akaike information criterion (570.598) and Bayesian information criterion (578.414) than Hollings disc equation.

Table 1: Parameter estimates of the functional response equation for *C. lividipennis* feeding on eggs of brown planthopper

Parameter estimates		Asymptotic Standard Errors	RMSE	AIC	BIC	F	p
Holling's Disc equation							
a	0.2834 (0.187-0.464)	0.0711	4.11815	570.863	578.679	3.988	0.000128
T_h (day)	0.06591 (0.047-0.085)	0.0104				6.332	7.32E-09
Rogers Random predator equation							
a	0.31846 (0.204-0.539)	0.08493	4.11319	570.598	578.414	3.75	0.000299
T_h (day)	0.06793 (0.045-0.087)	0.0104				6.534	2.88E-09

a= attack rate; T_h= handling time; Values in square brackets were 95% confidence limits
RMSE= Root mean square error; AIC=Akaike information criterion ; BIC=Bayesian information criterion

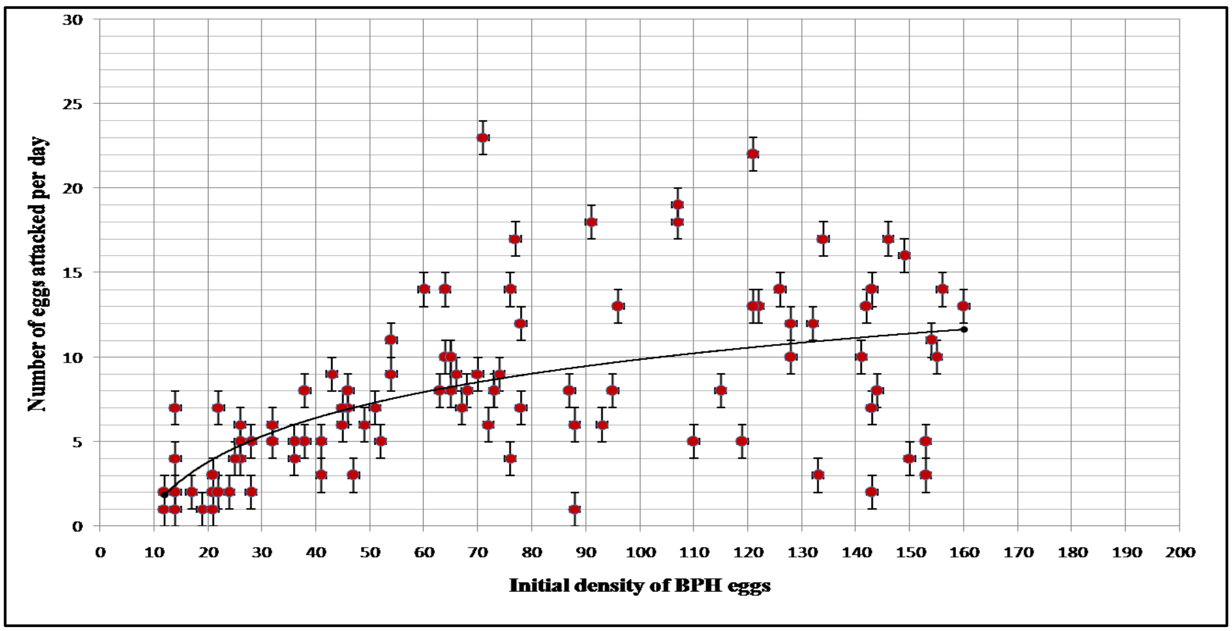

Figure 1: The Functional response of *C. lividipennis* feeding on BPH eggs (The vertical bars are Standard errors)

