CHAPTER V

EVALUATION OF BIOCONTROL POTENTIAL OF RHYNOCORIS FUSCIPES (FABRICIUS) AND EUAGORAS PLAGIATUS (BURMEISTER) BY FUNCTIONAL RESPONSE
Biological control by predators such as assassin bugs helps in the regulation of insect pest population in Integrated Pest Management (IPM). Biological control refers to the regulatory action of parasites, predators or pathogens to maintain the density of an organism (pest) at a lower level than would occur without these natural enemies (Andres et al., 1979). Pest management employs the strategy of maximising natural control forces, i.e., natural enemies and plant resistance and utilising any other tactics with a minimum of ecological disturbance. Hence more impetus is given to biological control of insect pests using predators, parasitoids and insect pathogens along with other methods of control. The possibilities of conserving and augmenting natural biological control agents to control insect pests have been considered by many workers (Ridgway et al., 1977; Arbogast, 1983; Van Driesche and Bellows, 1996). The goal of biological control by augmenting should be suppression of pest and its damage to acceptable levels (King et al., 1989).

Reduviids are exclusively predatory mostly on insect pests (Ambrose, 1988, 1991, 1995, 1999). Evidences of the ability of reduviids as effective generalized predators in several agroecosystems is well documented (Werner and Butler, 1957; Whitcomb and Bell, 1964; Altieri and Whitcomb, 1980; McPherson et al., 1982; Cohen, 1990; James, 1994b; Ambrose, 1995). Reduviids have good searching ability, a high degree of host specificity, higher reproductive capacity and are amenable to mass culture in the laboratory (Rabb et al., 1976; Ambrose, 1996; Ambrose et al.,
1996). They individually require more food and consume larger amounts than other predators (Balduf, 1950; Evans, 1962; Schaefer, 1988; Ambrose and Kumaraswami, 1990; Ambrose and Claver, 1995 a). They attack a greater number of prey at higher prey density than at a lower prey density (McMahan, 1982, 1983; Ambrose, 1995). Since they are specific, safer to nontarget species, beneficial insects, higher animals and man and has the least effect on the ecosystem, they have been used as highly successful group of biocontrol agents in Insect Pest Management.

Generally, the predator exhibits two types of responses to suppress the increasing prey population. When an individual predator attacks a greater number of prey at a higher prey density than it can do at a lower prey density, the response of the predator is called functional response. Sometimes, when the prey population increases, the predator also increases its own population instead of attacking more prey, this response is called numerical response (Solomon, 1949). The functional response probably affects the numerical response of invertebrate predators, which in turn influences the death rate of prey and the potential ability of the predator to suppress and stabilize prey population (Huffaker et al., 1971; Takafuji and Chant, 1976). The functional response and numerical response of predators (Solomon, 1949) were subsequently elucidated by Holling (1959, 1961, 1965 and 1966). A thorough knowledge about the functional response is needed for proper modelling of prey-predator interaction (Huffaker et al., 1971).

Several factors, both internal and external to the predator, such as, predator age (Morris, 1963; Holling, 1966; Mukherjii and Le Roux, 1969; Eveleigh and Chant, 1981a and b; Propp, 1982; Sahayaraj, 1991 and Kumaraswami 1991); predator

The functional response of reduviids already reported include *Sycanus indagator* Stål (Bass and Shepard, 1974); *Zelus renardii* Kolenati (Ables, 1978); pentatomid *Podisus maculiventris* (Say) (Le Cato and Arbogast, 1979); *Alloeocranum biannulipes* Montr. and Sign (Awadallah et al., 1984); *Rhynocoris marginatus* Fabricius (Ambrose and Kumaraswami, 1990); *Rhynocoris kumarii* Ambrose and Livingstone and *Rhynocoris fuscipes* Fabricius (Kumaraswami, 1991); *Ectomocoris tibialis* Distant, *Acanthaspis pedestris* Stål, *Neohaemattorrhophus therasii* Ambrose and Livingstone (Sahayaraj and Ambrose, 1991, 1994 b and 1996 a, b); *Rhynocoris longifrons* Stål and *Coranus obscurus* Kirby (Kumar and Ambrose, 1996); *Acanthaspis siva* Distant, *R. kumarii* and *R. marginatus* (Ambrose et al., 1994 and 1997); *R. marginatus* (Ambrose et al., 1996, 2000); *Canthecona furcellata* Wolff *Alcmena spinifex* Thunberg (Das, 1996); *R. fuscipes* (Claver and Ambrose 2002); *R. longiforns* (Ravichandran et al., 2003); *Coranus spiniscutis* Reuter (Claver et al., 2004).

