Pest Control Mechanism of Reduviids

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1.1 Introduction

The word "bug" is sometimes used to refer to insects in a general sense. However, insects are a difficult group to generalise about since their ranks include one million described species on earth today. Entomologists believe that there may be as many as 10 million to 30 million more species of insects left to describe and explore. For comparison purposes, consider that there are only 4,629 species of mammals on earth and a total of 44,000 species of vertebrates including all birds, reptiles, amphibians, mammals and fish. What is a bug? Scientifically speaking, a "bug" is a type of insect that belongs to the order of Hemiptera or Heteroptera. This group bears the common name of "true bugs" and includes 35,000 different species. Examples of true bugs are giant water bugs, backswimmers, water boatmen, stink bugs and assassin bugs. They can be distinguished from other insects by their mouthparts and wing structure. The mouthparts of true bugs are formed into a piercing-sucking structure used for sucking plant juices or animal fluids for food.

The suborder Hemiptera: Heteroptera or true bugs contains nearly 6,224 species (Capriles, 1990). While most species are zoophagous, there are many that are predators. Distant (1902 and 1910) recorded 342 species from 106 genera and 13 subfamilies from Indian faunal limits, later 69 species and 11 genera were included (Ambrose and Vennison, 1989a; Ambrose and Livingstone, 1986a and 1986c, Vennison and Ambrose, 1988b; Ambrose, 1999) from the same location. I know approximately 120 species of bugs from the state of Tamil Nadu (unpublished). Livingstone and Ravichandran (1988a, b, c, 1989a, b, c, 1990a, b, 1991, 1992), Murugan (1988), Ravichandran (1988) and Murugan and Livingstone (1995a and 1995b) also reported many species of these bugs from different parts of Tamil Nadu. Future collections will enrich our knowledge of the species. I thank all those who worked so hard to bring this knowledge to us, especially those involved in the actual collection of the material and label all of the specimens. Their efforts are much appreciated. The assassin bugs constitute a large group of insects belonging to the family Reduviidae of true bugs. None of the insect species occurs naturally throughout the world. The cousins in the order Hemiptera include plant bugs, damsel bugs, lace bugs, stink bugs and bed bugs.

1.2 Nicknames

The family Reduviidae includes the Assassin bugs, Ambush bugs and the Thread-Legged Bugs Reduviids belong to the genus emesinae are called "thread-legged bugs". The Assassin bugs look like Squash bugs and Leaf-Footed bugs too. The masked hunter assassin bug tends to be rather large. It is found in the basement of homes in Milwaukee. The wheel bug, an assassin bug, is usually brown or black (*Arilus cristatus* Linnaeus). This Wheel bug is found in a Maple tree in Waukesha County It has been occurring from Ontario and New York, south to Florida and west to Lowa, Kansas, and New Mexico; it also has been reported from Mexico and Guatemala This species is commonly found on trees and shrubs, but can be collected from other vegetation. Apiomerinae have the habit of coating their forelegs or body with resin for the purpose of coating prey and hence they called as "resin bugs" (Usinger, 1956). In some tropical countries, Assassin bugs are a human pest and can cause some serious discomfort by sucking blood. These, assassin bugs, sometimes known as Conenoses or Kissing bugs are killer insects that feed on blood or other insects. The kissing bug label comes from the insect's ability to steal a blood meal by piercing the lips, eyelids or ears of a sleeping human victim. However, most are predaceous on insects and other arthropods

Many species may bite humans if carelessly handled. Their bite can be very painful. The marked hunter bug is a plearctic European species that has been introduced into the U.S. It is now a wide spread U.S species that is commonly found in Vermont homes. The Wheel bug, *Arilus cristatus* is a moderately common and distributed in Florida, Mexico, Guatemala and U.S. It was given the name because of crested pronotum, notched along the median line. Young children because of its interesting appearance frequently pick it up They quickly learn, however, that this predator of other insects will inflict a painful bite as a defensive tactic. Emesinae from the Netherlands are so called "thread-legged bugs" is characterised by elongate body shape, very long and slender legs and antennae, raptorial forelegs with elongate coxae and acetabula opening forward (Cobben and Wygodzinsky, 1975). There are more than 160 species in the family Reduviidae in North America, many of which are fairly common. The bug *Pristhesancus plaqipennis* Walker is called as Large Australian Assassin Bug. The masked hunter gets its name from looking like a moving dust bunny. The younger ones accumulate dust on their bodies and lurk for unsuspecting insects to eat. *Acanthaspis* spp. present in Wisconsin is called Asian Ladybugs. Hunting bugs from Africa are called Ant Chasing Bug *Rhynocoris* spp. dwelled in different parts of Tamil Nadu, India is called DMK poochi (poochi = insect). *Rhynocoris kumarii* Ambrose and Livingstone present in Kanyakumari district, Tamil Nadu, India, are called kotti. *Catamiaraus brevipennis* Distant is commonly known as "Kallukatti". This reduviid is found underneath the large boulders. *Melanolestes picipes* is commonly called "black bugs". *Pasahus bighttatus* was found in South Western states of Mexico and West Indies and it is commonly called "Corsairs." Since almost all the predatory reduviids hunt its prey by rostrum, "hunter reduviid" is an appropriate term for predatory reduviids.

1.3 Where to find them

Assassin bugs can be found throughout the world in areas including both tropical and temperate countries like Africa, America, Ukraine, Australia, Brazil, Canada, Malaysia, Singapore, etc. Reduviids are quite diverse in the tropics and inhabiting a variety of habitats on the ground, herbs, shrubs, on the bark and foliage of trees of semiarid zones, scrub jungles, forests and agro-ecosystems. They are not only present in the plains but also in the islands. For instance Cobben and Wygodzinsky (1975) collected 6 emesinae, 1 saicinae, 8 harpactorinae, 1 peiratinae, 4 stenopodinae and 1 phymatinae from Curacao and other Caribbean islands of the Netherlands. *Empicoris orthoneuron* McAtee has been collected from flood debris, Spanish moss, and under dead leaves (Elkins, 1951). Generally they are associated with particular food, defence and breeding requirements for various species. Thus, ant-feeding reduviids are found under the loose bark of primary forest trees while millipede feeders are found on the ground underneath leaf litter. They have been known to hide out in bathtubs, sinks and drains, but they are more commonly found in savanna and forest habitats on bushes, tall vegetation or in wood, rat nests and raccoon dens. Reduviids are mainly present in semi-arid zones, scrub jungles, forests and agro-ecosystems where they inhabit on the ground, herbs, and shrubs and on the bark and foliage of trees. In semi-arid zones and scrub jungles reduviids are mainly present underneath the stones (both small and large). *Stenolemus lanipes* Wygodzinsky (Emesinae) have been reported to associate with spider webs (Brown and Lollis, 1963). Similarly another emesine, *Stenolemus susainathan* Wygodzinsky and *Rhynocoris atkinsoni* Bergroth were collected from nest of the termites (termitorium) (Ambrose, 2001b). *Melanolcstes picipes* is a common black bug found under stones, logs and moss. Blatchley (1926) collected nearly 50 hibernating *Oncerotrachelus accminatus* (Say) beneath logs in Indiana. He further said that three pairs of adults, one female, and three nymphs are found in groups. Many reduviids dwell in more than one place. In India most of the reduviids are present in forests followed by semi-arid zone, scrub jungles, and agro-ecosytems African assassin bugs mainly dwell in the tress of sub-humid savanna and the gallery forest of the Ivory Coast. Many reduviids are often attracted to lights in the home. Blinn (1994) collected the reduviids at night, either at ultraviolet or mercury vapour lights. A bug from Java *Ptilocerus ochraceous* an ant feeder frequents the bamboo rafters of house and frequently occurs in large numbers For instance, I found that reduviids either co-inhabitation with other reduviids or other insects from different orders especially Coleoptera, Blattaria or Orthoptera or vertebrates like amphibians or reptiles. *Catamiarus brevipennis* is found underneath the large boulders. It was found together with snakes and carabid beetles. *Acanthaspis pedestris* Stal lives either in single or in solitary conditions. Further, number of males (5) and females (2) of this bug were found together and also with nymphs (3) and adults of other reduviids like *Catamiarus brevipennis* (7). Different stages of the *Coranus subapterus* De Gree prefer to live in different habitats. For instance, the early stages live in the sand, intermediate stages prefer moss and lichens and late stages live in *Salix or Carex* (Wallace, 1953). Similarly *Platymerus rhadamanthus* Gerst early instars frequently found in shady parts of the crown of the coconut palm during the daytime, later instars and adults hiding near each other in the debris in the axils of leaves of the crown of the coconut palm (Vanderplank, 1958). *Holoptilus melanospilus* Walker adults and nymphs were always associated with small black ants. *Ectrychotes artipennis* Stal population coincided with the presence of millipede in Godayar tropical rain forest. *Rashuas biguttatus* Stal lives under the re-rocks or logs and is very active whenever they inhabit in logs Some species of the genus *Conorhinus* are found in houses where the young have been seen with a covering of dust etc. adhering to the body. Nymphal instars of *Salyavata variegata* mainly lives in palm and nymphs on the repairing mouth of *Nasutitermes corhiger* termite nests. Both nymphs and adult of *Acanthaspis siva* freely lurk around the hives, crevices or in tree trunk near the location of the nests of the Indian bee. Similarly *Pristhesancus papuensis* Stal has also been observed on honey bees *Apis mellifera* Linn. Occasionally, reduviids like *Allaeocranum biannulipes* (Montr. Et. Singh) was collected from flour mills in Lower Egypt.

1.4 Classification

Animal Kingdom: Invertebrates
Phylum: Arthropoda
Class: Insecta (32 orders)
Order Hemiptera
Pronunciation: he-MIP-ter-ra
Suborder Heteroptera
Division: Gymmocerata
Superfamily: Reduviidae
Family: Reduviidae
Common name: true bugs/assassin bugs

1.5 Salient features of Hemiptera

The members of this order commonly referred to as bugs, vary greatly in size. They are mostly terrestrial, some are aquatic or semi-aquatic. They are widely distributed throughout the world. Front wings generally hemelytrous, *i.e.*, thickened at the base and membranous at the tip. Hind wings are always membranous and generally shorter than the fore wings. Antennae consist of five or fewer segments. Mouth parts with a three or four segmented beak arising from the front of the head. The most distinctive feature of the Hemiptera is the piercing and sucking type of mouthparts Tarsi consist of 3 or fewer segments.

Similar looking orders.

Homoptera: front wings of uniform texture rather than hemelytrous, beak arising from rear of head.

Coleoptera: front wings meet in straight line down the back, antennae with 8 or more segments; mouth parts chewing; tarsi often with 4 or 5 segments.

Orthoptera, Phasmida, Mantodea: antennae many segmented, moth parts chewing

1.5.1 Family Identification

Hemiptera: Reduviidae
Pronunciation: reh-deu-VIE-i-dee
Common names. assassin bugs, thread-legged bugs, kissing bugs, conenoses etc.

Initially China and Miller (1959) reported 29 sub families in Reduviidae Recently, Capriles (1990) recognised 24 subfamilies with 913 genera, consists of 6,224 valid species. From India, Distant (1902, 1904 and 1910) described 342 species of reduviids belonging to 106 genera and 13 sub-families including Nabidae, Reduviidae, Triatominae and Cenmtrocheminae and Acanthaspidinae. The subfamilies included Harpactorinae, Reduviinae, Peiratinae, Ectrichodinae, Stenopodainae, Emesinae, Salyavatinae, Triatominae and Tribelocephalinae. To be seen your insect is an Assassin bug, it has the following features

1.5.2 Reduviid morphology

The typical insect body has been derived from an ancient ancestor composed of 20 segments. Through the specialisation of functions in different regions, these segments came to be grouped into three body regions. Six segments amalgamated to form the head, three to form the thorax, and eleven to form the abdomen. By modification, fusion and deletion, the separate segments of the head have all but lost the suggestion of their segmented origin The thoracic segments, though often strongly fused and much modified can be clearly recognised. The abdominal segments have generally retained a looser association and retain some indication of the definitive number. The insect body is divided into three major parts such as head, thorax and abdomen. The head bears the sensory and oral organs, the thorax has locomotory appendages and the abdomen has reproductive organs (see Figure 1). The Reduviidae vary greatly in body size and shape, ranging from small and either slender or robust to fairly long and slender like some walking sticks. The characteristic feature that distinguishes them from all other hemipterans is the stout 3-segmented beak that fits into a groove on the pro-sternum. Once students view a number of specimens from the side and become familiar with this characteristics, this family is readily identified the large, smooth or hairy predatory assassin bugs.

1.5.2a Head

The head comprises the anterior body region. It is normally a capsule with a sclerotised upper portion protecting the brain and a membranous floor in which is situated the oral opening or mouth. Head is more or less elongate, mobile and immersed to the eyes. Its long narrow head holds the deadly weapon which is used to prey on its victims—a segmented proboscis (beak) (Fig.1a.). Anteocular area is shorter than the postocular area or equal or sub-equal in nature. Generally head longer than broad, often freely movable. Assassin bugs have a structure behind the eyes that looks like a neck and constructed behind The structures present on the head capsule are: eyes, antennae

1.5.2b Eyes

Compound eyes are usually large, many-faceted structures on the upper side of the head capsule. Compound eyes are large and protruded outside and placed at a considerable distance from thorax. Ocelli when present are three single-faceted organs usually between the antennae and forming an inverted triangle on the front of the head. They have these little ocelli or the simple eyes—behind the big compound eye size of its eyes large, when they are compared with penny. Ocelli when present are placed behind the eyes or absent.

1.5.2c Antennae

There is a pair of movable segmented appendages usually situated between the eyes whose function is largely the perception of chemical stimuli. They are extremely varied in shape and numbers of segments and are important diagnostic features. Names have been applied to the more striking types. Diversity of antennal details provides diagnostic features. Examples of antennal types are: Thread-like antennae of a bug like reduviids. The wheel assassin bug has a dinosaur like structure on its back, antennae thread-like at the tip, longer than the head; close up of the hairy wheel of the wheel assassin bug. Antenna usually having 3-8 segments, of moderate length, is sometimes very long and in some cases hairy (Figure 1b).

