SMALL SCALE LABORATORY REARING OF A REDUVIID PREDATOR, *RHYNOCORIS MARGINATUS* FAB. (HEMIPTERA: REDUVIIDAE) ON *CORCYRA CEPHALONICA* STAINTON LARVAE BY LARVAL CARD METHOD

SAHAYARAJ K.

ABSTRACT

A reduviid predator, *Rhynocoris marginatus* Fab. was reared at four different densities (25, 50, 75 and 100) on *Corcyra cephalonica* Stainton larvae. Fifty predators per rearing container were the suitable density for small scale laboratory rearing of this predator because this density had shorter nymphal developmental, preoviposition and incubation periods, female biased sex ratios minimum food requirements and maximum fecundity and hatchability. A life table was constructed in relation to the predator density. The net reproductive rate was higher in the 50 predator group and it decreased with an increase in the predator density. *R. marginatus* population doubling time (14.9 days) was found to be higher in the 100 predator category and increased as the predator density decreased. Cost of production of this predator for field release was also lower when compared to insecticide or NPV application.

KEY WORDS: reduviid predator, predator density, laboratory rearing, life table, development, fecundity, larval card.

Manuscript received: February 10, 2002.
Accepted for publication: June 15, 2002.

JOURNAL Central European Agriculture ISSN 1332-9049

INTRODUCTION

Rhynocoris marginatus Fab., a generalist reduviid predator is predominantly found in agroecosystems such as cotton, soybean, tomato and groundnut crops, scrub jungles, semi-arid zones and tropical rain forests of Tamilnadu, India. It is considered to be an effective biological control agent against nearly 20 insect pests of various cultivated crops [1,2]. Biological control by augmentation of predators and parasites that have been mass produced in insectaries provides a means of insuring the presence of numbers that are adequate to supress pest populations to a desired level. Production of parasites and predators for augmentation has been considerable interest to workers in biological control since the beginning of the twentieth century. The chief obstacle to the wide spread application of the augmentation method of pest control was the difficulty in mass producing or mass collecting entomophagous arthropods at economical costs [3].

The concept of commercial production in promoting biological control in India was first conceived by many authors. [4 - 8] expressed the urgent need for evolving strategies to mass rear predators for their large scale release into the pest infested agro-ecosystem and to assess their biological control potential. Selection of a host is very important in the mass culture programme of any natural enemy including the reduviid predators. FINNEY and FISHER [9] reviewed the use of natural and unnatural hosts for rearing entomophagous arthropods. They defined a natural host as one that is usually attacked in nature by parasites or predators. An unnatural host is not normally attacked, because of some isolating mechanism, but it serves as a suitable host for rearing a biological control agent in the insectary. The advantages of using an unnatural host are reduced production costs, convenience and ease of handling. The eggs and larvae of rice moth, *C. cephalonica* Stainton are serving as unnatural hosts for many natural enemies including the reduviid predators. JOSEPH [10] used *Corcyra* larvae as food for the reduviids by releasing them on filter paper in glass jars. These larvae were also used by other authors [11,12] for rearing reduviids. The biocontrol potential and the development of *R. marginatus* on different hosts have been studied by many authors [1,2,13 - 15]. One of the basic requisites for a successful biological control agent is the availability of a sound, low cost rearing and mass multiplication technique, which also was not found to be available for *R. marginatus*. Predator density is an important limiting factor in the mass production programme. SAHAYARAJ [7] recommended the larval card method for laboratory rearing of reduviids. He added that the problems of the technique arise mainly from the imperfections due to poor skill of the workers, number of larvae fixed in the card and alsoto the quality of the cellotape used. Based on these constraints, the present study is aimed at finding out the suitability of the larval card method, as described by LAKKUNDI and PARSHAD (1987) [16] and optimum predator density for the mass production of this reduviid and also at finding out the production cost.

MATERIALS AND METHODS

Reduviid predator

R. marginatus adults and nymphs were collected from cotton, groundnut, tomato and soybean of Tamilnadu, India. They were maintained in the laboratory (30 ± 2°C; 11L and 13D photo period; 75 ± 5% r.h.) on *C. cephalonica* larvae. The egg batches laid by the female bugs in the laboratory were incubated in moist cotton swabs in small plastic vials (30 ml volume) to provide humidity. Newly hatched first nymphal instars were used for this study. Blotting paper was placed in the bottom of large plastic vials (1000 ml volume), and newly hatched nymphs were released into the vial. To study the effect of the nymphal density during development, four treatments of 25, 50, 75 and 100 nymphs per rearing containers were selected and were replicated 20 times in a generation. The vials were covered with a muslin cloth. The actual data on observations regarding different biological parameters and predatory rate of *R. marginatus* were observed for two generations continuously. From these data, the average and standard deviation were worked out and are presented in the results and tables.