*R. fuscipes* and *Euagoras plagiatus* (Burmeister), the entomosuccivorus, polyphagous crepuscular, assassin bugs are excellant predators predominatly found

However there is no report available on the predatory behaviour and functional response of *R. fuscipes* and *E. plagiatus* to *Pterophorus lienigianus* (Z.) a pest of *Solanum melangena* Linn. (brinjal). Hence an attempt was made to study the prey consumption in relation to prey density (functional response) of *R. fuscipes* and *E. plagiatus* on *P. lienigianus*, the pest of *S. melongena* to understand the basic mechanism underlying the prey-predator interactions and to evolve strategies for mass rearing (to conserve, augment and to employ these predators in biocontrol programme) and subsequent large scale release of this predator in the *S. melongena* agroecosystem to manage insect pests.

5.1. MATERIALS AND METHODS

The laboratory raised adult females of *R. fuscipes* and *E. plagiatus* starved for 24 hours were used in this experiment. The functional response experiments were performed in the infested brinjal agroecosystem at Thittuvilai village (7km Northeast of Nagercoil). In field trials on functional response, one female predator of each species was allowed on the branches of infested brinjal and covered over
by synthetic net material. The prey was also within the net cover. The branches were selected in such a way that the particular portion of the branch had 1, 2, 4, 8 or 16 rolled leaves containing an equivalent number of caterpillars of *P. lienigianus*, the pests. The rolled leaves were slightly opened, exposing the pest partially enabling the predator to track the prey easily.

Thus, five different categories of experimental setup with five different prey levels were maintained separately for each predator for 6 days. Six replicates were made for each category. After 24 hours the number of prey consumed or killed was monitored and the prey number was maintained constant by using other infested plants throughout the experimental period. “Disc” equation of Holling (1959)

\[ Y' = a(Tt-by)x \]

was used to describe the functional response of both predators to *P. lienigianus*.

Where

\[ x = \text{Prey density} \]
\[ y = \text{Total number of prey killed in given period of time (Tt)} \]
\[ y/x = \text{Attack ratio} \]
\[ Tt = \text{Total time in days when prey was exposed to the predator} \]
\[ b = \text{Time spent in handing each prey by the predator} \]
\[ a = \text{Rate of discovery per unit of searching time (y/x / Ts)} \]

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 predation was represented by ‘K’
value and it was restricted to the higher density. Another parameter ‘a’, the rate of
discovery was defined as the proportion of the prey attacked successfully by the
predator per unit of searching time.

Assuming that the predators efficiency is proportional to the prey density and
to the time spent by the predator in searching prey (Ts) the expression of relationship
is

\[ Y' = a \cdot Ts \cdot x \quad \text{--- (1)} \]

However, the time available for searching is not constant. It is equivalent to
the total time (Tt) minus the time spent for handling the prey (b) for the
consumption, then

\[ Ts = Tt - b \cdot y \quad \text{--- (2)} \]

Substituting (2) in (1), Holling ‘disc’ equation is

\[ Y' = a \cdot (Tt - b) \cdot x \]

Linear regression analysis was made to establish the relationship between the
prey density and the number of prey consumed, the searching time and the attack
ratio (Daniel, 1987).
5.2. RESULT

5.2.1. Number of prey killed:

The number of prey killed gradually increased with increasing prey density from 1 prey/predator to 16 prey/predator. The maximum predation was represented by K value and was restricted to the higher prey density ($K = 9.66 \pm 1.31$ and $7.55 \pm 0.79$ for *R. fuscipes* and *E. plagiaius* respectively). A positive correlation was obtained between the prey density and the prey attacked ($Y = 0.83 + 0.56x; r = 0.99$) for *R. fuscipes* and ($Y = 0.92 + 0.43x; r = 0.99$) for *E. plagiaius* (Table 5.1 & 5.2, Fig. 36 & 37).

5.2.2. Searching time:

The searching time decreased as the prey density increased from 1 to 16. It decreased from 5.38 to 0.01 in *R. fuscipes* and 5.27 to 0.34 for *E. plagiaius*. A negative correlation ($Y = -0.35x + 5.49; r = -0.99; Y = -0.32x + 5.21; r = -0.98$) was obtained for *R. fuscipes* and *E. plagiaius* respectively (Table 5.1 & 5.2, Fig. 36 & 37).

