Res. Popul. Ecol. (1990) **32**, 255–262.

PREDATION OF *CYRTORHINUS LIVIDIPENNIS* REUTER ON EGGS OF THE GREEN LEAFHOPPER AND BROWN PLANTHOPPER IN RICE

K. L. Heong, Saad Bleih[1] and Amor A. Lazaro

Entomology Department, International Rice Research Institute, Los Banos, Philippines

Introduction

Cyrtorhinus lividipennis Reuter (Hemiptera: Miridae) is an important egg predator of planthoppers and leafhoppers in tropical rice fields. It occurs in many rice growing areas and has been found to be closely related to populations of the brown planthopper (BPH) (*Nilaparvata lugens* Stal.) (Hinckley, 1965; Kuno and Dyck, 1984). In the greenhouse, BPH populations caged with *C. lividipennis* were often significantly reduced (Bae and Pathak, 1966; Manti, 1989). Beside BPH eggs, *C. lividipennis* feeds on the early instar nymphs of BPH (Sivapragasam and Asma, 1985), eggs of the green leafhopper (GLH) (*Nephotettix virescens* Dist.) (Reyes and Gabriel, 1975) and *Sogatella furcifera* Horvath (Hinckley, 1963). When eggs of BPH, GLH and *S. furcifera* were caged together with *C. lividipennis*, greater proportions of BPH eggs were consumed (IRRI, 1981). In such a multi-prey environment, several aspects on the searching behavior of the predator are of particular interest; (a) preference; (b) switching; and (c) relevance of the searching parameters in such behavior.

Prey preference among polyphagous predators has been well discussed by Murdoch (1969, 1973), Hassell (1978) and Cock (1977, 1978). The use of preference indices have been extensively reviewed by Cock (1977, 1978) and he proposed a convenient recipe to analyze preference. Murdoch's (1969, 1973) use of the disc equation to predict preference assumes that exploitation is negligible or that the prey eaten is being replaced. With exploitation, the more appropriate model to use is the Random Predator Equation (Lawton et al., 1974; Cock, 1977) and the Random Parasitoid Equation (Hassell, 1978).

Chesson (1983) showed that Manly's measure of preference, α, (Manly et al., 1972) has many advantages. Values of α varies from zero to unity with 0.5 representing no preference. Besides, it does not vary with food density unless the predator behavior also changes with food density and is thus useful in detecting such changes.

In this paper, we estimated the searching parameters of both male and female adults of *C. lividipennis* feeding on BPH and GLH eggs. Feeding preference and switching was determined using independent experiments and Manly's index and the

---

[1] Present address: Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt.

results compared with the ratios of searching efficiencies.

MATERIALS AND METHODS

Experiments

Greenhouse cultures of BPH and GLH were reared on rice (Variety: Taichung Native (1) (TN (1)) using a standard method described by Heinrichs *et al.* (1985). The culture of *C. lividipennis* was maintained using BPH eggs. Adult BPH and GLH gravid females from these cultures were placed onto 60-d-old rice plants (TN (1)) for 24 hours for egg oviposition. In the functional response experiments, the egg densities were varied by placing 1 to 9 females onto rice plants. The total numbers of GLH and BPH eggs were determined after interaction with the predator.

The experimental arena used for the functional response and preference experiments consisted of a 60-d-old rice plant (TN (1)) trimmed to 4 tillers in a cylindrical mylar cage (13 cm diam.; 50 cm ht) with its top and a 15 × 15 cm^2 cut-out window covered by muslin cloth. The *C. lividipennis* were released into the arena through the cage window. Both male and female *C. lividipennis* were used separately. In all experiments, single freshly emerged adults were caged with the prey for 24 hours. For functional response experiments, a total of 100 arenas with different egg densities were used. In the preference experiments, a total of 50 arenas with both BPH and GLH eggs were used. Total eggs available and eggs that were eaten of both hopper species in each arena were determined using a binocular microscope after exposure to the predator. All the experiments were conducted in the insectary (RH: 70–90% temp., 24–30°C; 12/12 hr illumination).

