Functional Response of an Assassin Bug *Rhynocoris kumarii* Ambrose and Livingstone (Insecta: Hemiptera: Reduviidae) to *Odontotermes Brunneus* (Hagen) (Insecta: Isoptera: Termitidae)

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Abstract

The functional response of the assassin bug, *Rhynocoris kumarii* Ambrose and Livingstone to *Odontotermes brunneus* (Hagen) was investigated. Different levels of termite densities - 1, 2, 4, 8, 16 and 32 were used. Each density was placed in a test cage (14 x 22 x 10cm) and then exposed to 24hr starved fourth and fifth nymphal instars and adult males and females of *R. kumarii* under laboratory conditions (28-34°C temperature; 12 ± 1hr. photoperiod; 65-70 % relative humidity). All the experimental life stages of *R. kumarii* responded to the increasing prey density of O. brunneus by killing a greater number of preys than at lower prey densities. Thus, the predators exhibited the type II curvilinear functional response. The maximum predation (K) was restricted to high prey density (24.889, 24.722, 22.889 and 24.194 for IV, V nymph and adult male and female respectively). The searching capacity of *R. kumarii* increased with increasing termite density and this reflected its predatory potential.

Keywords: Assassin bug; Reduviidae; *Rhynocoris kumarii*; Termitidae; *Odontotermes brunneus*, Functional response

Introduction

The understanding of predator-prey interactions has been the purpose of numerous studies, especially those related to predator use in biological control in agroecosystems. Predation is assumed to be one of the significant biotic mortality factors reducing insect pest populations and using them in insect pest management programmes has been receiving increased attention because of the current need to reduce the exclusive use of insecticides for pest control [1-3]. Functional response of a predator is one of the important key factors regulating population dynamics of predator–prey systems [4], and functional response curves can be used to infer basic mechanisms underlying predator–prey interactions, clarify coevolutionary relationships and enhance biological control [5].

One of the fundamental aspects of a predator–prey interaction is the relationship between prey density and predator consumption, to which Solomon [6] attributed the term "functional response". According to Holling [7-9], there are four basic types of functional response which include type I (linear), type II (curvilinear), type III (sigmoidal) and type IV (dome-shaped); governed by components such as exposure time, prey searching time, instant discovery rate or attack rate, prey searching efficiency and prey handling time [10,11]. The responses of types I and II are found in most invertebrates, whereas type III is more common in vertebrates, although some arthropods can also show this response when their preferential prey is not available [12,13]. Type IV response occurs only when other prey of the same or of a different species interferes in predator handling or if the prey shows defense behaviour, which can intensify at higher densities [13]. It is usually measured to provide insights into the suitability of a predator as a biological control agent [14]. Hence, knowledge on the type of functional response is important to understand the underlying mechanisms in a predator–prey interaction, in elucidating the practical role of co-evolutionary relationships and in contributing towards biological control using this kind of interaction [5].

The Reduviidae is the largest family which is considered as economically important taxa because it includes an important group of generalist predators associated with many types of pests in different agricultural systems [15-17]. Though they are polyphagous they attack a greater number of preys at high prey densities than at lower prey densities [15,18-21]. The reduviid predator *Rhynocoris kumarii* Ambrose and Livingstone is a polyphagous insect predator which preys upon *Helicoverpa armigera* (Hübner), *Spodoptera litura* (Fabricius), *Mylabris pustulata* Thunberg, *Dysdercus cingulatus* Fabricius, *Earias vitella* (Fabricius), *Pectinophora gossypiella* Saunders, etc. [15].

In the present study we aimed to determine the biocontrol potential of an assassin bug *R. kumarii* to the termite, *Odontotermes brunneus* (Hagen). *O. brunneus* is a widely distributed species building dome shaped mounds [22]. It damages the maize, *Zea mays* L. [23].

Materials and Methods

The nymphs and adults of *R. kumarii* were collected from Pilavaikal tropical evergreen forest (77°30'E 9°35N) Virudhu Nagar District, Tamil Nadu, South India. They were separately reared in the laboratory (28-34°C temperature; 12 ± 1hr. photoperiod; 65-70% humidity) in plastic containers (14 x 22 x 10cm) on rice meal moth, *Corcyra cephalonica* Stainton.

The functional response experiments were conducted in plastic containers (14 x 22 x 10cm) at 1, 2, 4, 8, 16 and 32 prey densities. The prey was first introduced into the container and allowed to acclimatize in the container. Thereafter, 24hr. pre-starved adult predator was introduced into the container. After 24hr. the number of preys consumed or killed by the predator was evaluated. The prey number was maintained constant throughout the experiment by replacing the dead or consumed prey with fresh prey. Disc equation of Holling [8] was used to find out the functional response. Disc equation was derived from the following equation which signified the effects of prey density on attack.

$$Y = aT_s x - - - - - - - - - - - (1)$$

Where:

A = rate of discovery per unit of searching time [(y/x)/Ts].