5.2.3. Attack ratio:

The attack ratio decreased as the prey density increased. The highest attack ratio was observed at the density of one prey/predator and the lowest ratio was observed at the density of 16 prey/predator. Like searching time, the attack ratio
Table 5.1: Summary of calculations used in analysing the functional response ($Y'$) for 6 days in *R. fuscipes* (adults) at five different densities of *P. lienigianus* ($n = 6$)

<table>
<thead>
<tr>
<th>Prey density $x$</th>
<th>Prey attacked $y$</th>
<th>Max $y$ ($k$)</th>
<th>Days / $y$</th>
<th>Days all $y$'s (by)</th>
<th>Days searching $Ts = Tt$-by</th>
<th>Attack ratio $y/x$</th>
<th>Rate of Discovery ($y/x$) / $Ts = a$</th>
<th>Disc equation $Y' = a(Tt$-by)$x$</th>
<th>$Y'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00±0.0</td>
<td>9.66±1.31</td>
<td>0.62</td>
<td>0.62</td>
<td>5.38</td>
<td>1</td>
<td>0.19</td>
<td>0.19(5.38)x1</td>
<td>1.02</td>
</tr>
<tr>
<td>2</td>
<td>1.92±0.15</td>
<td></td>
<td></td>
<td>1.19</td>
<td>4.81</td>
<td>0.96</td>
<td>0.20</td>
<td>0.20(4.81)x2</td>
<td>1.92</td>
</tr>
<tr>
<td>4</td>
<td>3.50±0.24</td>
<td></td>
<td></td>
<td>2.17</td>
<td>3.83</td>
<td>0.88</td>
<td>0.23</td>
<td>0.23(3.83)x4</td>
<td>3.52</td>
</tr>
<tr>
<td>8</td>
<td>5.49±0.96</td>
<td></td>
<td></td>
<td>3.40</td>
<td>2.60</td>
<td>0.69</td>
<td>0.27</td>
<td>0.27(2.60)x8</td>
<td>5.62</td>
</tr>
<tr>
<td>16</td>
<td>9.66±1.31</td>
<td></td>
<td></td>
<td>5.99</td>
<td>0.01</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60(0.01)x16</td>
<td>9.60</td>
</tr>
</tbody>
</table>

$x =$ Prey density; $y =$ prey attacked; $k =$ maximum $y$; $b =$ handling time (in days) by = days all $y$'s; $Ts =$ searching time (in days) $y/x =$ attack ratio; $a =$ rate of discovery; $Tt =$ total time (in days) for which prey was exposed to the predator.
Table 5.2: Summary of calculations used in analysing the functional response \( (Y') \) for 6 days in *E. plagiatius* (adults) at five different densities of *P. lienigianus* \( (n = 6) \)

<table>
<thead>
<tr>
<th>Prey density ( x )</th>
<th>Prey attacked ( y )</th>
<th>Max ( y ) ( (k) )</th>
<th>Days / ( y ) ( b = Tt/k )</th>
<th>Days all ( y ) 's (by)</th>
<th>Days searching ( Ts = Tt-by )</th>
<th>Attack ratio ( y/x )</th>
<th>Rate of Discovery ( (y/x) / Ts = a )</th>
<th>Disc equation ( Y' = a (Tt-by)x )</th>
<th>( Y' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.92±0.09</td>
<td>7.55±0.82</td>
<td>0.73</td>
<td>5.27</td>
<td>0.92</td>
<td>0.17</td>
<td>0.17(5.27)x1</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.67±0.17</td>
<td></td>
<td>1.32</td>
<td>4.68</td>
<td>0.84</td>
<td>0.18</td>
<td>0.18(4.68)x2</td>
<td>1.68</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3.05±0.33</td>
<td></td>
<td>2.41</td>
<td>3.59</td>
<td>0.76</td>
<td>0.21</td>
<td>0.21(3.59)x4</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4.75±0.75</td>
<td></td>
<td>3.75</td>
<td>2.25</td>
<td>0.59</td>
<td>0.26</td>
<td>0.26(2.25)x8</td>
<td>4.68</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>7.55±0.82</td>
<td></td>
<td>5.66</td>
<td>0.34</td>
<td>0.47</td>
<td>1.38</td>
<td>1.38(0.34)x16</td>
<td>7.51</td>
<td></td>
</tr>
</tbody>
</table>

\( x = \) Prey density; \( y = \) prey attacked; \( k = \) maximum \( y \); \( b = \) handling time (in days) \( by = \) days all \( y \)'s; \( Ts = \) searching time (in days)  
\( y/x = \) attack ratio; \( a = \) rate of discovery; \( Tt = \) total time (in days) for which prey was exposed to the predator.
Fig. 36 : Functional response curve of *R. fuscipes* to *P. lienigianus*

Fig. 37 : Functional response curve of *E. plagiatus* to *P. lienigianus*
was also negatively correlated to the prey density \( Y = -0.03x + 0.99; r = -0.95 \) for \( R. fuscipes \) and \( Y = -0.03x + 0.90; r = -0.96 \) for \( E. plagiatus \) (Table 5.1 & 5.2, Fig. 36 & 37).

