SUMMARY: The effective utilization of any biological control agent relies upon its comprehensive knowledge on bioecology, ecophysiology and behaviour. Hence, in the present study, the biology and predatory behaviour of third, fourth and fifth nymphal instars and adults of an assassin bug, *Sycanus collaris* (Fabricius) to the larvae of rice meal moth, *Corcyra cephalonica* (Stainton) and leaf armyworm, *Spodoptera litura* (Fabricius) was observed in the laboratory. The eggs were laid in clusters and cemented to each other and the surface of the plastic cylinder. The egg hatched after 11 to 15 days with each cluster having 15 to 70 eggs. Five nymphal instar stages were recorded. The mean longevity of each nymphal stage was 11.38±0.55, 12.24±1.87, 12.58±1.24, 14.62±1.67, 15.42±1.14 days when fed with *C. cephalonica* and 12.54±0.57, 12.24±1.12, 13.26±1.16, 14.42±0.86, 16.58±1.70 days when fed with *S. litura*. The mean longevity of male and female adult fed with *C. cephalonica* was 73.58±2.12 and 80.64±3.40 days, respectively. The mean longevity of male and female adult fed with *S. litura* was 75.82±2.82 and 85.48±3.20 days, respectively. The sequential acts of predatory behaviour and the time taken for each predatory act such as arousal, approach, capturing, paralysing, sucking and postpredatory behaviour and the number of piercing and sucking sites were observed. The predator took less time to predate upon the larvae of *S. litura* than that of *C. cephalonica*.


BACKGROUND AND OBJECTIVES

The Reduviidae is the largest family of predaceous land Hemiptera and many of its members are found to be potential predators of a number of insect pests (Ambrose, 1999, 2000 and 2003 and Ambrose et al., 2009).

Since they are polyphagous predators they may not be useful as predators on specific pests but they are valuable predators in situations where diverse insect pest species occur. However, they exhibit certain amount of host as well as stage preferences. Hence,
they should be conserved and augmented to be effectively utilized in Integrated Pest Management (IPM) programmes (Ambrose, 1999, 2000 and 2003 and Ambrose et al., 2003, 2006 and 2007). Conservation and augmentation of any biological control agent rely on its comprehensive knowledge on bioecology, ecophysiology and behaviour (Ambrose and Claver, 1996; Ambrose et al., 2009 and Das et al., 2008). The genus *Sycanus* is a predominate group of harpactorine reduviids in India and its members are very good predators with biological control efficiency. The impressive prey record of *Sycanus collaris* (Fabricius) (Ambrose, 1999; George et al., 1998; Singh, 1998 and George, 2000a) prompted the authors to study the feasibility of utilizing this biological control agent by augmenting and subsequently releasing it into the agro-ecosystem. Though information on predatory behaviour of many reduviids is available very little information is documented for *S. collaris*. Hence, an attempt was made to study the biology and predatory behaviour of *S. collaris* two lepidopteran prey viz., rice meal moth *Corcyra cephalonica* (Stainton) and leaf armyworm *Spodoptera litura* (L.).

**RESOURCES AND METHODS**

The adults of *S. collaris* were collected from tomato field, NIPHM, Hyderabad, South India. They were reared in the laboratory in plastic containers (30 x 10 cm) on rice meal moth *C. cephalonica* under laboratory condition (temp. 32±2°C, 75±5 rh and 12±1 hr photo period). The adults that emerged were allowed to mate. The containers were carefully examined at regular intervals to record the eggs laid as well as spermatophore capsules ejected after successful copulation. The eggs laid in the laboratory were allowed to hatch in individual petri dishes (9.2 x 2 cm) with wet cotton swabs for maintaining optimum humidity (85%), separately. The cotton swabs were changed periodically in order to prevent fungal attack. Mated females were maintained individually in order to record the number of batches of eggs and number of eggs in each batch laid by them. Each batch of eggs allowed to hatch in individual containers. The predators were reared in the laboratory for two generations to find out the incubation period, stadial period, fecundity, longevity and sex ratio.

The predatory behaviour was assessed by taking one day prey deprived third, fourth and fifth nymphal instars and adults were used for the experiment. Each predator was placed in a plastic container (16 x 7 cm) with the test prey species *i.e.*, about 1.5 cm long *C. cephalonica* and 2.5 cm long *S. litura* larvae, separately. For each life stage of the predator six replicates were maintained. The sequential pattern of predatory behaviour and the time taken for each predatory acts such as arousal, approach and capturing, paralysing, sucking, post predatory acts and the number of piercing sites were recorded for each test predators.