Rearing of Corcyra cephalonica

C. cephalonica eggs were purchased from the Govt. Agricultural office, Palayamkottai. Each 0.5 cc of eggs were reared on a newly formulated medium consisting of jowar flour (1 kg), groundnut (200 gm), multivitamin tablet powder (500 mg), streptomycin

(20 mg) and Wesson's salt mixture (15 gm) in plastic trough (22 cm lower diameter, 28 cm upper diameter and 10 cm height) and the troughs were covered with a muslin cloth. Each such trough with culture medium was enough to rear 3 generations of *C. cephalonica* [17]. The cost of production including labour for rearing 5000 reduviid predator was determined.

Preparation of larval card strips

Larval cards (LC) were prepared following the standard procedures [7,16]. A reference card strip of 25 X 6 cm was selected and divided equally at a distance of 3 cm. Each strip was then divided vertically into 25 equal divisions. Each such division was enough to accommodate a larva. The fourth and fifth instar *Cocryra* larvae were collected in a petri dish and kept for 10 minutes in the freeze chamber of the refrigerator with a view to immobilise them. The weight of each larva ranged from 30 - 50 mg (mean 41.02 mg). After immobilization, the larval head and thorax were stuck on the larval card strips with the help of cellotape stripes of about one centimetre breadth, leaving rest of the larval body free. A total of 50 larvae were stuck on a single strip in two rows. Number of such LC's were prepared and maintained at 27 ± 1°C and 70 per cent relative humidity in the BOD incubator. They could be stored for a maximum of 4 weeks in a live condition provided no fungi or any disease sets in.

Feeding the Reduviids

The larval cards were folded in zig-zag pattern and were provided to the nymphs for feeding. Different nymphal instars of different predator density categories were provided with different numbers of LCs. The first nymphal instars of 25 and 50 predator categories were supplied with one LC and 75 and 100 predator categories were supplied with 2 LCs each. Second nymphal instars of 25, 50, 75 and 100 predator categories were provided with one, two, two and four LCs/ container for each set. Third, fourth and fifth nymphal instars were supplied with two, two and three LCs /container for 25 predators category set; three, four and six for 50 nymphs set; four, five and seven for 75 nymphs category and four, six and eleven cards for 100 predator category respectively. The 25, 50, 75 and 100 nymphal categories were provided with 9, 16, 20 and 27 LCs/container respectively. All the adult categories were provided with one LC/week/container. A total of 450, 800, 1000 and 1350 larvae were supplied to 25, 50, 75 and 100 predators groups in their whole developmental period.

Biology and Bionomics

The number of immature predator surviving, moulting changes and quantity of prey consumed per predator were recorded daily. From the quantity of prey consumed per predator and stadial period data, quantity of prey consumed per predator per stadium was calculated. The sex ratio in this study was calculated from the adults emerged in the laboratory. The adults emerged in the laboratory from each category were grouped as five pairs separately in plastic containers (1000 ml capacity) and totally 20 replications were made for the two generations to ensure 200 adults in each treatment. The containers were carefully examined daily to record the eggs laid. Number of batches of eggs and total number of eggs laid were also recorded. The number of eggs in each batch was carefully recorded and they were allowed to hatch in an individual container (30 ml capacity) with wet cotton swabs and the incubation period was noted. Pre-oviposition and oviposition periods, number of eggs laid/female, number of eggs hatched, average number of eggs per batch was calculated. The adults were maintained till their death and their adult longevity was also recorded.

Life Table Studies

A life table was constructed according to the methods of BIRCH [18] and elaborated by others [19,20]. In life table statistics, the intrinsic rate of increase was determined by using the equation $\Sigma e^{-r}{}_m$ X $l_x m_x$ - 1, where 'e' is the base of the natural logarithms, 'X' is the age of the individuals in days, l_x is the number of individuals alive at age 'X' as the proportion of 1 and $`m`_x$ is the number of female offsprings produced per female in the age interval `X`. The sum of the products of $l_x m_x$ is the net reproductive rate ($R_o = \Sigma \ell x m x$). The rate of multiplication of population for each generation was measured in terms of females produced per generation. The value of cohort generation was calculated as:

$$T_c = \frac{\sum I_x m_x X}{\sum I_x m_x}$$

The arbitrary value of innate capacity for increase r_c was also calculated

$$r_c = \frac{\log_e R_0}{T_c}$$

This is an appropriate r_m value. The values of negative exponent of $e^{-r_m}X$ ascertained from this experiment often lay outside the range. For this reason both sides of the equation were multiplied by a factor of $\sum e^{7-r_m} x 1_x m_x - 1096.6$ [18, 19]. The two values of $\sum e^{7-r_m} x 1_x m_x$ were then plotted on the horizontal axis against their respective arbitrary rm on the vertical axis. Two points were then joined to give a line which was intersected by a vertical line drawn from the desired value of $e^{7-r_m} x 1_x m_x$ (1096.6).

