THE FUNCTIONAL RESPONSE AND PREDATORY ABILITY OF THE REDUVIID *CORANUS FUSCIPENNIS* REUTER (HETEROPTERA: REDUVIIDAE) FED ON THE RICE MEAL MOTH *CORCYRA CEPHALONICA* (STAINTON)

Truong Xuan Lam¹², Nguyen Thi Phuong Lien¹², Nguyen Quang Cuong¹

¹Institute of Ecology and Biological Resources (IEBR), Vietnam Academy of Science and Technology
²Graduate University of Science and Technology (GUST), Vietnam Academy of Science and Technology

To whom correspondence should be addressed. E-mail: txlam.iebr@gmail.com

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SUMMARY

The reduviid *Coranus fuscipennis* Reuter (Heteroptera: Reduviidae) is an important predator for biological control the pests of vegetables in Vietnam. The functional response of the 2nd, 3rd, 4th, 5th nymphal instars and adult male and female of the predator *C. fuscipennis* to the larvae of rice meal moth *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) was evaluated in laboratory conditions (temperature 30±2ºC; relative humidity 75±5%; and 14:10 h Light:Dark). The results show that the nymph and adult of *C. fuscipennis* responded to different densities of prey. They killed more number of prey at higher prey densities and less prey at lower prey densities that produced a curve linear type II functional response (Holling 1959). The maximum consumption was always found restricted when rearing the *C. fuscipennis* at high prey densities. The relationship between the predation rate of the *C. fuscipennis* and the prey densities was negative correlation (R is between 0.70 and 0.98), but between the number prey killed and the prey density is positive correlation. The searching time prey of the *C. fuscipennis* decreased when the prey densities increased that was confirmed by the negative correlation (R between 0.85 and 0.98). The reduviid *C. fuscipennis* bred by the *C. cephalonica* in laboratory and they can use for biological control some pests of vegetables (*P. rapae*, *S. litura* and *P. xylostella*) in Vietnam.

Keywords: *Coranus fuscipennis*, predation, prey, density, function response.

INTRODUCTION

The functional response of a predator is one of the important key factors regulating population dynamics of predator and prey systems which describes the relationship between the consumption rate of an individual predator and prey density, and the variation in the number of prey consumed per unit time in relation to prey density (Mandour *et al.* 2006). The functional responsive curves can be used to infer basic mechanisms related to predator and prey, enhancing biological control (Houc & Strauss 1985). When the number of predators per unit time is plotted against the number of prey available per predator, any one of the following types of functional responses can occur: i) an increasing linear relationship (type I), ii) a decelerating curve relationship (type II) and iii) sigmoidal relationship (type III), and the functional response of most beneficial arthropods is either type II or type III (Holling, 1959, Luck, 1985).
The cabbage white *Pieris rapae* (Linnaeus) (Lepidoptera: Pieridae), leafworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) and diamond back moth *Plutella xyllostella* (Linnaeus) (Lepidoptera: Plutellidae) are key pests and very dangerous to all cruciferous vegetable crops. These pests species are very difficult to control in the field because of genetic resistance to insecticides (Singh, Jalali, 1997; Liu et al., 2002). The rice meal moth *Corcyra cephalonica* Stanton (Lepidoptera: Pyralidae) is one of the most dangerous pests of stored rice and corn (Ambrose, 2002). The reduviids are polyphagous predators of many pests and very dangerous to all cruciferous vegetable crops. These pests species are mass reared in laboratory to produce moth egg parasite *Trichogramma* spp. for biological control pest in Vietnam (Con, Chau 2001).

Therefore, this study was conducted to understand the functional response of nymphal instars and adult male and female of the reduviid *Coranus fuscipennis* Reuter in plastic containers (height =25, diameter =20 cm) to collect eggs. The eggs of *C. fuscipennis* were placed separately in plastic containers (height=15 cm, diameter=10 cm). The nymphs hatched from eggs were reared separately in plastic containers (height=20 cm, diameter=15 cm) using prey sources (*C. cephalonica*). The adults of *C. fuscipennis* (developed from 5th nymphal instar) were reared in plastic containers (height=25, diameter =20 cm) also by the prey sources, after 24h adults were separated and sexed according to the size and genitals (male smaller than female in size). In each plastic containers the wet cotton swabs were changed periodically in order to prevent fungal growth, and 10% honey solution was also provided every day.