1.5.2d Mouthparts

Insect mouthparts have become variously modified to perform the function of ingestion The mouthparts of the mature adult insect may be of a different type than those of its immature form. The sucking mouth or beak or rostrum short, curved with 3-segmented rostrum, has the tip a striated furrow between fore coxae. It is used like a straw to suck the tasty juices of its victims. The rostrum of Harpactorinae is long and slender and capable of considerable forward extension (Figure 1c). This is aptly suited for the pin and jab type of feeding behaviour. Some sub-family has short curved rostrum capable of less than 45° forward extensions. Assassin bug's mouthpart is piercing and sucking type.

1.5.3 Thorax

The thorax is the body region present between the head and the abdomen. It is composed of three segments, the prothorax, mesothorax, and metathorax (see Figure 1b). The prothorax bears the first pair of legs; the mesothorax the second, and the metathorax the third The first pair of wings is borne on the mesothorax, the second, if present, on the metathorax. The prothorax is well developed and often bears a transverse constriction in the middle. Meta-thoracic scent glands are absent.

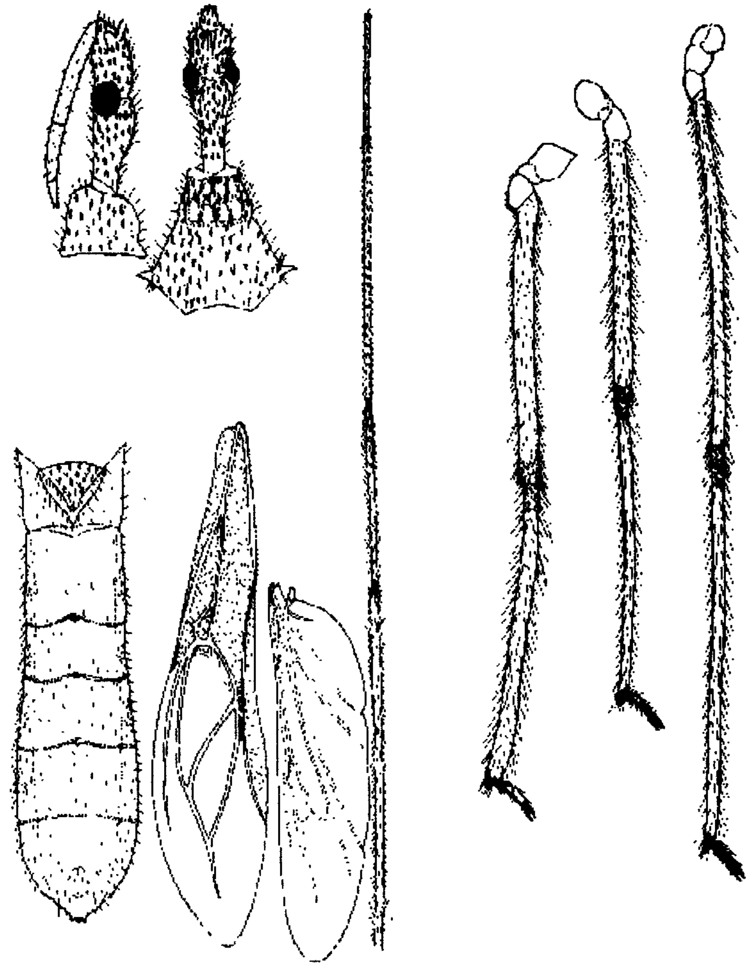


Figure 1. Body parts of a reduviid *Endocus umbrinus* (Head and pronotum dorsal view - a; lateral view - c; antenna - b; legs - d; wings - e and abdomen dorsal view - f)

1.5.3a. Legs

Insect legs are true appendages, jointed (articulated) and paired, and each consists of a more or less standard number of segments. Terminology applied to sub-divisions of the legs also serves diagnostic purposes (see Figure 1d). The coxa is the basal segment forming the joint with the thorax. It is usually small, oval or rounded and rather closely attached to the body in a ball-and-socket manner. The trochanter is a very small second segment, often largest on the inside surface of the leg, although it is absent in some insects and may become double in others. The femur is the third segment but is always the first large and evident segment. The femur of many insects contains most of the muscles that is used for walking and jumping. The tibia, the fourth segment, is also usually long. Based upon the presence and absence of tibia, reduviids are divided into two groups, namely tibial pad group or tibialorate and non-tibial pad group or non-tibialorate. Most insects walk with the end of this segment serving as the plantar surface. The tibia is frequently furnished with one or two spines on the underside of the distal end In some species legs are long and slender and in many cases hairy Some forms have the femora and tibial spines, while the forelegs are often dilated and spined. Tarsi are formed of 1, 2 or 3 segments. The tarsus is a jointed appendage attached at the apex of the tibia useful in grasping and holding on. The number of segments varies from one to five. In most insects the outer or last tarsal segment bears a pair of apical placed tarsal claws and sometimes—additional organs which provide a sticky or suction surface with which the claws enables the insect to stay or walk on inverted surfaces. Insect legs have been variously adapted for running, jumping, grasping, swimming or digging An examination of insect legs can often tell much about the habits of the insect.

1.5.3b Wings

Insect wings are unique among all animals. They are outgrowths of the body wall rather than modified appendages. Wings may present or absent. Winged reduviids typically have two pairs (Figure 1e) borne on the meso- and metathorax but some forms have only one pair borne on the mesothorax, the second pair may be present in a greatly modified form such as a club- or hair-like process called a halter on flies. In others the wings may be absent or rudimentary (non-functional); such insects are termed apterous (a = Greek, without; pterous = wings). Basically, insect wings are very simple flap-like extensions of the body wall, with an upper and lower membrane between which run hollow tubes known as the veins. The venation (arrangement of veins) varies from very simple to extremely complex and is an important character in identification of many orders, families and genera. Wings become functional only in the adult stage. Insect wings have been modified in many ways; for example: The wings of a moth are covered with minute scales which are often brightly coloured. The fore wings of a beetle are hardened and form a protection (the elytra) for the membranous hind wings. Some bugs have half-leathery, half-membranous fore wings (hemielytra). Based upon the wings reduviids have micropterous (rudimentary), brachypterus (wing present up to the middle of the abdomen), alate (absence of wings) (Sahayaraj, 1991). Most of the reduviids are alate followed by apterous, micropterous and brachypterous. The membrane of wing having a long vein starts from the top of appears closed cell Wings are well developed, vestigial or absent. Corium and clavus differentiated but no cutaneous membrane with 2-3 large basal cells.

1.5.4 Abdomen

The abdomen is the third and posterior region of the insect body (see Figure 1f). The abdomen of adult insects contains no legs or wings and usually consists of eight segments. However, in many orders, reduction has occurred or the segments are concealed or modified. Appendages of the abdomen are practically always on the terminal segments and are divided roughly into those not associated with reproduction and those developed for reproductive activities, such as mating and oviposition. Non-reproduction appendages such as cerci, tactile organs on the eleventh segment are found in many insects Assassin bugs have a flat, narrow body, with an abdomen that is sometimes widened in the middle. Abdomen present dorsally, often concave. into which the wings fir, usually the abdomen is broad at the middle and the margins of the segment beyond the wings are exposed. Male genitalia symmetrical, female egg laying organ (ovipositor) is plate like. Respiratory organ is called spiracle and present in the abdomen (8). Apex of the scutellum is broad or triangular or sub-triangular with or without posteriorly projecting thorns. There is usually very little difference between the sexes, but in some species, males have been noted to be slightly thinner than females (Figure 1e)

1.6 Special Characteristics

Assassin bugs have an elongate head with the part behind the eyes long and neck-like. The beak is short and fits into a groove on the underside of the thorax An antenna is usually four segmented (Figure 1b). Many species are black or brown but there is a lot of variety in colour and shape The abdomen is widened in the middle and visible from above out to the sides of the wings. Furthermore, this group has special characters and they are listed below:

1. Reduviids typically have front legs that grasp and hold their prey. In addition the tibial pads are mainly used for holding the prey The predatory efficiency is enhanced by the presence of tibial pad and/or tibial comb.
2. The reduviids migrate from place to place in search of the food when the population of the prey is depleted in one particular period.
3. Distributed in semi-arid zones, scrub jungles, forest and agro-eco-systems and with stand a wide range of temperature and humidity
4. They consume more number of preys than they need to satiate it
5. As a member of the Hemiptera order, the young ones are merely smaller than the adults
6. Assassin bugs usually have only one generation per year, and
7. They have the capability to recognise the chemical cues geminating from the preys and also opposite sex

1.7 Distribution in agro-ecosystems

Nearly 115 species are reported as predators of many insect pests Reduviids are distributed in agro-ecosystem and their border ecosystem such as scrub jungles, semi-arid zones and tropical rain forests. Many reduviids are distributed in more than one ecosystem Among the habitats, reduviids were abundant in tropical rain forests followed by semi-arid zones, scrub jungles and agro-ecosystems. While considering the microhabitat, reduviids live under boulders, on shrubs, under the barks and in litter. The integration of reduviid predators as an ingredient in the Integrated Pest Management (IPM) in such situations would probably reduce the burden and the cost of maintenance of the natural balance here. Though reduviids are polyphagous predators, being less specific in selecting the prey (hosts) and with wide range could possible serve to reduce the outbreak population of most species and could be of immense help in checking the damage of agricultural crops. Many scientists considered reduviids as less specific in their choice of prey but most of the entomologists continued to stress that they could play a vital role in biological control programme. Unfortunately, the biological control potential of the reduviids has never been investigated in the field situation although these bugs are large, active predacious and wide spread. Reduviids have been reported in many agricultural ecosystems worldwide (Table 1.1). The Table 1.1 shows reduviids richly distributed all over the world and the diversity is uniform in all the ecosystems. Hence, there is a better scope for utilising the reduviids in the biological control programme. Recently Ragupathy and Sahayaraj (2002) pointed out that among the reduviids harpactorine reduviids are closely associated with the agricultural pests. So they were mainly present either in agricultural ecosystems or nearby ecosystems. Navarajapaul (2003) listed 18 reduviids which are predominant in various agricultural fields.

Table 1.1 Distribution of hunter reduviids in agricultural ecosystems

Reduviids	*Agro ecosystems— Nation*	*References*
Acanthaspis quinquespinosa (Fabricius)	Sugarcane – India	Butani, 1985
Acanthaspis pedestris *(Stal)*	Cotton – India	
Acanthaspis pedestris (Stal),	Groundnut, maize,	
Acanthaspis quinquespinosa (Fabricius),	Groundnut, maize, wheat, sunflower—India	Rajagopal, 1984
Acanthaspis subrufa (Distant)		
Allaeocranum quadrisignatum (Reuter)	Coconut – India	Sahayaraj, 1991
Catamiarus brevipennis (Serville)	Groundnut - India	Pawar *et al* 1986

Ectrychotes dispar (Reuter)		
Rhynocoris marginalis (Fabricius)	Cotton – India	Singh *et al*, 1987
Coranus aegypticus (Fabricius) Coranus atricapillus *Distant*	Tobacco, Groundnut – India	Singh, 1994
Coranus nodulosus Ambrose and Sahayaraj	Cotton – India	Sahayaraj, 1991
Coranus spiniscutis (Reuter)	Tobacco, Groundnut - India	Singh, 1994
Coranus spiniscutis (Reuter)	Sweet potato, Rice -Bihar` Soybean, maize, cowpea, tobacco, mustard -India Maize - India	Bose, 1949 Jalali and Singh, 2002
Ectomocoris cordiger (Stal) *Cydnocoris gilvus* (Burmeister) *Obchocephalus impudius* (Reuter)	Teak – India	Misra, 1975
Isyndus heros (Fabricius) *Endocus inornatus* (Stal)	Mango – India	Singh *et al*, 1993
Oncchocephalus annulipes Stal	Groundnut – India	Sahayaraj and Raju, 2003
Panthous bimaculatus (Distant)	Ailanthus**	Varma, 1989
Phonoctonus nigrofasciatus Stal	Cotton - England	Evans, 1962
Phonoctonus fasciatus (P de B) and *Phonoctonus subimpictus* Stal	Cotton - Nigeria	Parker, 1972
Pisilus tipuliformis Fab	Secondary forests – West Africa	Parker, 1965a
Polytoxus fuscovittatus (Stal)	Rice – India	Satpathi, 2001
Platymeris laevicolis Gerst	Coconut – India Coconut – East Affrica	Antony *et al* 1979 Vanderplank, 1958
Pristhesancus papuensis (Stal)	Cotton – Australia	Martin and Brown, 1984
Pristhesancus papuensis (Stal)	Soybean – Australia	Shepard *et al*, 1982
Pristhesancus plagipennis (Walker)	Cotton – Australia Sugarcane – Queensland Citrus – New South Wales Cotton & Soybean— Australia Citrus – Queensland	Pyke and Brown, 1996 Illingworth, 1921 James, 1994 Grundy and Maelzer, 2000 Murray, 1987
P plagipennis	Soybean, sunflower, and cotton – Australia Citrus - India	Hasson and Maelzer, 2000 Smith *et al* 1997