The point of intersection gives the value of r_m accurate to three decimal places. The precise generation time (T) was then calculated from equation.

$$T = \frac{\log_e R_0}{r_m}$$

Where r_m is the adjusted value. The finite rate of increase (λ) was calculated as T = anti log $e^{r m}$. This T represents the number of individuals added to the population per female per day. The weekly multiplication of predator population was calculated as anti log $(e^{r m})^7$. The doubling time was calculated as log2 / log λ.

Statistical Analysis

Analysis of Variance (ANOVA) was used to determine the difference between first nymphal instar and second, third, fourth and fifth nymphal instars separately for 25, 50, 75 and 100 nymphs categories. It was applied in all parameters of this study such as stadial period, adult longevity, oviposition, fecundity, hatchability, mean number of eggs per batch and food consumption. Duncan's Multiple Range Test (DMRT) was used to separate treatment means. Chi-square was used to determine the statistical significance in sex ratio of adult predators[21].

RESULTS AND DISCUSSION

Biology and Bionomics

Stadial period

In all four predator densities tested, the shortest total developmental period (44.23 days) was observed in the group of 50 predators followed by 25 (46.53 days), 75 (47.00 days) and 100 (49.73 days) predator categories respectively and hence 50 predator/container can be considered the most suitable for *R. marginatus* (Table 1). The developmental period of this predator increased as the predator density increased except in the 50 predator category and this density may be an optimum density for this predator for its quick development. However, statistical significances were not observed between the predator categories. The developmental rate of individual predator was significantly affected by predator density. AMBROSE *et al.* [22] reported that the total nymphal period of *R. marginatus* was 84.70 ± 1.01 days when it was reared in solitary condition on *Odontotermes obesus* Rambur. However, the developmental period was very short (38.82 ± 1.64 days) when it was reared on *S. litura* in isolation [12]. It was reported that rearing in groups decreased the total nymphal period from 70.47 days to 61.13 days in *Acanthapis pedestris* Stĺl. and 78.84 days to 61.03 days in *A. quinquespinosa* Fab. as compared to rearing under solitary condition [12]. Similar results were obtained in another reduviid *Coranus soosai* [23]. In all four density categories, the longest stadium was the fifth nymphal instar. In all the categories the developmental period increased when the predator grew older except in the second nymphal instars of 25 and 75 predator/container category.

Nymphal mortality

Nymphal mortality increased as the predator density increased. In the 25 and 50 predator groups, the total nymphal mortality was 8 and 10 % respectively. In the 75 and 100 predator groups, the mortalities were 30 and 32.5 % respectively. Statistical analysis showed that mortality data were highly significant ($p < 0.05$). With increasing predator density, the survival rates of the immature instars decreased. This decrease in survival rates at high predator densities occurred because not all of the prey were equally available to each predator and underfed predators tend to become cannibalistic [24]. Cannibalistic behaviour was not observed among the immature stages of *R. marginatus.* In the present study, the nymphal mortality at 25 and 50 predator categories was very low when compared to that in higher density categories. AMBROSE and JENOBA [23] reported that four predators/container caused a significant increase in the nymphal mortality in *C.*

soosai from 41.6% to 94.4% in one and four predator density, respectively.

Table 1: Effect of predator density on development and adult longevity (in days) and sex ratio of *R. marginatus*

Life stage	Predator density (in numbers) 25	50	75	100
		Developmental period		
I nymph	7.6 ± 0.2	7.5 ± 0.1	7.2 ± 0.1	6.8 ± 0.1
II nymph	7.4 ± 0.3	7.6 ± 0.1	6.4 ± 0.2	7.6 ± 0.2
III nymph	8.3 ± 0.4	8.1 ± 0.3	8.6 ± 0.3	10.0 ± 0.2
IV nymph	9.3 ± 0.5	9.0 ± 0.4	9.1 ± 0.4	9.2 ± 0.2
V nymph	14.0 ± 0.8	12.1 ± 0.5	15.7 ± 0.6	11.1 ± 0.7
I to Adult (total)	46.5^{a}	44.2^{ab}	47.0^{ac}	49.7^{c}
		Adult longevity		
Male	198.4 ± 8.4^{a}	132.2 ± 12.0^{b}	167.3 ± 6.5^{c}	188.0 ± 10.5^{d}
Female	165.5 ± 7.1^{a}	148.4 ± 8.5^{b}	162.5 ± 10.3^{ac}	140.7 ± 12.8^{bc}
		Sex ratio		
Male: Female	1.00: 0.967	0.875: 1.00	1.00: 0.921	1.00: 0.75

Mean followed by the same alphabets in a row are not significantly different at 5% (p> 0.05) by using the Duncan's Multiple Range Test (DMRT)

Sex ratio

Female biased sex ratio was observed in the 50 predator category; whereas in other categories it was male biased and statistical significance was observed among the categories. In the 100 predator category, the sex ratio was highly male biased. Sex ratios between 25 to 50 and also between 50 to 75 and 100 predator categories were statistically significant ($P < 0.05$). Crowding of the parasitoid *Nasonia viripennis* (Walker) caused a shift in the sex ratio towards males[25]. Since many reduviid predators, including *R. marginatus*, have a similar haplodiploid method of sex determination [1], higher predator population may also affect their sex ratios in the same manner. The effect of crowding on the sex ratio of *A. pedestris* was not clearly understood [26]. So further detailed studies are necessary to find out the relationship between crowding and sex ratio.