Data Analysis

The functional response data were fitted to the random predator of Royama (1971) and Rogers (1972) using the non-linear least-squares procedure, NLIN (SAS Institute, Inc., 1985). All the individual data points were used in the analyses so as to provide better estimates of the S.E.s in the parameter estimates (Juliano and Williams, 1987).

In the case of predators, where food depletion is significant, preference may be approximated by:

$$\alpha_i = \frac{\ln((n_{i0} - r_i)/n_{i0})}{\sum_{j=1}^{m} \ln((n_{j0} - r_j)/n_{j0})}, \quad i = 1, \ldots, \mathrm{m} \tag{1}$$

where n_{i0} is the number of prey i present at the beginning of the period. Statistical tests are described by Manly (1974). Applying the random predator equation (Royama, 1971; Rogers, 1972),

$$r_i = n_i\{1 - \exp[-a_i(1 - \sum_{j=1} r_j T_{hj})]\}, \tag{2}$$

Chesson (1983) obtained,

$$\alpha_i = \frac{a_i}{\sum_{j=1}^{m} a_j}, \; i=1, \ldots, m. \tag{3}$$

where a_i are the respective searching efficiencies and T_{hj} are the respective handling times. Thus, provided values of a_i, remain constant, α will not change.

Values of α_i were computed using Equation (1) and compared with values obtained from Equation (3). Deviations from 0.5 (no preference) were computed using the method described by Manly et al., (1974). The relationship between α_i values and the proportion of prey *i* available in the environment was also analyzed.

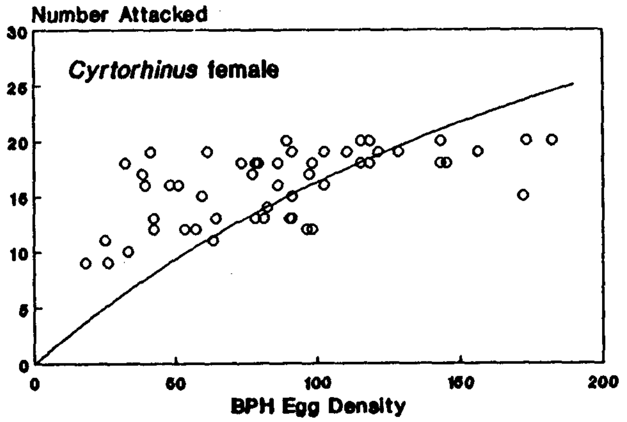
RESULTS

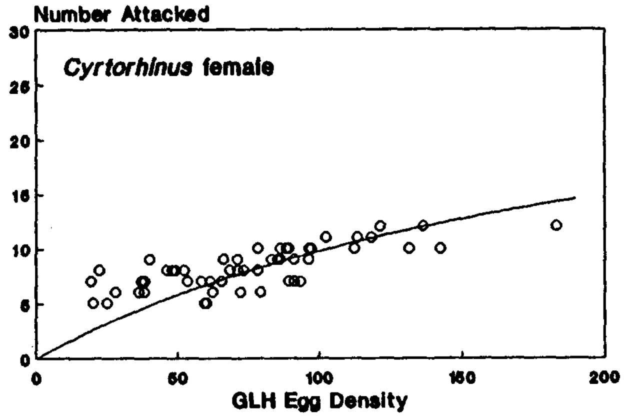
The functional responses for both BPH and GLH eggs by *C. lividipennis* showed Holling's Type II (Fig. 1). Judging from the CV, F and R^2 values for the estimates of *a* and *Th* by equation (2), the data for both prey species fitted the predator model satisfactorily (Table 1). When the male predator was exposed to GLH eggs, a negative T_h using the predator equation was produced. The estimates in all other cases were acceptable. Since hopper eggs are completely destroyed after attack, we can assume that they are not available for search. In such cases, *C. lividipennis* may be regarded as a true predator and prey depletion is thus important.