Rhynocoris albopunctatus Stal	Cotton – Uganda	Nyiira 1970
Rhynocoris costalis (Stal)	Tobacco - A P, India	Sitaramaiah *et al*, 1975
Rhynocoris fuscipes (Fabricius)	Rice – India	Singh, 1985
	Rice – India	Singh and Gangrade, 1975
	Cotton, bendhi, chillis, groundnut, soybean – India	Singh and Singh, 1987
	Pumpkin – India	Cherian and Brahmachari, 1941
	Soybean – India	Singh and Singh, 1987
Rhynocoris fuscipes (Fabricius) and *Scadra annulipes* Reuben	Soybeans – Jabalpur, India	Singh and Gangrade, 1975
Rhynocoris kumarii Ambrose and Livingstone	Groundnut – India	Sahayaraj, 1994a
Rhynocoris lapidicola Samuel and Joseph	Tobacco - India	Joseph, 1959
Rhynocoris longifrons (Stal)	Groundnut – India	Sahayaraj and Raju 2003
Ectomocoris cardiger (Stal)	Groundnut - India	*
Rhynocoris marginatus (Fabricius)	Groundnut, Cotton, Soybean - India	Sahayaraj, 1995a
	Sugarcane - India	Eswaramoorthy *et al*, 1998
Rhynocoris marginatus (Fabricius) *Irantha armipes* (Stal), *Sycanus pyrrhomelas* (Walker) *Rhynocoris longifrons* (Stal)	Pigeonpea - India	Ambrose and Claver, 2001a
Rhynocoris mysiiphagus Samuel and Joseph	Tobacco - India	Joseph, 1959
Rhynocoris squaliua (Distant)	Tobacco, Groundnut	Singh, 1994
	Tobacco – India	Rao *et al.*, 1981
Sinea didema (Fabricius)	Soybean – USA	Slater & Baranowsky, 1976
Sinea spenispes (Herrich - Schaeffur)	Soybean – USA	Irwin & Shepard, 1980
Sinea complexa Caudull	Soybean – Brazil	Irwin & Shepard, 1980
Sycanus indagator (Stal)	Soybean – India	Green, 1973

Sycanus pyrrhomelas Walker *Rhynocoris longifrons* Stal, *R fusicpes* Fab , *Irantha armipes* Stal, *R kumarii* Ambrose and Livingstone	Pigeonpea, India	Ambrose and Claver 2001a
Salyavata variegata Amyot	Lowland Forest – Costa Rica	McMahan, 1983a
Spendanolestes variabilis	Potato – India	Trivedi and Rajagopal, 1988
Sycanus collaris (Fabricius)	Cinnamon ** – India	Singh *et al*, 1978
Sycanus leucomesus Walker	Acasia mangium–Malasia	Sajap *et al*, 1999
Tribelocephala indica (Walker)	Rice – India	Goel, 1978
Zelus exsanguis (Stal), *Zelus cervicalis* Stal, *Zelus socius* Uhler	Cotton – North America	Ables, 1978
Zelus socius	Soybean – U S A	Irwin & Shepard, 1980
Zelus longipus (Lin)	Soybean – Colombia	Irwin & Shepard, 1980
Zelus renardii Kolenati	Cotton - California	Cisneros and Rosenheim, 1997
Zelus renardii Kolenati	Cotton – America	Bosch & Hagen, 1966
Zelus sp and *Sinea* sp	Cotton – Brazil	Gravena and Sterling, 1983
Zelus spp	Soybean – Florida	Godfrey *et al*, 1989

* Present observation, ** Tree

1.8 Recommendations

1. By using pit fall traps, light traps and sweep nets all the available hunter reduviids in different agro-ecosystems will be collected and made a database system.
2. Sound taxonomy is obviously a critical complement of integrated pest management (IPM) and hence the taxonomy of this group is very essential in order to building its wide reorganisation.
3. Taxonomical studies will be carried out by using multiple approaches including recent technologies like RAPD.

2

Bionomics

2.1 Apiomerinae

The only available biological information in this genus is ***Apiomerus crassipes*** (Fab.) (Swadener and Yonke, 1973a) who reported that it was predating up on *Nabis alternatus* Oarshky, *Chauliognathus marginatus* (Fab.), *Poelabrus rugulosus* Leconte and *Photinus pyralis* (Linn.). It is also a good predator of other pests such as *Gaurotes cyannipennis* (Say), *Conderus vespertinus* (Fab.), *Podisus maculiventris* (Say), *Epilachna borealis* Fab. (Blatchley, 1926); *Aphis gossypii* Glover (Thompson and Simmonds, 1964). Very little information is available about its life cycle. According to Swadener and Yonke (1973a), a female laid 15 to 59 eggs (mean 36 eggs/female). The eggs took 16.7 days as incubation period. Within 123.80 day the newly emerged young one transferring into adults There was no favourability among male and female (1.0: 1.0 for male and female respectively) from the laboratory emerged adult. Males lived shorter (45.0 days) than the females (79.0 days).

Prey Record: *Gaurotes cyannipennis* (Say) *Ccnderus vespertinus* (F.), *Podisus maculiventris* (Say), *Epilachna borealis* Fab. (Blatchley, 1926, Taylor, 1949); *Aphis gossypii* Glover (Thompson and Simmonds, 1964), *Nabis alternatus* Oarshky, *Chauliognathus marginatus* (F.), *Poelabrus rugulosus* Leconte, *Photinus pyralis* (L.) (Swadener and Yonke, 1973a).

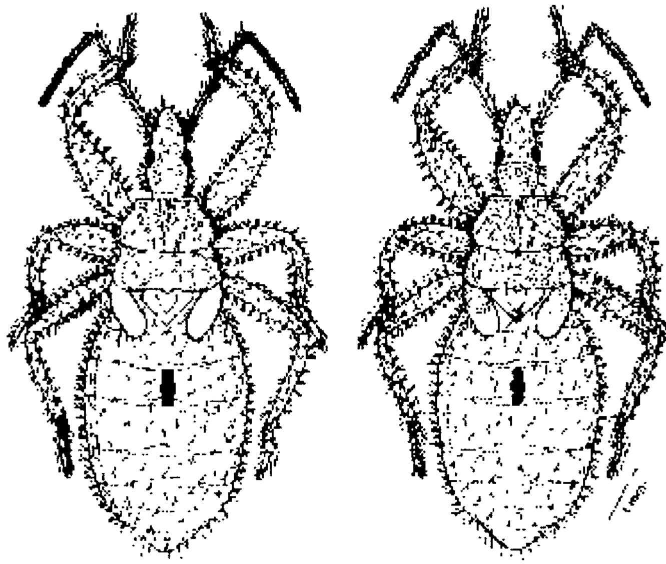
2.2 Ectrichodinae

The only available species that belong to this new genus is ***Neohaematorrhophus therasii*** (Ambrose and Livingstone). It is a newly described species from India by Ambrose and Livingstone (1986c). Total length of this animal is 7 mm. It is mainly present in the semi-arid zones, scrub jungles and cotton ecosystems and mainly predating upon *D. ingulatus* and *O. hyalinipennis. N. herasii* is a polymorphic hunter bug having five different morphs (Sahayaraj, 1991) They are entire violaceous black female, entire red female, entire violaceous black male, entire red male and violaceous black male with pale red corium (Figure 2). Using *C.cephalonica* as prey, I investigated the biology of this bug in 1990 The average preoviposition period was 15 days. The eggs are laid either in single or as group (5 to 8) and totally a female laid 46 eggs with 12 batches. 88.5% of the eggs were hatched and they took 9.71 day as incubation period. The total average nymphal developmental period was 112 days The survival rate of the nymphal instars was moderate (60.33%). On an average male and female lived 37 and 69.46 day, respectively Sex ratio is female biased (0.88). Developmental and reproductive variations in relation to the polymorphic forms were studied in detailed by Sahayaraj and Ambrose (1997b)

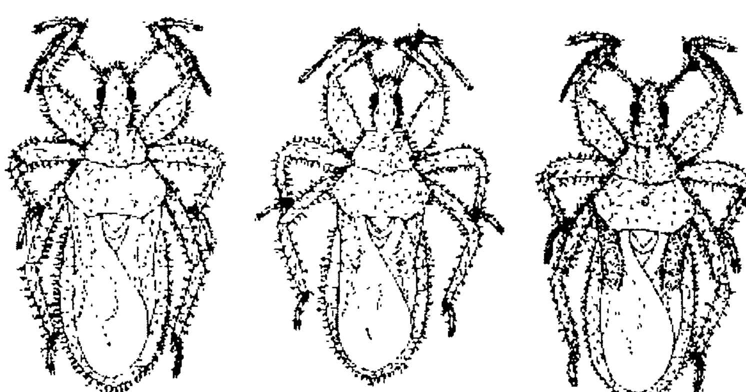
Prey Record: *Odontotermes obesus* Rambur (Ambrose, 1988); *Odontotermes assumthi* (Ambrose, 1980, 1987); *Holmgren, Camponotus compressus* Fabricius (Ambrose and Livingstone, 1991). It also prey *on D cingulatus, O.hyalinipennis, H. armigera, S.litura, C. cephalonica*, and *P. gossypiella*

2.3 Emesinae

Emesaya brevipennis (Say) is a univoltine reduviid, a cosmopolitan group of bugs characterised by markedly slender bodies and appendages. This New World species is divided into three subspecies, *E. b. australis* McAtee & Malloch, *E. b. occidentalis* McAtee & Malloch, and *E. b. brevipennis* (Say), all of which occur in America north of Mexico. *E. b. brevipennis*, which is the most widely distributed of the three subspecies, occurs from New York and Massachusetts south to Florida and west to Iowa, Kansas, Texas, and California. It occurs throughout Illinois.



Violaceous black female Red female



Violaceous black male Red male Black male with pale red corium

Figure 2 Polymorphic forms of *Neohaematorrhophus therasii*

Emesaya b. brevipennis has received much attention over the years, probably due, in part, to its large size (33.0-37.0 mm) and wide distribution. Published information on its biology has consisted mainly of scattered notes. It has been collected under bridges; in sheds, barns, and outbuildings; from vegetation. The eggs are oviposited in the summer and early fall and are attached to spider webs (Brown and Lollis 1963), rafters of wooden structures, and twigs of bushes and trees. This presents information is mainly focusing on the biology of *E. b. brevipennis* (Hagerty *et al.*, 2001). As with nymphs, the filter paper was moistened with 8-10 drops of distilled water daily, and the bugs were fed five *Drosophila* sp. adults per day. This species apparently over wintered as eggs, which were glued lengthwise to the vines, webs, and rock surface. We could not distinguish fertile eggs in the field because the eggs are dark and durable, even if not fertile. Of the 238 eggs collected in February and March for the laboratory-rearing study, 121 (50.8%) hatched. We assumed all had been oviposited the previous fall. First instars were found primarily from early to late May and mid-July to mid-August, second instars from late May to early June and from late July to mid-August, third instars from late May to mid-June and during August, fourth instars primarily from early June to early July and early to late August, fifth instars primarily from mid-June to mid-September, and adults from late June to early December. A few nymphs were found outside the primary times of occurrence in the field of their respective instars, including four firsts and fourths each and seven fifths. We believe that this was atypical and the result of unusually mild temperatures during the spring and fall. Copulation was observed in late September and early October. Interestingly, it was also observed during November, a male was seen in copulation with an apparently dead female.

Eggs were glued singly and lengthwise to the paper towelling, screening, filter paper, and sides of the jar Each egg was dark brown to black with longitudinal rows of thin, tooth like projections and capped by a cephalic operculum with a central tubercle, as described by McAtee and Malloch (1925). The incubation period averaged 33.91 days The first instar emerged through the cephalic end of the egg, pushing aside the operculum. It was whitish, almost transparent, but became more visible after feeding. The first through fifth stadia averaged 11.27, 7.84, 8.85, 11 14, and 16 75 day respectively. The total developmental period averaged 89.76d. Most nymphs died during the fifth stadium, which resulted from incomplete ecdysis. Brown and Lollis suggested that females have a sixth instars, however, none of the reduviid biology supported Brown and Lollis statements.

2.4 Harpactorinae

The subfamily Harpactorinae comprises a large group of diurnal reduviids distributed in all biogeographically. ***Agriosphodrus dohrni*** Signoret is a univoltine reduviid living in trees and feeding on various species of arthropods. In Japan, the female lays eggs in mass during mid-June which hatches simultaneously after about a month. Nymphs hibernate in the final instar and adults emerge in mid-spring in the next year. Egg masses are deposited at hollows in tree trunks and the juveniles form stationary aggregation including different batches.

The wheel bug, ***Arilus cristatus*** (L.), distributed from Ontario and New York south to Florida and west to Iowa, Kansas, and New Mexico. It also has been reported from Mexico and Guatemala (Froeschner, 1988a and 1988b). Adults are recognised easily because of their large size (26-36 mm), blackish brown body, reddish brown antennae, and a distinctive, high, toothed, median ridge on the pronotum Although it is a common species, most published information on its biology consists of scattered notes. In over winters the eggs (Froeschner 1944; Garman 1916; Readio, 1926, 1927a and 1927b, Todd 1937) are laid in clusters on the bark of tree trunks and twigs (Froeschner, 1944). The eggs hatch the following spring and nymphs are found from May to July and adults from June to October (Froeschner, 1944). Not unexpectedly, the life cycle is somewhat different in Florida; for example, nymphs appear in April and some adults survive into the winter (Mead, 1974). This species has been reared in an insectary under uncontrolled conditions (Todd, 1937), and the eggs (Readio, 1926, 1927a and 1927b) and nymphal instars, except the second (Readio, 1927a and 1927b), have been described. It was univoltine and overwintered as eggs, which were laid in hexagonal clusters and glued to the trunks of sassafras *Sassafras albidum* (Nuttall), beech *Fagus grandifolia* Ehrhart, and maple *Acer sp* trees. First instars were found from early May to late June, second instars from mid-May to early June, third instars from late May to early July, fourth instars from early June to mid-July, fifth instars from early June to mid-August, and adults from early July to late November. Copulation was observed in September. Unhatched egg clusters were found during the early October. Nymphs were collected most often by sweeping weeds and short woody vegetation along the margins of forested areas. Adults were frequently collected by sweeping or beating the branches of trees. Several prey were collected during the study, all of which had been captured by late instars or adults. These items and the attacking stages included single adult specimens of the cercopid *Clastoptera proteus* Fitch (fourth instar), the chrysomelid *Ophraella* sp. (fifth instar), and a halictid by adult. Also, two bugs (1 fifth instar, 1 adult) were observed with their beaks inserted in the cases of bagworms (*Thyridopteryx* sp.?). One adult male was seen inserting its beak into a flower of goldenrod (*Solidago* sp.). As noted earlier, several field-collected egg clusters were heavily parasitised The parasitoids were identified as *Ooencyrtus johnsoni* and *Anastatus reduvii*. Field-collected eggs were dark brown to black cephalad, red posterad, and attached by their posterior ends. Eyespots were not visible. The first instars emerged through a circular opening in the cephalic end of the egg, pushing aside a cap. They were orangish at this time but darkened to the more typical coloration (*i.e.*, head, thorax, and appendages black; abdomen red) within 3-4 h. They fed on *Tenebrio* sp. larvae within 1 day. The first, second, third, fourth, and fifth stadia averaged 15.64, 14.04, 15.17, 20.53, and 28.61 day, respectively. The total development period averaged 93.99 day. Mortality during the nymphal stadia resulted from incomplete ecdysis, predation by other nymphs, and unnatural causes (*e.g.*, drowning in water condensation in the dishes). Each of the two females collected for ovipositional data deposited a single egg cluster on the wall of its jar. The clusters contained 79 and 48 eggs, which hatched in 60 (n = 58 eggs, 73.42%) and 61 (n = 23 eggs, 47.92%) days, respectively (McPherson, 2000). Therefore, a cold period apparently is not necessary for normal egg development. Sailer reported that eggs he collected in late September hatched in early December.