Adult longevity

Females emerged from the category of 50 individuals lived longer (148.4 ± 8.5 days) than males (132.2 ± 11.9 days) and the statistical comparision between the groups was significant ($P < 0.05$) (Table – 2). The same trend was observed when this predator was reared on *S*

Table 2: Pre-oviposition, oviposition and incubation periods (in days) and fecundity and hatchability of *R. marginatus*

Parameters	Predator density (in numbers) 25	50	75	100
Pre-oviposition period	38.4 ± 1.2^{a}	29.0 ± 1.0^{b}	41.1 ± 3.1^{c}	45.4 ± 2.1^{c}
Oviposition period	127.1 ± 6.5^{a}	114.4 ± 7.7^{b}	122.1 ± 9.0^{ac}	95.7 ± 11.1^{d}
Total number of eggs/female	632.1 ± 88.0^{a}	770.0 ± 69.6^{b}	470.6 ± 61.2^{c}	391.5 ± 57.0^{d}
Incubation period	6.5 ± 0.1^{a}	6.3 ± 0.1^{ab}	6.8 ± 0.03^{abc}	7.0 ± 0.1^{bc}
Hatchability (%)	86.4 ± 1.5^{a}	88.8 ± 1.1^{ab}	82.6 ± 2.1^{ac}	86.6 ± 3.4^{abc}
Average number of eggs/batch	31.3 ± 6.31^{a}	42.8 ± 7.2^{b}	34.7 ± 5.4^{ac}	33.5 ± 6.4^{acd}

Mean followed by the same alphabets in a row are not significantly different at 5% (p> 0.05) by using the Duncan's Multiple Range Test (DMRT)

Oviposition period

It has been observed that the oviposition period was longer than pre-oviposition in all the categories ($p < 0.05$), which is a desirable feature from the viewpoint of biological control. The shortest pre-oviposition period (28.95 ± 1.1 days) was observed in the 50 predator group followed by the 25 (38.40 1.186 days), the 75 (41.05 ± 3.096) and the 100 (45.4 ±

2.092) predator categories. This result agrees with the results of AMBROSE *et al.* [33]. All the pre-oviposition data were statistically significant ($P < 0.05$), except between the 25 to the 75 predators density.

Total number of eggs

Total number of eggs per female was highest in the 50 predator group (770.03 ± 69.6 eggs) followed by the 25 (632.10 ± 87.9 eggs), the 75 (470.6 ± 61.2 eggs) and the 100 (391.46 ± 57.0 eggs) predator groups (Table 2). The comparison between the different predator densities was statistically significant ($P < 0.05$). The total eggs per female in the 50 predator category was nearly twice as high as for the 100 predator category. Similar results have been reported for another predatory bug, *Anthocoris confusus* Reuter [35]. Furthermore, Eveleigh and Chant [24] reported that the mean fecundity of a predator, *Phytoseiulus persimilis* Athias - Henriot decreased as the predator density increased and this might be due to some kind of interference between the predators.

Average number of eggs per batch

Among the four densities tested, the average number of eggs per batch was the highest and lowest in the 50 (42.8 eggs) and the 25 (31.3 eggs) predator category respectively. The statistical analysis between the 50 predator density to other densities was statistically significant ($P < 0.05$).

Incubation period and hatching percentages

Incubation period was comparatively lower in the 50 predator group (6.32 ± 0.1 days), which was not significantly different from the other categories. Hatching percentage was the highest in the 50 predators category (88.8 ± 1.1 percent) and the lowest in the 75 predator category (82.6 ± 2.1 percent) and the data were not statistically significant.