Ts = total number of preys killed in a given period of time.

x = prey density.

But time available for searching is not constant. Reduced from the total time (Tt) by the time spent in eating or handling the prey. If we presume that each prey requires a constant amount of time 'b' for consumption, then,

$$Ts = Tt - by - - - - - - - - - - - (2)$$

Tt = total time in days when prey was exposed to the predator

B = Tt/k = time spent for handling each prey by the predator

K = the maximum prey consumption

Substituting 1 in 2

$$Y' = a(Tt - by)x - - - - - - - - - - - - (3)$$

(or)

$$Y' = \frac{Tt\ ax}{1+abx}$$

Regression analysis was done to determine the relationship between the prey density and the number of preys consumed, searching time, attack ratio and handling time [24].
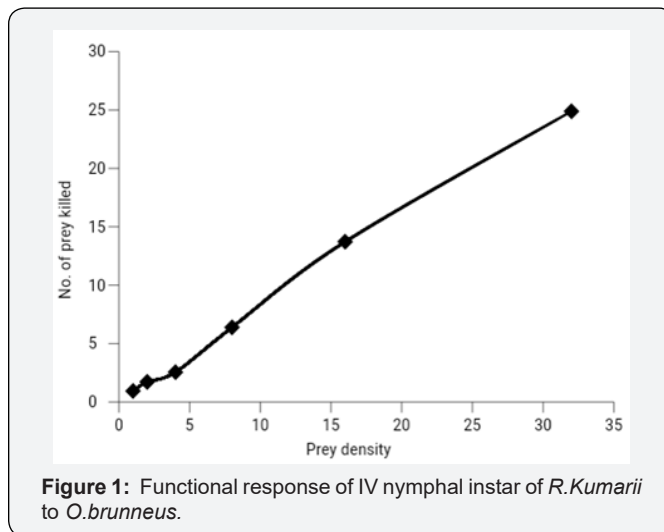
Results and Discussion

Figure 1: Functional response of IV nymphal instar of *R.Kumarii* to *O.brunneus.*
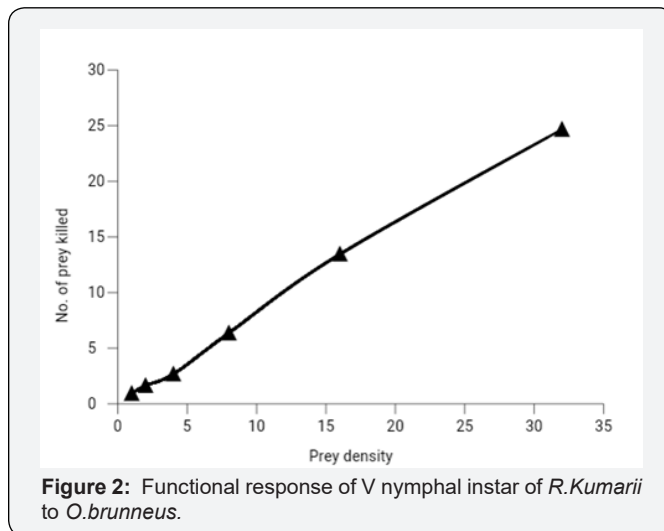

Figure 2: Functional response of V nymphal instar of *R.Kumarii* to *O.brunneus.*
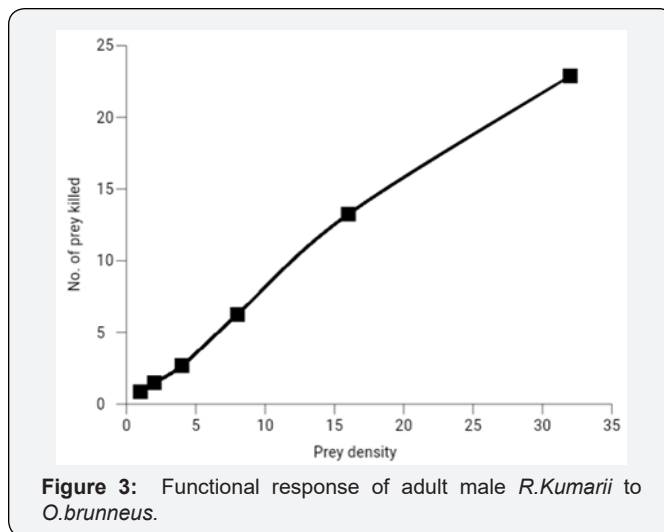