Prey Record: (Chittenden (1905); Tortricids (Watson, 1918); Other caterpillars of citrus, Pumpkin bug, Locust borer (*Cyllene* *robinae*) (Garman, 1916); Fall webworm (*Hyphantrea cunea*) (Britton (1917)); Cabbage worm (*Pontia rapae*) Chittenden (1916); Southern corn rootworm (*Diabrottica 12-punctata*), Caterpillars of shade tree.

Brassivola hystrix Distant (Euagorasaria) is a new record to Indian reduviid fauna (Lakkundi, 1989). Hence, field observations and other studies mentioned by him were also recorded for the first time. He also studied the biology and feeding behaviour of this reduviid in details. Distant (1902) reported this reduviid from Sri Lanka Average of total stadial period was 73 17 days. The average stadial period in descending order was 27.00 day for V stadium, followed by 15.58 days for IV stadium, 13.17 days for I stadium. Average pre-oviposition period was 38.67 day, comparatively lower than 50.50 day of oviposition period Mean total longevity of male and female were 99.67 and 107.33 days, respectively. The total survival rate of nymph was 38.48%. The average total feeding of nymphal stages was 73.00 *C. cephalonica* larvae.

Prey Record: *Helicoverpa obsolete* (Fabr.) (Taylor, 1932); *C cephalonica* (Nayar *et al.*, 1976); *Hybloea puera* (Mohanadas, 1996); *A janata, Leptocoris acuta* Thunb (Ambrose, 1999).

According to Wallace (1953), ***Coranus subapterus*** DeGree laid the eggs in batches of two to seven eggs in batches on plant bark of stumps, pine slash or in the lichen and moss. They are dark brown with cream-coloured sculpture cap. Butler (1918) stated that *Coranus* adults sometimes hibernate in the winter, and appear again about in March. The first, second, third, fourth and fifth nymphal instars were last for 12, 17, 18, 25 and 27 days respectively. Adults are having both brachypterous and macropterous forms.

Prey Record: Elaterial larvae, *Forficula auricularia* nymphs, *Coelocrabro ambiqutus*, *Lasius niger*, *Myrmicaq laevinodis*, Ichneumona and a Lycosid spider.

In India, the widely present *Coranus* sp. is ***Coranus nodulosus*** Ambrose and Sahayaraj. It was collected from the cotton ecosystem from Tamil Nadu, India. Adults were present along with the *Oxcycarenus hyalinipennis* Costa of cotton. Sahayaraj (1991) reported that both the nymphs and adults feeding on *D. cingulatus* and *O. hyalinipennis* in field conditions. It was reared on *C. cephalonica* and all the biological parameters were observed.

Overall colour of the animal is black having nodulations all over the body The total length of the animal is about 8.72 mm The averaged preoviposition period of the female is 7 6 day. The female laid elongately oval, white coloured egg with a white distinct operculum. Eggs are laid singly as well as in small clusters. Each cluster consists of 1 to 7 eggs In the laboratory, the eggs were laid slightly vertically or erectly and cemented basally to the substratum or inserted into the wet cotton swabs. Totally a female laid 43 eggs with 13.5 batches during its lifetime. Almost all the laid eggs hatched in to nymphs (94.28%). The developmental period of first, second, third, fourth and fifth nymphal instars last for 6.39, 5.56, 6.46, 8.22 and 13.07 day, respectively The averaged total developmental period of this bug was 39.13 day Total survival rate was also very higher for this bug (91.66%). The sex ratio was in favour of females (0.73). Adults lived longer than the nymphal developmental time (42.68 and 49.35 day for male and female respectively) (Sahayaraj and Ambrose, 1993a).

Prey Record: Aphids, Lepidopterous larvae, [*Diacrisis (Spilosoma) lubricipeda*] (Butler, 1918).

Detailed biology of ***Endocus inornatus*** Stal (Euagorasaria) was studied by Lakkundi (1989) Previously Distant (1902) first reported this species from North India Sundararaju (1984) reported it feeding on cashew pests from Goa, India and Ambrose (1985) reported from this reduviid in tropical rain forest of Tamil Nadu Haridass (1986a and 1986b) studied the ultrastructure of its egg. The average total stadial period in 1 to 3 generations was different (41.60, 58.50 and 48.55 day first, second and third generation respectively). The higher average stadial period was recorded in the V stadium. The survival rate was 3.09, 18.49 and 36 67% for first, second and third generations respectively. ***Endocus parvispinus*** Distant (Euagorasaria) is new to Indian reduviid fauna. First time Lakkundi and Parshad (1987) described the habitat and biology of this reduviid. This species was collected from a grass, *Andropogon* sp It was first reported that this species was infected by *Aspergillus flavus* and it reduced the preoviposition and oviposition period of this bug. Female laid the eggs in two rows unlike the honeycomb pattern which was observed in *E. inornatus*. As observed in majority of the reduviids the lower stadial period was observed in the second instar (9 76 day) and higher in fifth stadium (19.52 day). The first, third and fourth stadia had lower average stadial periods *i.e.* 14.55, 14.31 and 16.34 day respectively. Average male and female longevities were 48.33 and 58.06 days, respectively Total mortality in all stadia was 78.87%.

Prey Record: *Caenobius* sp , *Helopeltis antonii* Sign. (Singh *et al.*, 1982); *S. litura* [(Sundararaju (1984)]; *H. armigera* (Lakundi, 1989); *D. koengii* (Ambrose, 1999)

Another species that belongs to the Endocus genus is ***Endocus umbrinum*** Distant. It was collected from the Courtallum tropical rain forest from Tamil Nadu, India. In the laboratory, its biology was carried out with *C cephalonica* (1 prey/predator/day up to III instar and 2 preys/predator/day till fifth instar and 3 prey/predator/day for adults). The adult is about 15.76 mm in length. Overall colour of the adult is brownish-ochraceous. The average pre-oviposition period is 17 75 day The eggs are laid in batches. A female can lay 48.5 eggs with the minimum of four and a maximum of 24 eggs in a batch. More than 87 per cent of the eggs were hatched in to nymphs within 9.28 day. During the adult lifetime, a female laid its egg for 9 days Averaged nymphal developmental period was 52.13 day (10 09, 9.86, 8.6, 10.08 and 14.4 days for first, second, third, fourth and fifth nymphal instar respectively). Thirty-nine per cent of the nymphs only survived during the nymphal stage. Among the emerged adults, female population was higher (1.00) than the male (0.61) and the former sex lived longer (38.46 days) than the later sex (29.33 days) (Sahayaraj and Ambrose, 1992b).

Prey Record: *H. armigera, D. cingulatus, C. cephalonica, S. litura* (Sahayaraj, 1991).

Fitchia aptera (Stal) is one of the less known reduviid of North America. Adults pass the winter in hibernation under stones, boards, or around the roots of grass and clumps. It was reared on small flies and drosophilae in containers having a small branch of blueberry, *Vaccinium* sp. which retained its leaves well for several days. A female laid 134 eggs in her lifetime. Eggs took 15.5 days to hatch and nearly 50 per cent of the eggs hatched in to nymphs. According to them the eggs are pale brown in colour and laid in cluster. Both the nymphs and adults won't accept aphids and variety of species of beetles Fourth instar nymphs were observed inserting their stylets into freshly cut apple, presumably to obtain water. They also take water from wet paper towelling. The duration of the egg stage is 7 to 14 days, averaging 10 days. First, second, third, fourth, and fifth instars last for 9.6, 9.0, 9.5, 18.7 and 18.0 day, respectively. Totally they took 60 days for completing egg to adults.

Distant (1902) reported ***Isyndus heros*** (Fab.) (Euagorasaria) from Assam as well as from Bangalore, India. Miller (1956) reported this reduviid from Malayasia. Veeresh and Puttarudriah (1970) collected this species on mango tree at Hebbal, Bangalore, India and studied its biology by feeding with silkworm and *Corcyra* larvae, grasshoppers etc. This species was also collected from similar location and habitat; however, its biology was studied using *Corcyra* larvae. Therefore, the following observations recorded, differed slightly from the earlier work. Veeresh and Puttarudriah (1970) recorded 22–24 days of preoviposition period and 90 days of oviposition period. According to Lakkundi (1989), the average preoviposition and oviposition periods were 43.45 and 36.77 day respectively. They further reported that a maximum of nine egg masses were laid by this reduviid. While Veeresh and Puttarudriah (1970) recorded only four such masses. Average total period of all stadium was 78.73 day, with a range of 60 – 115 day, unlike 90 – 100 days of total stadial period recorded by Veeresh and Puttarudriah (1970). In the present study, the average longevity of male and female was 91.44 and 114.32 days, respectively. At Bangalore (1970) the males of this bug had longevity of 52 day, while female lived for 108 days with a sex ratio of 1:1. The sex ratio of female to male in this study was 1.00: 0.87. The total mortality in nymphal period in the present study was 52.76 per cent, the highest being in first and fifth stadia, while it was the least in third and fourth stadia, which was not recorded earlier. Such differences in the biology may be due to the variations in rearing conditions of the respective laboratories.

Prey Record: *Idocerus* sp. (Singh, 1992); *Helopeltis cinchorae* Mann (Corbett and Pagden, 1941); *H. bradyi* Waterh. *H. armigera* (Lakkundi, 1989); *S. litura, D. koengii. Idocerus* sp. (Singh, 1992); *H. cinchonae, H. bradyi, M. corbetti, S. asigna* (Ambrose, 1999).

Distant (1902), Sundararaju (1984), Ambrose (1985) and Lakkundi (1989) collected ***Irantha armipes* Stal** (Harpactorinae: Polididusaria) from Sri Lanka, Goa on cashew tree, tropical evergreen forest from Tamil Nadu and mango trees from Bangalore, India respectively. However, field observations and the detailed study of the biology and bionomics was carried out by Lakkundi (1989) for the first time. According to Lakkundi (1989) the average preoviposition period (31.60 day) recorded was lower than oviposition period (54.30 day). The average lowest stadial period was observed in second instar, followed by fourth instar and first instar. The highest stadial period was recorded for fifth instar followed by third instar. Average longevity of male (116.80 days) was slightly higher than that of female (112.40 day). The highest nymphal mortality was in first instar (67 74%); there was no mortality in fourth and fifth instar. Total survival rate of all stadia together was 6.45 per cent.

Prey Record: *Caenobius* sp., *Helopeltis antonii* Sign. (Sundararaju (1984)); *A. janata* (Babu *et al.*,1995); *A. biguttula biguttula* (Lakkundi, 1989); *H. armigera, C. cephalonica* (Livingstone and Yacoob, 1986); *O. obesus, Tephrina pulinda* (Walker), *Teleonemia scrupulosa* Stal (Ambrose, 1999).

Occamus typicus Distant adults and nymphal population were observed throughout the year in the canopy of cashew and maximum of 1 to 3 nymphs/adults per m^3 of canopy was noticed in some of the trees during the months of January and February which was incidentally the period of peak incidence of tea mosquito bug *Helopelitis antonii* Sign (Sundararaju, 1984). Parental care of eggs by the adult female was noticed up to hatching of eggs and the egg period lasted from 6 to 7 day. No nymphs attained adults stage as all of them died within a period of 11 days from the hatching.

Prey Record: *Caenobius* sp., *Helopeltis antonii* Sign. (Sundararaju (1984).

Polididus armatissimus Stal is an alate, entmosuccivorous, polyphagous, multivoltine, and crepuscular hunter bug. Usually they are found in the grass field and migrate from place to place. Ambrose and Vennison (1989b) carried out the life history of this hunter bug. They laid first batch of eggs 33.5 days after the imaginal moult. Eggs are laid in single and some time the eggs are inserted in the wet cotton swabs Eggs are elongately cylindrical but slightly convex marginally, very much similar to another reduviid *Sinea undulata* (Miller, 1953). During the lifetime, a female can lay 101 eggs. The nymphs are hatched within 9.1 day The nymphs are transformed into adults between 40 and 69 day. Maximum nymphal mortality was observed in the first nymphal instar followed by fifth, second, third and fourth nymphal instars. Maximum males were emerged from the laboratory than the females. The life span of the adult female and male are 80.8 and 71 12 day respectively.