Life table

The life table parameters of *R. marginatus* on the four predator densities is given in Table 3. Both the survival and the female birth of the predators were found to be different when reared at four different predator densities. The fecundity rate (m_x) and the reproductive rate ($l_x m_x$) of all the density categories showed decreasing trends with increasing predator age. The total number of female births accounted for a net reproduction rate (R_o) of 284.42 females/female/generation at 25 predators, 297.38 at 50 predators, 184.498 at 75 predators and 144.81 at 100 predators, respectively (Table 3). These values in *R. marginatus* are higher than those of other reduviid species studied [36,37], which were 20.62 for *A. siva* and 31.90 for *Cydnocoris gilvus* Burm. The corrected mean generation time (T) was more or less equal in the 25, 50 and 75 categories in the laboratory (Table 3). The true intrinsic rate of natural increase (r_m) was calculated graphically and it came to nearly 0.053 for the 25 and 50 predator categories and 0.047 for the 75 and 100 predator categories, respectively. The value of the true intrinsic rate of increase was slightly higher than the capacity for increase in number, which is evident as pointed out in other insects [20, 38] having overlapping generations. The value of the true intrinsic rate of increase in the present study was higher than those reported in *A. siva* [36] and *C. gilvus* [37]. The superiority of r_m as an index of population increase signifies that the number of individuals added to the population will multiply per unit of time, designated as finite rate of increase (λ). The values were also more or less the same in the former two (25 and 50 predators/container) and latter two predator categories. Further, the time required to double the population increased as the predator density was increased. The weekly multiplication rate of *R. marginatus* was the same in the 25 and 50 predator categories and the 75 and 100 predator categories, too. This predator had quicker rate of multiplication than other reduviids such as *A. siva* [36], *C. gilvus* [37], and *A. pedestris* [39]. In all these three reduviids, the weekly multiplication rate was less than 2. This indicates that *R. marginatus* is capable of rapid multiplication in the laboratory with *C. cephalonica* larvae.

Food consumption and predatory rate

The total number of larvae consumed by an individual predator during its immature stage increased from lower density to higher density levels (14.3, 14.9, 15.6 and 16.6 for the 25, 50, 75 and 100 predator densities, respectively). However, the difference was very low and not statistically significant. The per capita consumption of prey by predacious phytoseiid mites, *P. persimilis* and *Amblyseius degenerans* (Berlese) was not affected by the predator density [24]. The total quantity of prey consumed by each stadium was gradually increased

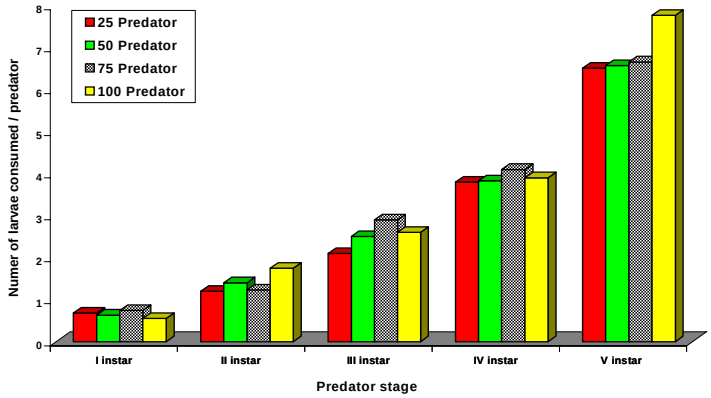
from first nymphal instar to the fifth nymphal instar (Figure 1). The food consumption by single adult was the highest in the 25 predator group (168.57 larvae) and followed by 100 (155.46 larvae), 75 (140.63 larvae) and 50 (131.83 larvae) predator groups and are statistically significant ($P < 0.05$). Irrespective of the predator density, very similar values of the feeding rate per individual per day were observed during the nymphal period (0.31, 0.34, 0.33 and 0.33 for the 25, 50, 75 and 100 predator/container) and adult stage (0.92, 0.94, 0.85 and 0.95 for the 25, 50, 75 and 100 predator density) respectively.

Table 3: Life table parameters of *R. marginatus* by larval card method

Demographic parameters	Predator density			
	25	50	75	100
Net reproductive rate(R_o)	284.420	297.383	184.498	144.81
Mean length of a generation (Tc)	130.459	134.632	136.946	128.28
Innate capacity for increase in number (rc)	0.043	0.042	0.038	0.387
Corrected r_m	0.0517	0.0518	0.047	0.046
Corrected generation time(T)	109.28	109.942	109.83	106.989
Finite rate of increase in number (WMR)	1.053	1.053	1.048	1.047
Rate of weekly multiplication of the population (RWM)	7.371	7.371	7.336	7.332
Doubling time (DT) (Days) log 2/log λ	13.437	13.68	14.827	14.975

These values are higher than those observed in *Rhynocoris fuscipus* Fab. [40]. Lakkundi [11] reported that the feeding rate was higher in immature stages than in adults. Sexual and reproductive activities in the adult might be the reason for lower feeding rate in adult predators. During the entire life time, a minimum quantity of prey was consumed by the 50 (146.8 preys/predator) followed by 75 (156.7 preys/predator), 100 (172.03 preys/predator) and 25 (182.9 preys/predator) predator groups, and the statistical comparisons were significant ($P < 0.05$).