Figure 3: Functional response of adult male *R.Kumarii* to *O.brunneus.*

Predation by fourth and fifth nymphal instars and adult males and females of *R. kumarii* responded to the increasing prey density of *O. brunneus* by killing a greater number of prey than killed

at lower prey densities yielded a curvilinear type II functional response [8] (Figure 1-4). Most predators consumed all or most of the prey provided at lower prey densities and showed a declaration in rate of predation with greater variation at higher prey densities. This was further confirmed by the positive correlation obtained between the prey density and the prey killed (e.g. for IV nymphal instars: Y = 0.095 + 0.788x; r = 0.998; for V nymphal instars: Y = 0.098 + 0.779x; r = 0.998; for adult males: Y = 0.282 + 0.726x; r = 0.996; for adult females: Y = 0.305 + 0.773x; r = 0.995). The maximum predation represented by K value was restricted to high prey density (K = 24.889, 24.722, 22.889 and 24.194 for IV and V nymphal instars and adult males and females, respectively) (Table 1). The searching time decreased as the prey density was increased. Negative correlations were obtained between prey densities and the searching times of predator at all prey densities for all experimental life stages (e.g. for IV nymphal instars: Y = 5.977-0.189x; r = -0.998; for V nymphal instars: Y = 5.975-0.189x;

r = -0.998; for adult males: Y = 5.926-0.190x; r = -0.996; for adult females: Y = 5.924-0.191x; r = -0.995) (Table 1).

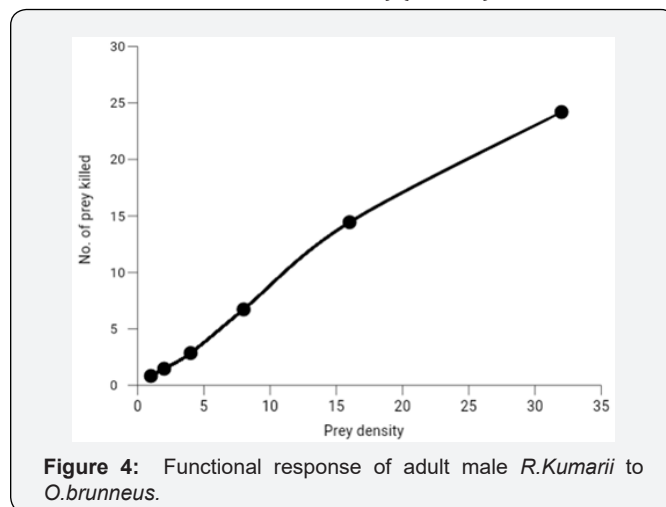**Figure 4:** Functional response of adult male *R.Kumarii* to *O.brunneus*.

Table 1: Cumulative functional response of different life stages of *R. kumarii* to *O. brunneus* (n=6).

Life Stage	Prey Density (X)	Prey Attacked (Y)	Maximum Y = k	Days/Y b=Tt/k	Day's All Y's (by)	Days Searching Ts=Tt-by	Attack Ratio Y/X	Rate of Discovery Y/X/Ts=a	Discovery Equation Y'=a(Tt-by) X	Y'
IV Nymph	1	0.944	24.889	0.241	0.228	5.772	0.944	0.164	Y'=0.15(6-0.241y)x	0.866
	2	1.722			0.415	5.585	0.861	0.154		1.676
	4	2.556			0.616	5.384	0.639	0.117		3.23
	8	6.389			1.539	4.461	0.799	0.179		5.352
	16	13.722			3.307	2.693	0.858	0.319		6.463
	32	24.889			5.998	0.002	0.778	-		-
V Nymph	1	0.917	24.661	0.243	0.223	5.777	0.917	0.159	Y'=0.15(6-0.243y)x	0.867
	2	1.639			0.398	5.602	0.819	0.146		1.683
	4	2.667			0.648	5.352	0.668	0.125		3.211
	8	6.361			1.546	4.454	0.795	0.178		5.345
	16	13.444			3.267	2.733	0.84	0.307		6.559
	32	24.661			5.992	0.008	0.771	-		-
Adult Male	1	0.861	22.889	0.262	0.226	5.774	0.861	0.149	Y'=0.15(6-0.262y)x	0.867
	2	1.5			0.393	5.607	0.75	0.134		1.682
	4	2.694			0.706	5.294	0.674	0.127		3.176
	8	6.25			1.638	4.362	0.781	0.179		5.234
	16	13.25			3.472	2.528	0.828	0.328		6.07
	32	22.889			5.997	0.003	0.715	-		-
Adult Female	1	0.833	24.194	0.247	0.206	5.794	0.833	0.144	Y'=0.16(6-0.247y)x	0.927
	2	1.472			0.364	5.636	0.736	0.131		1.717
	4	2.861			0.707	5.293	0.715	0.135		3.388
	8	6.722			1.66	4.34	0.84	0.194		5.555
	16	14.444			3.568	2.432	0.903	0.371		6.226
	32	24.194			5.976	0.024	0.756	-		-