5.2.4. Projected attack ratio:

Using Holling’s Disc equation, the number of prey expected to be attacked by the predators at specified prey densities was calculated as \( Y' \). The observed \( y \) values were similar to the calculated \( Y' \) values. At a prey density of 16, \( y \) was 9.66 and \( Y' \) was 9.60 for \( R. fuscipes \) and 7.55 and 7.51 for \( E. plagiatus \) (Table 5.1 & 5.2, Fig. 36 & 37).

5.3. DISCUSSION

Since reduviids are polyphagous predators, they regulate the insect population (Ambrose, 1987 a, 1988, 1991 and 1995). They differ in their capacity to capture and consume different prey (Ambrose and Kumaraswami, 1990; Sahayaraj, 1994; Sahayaraj and Ambrose, 1994 a and b). Functional response studies could be used to infer basic mechanisms underlying the interactions of predator-prey behaviour, to clarify co-evolutionary relationship and to enhance practical predactive powers for bio-control operations (Houck and Strauss, 1985).

\( R. fuscipes \) and \( E. plagiatus \) responded to the increasing density of pest by killing more prey than at lower densities. The number of prey killed \( (x) \) increased from one prey/predator to 16 prey/predator. Such a response can increase the probability of predator being an effective control agent. This was further confirmed
by the positive correlation obtained between the prey density and prey killed. This findings corroborated the view of Sinha et al. (1982) that the prey density has a significant influence on the prey consumption. It also confirmed the type II model of Holling (1959). This type II functional response accurately described the curve linear relationship of varying insect predators (Hassell, 1978 and Hassell et al., 1978).


The maximum predation represented by ‘K’ values for R. fuscipes and E.plagiatus was found restricted to the higher prey density because the time for searching of prey required was less at higher prey density as reported by Morris
(1963). The predation rate showed a steep rise with prey density and was more for *R. fuscipes* (9.66 ± 1.31 for *R. fuscipes* and 7.55±0.79 for *E. plagiatus*). However in a study on the functional response of the pentatomid bug *Eocanthecona furcellata* (Wolff) on the lepidopteran prey *Latora lepida* (Cramer), Senrayan (1988) showed that the maximum predation occurred even at the lower prey densities. Hagen and Bosch (1968) reported that predators were more attracted to prey at higher prey population.

In *R. fuscipes* and *E. plagiatus* a negative correlation was obtained between prey density and searching time of predator at all prey densities. They spent lesser time for searching the prey at higher prey densities as observed by Subga *et al.* (1982); Senrayan (1988) and Claver and Ambrose (2002). It was presumed that the predator took lesser time to search the prey and spent more time for nonsearching activities at higher prey densities which in turn might have caused a perceptive decline in the attack rate of the predator at higher prey density until hunger was established. This factor coupled with the fact that the predator subdued the prey more quickly and consumed them faster at higher prey density than at low prey density. Rogers and Hassell (1974) and Beddington (1975) emphasized that searching efficiency continued to rise as prey number become scarce. Morris (1963) reported that the time for searching of prey required was less at higher prey density. The higher searching time (Ts) and the lower handling time (b) recorded confirmed the observation of Bass and Shepard (1974). In both the predators, the searching time, the interval between successive predation and the handling time decreased as the prey density increased, similar to the findings of Sahayaraj and Ambrose (1996 b) in *N. therasii* for *D. cingulatus*. 
Like the searching time, the attack ratio also decreased as the prey density increased in both predators. The highest attack ratio was observed at density of one prey/predator and the lowest attack ratio was found at the density of 16 preys/predator. Hence, a negative correlation was obtained between the prey density and attack ratio for both the predators. The satiated bugs would not search for another prey and the attack rate decreased with the increasing prey density in all predators having type two functional response. Hassel *et al.* (1976) stated that the attack rate decreased with increasing prey density in the case of predators having type II functional response. The inverse relationship between the attack ratio and prey level in *R. fuscipes* and *E. plagiatus* was in agreement with the findings of Propp (1982) in *Nabis amercicoferus*; Awadallah *et al.* (1984) in *A. biannulipes* on *C. cephalonica*; Senrayan (1988) in *E. furcellata* on *L. lepida*; Ambrose and Kumaraswami (1990) in *R. marginatus* on *D. cingulatus*, Sahayaraj (1991) in *A. pedestris, C. brevipennis, E. tibialis* and *N. therasii* on *Earias insulana Biosdual, Pectinophora gossypiella* Saunders and *Oxycarenus hyalinipennis* Costa and Kumaraswami (1991) in *R. marginatus, R. kumarii* and *R. fuscipes* on *O. hyalinipennis* and *S. litura*.