Preference for BPH eggs, α_B was obtained using Equations (1) and (3) and the results presented in Table 2. In the latter, *a* values obtained from the random predator equation (Table 1) were applied to Eq. (3). The α_B value for male *C. lividipennis* obtained using *a* values (Eq. 3) was similar to that obtained using Manly's method (Eq. 1), while for the female, the difference was substantial. Even using the extremes in the S.E.s of the *a* values, α_B of 0.709 was still lower than that estimated using Manly's index. For both male and female *C. lividipennis*, preference for BPH was significant since the α values deviated from 0.5.

Table 1. Parameter estimates of the functional response equation for *Cyrtorhinus lividipennis* feeding on eggs of the brown planthopper and green leafhopper.

Eggs	Parameter estimates		Asymptotic S.E.s	CV (%)	F	R^2 (%)
Female						
Brown planthopper	a T_h	0.247 0.017	0.067 0.010	35.9	192	88.0
Green leafhopper	a T_h	0.153 0.033	0.022 0.010	28.0	337	92.8
Male						
Brown planthopper	a T_h	0.061 0.037	0.009 0.022	27.6	348	93.0
Green leafhopper	a T_h	0.023 −0.126	0.006 0.101	32.6	265	91.0





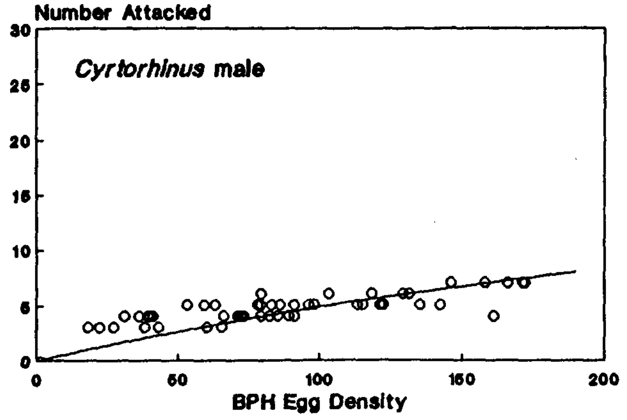


Fig. 1. The functional response of *Cyrtorhinus lividipennis* feeding on eggs of BPH and GLH. The solid curves and the expected responses of the random predator equation obtained by an iterative method using estimates from Table 1.

Table 2. Analysis of preference of *Cyrtorhinus lividipennis* feeding on BPH and GLH eggs.

	Preference for BPH, α_B ($\bar{x} \pm$S.E.)	
	estimated using a values (Eq (3))	estimated using Manly's index (Eq (1))
Male	0.726	$0.718^* \pm 0.061 n=53$
Female	0.618	$0.722^* \pm 0.037 n=53$

* α_B significantly different from 0.5, $p<0.05$.

Both the α_B values increased as the relative density of BPH increased. However the regression for the female *C. lividipennis* was not significant ($F=0.06$, d.f. 1, 52, $p=0.8$) while for the male, just marginally significant at $p=0.05$ ($F=4.33$, d.f. 1, 52, $p=0.042$). There is thus insufficient evidence to conclude that *C. lividipennis* displayed any switching behavior.

Discussion

Searching efficiencies of *C. lividipennis* for both BPH and GLH eggs approximated that of Holling's (1959) Type II functional response. The females showed significantly higher attack rates than in the males for both prey. Sivapragasam and Asma (1985) found that the a and T_h values for both sexes did not differ. Their estimates of a were also higher. This may be due to the small arena (7.5 cm × 2.5 cm diam.) used in their experiments. In our set-up, we tried to emulate as closely as possible the natural environment of the predator using a large cylindrical cage with a total space of 66.4 cm^2. However the arena remains artificial as it still limits the predator's free movement. Nevertheless, it is perhaps a better estimate of the predator's searching in the field when a more realistic arena is used. In its lifetime (14.4 days) a female consumes about 124 BPH eggs as compared to only 44 in the male (9.6 days) (Chua and Mikil, 1989). This accounts for the large differences in searching parameters between the male and female.