The 2nd, 3rd, 4th, 5th nymphal instars of the *C. fuscipennis* starved for 2h, and the female and male adult starved for 24h before being used. The prey *C. cephalonica* were introduced to in plastic containers (height =25, diameter =20 cm). After 15 minutes, each stages of the predator *C. fuscipennis* was introduced to in plastic containers at prey densities 2, 4, 6, 8, 10 and 12 individuals. The number of prey in plastic containers is always constant by replacing the dead prey individuals with the live ones. The observation time for the 2nd, 3rd nymphal instars of *C. fuscipennis* were 5 days, for the 4th, 5th nymphal instars, female adult and male adult were 6 days. Six replicates were maintained for each prey density. All killed and consumed preys were recorded at 24h intervals.

The study on predatory ability of instars and adult of the predator *C. fuscipennis* fed by the *C. cephalonica* was carried out in plastic containers (height= 30, diameter = 20 cm). The preys (*P. rapae, S. litura and P. xyllostella*) was introduced to cabbage plants in broad plastic cages (25 cm wide, 30 cm long, 35 cm high), and these species are maintained on cabbage plants in the experimental period. The 2nd, 3rd, 4th, 5th nymphal instar of the *C.

**MATERIALS AND METHODS**

**Materials maintenance**

The adults (female and male) of *C. fuscipennis* were collected from Ea Kar District, Dak Lak Province (altitude: 450±7.85 m; latitude: 108°31’ E and 12°46’ N), Central Highlands of Vietnam. In the laboratory conditions (temperature 30±2°C; relative humidity 75±5%; and 14:10 h Light:Dark) they were reared by prey (rice meal moth larvae *C. cephalonica*) in plastic containers (height =25, diameter =20 cm) to collect eggs. The eggs of *C. fuscipennis* were placed separately in plastic containers (height=15 cm, diameter=10 cm). The nymphs hatched from eggs were reared separately in plastic containers (height=20 cm, diameter=15 cm) using prey sources (*C. cephalonica*). The adults of *C. fuscipennis* (developed from 5th nymphal instar) were reared in plastic containers (height=25, diameter =20 cm) also by the prey sources, after 24h adults were separated and sexed according to the size and genitals (male smaller than female in size). In each plastic containers the wet cotton swabs were changed periodically in order to prevent fungal growth, and 10% honey solution was also provided every day.

The 2nd, 3rd, 4th, 5th nymphal instars of the *C. fuscipennis* starved for 2h, and the female and male adult starved for 24h before being used. The prey *C. cephalonica* were introduced to in plastic containers (height =25, diameter =20 cm). After 15 minutes, each stages of the predator *C. fuscipennis* was introduced to in plastic containers at prey densities 2, 4, 6, 8, 10 and 12 individuals. The number of prey in plastic containers is always constant by replacing the dead prey individuals with the live ones. The observation time for the 2nd, 3rd nymphal instars of *C. fuscipennis* were 5 days, for the 4th, 5th nymphal instars, female adult and male adult were 6 days. Six replicates were maintained for each prey density. All killed and consumed preys were recorded at 24h intervals.

The study on predatory ability of instars and adult of the predator *C. fuscipennis* fed by the *C. cephalonica* was carried out in plastic containers (height= 30, diameter = 20 cm). The preys (*P. rapae, S. litura and P. xyllostella*) was introduced to cabbage plants in broad plastic cages (25 cm wide, 30 cm long, 35 cm high), and these species are maintained on cabbage plants in the experimental period. The 2nd, 3rd, 4th, 5th nymphal instar of the *C.
fusciennis starved for 2h, the female and male adult starved for 24h before being used. All killed and consumed preys were recorded at 24h intervals, the number of preys is always constant by replacing the dead prey individuals with the live ones. Three repetitions were maintained for each experiment. The body weight of the 2nd, 3rd, 4th, 5th nymphal instars, male and female adults were measured individually by the CP-Sartorius ED 224S analytical balance with a precision of 0.1 mg.