Although the real efficacy of this predator in biocontrol programmes could be arrived only after evaluating its numerical response by further investigations, the present investigation on the functional response in *R. fuscipes* and *E. plagiatus* suggested that they were capable of suppressing the increasing pest population by killing more number of pest. Hence, they could be mass cultured and effectively employed as biocontrol agents for suppressing pest population of brinjal. At all prey densities *R. fuscipes* killed more number of prey than *E. plagiatus*. This
might be due to the inherent difference in the predatory potential of these two species i.e., *R. fuscipes* was quicker and more successful in prey capture and killing. The present observations suggest *R. fuscipes* is a potent biocontrol agent of *P. lienigerianus* as compared to *E. plagiatius*. 
Extensive field collections of reduviids were made at Kalluvilai Semiarid Zone (8° 16' 43" N, 77° 16' 33" and MSL 77.1 meters) and Murungavilai Pothai (Tipramalai) Scrub Jungle (8° 15' 00" N, 77° 15' 00" E and MSL 200 meters) areas and nine species of reduviids were collected from the herbs, shrubs and litter habitats of these two ecosystems.

Of the nine species, the distribution and abundance of *I. armipes*, *E. plagiatus* and *S. minusculus* of both semiarid zone and scrub jungle, the prey fauna and meteorological factors were recorded fortnightly for 16 months from Feb 2000 to May 2001. *I. armipes* and *E. plagiatus* of both ecotypes were found to be controlled by both biotic and abiotic factors whereas *S. minusculus* of both ecotypes was regulated solely by prey fauna especially the flies.

The ecotype of *I. armipes*, *E. plagiatus* and *S. minusculus* of semiarid zone and scrub jungle were maintained in the laboratory and various biological parameters viz., incubation and stadial periods, adult longevity, fecundity, hatching percentage and sex ratio were recorded. Morphometric analysis of head, cephalic appendages, prothorax, thoracic appendages and abdomen were made in both ecotypes and compared with each other. There was pronounced deviation in both ecotypes and *I. armipes* and *S. minusculus* of scrub jungle showed higher fecundity, higher hatching percentage, longer female longevity, short stadial period etc, whereas *E. plagiatus* of the semiarid zone showed the above mentioned biological parameters which proved that *I. armipes* and *S. minusculus* preferred scrub jungle and *E. plagiatus* preferred semiarid zone.
Predatory behaviour and chronology of predation of *I. armipes* and *E. inornatus* in relation to three types of prey viz., *O. obesus*, *C. cephalonica* and *S. litura* was studied. The generalized sequential pattern of feeding such as arousal - approach - pouncing - rostral probing - piercing - paralysing the prey - sucking the contents of the prey-post predatory cleaning was observed in both species. The nymphs showed congregational feeding. The females were found to be active predators than males. In both the species adults were found to be more predatory than nymphal instars. Both the species showed the typical "pin and jab" type of feeding.

Prey influence on the growth, development and size was carried out in *I. armipes* and *E. inornatus* on four types of prey such as *O. obesus*, *C. cephalonica*, *S. litura* and a mixture type of prey. Incubation and stadial period, female longevity, fecundity and hatching percentage were more for *I. armipes* and *E. inornatus* reared on *O. obesus* and *S. litura* respectively suggesting *O. obesus* as suitable prey for mass rearing of *I. armipes* and *S. litura* for mass rearing of *E. inornatus*.

Biocontrol potential was surveyed in *E. plagiatus* and *R. fuscipes* on *P. lienigianus*, the pest of *S. melangena* (brinjal) agroecosystem. Holling's disc equation was applied to assess their predatory potential. It was observed that both the species showed a similar positive functional response at different prey densities and their prey suppressing ability increased with increased prey densities. Since their prey killing efficiency and searching capacity was more with increased prey densities both could be used as efficient biocontrol agents of controlling *P. lienigianus* populations.