**OBSERVATIONS AND ANALYSIS**

*Sycanus collaris* (Fabricius) eggs were brown in colour and laid in clusters. The eggs glued together vertically with substratum. The average fecundity of female on *C. cephalonica* and *S. litura* was 256.58±5.68 and 340.82±3.56 eggs, respectively. The incubation period was 12.42±0.62 and 11.56±0.48 days on *C. cephalonica* and *S. litura*, respectively. The stadial periods of I, II, III, IV and V nymphal instars of *S. collaris* of *C. cephalonica* was comparatively shorter (11.38±0.55, 12.24±1.87, 12.58±1.24, 14.62±1.67 and 15.42±1.14 days, respectively) than those of *S. litura* (12.54±0.57, 12.24±1.12, 13.26±1.16, 14.42±0.86 and 16.58±1.70 days, respectively). The male and female adults fed with *S. litura* had longer life spans with 75.82±2.82 and 85.48±3.20 days. The range was nine to 127 days for the male and twelve to 142 days for the females. The longevity of male and female *S. collaris* adults fed with *C. cephalonica* was 73.58±2.12 and 80.64±3.40 days. Female biased sex ratios of *S. collaris* (male: female) were observed in *S. litura* (0.82:1) and *C. cephalonica* (0.85:1), respectively.

Immature stages of *S. collaris* attained 92.11% survival when nymphs were fed with an excess of leaf armyworm *S. litura* larvae. Such better survival was also observed in other reduviids namely *S. dichotomus* on larvae of *S. litura* and *C. cephalonica* (Zulkefli et al., 2004); *R. marginatus* (niger, sanguineous and nigrosanguineous morphs) on cotton leaf worm *S. litura* (George, 1999) and namely *R. kumarii* on larvae of *S. litura*, *Earias vitella* Fab. and *C. cephalonica* (George, 2000b). Nymphal mortality was mainly due to the pronounced cannibalistic tendency among nymphal instars. Newly moulted reduvid nymphs with soft cuticle were main victims of cannibalism (Ambrose, 1980 and 1999; Ambrose and Paniadima, 1988). Abnormalities and natural hazards in hatching, moulting, combat against...
powerful prey etc., were a few other causes of nymphal mortality in Spedanolestes signatus Distant and Velitra sinensis Walker (Vennison and Ambrose, 1990 a and b).

S. collaris exhibited a pin and jab mode of predation (Ambrose, 1999). The timetaken for the sequential acts such as arousal, approaching, capturing, paralysing, sucking and postpredatory behaviour and the number of piercing sites recorded for third, fourth and fifth nymphal instars and adults of S. collaris to the larvae of C. cephalonica and S. litura are presented in Table 1. The visual stimulus from the moving prey excited an arousal response in S. collaris. The III, IV and V nymphal instars and adults of S. collaris took 0.41±0.1, 0.36±0.06, 0.34±0.05 and 0.30±0.2 min for C. cephalonica larva and 0.45±0.07, 0.45±0.11 0.43±0.05 and 0.4±0.15 min for S. litura larva, respectively. The life stages of S. collaris took less time to arouse towards C. cephalonica larva than towards S. litura larva. The importance of vision in prey location and subsequent arousal response in predation was proved by eye blinding experiments in many assass in bugs (Ambrose, 1999; Ambrose et al., 2007; Das and Ambrose, 2008a and b). The moving prey offered a stimulus to the reduviids which lead the reduviid to arouse from a state of akinesis to a high level of excitement. The moving prey offered important stimulus in the primary sensory input for arousal in predation by reduviids (Ambrose, 1999; Haridass and Ananthakrishnan, 1980; Haridass et al., 1988; Louis, 1974; Nitin et al., 2017; Odhiambo, 1958 and Swadener and Yonke, 1973).