The functional response of *R. kumarii* reveal that prey consumption by a predator increased with increase in prey density, whereas per cent prey consumption decreased, which exemplifies Holling's Type II predatory response [8]. Type II functional

response is typical of the most heteropteran predators [25]. The present findings are in close agreement to those recorded for other reduviids [15,17-21,26-30]. Type II functional response was also exhibited by coleopteran predators such as *Harmonia axyridis* (Pallas) to *Aphis gossypii* Glover [31] and to *Myzus persicae* (Sulzer) [32], both *Sycmnus levaillanti* Mulsant and *Cycloneda sanguinea* (Linnaeus) to *A. gossypii* [14], *Adalia tetraspilota* (Hope), *Coccinella septempunctata* L., *Calvia punctata* (Mulsant) and *Hippodamia variegate* (Goeze) on the green apple aphid, *Aphis pomi* De Geer [33], *H. variegate* to *Aphis fabae* (Scopoli) [34] and *Adalia fasciatopunctata revelierei* (Mulsant) to walnut aphid *Callaphis juglandis* Goeze [35]. Some parasitoids also exhibited type II functional response [3,36-39]. Kakimoto et al. [40] reported that *Haplothrips brevitubus* (Harny) exhibited type II functional response to *Pseudodendrothrips mori* (Niwa). Hunger and time spent by the predator in searching and handling prey affect the prey consumption (pursuing, subduing and consuming the prey and then preparing itself for the further search) (Houck, 1991) [41]. A predator's functional response may vary with sex and developmental stages of the predator as well as that of prey, searching arena and the abiotic environment [42-44].

Increased prey consumption at higher prey density might be due to different phenomena operating simultaneously in predatory arena. Firstly, it results due to decrease in searching time because the probability of contacts between the prey and predator increases at higher prey densities, which results in increased prey consumption. Secondly, the predator stays in an arena where the prey aggregates and continues to feed until satiation or even beyond [20]. The inversely proportional relationship found between the attack rate and prey level corroborates the earlier observations of Claver & Ambrose [20] in *Rhynocoris fuscipes* (Fabricius) to three pigeon pea pests and in *Acanthaspis pedestris* (Stål) [21]. It is presumed that the predator required less time to search the prey and spent more time on non-searching activities at higher prey densities, which in turn might have caused perceptive decline in the attack rate until hunger was established. This releases the trade-off situations at higher prey density and closes the gap between optimal foraging and satiation [45]. Moreover, higher prey density also results in reduction of unsuccessful attacks of a predator on a prey, as there are less chances of escape when compared to those in scarce prey density, where there are more chances for the prey to escape from the predator [46].

At high prey density, less time was spent in searching; therefore, more time was spent in handling, whereas at low prey density the searching time always dominated the handling time [46]. Handling time depends upon factors such as speed of pursuit of predator and prey escape or prey capture success [47]. Disturbance by another prey at higher prey densities also aggravated a hungry predator during feeding which resulted in killing of more prey individuals than normal. Heteropteran predators are adapted to feeding on larger prey. A predator that skims nutrient-poor, highly diluted liquids would be likely to kill as many preys as it could capture [25]. Moreover, satiation is a possible reason for decreased prey consumption at higher prey densities, since satiated reduviids spent more time in prey handling due to which rate of prey capture decreased [15,18,20,26]. The size of the prey also plays an important role in handling time. In this study, as the termites are in small size the handling time is decreased. As a result, the predator consumed a greater number of preys to attain satiation. Thus, the performance of biological control agents is also affected by nature of prey. Therefore, the proper predator prey combination should be determined for biological control programme.

For the type II response, consumed prey is not density dependent: that is, the intensity of consumed prey does not increase with prey density [48]. In laboratory tests, predators are forced to remain in the patch, whereas under natural field conditions they probably leave the patch because of the very low prey density or because most prey are already consumed [49]. Fan & Zhao [50] pointed out that the relation between functional responses observed in the laboratory and field performance of natural enemies is not clear, but some studies showed a significant difference between the responses observed in laboratory and field environments. It is recognized that functional responses derived from laboratory studies may bear little resemblance to those that could be measured in the field [51]. Fan & Zhao [50] pointed out, however, that studies of functional response in the laboratory could be used to infer basic mechanisms underlying natural enemy-prey interactions. Such studies provide valuable information for biological control programmes.

The results from this study indicate that the searching efficacy and rate of consumption are maximum when the predator was searching at a density of 32 termites. This might be optimal for the release of this predator to manage the termites. The above findings clearly indicate that *R. kumarii* could be used as a biocontrol agent against the *O. brunneus*.

Acknowledgement

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