Prey Record: *H. armigera* (Ambrose and Vennison, 1989b)

General colour of the adults ***Pristhesancus papuensis*** Stal is dark brown. Antennae, rostrum and legs are uniformly light brown. Prothorax is nearly spherical, spined at anterior corners and dorsally; posterior corners rounded Mesothorax is convex above, bell shaped; hind margin of mesonotum crenulate, with four glabrous knobs. Scutellum with a similar knob from its dorsum. Abdomen is light brown, occasionally orange; deeply keeled, a cross-section at the fifth segment being almost an equilateral triangle. At resting, the wings projecting slightly beyond tip of abdomen. It laid eggs in masses having an average of 80 3 eggs/ mass. Mean incubation time was 15 6 days and 73.8 per cent of the eggs hatched into nymphs. The hatching percentage was increased when the eggs are placed in the soybean field (89.2%). At the same time the incubation period was prolonged for five days (20.5 day). On an average, total time required for completing its nymphal period was 59.9 day (12.7, 10.3, 10 1, 12.0 and 17.2 day for first, second, third, fourth and fifth nymphal instars, respectively) (Shepard *et al.*, 1982). Maximum nymphal mortality was observed in the fourth (25 0%), followed by first (23.7%), fifth (21.2%), second (16.4%) and third (13.7%) nymphal instars. Overall survival rate of the nymphal instar was 32.5 per cent. The longevity of adults was 92.5 days for male and 123.5 days for female. Preoviposition period was 33.5 day. A female laid 17 egg masses with an average of 50 eggs per batch.

Prey Record: *P. includens* (Martin and Brown, 1984); *Spodoptera exigua* Hubner (Shepard *et al.*, 1982); *Helicorapa zea* (Boddie), *Helicorapa virescens* (F) (James 1992, 1994).

Pselliopus barberi Devis is a common species in Missouri and is found throughout the year The incubation period of the eggs lasts for 11.3 days. Totally a female can lay 179 eggs in her lifetime. Among the eggs laid, 90 per cent of the eggs were hatched. Development from eggs to adult averaged 85 1 days (10 2, 10.8, 8.12, 13.5 and 27.5 days for first, second, third, fourth and fifth nymphal instars respectively) (Swadner and Yonke, 1975). Another well known and popular species that belong to this genus is ***Psellipus cinctus*** (Fab). It is a common reduviid present throughout the United States. Nymphs and adults are found on the leaves and barks of trees along woodland borders and in forests. Red cedar was the most common plant on which *P.cinctus* was collected. Eggs were deposited on a small amount of cement resting on the board of the egg at a slight angle with the substrate. They were deposited single or in linear cluster ranging from 2 to 5 eggs/ cluster. According to Readio (1927a), *P. cinctus* female deposited 82 eggs. Incubation period is last for 13.9 day. Eighty percentages of the eggs hatched. The average development from the eggs to the adult was 76.9 day (Swadener and Yonke, 1975). They further reported that first, second; third, fourth and fifth nymphal instars took 13.7, 11.1, 10.6, 11.1 and 16.5 day respectively for completing their life time.

Prey Record: Chinch bug (Webster (1907); Colorado beetle of potato (Chittenden, 1907).

Rhynocoris is a common and world wide distributed genus of the family Reduviidae. Here I mention the biology of seven species. All of them are predominantly present in agroecosystem and to be incorporated in the biological control programme in many crops. ***Rhynocoris albopunctatus*** Stal feed on a wide range of insects from Orthoptera, Coleoptera, Hemiptera, Diptera, Hymenoptera to Lepidopteran. They prefer to feed on *Helicoverpa armiger* than other preys offered (Nyiira, 1970) He also reported that it feeds not only on *H. armigera* but also on *Dysdercus* sp. Egg laying site of this predator was influenced by some plants like Legume plant, *Stylosanthes gracilis* (Nyiira, 1970) in addition, eggs were laid either on male or mounted on the back of the males or present nearer to the males (Odhiambo, 1959). Eggs are deposited singly on the foliage, peduncles, or stems of plants in horizontal rows, which formed clusters. When the egg deposition was delayed males touching the half-raised wings and abdomen of the females for inducing it to lay eggs (Nyiira, 1969). This kind of behaviour has not been observed in any reduviids studied here. The number of cluster varied from 5 to 250 (range of 75 clusters: 5–248). The egg is brown and gourd-shaped, with a spongeous operculum that has a honeycomb like structure and design The eggs laid by the female were brooded by the male until nymphs hatched Miller (1956) and

Odhiambo (1959) observed similar kind of results. Incubation period ranged from 5 to 6 day and hatched within 5 to 15 day. Odhiambo (1959) reported that the incubation period was ranged from 12 to 14 day. Males (61.5 day) lived shorter than the females (69.6 day). According to Odhiambo (1959), females took more days for completing the nymphal stage (71.4 day) than the males (66.4 day) when thrips were provided as preys.

Prey Record: *Heliothis obsolete* Fabr (Taylor (1932); *H. armigera*, *Earias biplaga* Walker, *E. insulana, P. gossypiella* (Nyirra, 1970); *Dysdercus* sp., *Antestiopsis lineaticolis* Intricata (Ghesv. and Carayon) (Carayon, 1950).

Sitaramaiah and Satyanarayana (1976) studied the life stages of ***Rhynocoris costalis*** Stal and their descriptions Eggs were laid singly or in cluster two to three day after copulation. They are light brown in colour, later changed to dark brown. It is elongated, tapering at the distal end with a round white flap at the apex and broadly rounded at base. It measured 1.50 mm long and 0.50 mm broad. Number of eggs laid by a female was 142 in 4 to 10 batches. First instar measured about 1.70 mm long and 0.60 mm broad Then it extended to 3.00 mm and 1.50, 6.00 and 2.00, 7.00 and 2.50, and 8.00 and 3.00 mm for second, third, fourth and fifth instars, respectively. In adults, head is elongated, narrow, longer than broader, and freely movable. Antennae are longer than the head, filiform with four segments. Rostrum is short, curved with three segments, the tip in a straighter furrow between coxae. Wings are well-developed, vestigial corium and clavus differentiated but no cuneus membrane of hemelytron having two large basal cells and a long vein proceeding from top of upper closed cell. Abdomen is dorsally concave into which the wings fit. The wings are black and flat on the abdominal segments dorsally and ventrally. Fore legs raptorial, no arolia. Females (1.2 mm long and 0.35 cm broad) are bigger than the males (1.0 and 0.3 cm long and broad, respectively) Adults are bright red in colour. A female can lay 42 6 eggs. During the lifetime *R. castalis* consumed 63 *S. litura* larvae (different instars).

Prey Record: *Spodoptera litura* (Sitaramiah & Satyanarayana (1976), Sitaramiah *et al.* (1975), Imms (1965), Nayar *et al.* (1976), David and Kumarswami (1978)); *Dysdercus cingulatus* F. (Ambrose, 1999)

Rhynocoris fuscipes Fabricius is a bright coloured, crepuscular, entomosuccivorous, polyphagous reduviid. Mainly it is found in the semiarid zones, scrub jungles and tropical forest. Almost all the ecosystem in Tamil Nadu contains this predator. Nymphal instars are found underneath the stones or on the shrubs. They are not found along with their parents or in groups. Adults are having nodding behaviour as defensive mechanism. Nymphal instars are orange red with black eyes, light yellowish green legs with brown spots. Black lateral and median abdominal spots and wing rudiments are seen in older instars. Rao (1974) first reported its development and breeding techniques. But he failed to provide the details of its biology. Ambrose and Livingstone (1986d) described the life history of this bug on houseflies, ants and caterpillars. It deposits first batch of egg at the age of 28 days after imaginal moult. Eggs are laid in batches and they are attached each other to the lateral side and basally to the substratum. The eggs (0.85 mm and 0.39 length and width respectively) are oblong, maroon or brown and pitcher-like The operculum of the egg is encircled with a white ring. Eggs are laid in batches, each attached to the laterally and basally to the substratum firmly with brown cementing material in a vertical fashion. Operculum is white with hexagonal sculpturations and completely enveloped by transparent, highly reticulate chorionic collar that remains expanded apically. Eggs hatched 9 to 11 day (September), but it varied with season to season. Ponnamma *et al.* (1979) reported incubation period of 8 days. The first instar nymphs did not feed for 2 or 3 days. The nymphs took 58.15 day and consumed 60.99 second/third instar *Neara viridula* Linn (Singh and Singh, 1987). Earlier, Singh and Gangrade (1976) observed this predator feeding on the *Diacriia oblique* Walker (Lepidoptera: Arctiidae). They reported that nymphal instars needed 102 to 110 days for completing the lifetime and consumed 96 to 101 larvae. In Madhya Pradesh, Ponnammal *et al.* (1979) observed total nymphal period range from 33 to 44 days on *Myllocerus curvicornis* (Fab), a pest of coconut palm in Kerala In Tamil Nadu, *R. fuscipes* completed its lifetime within 41.22 days on houseflies, ants and lepidopteran caterpillars (Ambrose and Livingstone, 1986d) Recently, George *et al.* (2000) found out that it need only 34.21 days to complete its nymphal stage. They used

C. cephalonica as a prey. They further reported that it laid 58.37 eggs.

Prey Record: *Heliothis armigera* (Rao, 1974), Nagarkatti (1982); *Corcyra cephalonica*, *Chilo partellus* (Swinh.), *Achaea janata* L., *Plutella xylostella* (F.), *Spodoptera litura* (F.), *Myzus persicae* S. (Rao *et al.*, 1981); *Dicladispa armigera* (Oliver) (Singh, 1985) ; *Epilachna 12-stigma* Muls., *E. vigintioctopunctata* (Fabr.) (Nayar *et al.*, 1976); *Raphidopalpa foveicollis* Lucas, *Semiothisa pervolagata* Walker, *Diacrisia oblique* Walk. (Singh, 1985); *Terias hecab* (Linn.), *Coptosilla pyranthe* (Linn.) (Hiremath & Thontadarya, 1983); *Calocoris angustatus* Leth., *Cyrtacanthacris succincta* Kirby, *Dysdercus cingulatus* Dist., *Earias vittelle* (F.) (Ambrose, 1985); *E. insulana* Biosd. (Ambrose, 1999).

Rhynocoris kumarii Ambrose and Livingstone is a newly described harpactorine reduviid from southern India (Ambrose and Livingstone, 1987a). It was recorded from July to October and also from March to September. The peak population has been observed in June. Young ones are present along with their parents. *R. kumarii* is found in tropical rain forest like Godayar forest, semi-arid zones, scrub jungles and agroecosystems like greens, groundnut, cotton etc. It was recorded from March to October. Peak population was present in June. This bug is a bright red and black, winged, entomosuccivorous, polyphagous, multivoltine hunter reduviid. Young ones are bright sanguineous in colour. However, eyes, margin of prothorax, wing pads, tibiae, tarsomeres, upper part, lateral margins and lower part of the abdomen are black. Legs of first to third instars are maroon and fourth and fifth instars are coral red. Middle leg is shorter and hind leg longer. Abdomen is wider than longer with three prominent median dorsal abdominal scent glands. The eggs (2.01 mm long and 0.63 mm broad) are pale yellow, cylindrical with a transparent operculum. The corion is reticulate. It resembles the eggs of *R. marginatus* (Ambrose and Livingstone, 1987b) in shape. The eggs were placed gently on the substratum by the tip of the genital segment one after the other by touching the available place by its abdominal tip A female on an average laid 6 ± 3 egg batches of eggs with a total of 29 ±5 eggs. In each batch the number varied from 3 to 23 eggs. They hatched in 8 to 15 days. Totally a nymph took 67 45 (first generation) or 68.03 day (second generation) for completing its nymphal stage

(Ambrose and Livingstone, 1987a). Male and female lived for 116 and 50 days, respectively Another species that belongs to this genus widely present in India is *Rhynocoris lapidicola* Samual and Joseph (Joseph, 1959). It is a general reduviid living under stones, under logs or leaves and feeding on plant juice or upon other insects. They laid their eggs under surface of the leaves. Each female lays 360 eggs and each cluster ranged from 34 to 40 eggs. The incubation period was about 16 days (77 to 78.8° F and 55 to 60 RH) but it reduced to 12 days when subjected to 65.3 to 64.4° F. However, it was reduced to 7 days during the summer (82.8 to 96.7° F and 52.8 RH) Eggs are elongate, cylindrical, slightly bent at the middle, broad at base and narrow at the top and having a distinct lid or operculum The lid is white and occupies at the fourth part of the whole egg. There is no orientation on the operculum. A dark spot is visible at the juncture where the operculum is marked off from the rest of the egg Adults are not very active. Adult can live for a period of 5 to 12 months with food and 1.5 months without food

Prey Record: *Heliothis armigera* Hubn (Ambrose (1985)); *Calocoris angustatus* Leth , *Dysdercus cingulatus* Distant, *Earias vittella* (Fabricius), *E. insulana* Boisd., *Mylabris pustulata, Patanga succincta* (Linnaeus) (Ambrose & Livingstone, 1987a). *C. compressus* (Ambrose, 1980), *H. armigera* (Ambrose, 1987a); *D. cingulatus* (Ambrose, 1995); *M. indica, P. gossypiella, S. litura, E. scintillans* (Ambrose and Claver, 1995); *E. merinone, C. cephalonica, E. insulana, E. vitella, O. hyalinipennis, E. mollifera, Tribolium confusum* Duv , *Papillo demoleus* Linn., *R. clavatus, C. gibbosa, D. indicus, E atomosa, D. indicus* (Ambrose, 1999).