Once the predator got aroused, it turned towards the direction of the prey and approached towards the prey and captured the prey. While approaching and capturing the prey, predator stood in juxta tibial position and extended its antennae towards prey. S. collaris took more time for approaching and capturing a C. cephalonica larva (0.14±0.02, 0.12±0.03, 0.12±0.03 and 0.1±0.04 min. for III, IV and V nymphal instars and adults, respectively) than a S. litura larva (0.15±0.04, 0.13±0.03, 0.13±0.03 and 0.12±0.03 min for III, IV and V nymphal instars and adults, respectively). The time taken for prey approaching and capturing, varied in other harpactorines due to their prey capturing potential, as well as the prey types (Ambrose, 1999). Edwards (1962) stated that antennal movement of the Rhynocoris carmelita Stål was the key sensory input to approach the prey. Claverand Ambrose (2001) stated that under normal circumstances information was first perceived through the compound eyes before eliciting a predatory movement. The sensory hairs of the fore legs were

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Coryza cephalonica</th>
<th>Spodoptera litura</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubation period</td>
<td>12.42±0.62</td>
<td>11.56±0.48</td>
</tr>
<tr>
<td>Nymphal periods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I nymphal instar</td>
<td>11.38±0.55</td>
<td>12.54±0.57</td>
</tr>
<tr>
<td>II nymphal instar</td>
<td>12.24±1.87</td>
<td>12.24±1.12</td>
</tr>
<tr>
<td>III nymphal instar</td>
<td>12.58±1.24</td>
<td>13.26±1.16</td>
</tr>
<tr>
<td>IV nymphal instar</td>
<td>14.62±1.67</td>
<td>14.42±0.86</td>
</tr>
<tr>
<td>V nymphal instar</td>
<td>15.42±1.14</td>
<td>16.58±1.70</td>
</tr>
<tr>
<td>Adult longevity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>73.58±2.12</td>
<td>75.82±2.82</td>
</tr>
<tr>
<td>Female</td>
<td>80.64±3.40</td>
<td>85.48±3.20</td>
</tr>
<tr>
<td>Preoviposition period</td>
<td>8.48±1.24</td>
<td>7.86±1.32</td>
</tr>
<tr>
<td>Oviposition period</td>
<td>48.52±2.61</td>
<td>53.48±2.14</td>
</tr>
<tr>
<td>Postoviposition period</td>
<td>15.18±2.28</td>
<td>12.56±0.93</td>
</tr>
<tr>
<td>Total no. of eggs/female</td>
<td>256.58±5.68</td>
<td>340.82±3.56</td>
</tr>
<tr>
<td>Sex ratio (male: female)</td>
<td>0.85:1</td>
<td>0.82:1</td>
</tr>
</tbody>
</table>

Table 1 : Biology of Sycanus collaris reared on larva of rice meal moth, Corcyra cephalonica and leaf armyworm, Spodoptera litura (n=6; X ± SE)

<table>
<thead>
<tr>
<th>Prey species</th>
<th>Predator stage</th>
<th>Arousal</th>
<th>Approach and capturing</th>
<th>Paralysing</th>
<th>Sucking</th>
<th>Post predatory acts</th>
<th>No. of piercing and sucking sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coryza cephalonica</td>
<td>III nymphal instar</td>
<td>0.41±0.1</td>
<td>0.14±0.02</td>
<td>0.05±0.02</td>
<td>37.07±0.82</td>
<td>0.08±0.02</td>
<td>5.86±1.52</td>
</tr>
<tr>
<td></td>
<td>IV nymphal instar</td>
<td>0.36±0.06</td>
<td>0.12±0.03</td>
<td>0.06±0.02</td>
<td>49.04±4.66</td>
<td>0.09±0.01</td>
<td>8.36±1.61</td>
</tr>
<tr>
<td></td>
<td>V nymphal instar</td>
<td>0.34±0.05</td>
<td>0.12±0.03</td>
<td>0.03±0.01</td>
<td>52.24±3.65</td>
<td>0.08±0.02</td>
<td>8.36±1.40</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.30±0.2</td>
<td>0.1±0.04</td>
<td>0.02±0.02</td>
<td>67.09±6.75</td>
<td>0.06±0.02</td>
<td>9.8±1.52</td>
</tr>
<tr>
<td>Spodoptera litura</td>
<td>III nymphal instar</td>
<td>0.45±0.07</td>
<td>0.15±0.04</td>
<td>0.06±0.02</td>
<td>47.01±5.76</td>
<td>0.1±0.02</td>
<td>11.27±1.12</td>
</tr>
<tr>
<td></td>
<td>IV nymphal instar</td>
<td>0.45±0.11</td>
<td>0.13±0.03</td>
<td>0.04±0.02</td>
<td>62.05±7.46</td>
<td>0.09±0.02</td>
<td>11.32±2.18</td>
</tr>
<tr>
<td></td>
<td>V nymphal instar</td>
<td>0.43±0.05</td>
<td>0.13±0.03</td>
<td>0.04±0.02</td>
<td>67.24±5.69</td>
<td>0.09±0.05</td>
<td>13.10±1.38</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.4±0.15</td>
<td>0.12±0.03</td>
<td>0.03±0.02</td>
<td>75.07±5.53</td>
<td>0.08±0.03</td>
<td>13.32±1.57</td>
</tr>
</tbody>
</table>
responsible for immediate capture of the prey (Putchkova, 1979). Edwards (1962), Ables (1978) and Ambrose (1999) stated that the reduviid predators with tibial pads are better adapted for capturing the prey. Moreover, antennal perception of kairomones and allomones plays a major role in the prey capturing (Hagen, 1987). Rani and Wakamura (1993) reported that the prey odours were first perceived by antennal receptors, triggering the approach.