**Data analyses**

The linear model II equation of Holling (1959) was used for to find out the functional response of the predator to different prey density following parameters: Y = a T, x (1).

Where : x = prey density; Y = total number of prey killed in given period of time (T); T = time spent by the predator in searching prey; a = rate of discovery per unit of searching time [b y=T]. If we presume that each prey requires a constant amount of time ‘b’ for consumption then T = T1 - by (2). Where: T1 = total time in days when prey was exposed to the predator; b = time spent handling each prey by the predator (T1/k), k = the maximum prey consumption. The parameters (b), (k), and (a) were directly measured in the present study. The handling time (b) was estimated as the time spent for pursuing, subduing, feeding and digesting each prey. The maximum prey consumption was represented by the k value. Substituting 2 in 1: Y = a (T1 - by) x.

The regression analysis was made to determine the relationship between the prey density and the number of prey consumed, searching time, attack ratio, handling and recovery time (Daniel, 1987). All statistical analyses were carried out at 1% level of significance (P< 0.01)

**RESULTS AND DISCUSSION**

The maximum prey consumption (k value) was always found restricted at high prey density (k=1.36, 2.13, 3.21, 4.35, 3.45 and 5.02 for the 2nd, 3rd, 4th, 5th nymphal instars, male and female adult of predator C. fusciennis to larvae C. cephalonica, respectively). This was confirmed by the relationship between the prey density and the prey killed which is positive correlation (y= 0.547 + 0.071x, R= 0.970; y= 0.517 + 0.147x, R= 0.979; y= 0.950 + 0.209x, R= 0.920; y= 1.369 + 0.280x, R= 0.882; y= 1.401 + 0.193x, R= 0.857 and y= 2.166 + 0.258x, R= 0.864 for the 2nd, 3rd, 4th, 5th nymphal instars, adult males and females of predator C. fusciennis to C. cephalonica larvae, respectively). However, the relationship between the predation rate and the prey density is negative correlation (y= 30.610 - 1.815x, R= -0.93; y= 36.019 -1.598x, R= -0.94; y= 54.429 - 2.326x, R= -0.92; y= 73.241 - 2.964x, R= -0.77; y= 108.690 - 5.988x, R= -0.77 and y= 70.120 -3.555x, R= -0.92 for the 2nd, 3rd, 4th, 5th nymphal instars, adult males and females of predator C. fusciennis to C. cephalonica larvae, respectively) (Figs1, 2). The female predators were more vigorous in responding to the increasing prey density. This result is similar to the result of Ambrose et al. (2009), Manimuthu et al. (2011) and Jesu et al. (2011). The relationship between the predation rate of each stage of the predator C. fusciennis and prey densities was negative correlation which indicates the increase in prey consumption at high prey densities might be due to the probability of contacts between the predators and preys increased which makes the number of prey surviving at low prey density always higher than at high prey densities. This results was similar to the observations of Propp (1982), Claver, Ambrose (2002), Ravichandran, Ambrose (2006), Manimuthu et al. (2011), Jesu et al. (2011).

The negative correlations were obtained between the searching time prey of the predator C. fusciennis and all prey densities \(y = 2.285 - 0.205x, R^2 = 0.961; y = 3.047 - 0.276x, R^2 = 0.982; y = 4.099 - 0.390x, R^2 = 0.908; y = 4.109 - 0.386x, R^2 = 0.982; y = 3.561 - 0.335x, R^2 = 0.857 and y = 3.396 - 0.390x, R^2 = 0.862 for the 2nd, 3rd, 4th, 5th nymphal instars, adult males and
females of predator *C. fuscipennis* to *C. cephalonica* larvae, respectively).

This was also shows that the searching time prey of the 2nd, 3rd, 4th, 5th nymphal instars decreased from 2.94 to 1.38, and the attack rate of prey increased from 0.18 to 0.52. The adult females of predator *C. fuscipennis* searching time prey was shortest (b = 1.20), and attack rate of prey was highest (0.67). The handling time prey was depended on the size of the prey because the predator take a longer time to eat larger prey, so the successful attacks were more frequent on small prey and also reduced the risk of injury to the predator. This results was similar to studies on heteropteran predators as *Reduviolus americanaferous* Carayon (Flinn et al. 1985), *Sinea confusa* Caudell (Cohen 2000), *Canthecona furcellata* (Wolff) (Cogni et al. 2003), *Zelus renardii* Kolenati and *A. pedestr*is (Jesu et al., 2011).