Rhynocoris marginatus (Fab.) adults are usually 18 to 21mm long. It is brightly coloured (black and red). The elongated head is narrow with a distinct "neck" behind the often-reddish eyes. The long, curved mouth parts form a beak which is carried beneath the body, with the tip fitting in a groove on the underside of the body. The middle of the abdomen is often widened, so the wings don't completely cover the width of the body *R. marginatus* exists in three different morphs *viz* , with black connexivum (niger-N), with red connexivum (sanguineous – S), and with black red banded connexivum (niger sanguineous – NS). (Ambrose and Livingstone, 1988, 1989a) The female lays eggs in tight, upright clusters on leaves or in the soil. Nymphs resemble the adults, but are smaller, wingless and may be brightly coloured. This hunter bug is one of the largest and most easily recognised assassin bugs found in the semi-arid, scrub jungle, tropical forest and agro-ecosystems in Tamil Nadu The population of this bug has been present from January to June and also from November to February. However, peak population was observed during March and April The highest nymphal population can be observed in January. The adult is about 1" long, and 160 mg in weight red in colour Nymphal instars took 35 to 150 days for attain in to adults. Female biased sex ratio is common. But it differs according to the type of prey it fed. Females are much larger than the males. Preoviposition period is shorter than the oviposition and post-oviposition periods. This species is an important predator of crops insects. This bug feeds on aphids as young nymphs Later they attack caterpillars such as the *Spodoptera litura. Helicoverpa armigera,* ants, Colopteran, Hemipteran and Isopteran pests This species is common in the Southern India. Although they are small they can capture much larger insects, such as sixth instar larvae of prodenia and American bollworm. They lie in wait for their prey on foliage. Their prey is mostly crop pest, so they do contribute much to insect pest control in plantings. Rearing space has great influence on the biology of this bug Bigger size container (340 ml capacity) enhanced the fecundity (395 eggs/female) and hatchability of nymphs (95.95%) when eared on *M. domestica* (Veinnison and Ambrose, 1988a).

Prey Record: *Heliothis armigera* (Rao (1974), Bhatnagar *et al.* (1983), Pawar *et al.* (1986)), *Corcyra cephalonica, Cyrtacanthacris succincta* (Ambrose and Livingstone (1985b); *Calocoris angustatus* Leth. (Ambrose (1985); *Dysdercus cingulatus* Dist., *Earias vittella* (Febricius), *E. insulana* Biosd., *Mylabris pustulata* Lefroy, *Patanga succincta* (Linn.) (Ambrose, 1988), *C compressus* (Ambrose, 1980), *C. cephalonica* (Bhatnagar *et al.*, 1983); *E. fraternal* (Pawar *et al.*, 1986); *P. scintillans, H. armigera* (Ambrose, 1987a); *E. insulana* (Nayar *et al.*, 1976); *E. vitella, C angustatus, M. pustulata* (Imms, 1965; Nayar *et al.*, 1976); *M indica. D. cingulatus, P. demoleus, A. Janata* (Kumaraswami, 1991); *O. hyalinipennis, P. gossypiella*; *S. litura, C. horrens, R clavatus, C gibbosa, E atomosa. D. indicus* (Ambrose, 1999).

Rhynocoris punctiventris (H.–S.) has been provided with new hatchlings of *Dolycoris baccarum* as the food in order to investigate the laboratory rearing possibilities of the predator. Most of the *R. punctiventris* nymphs (91.83%) were died during their first three developmental stages. Almost half of died individuals seemed to attach to their exuviae without emergence. This was accepted as the nymphs of *D. baccarum* are not the appropriate food for *R. unctiventris* both in the nature and in the laboratory in spite of willingly feeding on the prey As a result it was considered that the additional food resources will be necessary for the normal development of the predator. Also the causal deficiency needs to investigate by the artificial feeding techniques. (Karsavuran, 1989)

The genus *Sinea* contains nearly 10 species in the United States. Among them two occurring in the southern and southwestern states each. Swadener and Yonge (1973a) studied the biology of ***Sinea confusa*** Caudell, ***S. diadema*** (Fab.) and ***S. spinipes*** (Herrich-Schaffer) *S. diadema* occurs throughout the United States and is the species most often encountered in soybean fields (Slater and Baranowski, 1978) who reported that *Sinea confusa* laid about 50 eggs during its lifetime. The eggs are laid in cluster and each cluster consists of one to 10 eggs The averaged egg in a cluster are 8.0 eggs But in *S. spinipes,* the number of eggs in a cluster is about 13 (ranged from 8 to 28) respectively. *S. diadema* feeds on a wide variety of prey species. (Readio, 1927a) *S. diadema* eggs are laid in double row on stem and leaves in masses averaging 8 – 12 eggs A single female can lay 412 eggs under laboratory conditions. The average length of time for an individual to reach the adult stage from the time the egg was laid is about 54 days. They recoded preoviposition and number of batches of eggs laid by these three hunter reduviids. The incubation period of *S. confusa*, *S. diadema* and *S. spinipes* eggs were 12, 12.6 and 13.6 days respectively. In *S confusa* 90.0 per cent and *S. diadema* 30.0% eggs were hatched into nymphs. Averaged nymphal period of *S. confusa* was 52 9 days (11 1, 7 5, 8.5, 10 7 and 15 1 days for I, II, III, IV and V instars, respectively) Some of the nymphal period is missing in other two *Sinea* spp The authors do not record the adult longevity and sex ratio of these species

The detailed life history of ***Sinea diadema*** (F.) was studied by

Shannon and McPherson (2003) in southern Illinois from February, 2001 to November, 2002, and the immature stages were described. The bug also was reared under controlled laboratory conditions. This bivoltine species occurs in herbaceous fields, often in association with leaves and stems of *Solidago missouriensis* Nuttall, and preys primarily on small bugs and beetles. It apparently overwinters as eggs. Nymphs emerged in mid-April and were found until mid-September. Adults were found from the third week of May until early October The bug was reared in the laboratory on larval beet armyworm, *Spodoptera exigua* (Hubner), at 26 ± 3.0°C under a 16:8 (L. D) h photoperiod The incubation period averaged 13.87 d. eyespots appeared in 7 days. The five stadia averaged 9.59, 7.80, 8.95, 11 80, and 12.97 days, respectively. Instars can be distinguished by differences in several anatomical features, including body length and width and progressive development of size, number, and pattern of spines Latter the life history of the harpactorine reduviid *Sinea spinipes* (Herrich-Schaeffer) was studied in southern Illinois during the same period by Rachel and McPherson (2005), and the immature stages were described The bug also was reared from egg to adult under controlled laboratory conditions. This univoltine species occurred on vegetation along roadsides within forests, in open fields beneath or near scattered trees, and along forest edges. It overwinters as adults, which emerged in mid-April and were found through early September. Nymphs were found from early June through late September The bug was reared in the laboratory on larval beet armyworm, *Spodoptera exigua* (Hübner), at 26 ± 3 0°C under a photoperiod of 16:8 (L:D) h. The incubation period averaged 15.13 d; eyespots appeared in 7 day. The five stadia averaged 8.15, 9.22, 9.21, 11.43, and 19 59 days, respectively. The total developmental period averaged 72.73 days Instars can be distinguished by differences in several anatomical features, including body length and width and progressive development of size, number, and pattern of spines.

Prey Record: *Sinea confusa* Caudell feeding on *S. exigua* (Cohen, 1990), *H. zea, H. virescens, P gossypiella* (Henneberry and Clayton, 1985) *Sinea diadema* (Fabricius) feeding on Cotton aphids (Ashmead, 1985), Caterpillars of cotton, Colorado potato beetle (Chittenden, 1907); Pear slug (Webster, 1912); Pepper weevil, Cotton boll (Morgan, 1907); *S. exigua*. *S. spinipes* (Herrich-Schaeffer) feeding on Grain bug (Stink bug) (Chlorochroa sayi) (Caffrey and Barber, 1919); *S. exigua* (Ambrose, 1999).

***Sphedanolestes signatus* Distant** is a violaceous black, alate, entomophagous hunter bug mainly found in the scrub jungles and the agroecosystems of southern India (Distant, 1904). It is a potential biological control agent on many cashew pests, such as, *Helopeltis antonii* Signoret (Sundararaju, 1984). It is a small hunter reduviid (6.5 mm). Vennison and Ambrose (1990b) observed the biology by using *M. domestica*, *Trilopphidia* sp and *H. armigera* as preys After the emergence (9.33 days) a female can lay 15.33 eggs. They are ochraceous with white operculum and elongately oval The eggs are laid singly and attached basally to the substratum with gelatinous cementing material At 32° C the laboratory laid eggs hatched in 10 to 15 days. It was reduced to 7 to 9 days, while reared on *C cephalonica* (Sundararaju, 1984). First, second, third, fourth and fifth nymphal instars took 8 to 20, 17 to 11, 8 to 20, 10 to 26 and 13 to 14 days respectively Total nymphal period ranges from 49 to 58 days. When it was reared on *C cephalonica* the time reduced to 43 to 63 days (Sundararaju, 1984) Survival rate was 26.66 per cent. The adult longevity was ranged from 11 to 100 days (Sundararaju, 1984) Cannibalistic behaviour is common when the nymphs were reared in groups. Among the cannibalistic, the newly moulted nymphs with soft cuticle are the main victims than the other nymphs. Generally males (27 5 days) lived longer than the females (21 days). Sex ratio was not biased to any sex (1:1 for male: female). Insects collected from different ecosystems had an impact on the development and fecundity. Ambrose (1983) had collected this bug from Maruthamalai in Western ghats and Azhagarmalai a tropical rain forest, Madurai District. Azhagarmalai dwelled bug developed faster (66.7 days), had higher fecundity (71 5 eggs female) and hatchability and adult longevity (138.5 days). Biology of *Sphedanolestes aterrimus* Distant was also briefly worked out by Ambrose and Livingstone (1986b).

Prey Record: *Caenobius* sp , *Helopeltis antonii* Sign. (Sundararaju (1984); *E. vitella* (Ambrose, 1999).

Sycanus collaris (Fab) has a black wing and measures 20 x 5 mm (male) and 25 x 7 mm (female) A gravid female lays about 103 to 115 eggs in a batch The eggs are subcylindrical. dark brown and 3.0 x 0 5 mm size. The incubation period is last for 11 days. Nymphal period comprising five instars (17, 11, 10, 15 and 24 days) last for 77 day. The longevity of the adults is 15 days in the laboratory (Sundararaju, 1984). The total life cycle takes for 103 days (Singh *et al.*, 1978).

Prey Record: *Hybloea puera* Cramer (Beeson, 1941); *P. machaeralis, E. machaeralis, H. cinchonae* (Corbett and Pagden, 1941); *H. bradyi, Sinohala helleri* Ohs., (Singh *et al.*, 1987); *R. clavatus*; *H. antonii* (Sundararaju, 1984; Pillai, 1988); *Pyrausta machaeralis*

Sycanus pyrrhomelas Walker is a red and black coloured hunter reduviid found in the tropical rain forest like Courtallum, Tamil Nadu, India *S. pyrrhomelas* is an entomosuccivorous. polyphagous, multivoltine bug Its general colour is red and black. Young ones and adults are litter dwellers. Ambrose and Paniadima (1988) studied the life history of this bug. Eggs are pale yellow and laid in batches. At the time of oviposition the female select an area free from foreign materials and remains at that particular spot with legs wide apart, wings slightly raised, pedicel and scape kept erect with dropping flagella segments. And then lay the eggs. A female can lay 89 eggs in its lifetime. The eggs hatched in 15 to 17 days and the hatching takes place in the afternoon and before dusk and seldom during forenoon. The stadial period between first and second instars ranges from 13–25 days (17.8). The second (12.6 days) and fifth (29.59 days) stadia are the shortest and longest stadia respectively. The third and fourth instars took 18.54 and 24.39 days respectively. General colour of the nymphs is ochraceous. Total survival rate of female was 58.76 per cent. The pre-oviposition period is 16 days. The life span of the adult female is 37.6 days and that of the male is 35.4 days. Male population was higher (100%) than the female population (90%).

Prey Record: *P. succincta. E. vitella, E. insulana* (Ambrose and Paniadima, 1988).

Sycanus reclinatus Dohrn, inhabits tropical evergreen forests of south India mainly on mango trees *Mangifera indica* Linn. Overall colour of the adult is ochraceous *Sycanus reclinatus* lays its first batch of eggs 22 days after emergence. Eggs are laid in cluster. A female lays 84 eggs in 1 3 batch. Each cluster consists of a mean of 67.9 eggs and the eggs are glued both basally and laterally at the base of the trunk of large trees by a gelatinous jelly like cementing material. The eggs hatch in 14 to 23 days invariably from 10.00 to 14.00 hours. Nymphs are congregational feeders whereas adults are individual feeders. The stadial period of first, second, third, fourth and fifth nymphal instars are ranged from 10 to 20, 5 to 14, 7 to 20, 6 to 28 and 4 to 46 days respectively. Altogether nymphs took 72 days to attain in to adults. The males and females live 5 to 54 and 5 to 50 days respectively. Laboratory breeding experiments indicated that this reduviid is multivoltine (Vennison and Ambrose, 1992). The sex ratio of male and female is 1.0: 0 8.

Prey Record: *H. armigera*, *E. insulana*, *E. vitella*, *Spodopera litura* and *D. cingulatus* (Vennison and Ambrose, 1992).

The genus *Zelus* contains nearly 13 species in the US, most of them occur in the southern and southwestern portion. Weeds are the common inhabitants of ***Zelus socius*** Uhler (Swadener and Yonke, 1973c) It is a univoltine reduviid. An average of 26 eggs is deposited in a circular mass, and a female can layup to eight egg masses The eggs of this bug are elongate to oval, slightly concave on each side of median longitudinal ridge Colour dark brown; concave areas lighter. Eggs were deposited in a somewhat circular mass. There is only one generation in a year. The developmental period for eggs averaged 9.0 days and the nymphal developmental period averaged 52.6 days (9.1, 7.1, 10.0, 15.6 and 10.8 days for I, II, III, IV and V instars respectively). Ninety-two percentages of the eggs were observed to hatch. A female can deposit an average of 17 eggs with a range of 12 to 36 eggs per mass. Among the *Zelus* spp. observed in US the most common and widespread species of *Zelus* is ***Zelus exsanguis*** Stal occurs from New England to the Pacific and south to Florida and Texas. Its biological aspects were observed by Edwards (1966) and Guerra and Rodriguez (1976). The laboratory laid eggs were hatched within 17.5 days (range of 14 to 21 days) with the hatching percentage of 87.4. Only 35.5 nymphs were hatched from the eggs The eggs are not cold resistant and do not survive 12 hours at –3° C First, second, third, fourth and fifth nymphal instars were emerged within 7.5, 9.0, 12 0, 36.0 and 54 0 days respectively The averaged nymphal developmental period was 118.50 days. The last two stadium occupies unexpectedly long period (32 to 40 and 50 to 58 days for fourth and fifth instars, respectively).