After the successful capturing of the prey the predator paralysed the prey by injecting its toxic salivary secretion. The predator took more or less same time (0.05±0.02, 0.06±0.02, 0.03±0.01 and 0.02±0.02 min for III, IV and V nymphal instars and adults, respectively) for C. cephalonica and (0.06±0.02, 0.06±0.02, 0.04±0.02 and 0.03±0.02 min for III, IV and V nymphal instars and adults, respectively) for S. litura. Complete paralysis of the prey was determined by the absence of clicking movement of the prey’s head. Similar observations were also observed in other reduviids (Ambrose, 1999; Ambrose and Claver, 1996; Ambrose and Ambrose, 2001; Ambrose et al., 2006, 2007 and 2009; Das and Ambrose, 2008a, b; Das et al., 2008 and Nitin, 2017). After paralysing the prey, the predator released its grip over the prey and sucked the predigested body fluid of the prey at ease by inserting the stylets all over the body without preferring a particular site of the prey. In contrary, Claver et al. (2004) reported that S. collaris preferred to suck around the head region followed by the abdominal region. The III, IV and V nymphal instars and adults (37.07±0.82, 49.04±4.66, 52.24±3.65 and 67.09±6.75 min, respectively) took more time for sucking a C. cephalonica larva than a S. litura larva (47.01±5.76, 62.05±7.46, 67.24±5.69 and 75.07±5.53 min, respectively).

After sucking the prey at all possible sites, predator started to clean its tibiae, antennae and rostrum. The duration of post predatory activities of III, IV and V nymphal instars and adults were comparatively shorter (0.08±0.02, 0.09±0.01, 0.08±0.02 and 0.06±0.02 min in, respectively) in C. cephalonica predation when compared to these in S. litura predation (0.1±0.02, 0.09±0.02, 0.09±0.05 and 0.08±0.03 min). In the final act of predation, the empty case of the host was dragged and left off and the predator cleaned its antennae and rostrum by the foretibial pads (Ambrose, 2002).

The number of piercing and sucking sites also decreased in C. cephalonica (5.86±1.52, 8.36±1.61, 8.36±1.40 and 9.8±1.52 in III, IV and V nymphal instars and adults of the predator, respectively) than in S. litura (11.27±1.12, 11.32±2.18, 13.10±1.38 and 13.32±1.57) due to the larger size of S. litura. Though the sequential acts of predatory behaviour of S. collaris on both the larvae of C. cephalonica and S. litura were similar, the prey type influenced predation. For instance, the life stages of S. collaris quickly predate the larvae of S. litura than the larvae of C. cephalonica by capturing and sucking. Such prey influenced predation as a function of prey predator interaction was reported for several reduviids (Ambrose, 1999). As the life stages grew, the efficiency of predatory acts such as capturing, paralysing and sucking also increased. This might be attributed to the predators’ size governed predatory efficiency and the larger quantum of toxic saliva available for paralysing the prey. Thus, the size of the predator in relation to prey size plays a vital role in prey capturing (Ambrose, 1999; Nitin, 2017). In the present study, S. collaris easily handled the natural prey, S. litura than the laboratory prey, C. cephalonica which reveals the specific prey-predator interaction.

Acknowledgement:

S. Jesu Rajan is grateful to Department of Science

Plate 1: Pin and jab predation of Sycanus collaris Nymph (a. on C. cephalonica and b. on S. litura) and adult (c. on C. cephalonica and d. on S. litura)
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