Figure 1: Effect of predator density on the food consumption of immature stages of *R marginatus*



Larval card (LC)

Releasing 5000 *R. marginatus* ha^{-1} (833 each eggs, first, second, third, fourth and fifth nymphal instars) reduced 95% *S. litura* and 93% *H. armigera* larval population and also increased the groundnut production (1022.82 and 1867.77 kg ha^{-1} for control and for the field with predators released, respectively) [41]. Considering the higher fecundity, shorter nymphal development, pre-oviposition and incubation periods and female biased sex ratio obtained in the treatment with 50 predators per rearing container it may be concluded that the

optimum density for rearing *R. marginatus* is 50 predators per container. Rearing 4167 nymphal instars of *R. marginatus* required 12,441 *Corcyra* larva (525, 1166, 2083, 3192 and 5475 larvae separately for the first, second, third, fourth and fifth instars respectively). Since we were accommodating 50 larvae in a LC, 249 larval cards were necessary for rearing 4167 *R. marginatus* nymphs. The cost of production of 5000 reduviids came to around 410 rupees, which is approximately $9.5 at $1=43 Rs (See Table 4). The newly formulated culture medium was enough to rear the *Corcyra* larvae for three generations consequently. In such a situation, the cost of *R. marginatus* production could be reduced to 350 rupees, or $8.1.

Table 4: Budget for rearing 5000 *Rhynocoris marginatus* on *Corcyra cephalonica* larvae by larval card method

Ingredients/materials	Quantity	AmountRs. P.
Jowar	4 kg	24.00
Groundnut	1 kg	26.00
Ricebran	2 kg	04.00
Streptomycin	15 mg	00.60
Multicitamin tablets	2 gms	08.00
Cellotape	1 No.	60.50
Card board	10 No.	30.00
Corcyra egg	1.5 cc	15.00
Ingredients	Total cost	168.10
Salary to workers (@ Rs.30/manual day)	8 days	240.00
Total cost		408.10
Rounded off amount @		Rs.410.00
@		$ = 9.53

@$ 1 = Rs.43

Advantages of LC

JOSEPH [10] used *Corcyra* larvae as food for the reduviid bugs by releasing them on filter paper on a glass jar. The present authors used the same technique but the persistent problems of webbing by *Corcyra* larvae in the rearing - containers led to poor feeding accessibility as well as the entanglement and consequent death of predators, and the avoidance of feeding by the host larvae on the reduviid bugs. In turn, the reduviids got caught in the web and starved. Often, other problems were of cannibalism amongst the *Corcyra* larvae, making them unavailable for predators. Furthermore, some larvae escaped through the muslin cover, thus making difficulties for quantitative studies. In the present technique, the *Corcyra* larvae fixed in the reference card wagged their abdomen which was free and this attracted the reduviid predators. The cellotape that holds the head and thorax of the *Corcyra* larvae firmly on the card brings about a simulated ligature at that point. This prevents the hormonal connection between the brain and posterior region of the body. This reminded us of the classical work about the role of hormones for moulting by KOPEC [42] in which he used silk thread ligatures in *Lymantris* caterpillars. The larvae, fed upon by reduviids, turned brownish black which made the recording of observations (qualitative feeding) easier. In general, no cannibalism was observed in reduviids. The zig-zag pattern of LC's gave the reduviids more surface area for movement and resting. Other advantages are: less manual labour involved; *Corcyra* larvae remained alive for about 3-4 weeks without feeding, webbing and moulting; fresh in appearance and good quality of food for the reduviids.

CONCLUSION

From the results, it is concluded that 50 nymphs/1 L container is the appropriate density for rearing this predator in the laboratory for small scale production with the LC method. It also ensured some desirable features such as a shorter developmental period and less nymphal mortality, high fecundity and hatchability and shorter pre-oviposition and longer oviposition periods, respectively. Furthermore, this group consumed a minimum quantity of prey (146.76

preys/predator) during its entire life time. The cost of production and release for reduviid was less (Rs.570/- or $ 13.25) when compared to pesticide (monocrotophos) spray (Rs.1073/- or $ 24.95) and *Spodoptera* and *Helicoverpa* NPV's (Rs.1800/- or $ 41.86).

ACKNOWLEDGEMENT

This work was financially supported by the Department of Science and Technology, Government of India. The authors also wish to thank Rev. Dr. A. Lourdusamy, S. J., Principal and Prof. M. Thomas Punithan, Head, Dept. of Zoology, St. Xavier's College, Palayankottai for the facilities provided.

REFERENCES

[1] Sahayaraj, K. 1995. Bio-efficacy and development of a reduviid predator, *Rhinocoris marginatus, on Spodoptera litura. International Arachis Newsletter,* 15, 56 - 57.

[2] Sahayaraj, K. 1998a. Forest dwelling reduviids and their role in IPM with special reference to *Rhynocoris marginatus* Fab. *Save Forest and Wildlife* (in press).

[3] Beirne, B. P. 1974. Status of biological control procedures that involve parasites and predators. *Proceedings of the summer institute on biological control of plant insects and diseases* (F.G. Maxwell & F. A. Harris, Eds.), pp. 69-76. Univ. Press of Mississippi, Jackson.