In the mixed environment of BPH and GLH eggs, *C. lividipennis* clearly preferred BPH eggs. Switching was not evident. The attack rates were able to account for the preference shown. Murdoch (1973) defined preference as the ratio of the searching efficiencies for 2 prey (a_1/a_2), when prey is being replaced. However, when prey is not replaced, the preference index is more complex and dependent on a and T_h values (Lawton et al., 1974; Cock, 1978). Thus, a recipe which requires estimating the functional response parameters independently to predict preference and carrying out preference experiments was proposed and used (Cock, 1978; Hassell, 1978; Southwood, 1978; Heong, 1981). Chesson (1983) showed that the Manly's index for both cases, when prey is being replaced and when prey is not being replaced, remains the same. She further argued that the index has other advantages. It can be interpreted as a relative contribution of each prey to the diet of the predator if every prey is equally abundant. While other indices vary with total prey densities, the Manly's index do not and thus can be used to detect bahavioural changes such as switching. In addition, values of α obtained in one experiment can be used to predict expected values of preference for other prey combinations.

The *C. lividipennis* shows high positive numerical response to hopper density in tropical rice (Kuno and Dyck, 1984). This implies that the mirid egg predator plays an important role in hopper population dynamics. Clearly, the availability of food determines this response, which is both behavioural and reproductive in nature. Since the rice ecosystem is predominantly inhabited by hemipteran phytophagous species, a polyphagous egg predator, like *C. lividipennis*, has a clear advantage. Although it prefers BPH eggs, it can easily survive on other less preferred food when BPH is scarce. Thus, *C. lividipennis* is an important asset to the natural control of hopper pests, particularly BPH.

SUMMARY

The functional response of *Cyrtorhinus lividipennis* feeding on brown planthopper (BPH) and green leafhopper (GLH) eggs was found to be Holling's Type II. The Random Predator Equation fitted the data satisfactorily. Using Manly's preference index, α, both the male and female *C. lividipennis* were found to prefer BPH eggs. There was, however, no evidence of switching and the ratio of the respective searching efficiencies could account for the preference.

ACKNOWLEDGEMENTS: We wish to thank all the technical staff in the Entomology Department at IRRI who have assisted in conducting the experiments, particularly, Mr. Ruperto Basilio for supplying the working insects, and Ms. Ellen Genil, who patiently typed the manuscript.

REFERENCES

Bae, S. H. and M. D. PATHAK. (1966) A mirid bug, *Cyrtorhinus lividipennis* Reuter, predator of the eggs and nymphs of the brown planthopper. *Int. Rice Comm. Newsl.* **15**(3): 33–36.

Chesson, J. (1978) Measuring preference in selective predation. *Ecology* **59**: 211–215.

Chesson, J. (1983) The estimation and analysis of preference and its relationship to foraging models. *Ecology* **64**: 1297–1304.

Chua, T. H. and E. Mikil. (1989) Effects of prey number and stage on the biology of *Cyrtorhinus lividipennis* (Hemiptera: Miridae): A predator of *Nilaparvata lugens* (Homoptera: Delphacidae). *Environ. Entomol.* **18**: 251–255.

Cock, M. J. W. (1977) Searching behaviour of polyphagous predators. Unpubl. Ph.D. thesis, Imperial College, London.

Cock, M. J. W. (1978) The assessment of preference. *J. Anim. Ecol.* **47**: 805–816.

Hassell, M. P. (1978) *Dynamics of Arthropod Predator-Prey Systems*. Princeton Univ. Press, Princeton, New Jersey.

Heong, K. L. (1981) Searching preference of the parasitoid, *Anisopteromalus calandrae* (Howard) for different stages of the host, *Callosobruchus maculatus* (F.) in the laboratory. *Res. Popul. Ecol.* **23:** 177–191.