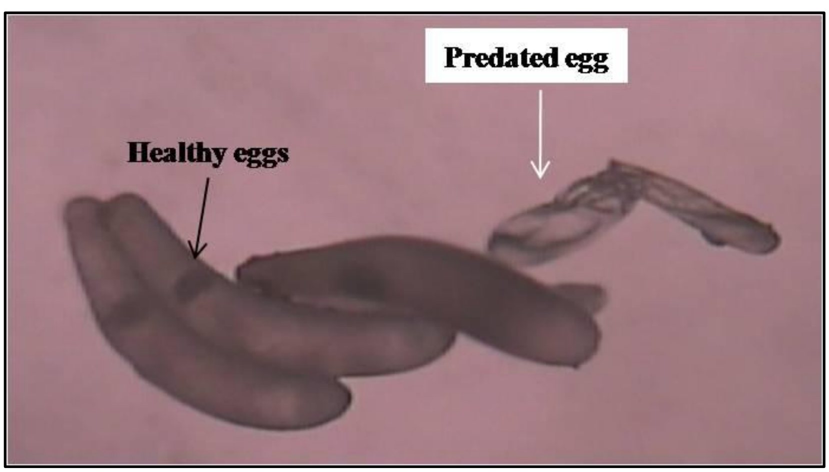

Figure 2: Healthy and green mirid bug predated eggs of BPH

Based on the estimates of handling time the mean number of eggs that one female *C. lividipennis* able to consume per day was 14.73 from Rogers' random predator equation and 15.17 from Hollings' disc equation.

Functional response studies provide useful predictive indices in the choice of biological control agents since such studies provide information on the killing power of the bio-agents at different host or prey densities. From the present study, it was clearly demonstrated that increase of prey numbers was related to daily consumption number of C. *lividipennis*. In the present investigation, the predation rate tend to decrease with increase in prey after a certain level, probably due to an increasing satiation of the predators, indicated that the predation rates followed a type II functional response. Similar finding of type II functional response of C. *lividipennis* on BPH eggs were earlier reported by several workers (Heong et al., 1990; Laba and Heong, 1996; Supanee and Sungwarl, 2002). From the present investigation, the predation parameters such as attack rate and handling time were 0.318; 0.283 and 0.0679; 0.0659 from Rogers random predator and Hollings disc equations respectively. These values were higher than the findings of Heong et al., (1990) (0.247 and 0.017); Laba and Heong (1996) (0.102 and 0.044) but the attack rate was lower and handling time was more than the values of Manti (1989) (0.491 and 0.031). The estimates of Sivapragasam and Asma (1985) were very high attack rates of 2.21 and low handling time of 0.034 on BPH eggs. This might be because of smaller arena size used.

In the present investigation, the handling times were more compared to previous findings. This may be because of the differences in various factors like speed of predator movement, physical traits of the plant can also influence the searching behavior of natural enemies (Price et al., 1980). The age of the predators is another factor for changes in handling time. Temperature and period of time the predator exposed have extreme effects on this parameter (Song and Heong, 1997).

In the present investigation, the maximum number of eggs attacked by a female C. *lividipennis* was 23.00. This finding was in agreement of earlier findings of Sivapragasam and Asma (1985) who reported a maximum of 22.00 eggs were attacked by single female mirid predator per day.

CONCLUSION

It would be concluded from the above results that the green mirid bug, *C. lividipennis* has a potential value to be considered as a bio control agent of the brown planthopper.

Further Research: The predatory efficiency of the green mirid bug is further assessed through functional response studies with different instar nymphs and male adults to BPH nymphs, eggs and first instar nymphs of white backed planthopper and green leafhopper.

ACKNOWLEDGEMENT

The authors are grateful to Acharya N.G. Ranga Agricultural University, Hyderabad for providing financial assistance to take up the present investigation. The authors are very much thankful to Dr. Y.G. Prasad, Principal Scientist (Entomology), CRIDA, Hyderabad; Dr. V. Jhansi Lakshmi, Principal Scientist (Entomology), DRR, Hyderabad for their timely help in statistical analysis. The authors acknowledge the cooperation rendered by the Associate Director of Research and other field staff, Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, A.P., India.

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