[4] Ambrose, D. P. 1995. Reduviidae as predators: Their role in Biological control; in biological control of social forest and plantation crops insects (ed.) T. N. Ananthakrishnan (New Delhi: Oxford & IBH publication Co. Ltd.) pp. 153 - 170.

[5] Cohen, A. C. 1993. Organisation of digestion and preliminary characterization of salivary trypsin-like enzymes in predaceous heteropteran, *Zelus renardii. J. Insect. Physiol,* 39(10), 823 - 829.

[6] Manjunath, T. M. 1984. Role of commercial insectaries in promoting Biological control; Proc. 1st Regi. Symp. On Biological Control University pertanian *Malay. Sarad. Selengor, Malay. Sept.* 3 - 5, 287 - 294.

[7] Shayaraj, K. 1998b. Laboratory rearing of predaceous bugs with special reference to reduviids (Insecta: Hemiptera:Reduviidae). *Zoo's Print.* 13(5), 17 – 18.

[8] Schaefer, C. W. 1988. Reduviidae (Hemiptera: Heteroptera) as agent of biological control; in proceeding of the International conferencne on Biological control of vectors with predaceous Arthropods (eds.) K. S. ananthasubramanian, A. Venkatesan and S. Sivaraman, Chennai 1, 27 - 33.

[9] Finney, G. L. and Fisher, T. W. 1964. Culture of entomophagous insects and their hosts. Biological control of insect pests and weeds (P. De Bach Ed.). Chapman and Hill, Ltd. London, pp. 329 - 355.

[10] Joseph, M. 1959. Biology, binomics and economic importance of some reduviids collected from Delhi. *Indian Journal of Entomology,* 21, 46 - 58.

[11] Lakkundi, N. S. 1989. Assessment of reduviids for their predation and possibilities of their utilization in biological control. *Ph.D. thesis. Indian Agricultural Research Institute.* New Delhi.

[12] Sahayaraj, K. 1991. Bioecology, Ecophysiology and ethology of chosen predatory hemipterans and the potential in Biological control (Insecta: Heteroptera: Reduviidae). Ph. D. thesis, Madurai Kamaraj University, Madurai, India.

[13] Vennison, S. J. and Ambrose, D. P. 1988. Impact of space on stadial period adult longevity, morphometry, oviposition, hatching and preyu capturing in *Rhinocoris marginatus* Fabricius (Insecta, Heteroptera, reduviidae). *Mitt. Zool. Mus. Berl.* 64(2), 349 - 355.

[14] Sahayaraj, K. 1994a. Biocontrol potential evaluation of the reduviid predator *Rhinocoris marginatus* Fab. to the serious groundnut pest *Spodoptera litura* Fab. by functional response. *Fresenius Envi. Bull.* 3(9), 546 - 550.

[15] Sahayaraj, K. 1994b. Capturing success by reduviid predators *Rhynocoris kumarii* and *R. marginatus* on different age groups of *Spodoptera litura,* a polyphagous pest (Heteroptera: Reduviidae) *Journal of Ecobiology,* 6(3), 221 - 224.

[16] Lakkundi, N. H. and Parshad, B. 1987. A technique for mass multiplication of predators with sucking type of mouth parts with special reference to Reduviids. *Journal of soil biology and ecology.* 7(1), 65 - 69.

[17] Sahayaraj, K., Sathyamoorthi, P. and Rajamanickam, K. 2001. Rearing media on *Corcyra cephalonica,* Stainton biology and life table*. Shashpa*. 8(2): 125 – 130.

[18] Birch, S. 1948. The intrinsic rate of natural increase in an insect populations. *Journal of Animal Ecology,* 17, 15 - 26.

[19] Watson, T. F. 1964. Influence of host plant condition on population increase of *Tetranychus telerium* (L) (Acarina: Tetranychidae). *Hilgardia,* 35, 273 – 322.

[20] Southwood, T. R. E. 1978. Ecological methods with particular reference to the study of insect population. *Chapman and Hall,* London. 524 pp.

[21] Daniel, W.W. 1987. *Biostatistics: A foundation for analysis in the health science*. New Yark, John Wiley & Sons.

[22] Ambrose, D. P., Saju, T. and Sahayaraj, K. 1990. Prey influence on the development, reproduction and size of assassin bug, *Rhynocoris marginatus. Environment and Ecology*, 8(1), 280 - 287.

[23] Ambrose, D. P. and Jenoba, T. 1988. Effect of crowding on the development and size of *Coranus soosai. Environment and Ecology,* 6(4), 843 - 848.

[24] Eveleigh, E. S. and Chant, D. A. 1982. Experimental studies on acarine prdator-prey interactions: the numerical response of immature and adult predator (Acarina: Phytoseiidae) *Canadian Journal of Zoology,* 60, 630 – 638.