Prey Record: *Eutettix tenella* Baker (Severin, 1924); Cotton bollworm larvae (Whitcomb and Bell, 1964); Mirids (Swadener and Yonke, 1973b); Cercopids, Cicadellids, Fulgorids, Aphids, Curculionids, Chrysomelids, Noctuids, Pierids, Pyralids, Orthoptera nymphs, and small dipteran adults.

S. himalayensis **(Cohen, 1996)** head, anterior lobe of pronotum, femora, tibiae and abdominal apex deep ochraceous, eyes testaceous with rufescent margin, posterior lobe of pronotum fuscous, hemelytra testaceous membrane hyaline, abdomen dorsally fuscous, ventrally stramineous, connexivum piceously spotted on the fifth and sixth segments dorsally. Head oblong, medially strongly impressed, pilose, eyes laterally protruding, shorter anteocular exarated from pulvinate and longer post ocular, antennae long, four segmented scape obscurely pilose, pedicel and flagellar segments richly pilose, distal flagellar segment the longest and pedicel the shortest; rostrum robust, three segmented, longer than head, mid segment the longest and distal segment the shortest Pronotum broader, pubescent, slightly shorter than head, laterally obtusely produced, posteriorly emarginate; smaller, bulbous anterior pronotal lobe sulcated from strigose, mid dorsally pulvinate posterior lobe; scutellum small, conical, scarcely acuminate; hind legs the longest and mid legs the shortest; anterior femora incrassated longitudinally, femora and tibiae richly pilose, three segmented tarsi, mid tarsus the longest and proximal tarsus the shortest; corium moderately pilose, membrane passes abdominal apex. Seven segmented abdomen, pulvinate and pubescent, third, fourth and fifth segments bear dorso medial scent gland orifices *S. himalayensis* laid single, elongated, rubescent eggs glued to the top of the rearing container. Eggs hatched within 9.6 days First instar took 9.8 days (8 – 11 days) to attain into second instar. Second, third, fourth and fifth instar took 10 2 (9 - 11), 11.2 (10 - 12), 8 6 (8 - 10), 9.2 (male) and 10.8 (for female), respectively. Averaged developmental period was 52.8 days (43 – 55 days). Eighty seven per cent of the nymphs attain into adults (2.1, 3.6, 3.3, 1.6 and 1.4 for first, second, third, fourth and fifth nymphal instars respectively) Sex ratio is female biased (1.0: 0.86 for female. male) Female took 9 8 days to lay eggs. During its life time female 14 1 days laid eggs Totally a female laid 74.8 eggs with 10 3 batches Maximum and minimum number of eggs in a batch was 10 4 and 3.2, respectively

Prey Record: *O. obesus*; *C. cephalonica* (Ambrose, 1999).

***Vesbius sanguinosus* Stal** was collected from agro-ecosystems especially from the foliage of *Tamarindus indicus* L. and was found feeding on *Oecophylla* sp. and *O. obesus*. Its microhabitat was cool and shady with abundant populations of hairy caterpillars, midges and hoppers. Nymphs too were abundant along with adults Head, eyes, antennae and membrane fuscous piceous; neck, pronotum, abdomen and corium rubescent; legs fusco-rufous. Head triangular, obsoletely pilose, laterally protruding eyes anteriorly placed and vertex tumid, bulbous postocular separated from shorter anteocular by a deep sulcus, head width equals to postocular length; antennae long, pubescent and four segmented, scape the longest, longer than head, pedical the shortest, equals to postocular in length; rostrum robust, slightly shorter than head, mid rostral segment the longest and distal segment the shortest; neck prominent. Pronotum broader, dorsally bulbous, pilose, collar obscure, anterolateral margins angularly, obtusely produced, posteriorly truncated smaller anterior lobe separated from larger posterior lobe by a sulcus, scutellum triangular, moderately acuminate; legs pilose, femora nodose, three segmented tarsi, mid tarsus the longest and proximal tarsus the shortest; hemelytra slightly longer than abdomen, corium smaller, pubescent, membrane large, shining; proximal membrane fuscopiceous and distally transparent, membrane extends beyond abdominal apex. Abdomen eight segmented, oblong, dorso-ventrally compressed, edges plain, second to fifth segments each with a mid dorsal median opening of abdominal glands, octoon rubescent, moderately pubescent. Eggs are hatched into young ones within 7.8 days. First, second, third, fourth and fifth instar nymphs took 6.2, 6.8, 7.2, 6 1 and 7.05 days respectively. The averaged nymphal period was 38.6 days (30 – 40 days). Maximum nymphal mortality was observed in the third instar (7.8%) followed by second (5.6%) and first instar (4.2%), mean survival rate of the nymphal instar was 77.3 per cent As observed in other harpactorine reduviids, the sex ratio was female biased (1:0 93 for female : male). Adult male and female lived for 61 2 and 68 1 days, respectively. During the female life time, they laid 49.8 eggs with 9.7 batches of eggs. Batches consist of a minimum of 2.8 and a maximum of 7.2 eggs. Female spent most of its time of egg laying than the pre (8.6 days) and post (2.3 days) oviposition days. Except 12 per cent, all other eggs are hatched into nymphs.

Prey Record: ***O. obesus, C. cephalonica*** (Ambrose, 1999).

In ***Alcmena spinifex*** Thunberg the head, pedicel, flagellar segments, rostrum, pronotum and abdomen ochraceous; femora and tibiae testaceous, scape rufous. Head oblong, pubescent, vertex pulvinate, eyes laterally protruding, shorter anteocular demarcated from postocular by a deep transverse sulcus, anteocular medially impressed, a pair of ochroleucus ocelli in the mid dorsal postocular; antennae pilose, four segmented, scape the longest and first flagellar segment the shortest, one prominent spine at the base of each antenna; rostrum robust, three segmented resting in the prosternal groove, first segment the longest and the third segment the shortest. Pronotum large, pilose, smaller, tumid anterior lobe deeply transversely sulcated from larger posterior lobe, anterior lobe with dorsal characteristic pattern formed by impubis tracks; posterior pronotal lobe posteriorly truncated and laterally produced on either side into a characteristic spine arranged on a conical tubercle; collar obscure with a pair of highly obliterated lateral spines, scutellum triangular, pubescent, not acuminate; hemelytra as long as abdominal apex, corium ochraceous, sabulose, membrane thin, transparent, bronzy; hind leg the longest and mid leg the shortest, apices of tibiae richly pubescent, tarsi three segmented, mid tarsus the longest and proximal tarsus the smallest. Abdomen slender and much longer than broader with seven prominent segments, four median glandular openings between third and seventh segments, connexivum obscure, abdomen ventrally richly pubescent with impubic regions showing a dotted pattern. Female slightly larger with elongated abdomen, connexiva of fifth and sixth segments greatly laterally dilated into a piceous conical flap.

Females laid the eggs in batches (8.6) and they took 10.1 days to hatch The averaged nymphal period was 61.2 days, with the range of 51 to 66 days (10.8, 11.2, 12.6, 11.8 and 13.6 days for I, II, III, IV and V instars, respectively). Eighty-two per cent of the nymphs survived during their life time. Among the nymphal instars minimum and maximum mortality was observed in fifth (2.08%) and third (45%) instars, respectively Sex ratio was female biased (0.81 for male) and they lived 9 days more (90 9 days) than that of male (82.1 days). Females spent maximum time (76 5 days) for laying eggs followed by preoviposition (10.2 days) and postoviposition (4.2 days). During her life time, a female can lay 196.6 eggs with a minimum of 12.2 and a maximum of 29 6 eggs per batch. Hatching percentage was 92 27 per cent.

Prey Record: *Odontotermes obesus* Rambur, *Euproctis fraternal* Moore, *Euproctis scintillans* Walker, *Ergolis merinone, C scales* (Ambrose, 1999).

Head, pronotum and scutellum ferruginous, abdomen ochraceous dorsally and griseous ventrally; posterolateral connexivum carries castaneous markings, pubescent, slender, elongate hairs arranged on small tubercles along the lateral margins or present all over the body of ***Scipinia horrida*** **Stal** Head elongate with a prominent neck covered with a coat of short fine hair, compound eyes protruding laterally, postocular bears a dorsal transverse sulcus, a pair of nitid nigrescent dorsal ocelli behind transverse sulcus, three pairs of slanting spines dorsally in the anteocular area, first pair moderately separated just behind the antennae, second pair arranged more closely, third pair arranged side by side presenting a triangular arrangement. Postocular area bears three pairs of comparatively shorter and smaller spines; a number smaller spines and spinules distributed on the dorsal aspect of head, anteocular much shorter than postocular; antennae filiform, ochraceous, four segmented, scape the longest followed by second flagellar segment; pedicel the shortest, pedicel and first flagellar segments subequal in length, intercalary segments in between scape and pedicel, pedicel and first flagellar segment, first flagellar segment and terminal flagellar segment, pedicel and flagellar segments richly pilose, scape shorter than foretibia, rostrum ochraceous, three segmented, moderately pilose with a midventral groove, slightly curved and resting in the antero mid ventral region of the prothorax; first segment longer than second, third segment the smallest; first segment shorter than scape but longer than pedicel and first flagellar segment separately, second segment slightly shorter than first flagellar segment but slightly longer than pedicel. Pronotum with a smaller richly pilose anterior and a larger posterior segments; transversely obscurely impressed, two pairs of dorsal prominent spines on anterior pronotum, number of less prominent spines in the antero lateral margins, antero lateral pronotal angles spinous, posterior lobe of pronotum shows two posterodorsal and two acute postero lateral angles, dorsal surface of pronotum with flavous impressions; scutellum triangular, pilose, granulate with a very small median spine at the apex. Anterior femora moderately incrassated, nodulose with a long dorsal spine near the apex and with a double series of ventral spines, mid and hind tibiae spinulose, tarsi three segmented with a pair of claws, hemelytra ochraceous, and membrane passing beyond abdomen. Abdomen ochraceous, connexivum deflexed upwards, moderates pilose, connexiva of fourth and fifth segments angularly produced and ferrugmous; oritices of glands open middorsally on a slightly elevated region in between the first and second, second and third and third and fourth abdominal segments.

Scipinia horrida female laid 214 2 eggs in her adult lifetime. Post-oviposition period was shorter (3.8 days) than the preoviposition period (9.4 days). *S horrida* laid the eggs in cluster. Each cluster has a minimum of 14 1 eggs and a maximum of 28.8 eggs. Among the 214.2 eggs, 202 eggs hatched in to nymphs (94.68%) within 9.2 days. Individual stadial periods were more or less equal to the incubation period (9.2, 9.1, 9.6, 9.8 days for first, second, third, fourth and fifth nymphal instars respectively) except IV (8.2 day) instars. Averaged developmental period was (48.6 days) (44 – 49 days). Among the emerged nymphs only 84 per cent were survived.

Prey Record: *Erosomyia indica* Grov. (Barrion *et al.*, 1987); *L. leucocephala* (Uthamasamy, 1995); *C. compressus, O. obesus, E. fraternal, E. scintillans, E. merionone* scales.

Irantha armipes Stal head rostrum, antennae, pronotum, femora, tibiae and venter of abdomen ochraceous; eyes bright rufescent; membrane bronzy. Head oblong, spinulose, shorter anteocular separated by a deep sulcus from bulbous and distinctly spinulose and longer postocular, a pair of spines in the vertex, a pair of spines one at the base of each antenna and a pair of dorsal rectus spines in the postocular; eyes laterally protruding; a pair of rufous mid dorsolateral ocelli just behind the eyes; neck long, prominent, devoid of spines; antennae four segmented, distal flagellar segment the longest and proximal flagellar segment the shortest, intercalary segments prominent, inbetween scape, pedicel and proximal flagellar segments, scape moderately pilose, pedicel and flagellar segments richly pilose; three segmented rostrum, robust, longer than head, first segment the longest and third the shortest, rostral tip reaches prosternal groove. Granulose pronotum with spines and munite tubercles, collar obscure, anterior pronotal lobe slightly shorter than posterior lobe, posterolateral angles prominent, posterior margin truncated, two pairs of middorsolateral rectus spines in the anterior pronotum, scutellum ochroleucus, unarmed, posteriorly attenuate but subspiniform; corium spinulose, membrane transparent, bronzy, hind leg the longest and mid leg the shortest, femora incrassated and nodulose, anterior femora pilose, distally with a long dorsal spine and four pairs of short ventrolateral spines, three pairs of stumpy tubercles inbetween these two rows of spines, anterior tibia, mid and posterior femora and tibiae richly pilose, tibial pad prominent, mid tarsus the longest and fore tarsus the shortest Eight segments of the abdomen is prominent, connexivum continuous with testaceous markings on the fourth and fifth segments, orificium ventral, four dorsomedian glangular openings at the junctions of the third and fourth, fourth and fifth, fifth and sixth and sixth and seventh segments.

Prey Record: *Caenobius* sp., *Helopeltis antonii* Sign (Sundararaju (1984)); *A. janata* (Babu *et al.*,1995); *A. biguttula biguttula* (Lakkundi, 1989); *H. armigera, C. cephalonica* (Livingstone and Yacoob, 1986); *O. obesus, Tephrina pulinda* (Walker), *Teleonemia scrupulosa* Stal.