The body weight of the nymphal instars, adult males and females of the reduviid *C. fuscipennis* fed on the larvae of *C. cephalonica* shown in table 1. The results showed that the body weights from 1st nymphal instar to 5th nymphal instar increased from 12.16 mg to 103.46 mg and the body weight of adult female was biggest.

![Figure 1](image_url). Functional response of predator *Coranus fuscipennis* Reuter to *Corcyra cephalonica* (Stainton) in the plastic containers. Points show mean number of prey eaten or killed by *C. fuscipennis* at different prey densities. The curves line shows the Hollings model for a type II functional response (Holling 1959). Error bars show standard errors.
Figure 2. The predation rate of predator Coranus fuscipennis Reuter to Corcyra cephalonica (Stainton) in the plastic containers. Points show the predation rate (%) of by C. fuscipennis Reuter at at different prey densities. Error bars show standard errors.

The predatory ability of the reduviid C. fuscipennis rearing on the rice meal moth C. cephalonica to some pests of vegetables (P. rapae, S. litura and P. xylostella) was recorded in table 2. The data shows that the 1st nymphal instar did not consume the pests. The 2nd, 3rd, 4th, 5th nymphal instars and adult consumed the larvae P. xylostella more than the P. rapae and S. litura. The number of pests (P. rapae, S. litura and P. xylostella) were consumed by female adult more than male adult. The number of larvae P. xylostella killed by female adult was highest. The number of P. rapae, S. litura and P. xylostella were killed by 5th nymphal instars more than the 2nd, 3rd and 4th nymphal instars. The body weight of the 1st, 2nd, 3rd, 4th, 5th nymphal instars, male and female adults of the reduviid C. fuscipennis reared by the larvae of C. cephalonica were smaller than the reduviid S. dichotomus with the prey the larvae of C. cephalonica, of the reduviid S. collaris with the prey larvae C. cephalonica and S. litura (Siti, Norman 2016, Rajanet al. 2017).
Table 1. Body weight (mean ± SD) of Coranus fuscipennis Reuter fed on the larvae of Corcyra cephalonica (Stainton). Temperature: 30±2ºC, relative humidity: 75±5% and Light:Dark 14:10 h.

| Development stages | Body weight (mg) |
|--------------------|------------------|
| 1\textsuperscript{st} nymphal instar (n=72) | 12.16 ± 1.85 |
| 2\textsuperscript{nd} nymphal instar (n=72) | 17.57 ± 3.14 |
| 3\textsuperscript{rd} nymphal instar (n=72) | 26.28 ± 4.81 |
| 4\textsuperscript{th} nymphal instar (n=62) | 55.23 ± 10.75 |
| 5\textsuperscript{th} nymphal instar (n=62) | 103.46 ± 21.88 |
| Adult male (n=48) | 144.39 ± 30.53 |
| Adult female (n=48) | 160.04 ± 33.84 |

Table 2. The number (mean ± SD) of Spodoptera litura Fabricius, Pieris rapae (Linnaeus) and Plutella xylostella (Linnaeus) were killed by the predator Coranus fuscipennis Reuter. Temperature: 30±2ºC, relative humidity: 75±5% and Light:Dark 14:10 h.

| Development stages | The pests of vegetables killed (larvae/24h) |
|--------------------|-------------------------------------------|
| S. litura          | P. rapae                                  | P. xylostella |
| 1\textsuperscript{st} nymphal instar | -                                         | -             |
| 2\textsuperscript{nd} nymphal instar | 0.85 ± 0.18 a                             | 1.08 ± 0.28 ab | 1.98 ± 0.80 b |
| 3\textsuperscript{rd} nymphal instar | 1.25 ± 0.35 a                             | 1.90 ± 0.64 b | 2.28 ± 1.10 c |
| 4\textsuperscript{th} nymphal instar | 1.64 ± 0.35 a                             | 2.56 ± 0.72 b | 3.46 ± 1.26 c |
| 5\textsuperscript{th} nymphal instar | 2.31 ± 0.67 a                             | 2.81 ± 0.81 ab | 4.62 ± 1.50 b |
| Male adult         | 2.06 ± 0.56 a                             | 2.65 ± 0.61 ab | 3.91 ± 1.26 b |
| Female adult       | 2.69 ± 0.56 a                             | 3.21 ± 0.67 b | 5.42 ± 2.19 c |