[25] Wylie, H. G. 1965. Some factors that reduce the reproductive rate of *Nasonia vitripennis* (walk) at high adult population densities. *Canadian Enthomologist.* 97, 970 – 977.

[26] Ambrose, D. P. and Sahayaraj, K. 1991. Camouflaging behaviour and the effect of decamoufaging on behaviour and development of *Acanthaspis pedestris* stĺl. in solitary and crowded conditions (Insecta: Heteroptera: Reduviidae). *Mitt. Zoo. Mus. Berl,* 67, 325 - 337.

[27] Ambrose, D. P. 1980. Bioecology, ecophysiology and ethology of Reduviids (Heteroptera) of the scrub jungles of Tamil Nadu, India. Ph. D. thesis, University of Madras, Madras, India.

[28] Kumar, S. P. 1993. Biology and bevaviour of chosen assassin bugs (Insecta: Heteroptera: Reduviidae). Ph. D. thesis, Madurai Kamaraj University, pp. 68 - 133.

[29] Kumaraswami, N. S. 1991. Bioecology and ethology of chosen predatory bugs and their potential in biological control, Ph. D. thesis, Madurai Kamaraj University, Madurai, India.

[30] Subbiah, M. S. and MAHADEVAN, V. 1957. The life history and biology of the reduviid *Acanthaspis siva,* a predator of the Indian honey bee *Apis indica. Indian Journal of Veterinary Science.* 27, 117 – 122.

[31] Ambrose, D.P. and Livingstone, D. 1985. Delopement of *Coranus vitellinus* Distant (Hemiptera: Reduviidae) . Journal of Soil biology and Ecology. 5, 65 – 71.

[32] Ambrose, D. P. and Livingstone, D. 1987. Biology of a new harpactorine assassin bug *Rhynocoris kumarii* (Hemiptera: Reduviidae) in South India. *Journal of Soil biology and Ecology.* 7, 48 – 58.

[33] Ambrose, D. P., Sahayarani, M. R. and Vennison, S. J. 1988. Effect of crowding on the camouflaging behaviour, size, development, oviposition pattern and hatchability of offspring of *Acanthaspis pedestris* Stĺl. A potential predator of insect pests (Heteroptera: Reduviidae) *Monitore Zool. Ital. (N. S.)* 22, 111 - 120.

[34] Sahayaraj, K. and Ambrose, D. P. 1994. Prey influence on laboratory mass rearing of *Neohaematorrhophus therassi* Ambrose & Livingstone, a potential biocontrol agent (Insecta: Heteroptera: Reduviidae) *Bio-science Research Bulletin,* 10(1), 35 – 40.

[35] Evans, H. F. 1976. The effect of prey density and host plant characteristics on oviposition and

fertility in *Anthocoris confusus* (Reuter). *Ecol. Ent.* 1, 157 – 161.

[36] George, P. J. E., Seenivasagan, R. and Kannan, S. 1998a. Influence of prey species on the development and reproduction of *Acanthaspis siva* Distant (Heteroptera: Reduviidae). *Entomon,* 23(4), 69 - 75.

[37] Venkatesan, S., Seenivasagan, R. and Karuppasamy, G. 1997. Influence of prey species on feeding response, development and reproduction of the reduviid, *Cydnocoris gilvus* Burm. (Reduviidae: Heteroptera) *Entomon.* 22(1), 21 - 27.

[38] Southwood, T.R.E. 1978. Ecological methods with particular reference to the study of insect population. Chapman and Hall, London. 524 pp.

[39] Sharma, K. C., Bhalla, O. P. and Chauhan, O. 1994. Life table and intrinsic rate of increase of *Eupeodes frequence matsmura:* a predator of *Brevicoryne brassicae* infesting cauliflower. *J. Biol. Cont.* 8(1), 56 - 58.

[40] George, P. J. E., Seenivasagan, R. and Kannan, S. 1998b. Biology and life table studies of *Acanthaspis pedestris* Stal. (Heteroptera: Reduviidae) population on three lepidoptern insect pest. *J. Biol. Control,* 12(1), 1 - 6.

[41] Ambrose, D. P. and Kumaraswami, N. S. 1993. Food requirement of *Rhynocoris fuscipes* Fab. *J. Biological Control.* 7(2), 102 – 104.

[42] Sahayaraj, K. 1999. Field evaluation of *Rhynocoris marginatus* (Fab.) against two groundnut defoliators. *International Arachis Newsletter,* 19, 41 - 42.

[43] Kopec, S. 1922. Studies on the necessity of the brain for the inception of insect metamorphosis. *Biological Bulletin.* 42, 323 - 342.

Kitherian Sahayaraj, ttn_ksraj@sancharnet.in,
Crop Protection Research Centre, Department of Zoology, St. Xavier's College,
Palayamkottai - 627 002. Tamilnadu, India ,
Tel (0461) 361957, Fax 0462 – 582765