Heinrichs, E. A., F. G. Medrano, and H. R. Rapusas. (1985) Genetic evaluation for insect in rice. Int. Rice Res. Inst., Los Banos, Philippines.

Hinckley, A. D. (1963) Ecology and control of rice planthoppers in Fiji. *Bull. Entomol. Res.* **54:** 467–481.

Hinckley, A. D. (1965) Pest of rice in Fiji. *Agric. Sci.* **1:** 18–21.

Holling, C. S. (1966) The functional response of invertebrate to prey density. *Memoirs Ent. Soc. Can.* **48:** 1–87.

Holling, C. S. (1959) Some characteristics of simple types of predation and parasitism. *Can. Ent.* **91:** 385–398.

International Rice Research Institute (IRRI) (1981) Annual report for 1980. Los Banos, Philippines.

Juliano, S. A. and F. M. Williams (1987) A comparison of methods for estimating the functional response parameters of the random predators equation. *J. Anim. Ecol.* **56:** 641–653.

Kuno, E. and Dyck, V. A. (1984) Dynamics of Philippine and Japanese populations of the brown planthopper: Comparison of basic characteristics. 1–9. In: Proceedings: ROC-Japan Seminar on the Ecology and the Control of the Brown Planthopper, National Science Council, Rep. of China.

Lawton, J. H., J. R. Beddington and R. Bonser (1974) Switching in invertebrate predation. 141–158. *In* M. B. Ushler and M. H. Williamson (ed) *Ecological Stability*. Chapman and Hall, Ltd.

Manly, B. F. J., P. Miller, and L. M. Cook (1972) Analysis of a selective predation experiment. *Am. Nat.* **106:** 719–736.

Manly, B. F. J. (1974) A model for certain types of selection experiments. *Biometrics* **30:** 281–294.

Manti, I. (1989) The role of *Cyrtorhinus lividipennis* Reuter (Hemiptera: Miridae) as a major predator of the brown planthopper *Nilaparvata lugens* Sta. (Homoptera: Delphacidae). Unpubl. Ph.D. thesis, Univ. of the Philippines at Los Banos, Philippines.

Murdoch, W. W. (1969) Switching in general predators. *Ecol. Monogr.* **39:** 335–354.

Murdoch, W. W. (1973) The functional response of predators. *J. Appl. Ecol.* **10:** 335–342.

Reyes, T. M. and B. P. Gabriel (1975) The life history and consumption habit of *Cyrtorhinus lividipennis* Reuter (Hemiptera: Miridae). *Philipp. Entomol.* 3(2): 79–88.

Rogers, D. J. (1972) Random search and insect population models. *J. Anim. Ecol.* **41:** 360–383.

Royama, T. (1971) A comparative study models for predation and parasitism. *Res. Popul. Ecol. Suppl.* **1:** 1–91.

Sivapragasam, A. and A. Asma (1985) Development and reproduction of the mirid bug, *Cyrtorhinus lividipennis* Reuter (Heteroptera: Miridae) and its functional response to the brown planthopper. *Appl. Ent. Zool.* **20:** 373–379.

Statistical Analysis Systems (SAS) (1985) SAS User's Guide. Statistics ver. 5 Edition. SAS Institute, Inc., Cary, N.C., USA.

Southwood, T. R. E. (1978) *Ecological Methods with Particular Reference to the Study of Insect Populations.* Chapman and Hall, London.

Cyrtorhinus lividipennis のタイワンツマグロヨコバイとトビイロウンカの卵に対する捕食

K. L. Heong・Saad Bleih・Amor A. Lazaro

C. lividipennis のトビイロウンカとタイワンツマグロヨコバイの卵に対する機能の反応は，Type II を示した．データには，捕食者のランダム捕食式 (The Random Predator Equation) がよくあてはまった．Manly の選好指数を用いてデータを分析したところ，*C. lividipennis* は，タイワンツマグロヨコバイの卵よりはトビイロウンカの卵を選好していた．卵の密度が高まっても，switching は起こらなかった．