Means followed by the same letter in row are not significantly different based on a one-way ANOVA (P<0.01)

CONCLUSION

The nymph and adult of C. fuscipennis killed more prey (the larvae of C. cephalonica) at higher prey densities and less prey at lower prey densities that produced a curve linear type II functional response (Holling 1959). The relationship between the predation rate of the C. fuscipennis and the prey densities was negative correlation (R= 0.70 - 0.98), and between the prey density and the prey killed is positive correlation. The body weights from 1\textsuperscript{st} nymphal instar to 5\textsuperscript{th} nymphal instar of C. fuscipennis fed on the larvae of C. cephalonica increased (12.16 - 103.46 mg). The number of the pests of vegetables (P. rapae, S. litura and P. xylostella) were killed by 5\textsuperscript{th} nymphal instars of C. fuscipennis more than the 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} nymphal instars.

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PHÂN ỨNG CHỨC NĂNG VÀ KHÁ NĂNG ĂN MƠI CỦA LOÀI BỘ XỊT BẤT MỚI Coranus fuscipennis Reuter (HETEROPTERA: REDUVIIDAE) ĐỐI VỚI LOÀI NGÀI GẠO Corcyra cephalonica (Stainton)

Trương Xuân Lâm1,2, Nguyễn Thị Phương Liên1,2, Nguyễn Quang Cuong1

1Viện Sinh thái và Tài nguyên sinh vật, Viện Hàn làm Khoa học và Công nghệ Việt Nam
2Học viện Khoa học và Công nghệ, Viện Hàn làm Khoa học và Công nghệ Việt Nam

TÓM TẮT

Loài bọ xít Coranus fuscipennis Reuter (Heteroptera: Reduviidae) là một loài bất mới quan trọng trên sinh quan rau ở Việt Nam. Phân Ứng chức năng của các thiếu trứng tuổi 2, 3, 4, 5 và trưởng thành của loài bất mới C. fuscipennis đối với ưu trưng nguyên giao Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae) được xác định trong điều kiện phòng thí nghiệm (niên độ 30±2°C; độ ẩm 75±5%; và 14:10 h sáng: tối). Kết quả cho thấy, các thiếu trứng và con trưởng thành đực và cái của loài bất mới C. fuscipennis có phân ứng với các mạt độ con mới khác nhau và giữ nét mức con ở mật độ con mới cao. Phân ứng chức năng này thể hiện phân ứng chức năng loại II (Holling, 1959). Mức tiêu thụ con mới cao nhất luôn bị giới hạn khi nuôi loài bất mới C. fuscipennis. Mời quan hệ giữa khả năng ăn mới của thiếu trứng tuổi 2, 3, 4 và 5, trưởng thành cái và đực của loài bọ xít bất mới C. fuscipennis với các mật độ con mới khác nhau luôn thể hiện là mối tương quan nghịch (R= 0,70- 0,98), trong khi mối quan hệ giữa mật độ con mới với số lượng con mới bị giết bởi bọ xít bất mới C. fuscipennis thể hiện mối tương quan thuận. Khi mật độ con mới tăng lên, thời gian tìm kiếm con mới của các thiếu trứng và trưởng thành của loài bất mới C. fuscipennis giảm theo hình mối tương quan nghịch (R=0,85-0,98). Loài bọ xít bất mới C. fuscipennis được nuôi bởi nguyên giao C. cephalonica có khả năng tiêu thụ tốt các loài gây hại trên rau như sâu xanh buồn trắng P. rapae, sâu khoang S. litura và sâu tỏ P. xylostella và có thể sử dụng bọ xít bất mới C. fuscipennis được nuôi bởi nguyên giao C. cephalonica để kiểm soát sâu hại trên rau ở Việt Nam.

Từ khóa: Bọ xít bất mới, con mới, mật độ, phân ứng chức năng, Coranus fuscipennis.