Sphedanolestes sp. was recorded from the undergrowth in Perunchani tropical evergreen forest mainly living among the tall grass, *Eragrostis atrovirens* (Desf.), feeding on small flies, tiny caterpillars and midges. Head, antennae, pronotum, scutellum and femora piceous, margins of eyes castaneous, extending as faciae into the postocular area up to the ochraceous ocelli, hemelytra nigrescent, tibiae testaceous, abdomen stramineous. Head pilose, vertex bulbous, shorter anteocular and longer postocular separated by a deep sulcus, head shorter than scape, eyes laterally protruding, neck prominent, antennae four segmented, distal flagellar segment the longest, pedicel the shortest second rostral segment the longest and distal segment the shortest, rostral tip touches midventral pronotal groove at rest Pronotum broader, sericeous, anterior pronotal lobe smaller, bulbous, moderately pilose, longitudinally impressed, collar prominent with the dorsolateral edges angularly produced, posterior pronotal lobe richly pilose, posterolaterally angularly produced, posterior edge truncated, scutellum obsoletely acuminate, corium sericeous, membrane shining, reaching up to abdominal apex, wing width equals to length of proximal flagellar segment, legs richly pilose, femora moderately incrassated, tibial pads rudimentary, hind tibia the longest, mid tibia the shortest, tarsi three segmented proximal tarsus the shortest and mid tarsus the longest. Abdomen with six prominent segments margin regular and pubescent, abdominal glands open mid dorsally on the second, third and fourth segments at the base of the tergal plates, abdominal width equals to mid tibial length, total length 7.335 ± 0.32 mm.

Prey Record: *S. litura* (Rao *et al.* , 1981).

Brassivola sp. was found to inhabit the shrubs of Keeriparai – Kalikesam tropical evergreen forest and feeding on *Poeciloceros* sp. and *Colemania* sp. They were found resting among *Morinda coreia* Buch-Ham. And usually occurred singly. Head, rostrum, pronotum, scutellum and corium luteus; femora and tibiae with prominent annulations of broad ochraceous bands alternating with narrow ochroleucus ones, eyes shining bright, testaceous, corium fuscotestaceous, membrane bronzy, shining. Head oblong, pubescent, distinctly sabulose, medially impubis, shorter anteocular separated from pulvinate postocular by a sulcus, anteocular produced beyond antennal base, eyes laterally protruding, one spine at the base of each antenna; scape and pedicel moderately pilose with straight and clavate hairs, flagellar segments pubescent, two annulations in the scape and a single annulation in the pedicel, a pair of laterally placed rufescent ocelli just behind tumid vertex, long, robust, three segmented rostrum slightly longer than head, reclined, resting in the prosternal groove; neck prominent. Pronotum large, sabulose and pilose, anterolaterally produced into a short stout spine on either side and middorsally with two rectus spines, and posterolaterally produced into a spine on each side and with two dorsal suberect spines and truncated just before the short and apically conically produced scutellum, anterior pronotal lobe impubis along the meson separated from richly pubescent posterior lobe by a transverse sulcus, hemelytra long, pubescent, membrane transparent extending beyond abdominal apex, femora and tibiae richly pilose, hind leg the longest and mid leg the shortest, tarsi three segmented, mid tarsus the longest and distal tarsus the shortest. Abdomen eight segmented, rubescent and pubescent, connexivum narrow, ochraceous, four orifices of abdominal glands along the meson inbetween third, fourth, fifth, sixth and seventh segments. *Brassivola* sp. laid thick piceous eggs with lateral dents in cluster of 2 – 14. They took 13.2 days as incubation period. First, second, third, fourth and fifth nymphal instars took 11.7, 12.3, 13.8, 14.2, 14.8 and 15 9 days for completing their development. Averaged developmental period was 69.8 days (59 – 71 days) with 94.7 per cent nymphal survival rate. Though the sex ratio was in favour of female, it was not significant to male (10: 0.95 for female: male). Male and female longevity were 90.9 and 98.6 days, respectively. Gravid female laid eggs within 12.1 days after the moulting. Totally a female laid 103.8 eggs. Among the eggs laid by a female 69.92 per cent hatched into nymphs. After egg laying is over female lived for 5.6 days.

Prey Record: *Corcyra cephalonica* Stainton, *H. armigera* (Ambrose, 1999), *Dasychira mendosa* (Babu *et al.*, 1995), *Eumeta cramerii, Euproctis lunata* (Kupusamy and Kannan, 1995).

***Coranus* sp.** head and pronotum pubescent, anteocular, anterior part of postocular, pronotum, scutellum except the middorsal line tawny, posterior postocular and lateral aspects of neck and head up to the eyes nigrescent, eyes and ocelli testaceous, abdomen dorsally ochraceous and ventrally stamineous, connexiva ochraceously spotted, both dorsally and ventrally membrane shining, griscent Head oval, pubescent, postocular region marked off by a sulcus, little anterior to the mid post ocular region laterally one pair ocelli, one on each side, dorsal surface of head tuberculate, antennae subtly ochraceous, scape mildy, pedicel and proximal flagellar segments densely munite, distal flagellar segment densely pilose, postocular longer than anteocular, head longer than scape, distal flagellar segment the longest; rostral tip reaches the midventral pronotum just in front of the forelegs, second rostral segment the longest, passing beyond the posterior margin of the eyes Pronotum pilose, pronotum broader than longer, anterior pronotal segment slightly shorter than the posterior segment, both separated by a deep sulcus, anterior pronotal lobe distinctly sculptured, Collar obscure, antero and posterolateral margins angularly produced, posterior pronotal lobe truncated posteriorly, excavate with two posteriorly directed rounded projections; scutellum backwardly directed with a short coriaceous apex, and a characteristic mid-dorsal ochroleucus band, legs sericeous, femora of the three legs with tawny longitudinal carinations, hind tibia the longest and mid tibia the shortest, tarsi three segmented, proximal the smallest and distal the longest, hemelytra ferruginous, clavus narrow, corium with castaneous venation, hind wing ochraceous, membrane does not reach abdominal apex, hemelytra longer than hind tibia. Abdomen gibbous, third to the sixth segments marked middorsally with a gradually broadening castaneous band, connexivum with castaneous spots, fifth and sixth segments obscurely granulate, on the dorsal surface of each of the second, third and fourth segments a median orifice of the abdominal glands open. Females lived longer (102.8 days) than the males (95.7 days). A female can lay 148.8 with 13 4 batches eggs during its life time. Eggs are ochraceous in colour. They hatched within 7.3 days. Pre and post oviposition periods were 10.4 and 4.9 days, respectively. Egg enclosed into adult by 49.8 days (43 to 53 days) (7.8, 8.6, 10.1, 10.1 and 12.4 days for first, second, third, fourth and fifth nymphal instars respectively). Survival rate of nymph was 89.0 per cent. Sex ratio was female biased (1.0 : 0.86 for female: male).

Prey Record: *Nysius inconspicuous* (Joseph (1959)); *Myzus persicae, Sylepta derogata, Myllocerus maculosus, Bagrada picta, Chilo zonellus, Heliothis armigera, Corcyra cephalonica, Naranga* sp. (Krishnaswamy *et al*., 1984).

All predators studied were alate, entomosuccivorous, crepuscular and multivoltine. These were collected from scrub jungles and evergreen forests in Kanyakumari District. *C. furcellata* inhabited the foliage of *Prosopsis juliflora* (SW) DC and were usually found in pairs feeding hairy caterpillars, *Colemania* sp. and *Erosomyia* sp. of the microhabitat. *A. spinifex* and *S. horrida* also occupied the same habitat and were found feeding on *Poeciloceros* sp. *Oecophylla* sp. or on *Componotus compressus* Fabricius. These predators were often found occupying the shady regions of *Acacia planifrons* Wight and *Prosopsis spicigera* (L.) along with *S. minusculus, R. longifrons* and very rarely with *I. armipes*

S. himalayensis*, *I. armipes and ***Coranus*** sp. were found to inhabiting the shrubs of Kodayar evergreen forest. These were found under the large leaves of *Macaranga indica* Wight and very rarely occur as mating pairs During heavy monsoon rains and winds, the predators were found to take shelter under the large leaves of plants like *Jatropha glandulifera* Roxb., *Solaman torvum* SW, and *Lantana camara* L. They were found feeding mainly on caterpillars, *Poeciloceros* sp , *Colemania* sp. and *C. compressus*. The co-inhibitants were certain plant bugs and reduviid predators like *E. plagiatus, R. marginatus, S. pubinotum, Macracanthapsis nodipes* Reuter, *R. kumarii, R. fuscipes, Cydnocoris gilvus* Stal and *Irantha consobrina* Distant. *S pubinotum* and *S. minusculus* were occasionally found to occupy the same microhabitat along with *E. plagiatus*

Oviposition pattern and hatchability

The highest adult female longevity was observed in *Coranus* sp. (102.8 ± 6.8 days) and lowest in *C furcellata* (58.2 ± 2.8 days); *Brassivola* sp. had the highest preoviposition period (12.1 ± 1.04) and *C. furcellata* the lowest (7.4 ± 0.62). The index of oviposition days was the highest for *A. spmifex* (15.2 ± 1.06) and the lowest for *Brassivola* sp. (8.16 ± 0.72) *C.furcellata* laid the highest number of eggs (364.8 ± 21.6) and *V. sanguinosus* the least number of eggs (49.8 ± 2.6). The hatching percentage was the highest *S. horrida* (94.68 ± 7.6) and the least in *Brassivola* sp. (69.92 ± 4.1). *V. sanguinosus*, sanguinous eggs singly, *A. spinifex* and *S. horrida* ocharaceous eggs in clusters of 15 – 28, *I. armipes* brownish eggs in a rosette of 6-8, *Brassivola* sp., thick piceous eggs with lateral dents in clusters of 2-14, *Coranus* sp., pale ochraceous single eggs and *Sphedanolestes* sp., yellowish ochraceous eggs laid singly or sometimes two or three eggs glued together.

Incubation and hatching

The longest incubation period was observed for *Brassivola* sp. (13.2 ± 0.65 days) and the shortest for *C furcellata* (6.2 ± 0.46). The eggs of all the predators hatched between 5 and 10 a.m. in the morning and 2 and 6 p m. in the evening Eclosion occurred in a regular pattern The head came out first by opening the opercular lid, followed by the porthorax. The young nymph wriggled out of the egg case with backwardly folded legs. Eclosion took place in about 4-8 min in all the predators except *C. furcellata* (2.3 min.) and *Brassivola* (7-10 min.). Tanning of the nymphs took place in about 50-70 min and the nymphs took their first feed about 6-8 h after hatching.

Stadial period

The stadial periods differed for each predator and the *V. stadium* was uniformly the longest. The IV stadium was the shortest in *C. furcellata, S. himalayensis, V. sanguinosus* and *S. horrida*; I stadium the shortest in *A. spinifex, I. armipes, Brassivola* sp., and *Coranus* sp., and II stadium the shortest in *Sphedanolestes* sp.

2.5 Peiratinae

Catamiarus brevipennis Distant is a brachypterous, crepuscular, entomosuccivorous, polyphagous hunter bugs. It is mostly found in the scrub jungles and semi-arid zones and their bordering ecosystems like cotton, groundnut of India. The adults and nymphs are present throughout the year. However, the peak adult and nymphal population of there bug was recorded in July and January respectively. Usually these bugs are found in groups with nymphs or other insects like carabid and tenebreonid beetles, snakes, frogs or scorpions. In the field it is feeding on large insect pests like Mumbai locust. Nymphal instars are black and legs ochraceous brown. Tibial pads are present in both fore and mid legs. Abdomen elongate in nature. It has three prominent median repugnatiorial glands in between third and fourth, fourth and fifth and fifth and sixth segments. Eggs (2.23 cm long and 0.92 mm broad) are elongate and pale yellow in colour. Cephalic end is slightly indented in nature. The operculum centrally convex and is hidden by the filamentous outgrowth of the chorionic collar around the mouth of the egg. They lay singly and not attached to the substratum not to fresh faecal matter. Eggs hatched between 17 to 30 days. Nymphal instars need 122.81 days for completing its development (Ambrose *et al.*, 1985). Nymphs are highly cannibalistic in nature. Among the laboratory emerged adults 60 per cent are male and remaining 40 per cent are female.

Prey Record: *Cyrtacanthacris succincta* (Ambrose *et al.*, 1985);

Mylabris pustulata, Patanga succincta (Linn.) (Ambrose, 1988); *Earias vittella* (Fabricius) (Ambrose, 1985); *E. insulana* Boisd., *Heliothis armigera* Hubn. (Bhatnagar *et al.*, 1983), Pawar *et al.*, 1986), *E. insulana* (Ambrose, 1987a); *M. pustulata, D. cingulatus* (Sahayaraj, 1991); *A. janata.*

Ectomocoris tibialis Distant polymorphic, entomo-succivorous, polyphagous, univoltine, crepuscular and warningly coloured hunter bug. Mainly present in the agro-ecosystems and their border ecosystem like semiarid zones and scrub jungles. The polymorphic forms are alate (16.42 mm length) and brachypterous (17.01 mm length) males and brachypeterous female (18.94 mm length) (Sahayaraj, 1991). At first time the biology was described by Ambrose and Livingstone (1989d) on houseflies, camponotine ants, carabide beetles and grasshoppers. Their description was not reported here. The reduviid was fed with *C. cephalonica* and its development and fecundity were observed (Sahayaraj, 1991). Adults and nymphs are black in colour. If it has wings then it is Pale straw yellow in colour, broadly oval, indented on one side with a translucent operculum. The pre-oviposition period was 13.29 day and a female can lay 43.83 eggs. Eggs are laid in single and having a minimum of 1 egg and a maximum of 5 to 6 eggs Among the laid eggs, 54.45 per cent of them were hatched and the incubation period was 14.78 days. Eggs are also found to be inserted in the substrates. Averaged total nymphal instar was 101.79 days (18.02, 18.16, 19.36, 17.85 and 29.0 days for first, second, third, fourth and fifth nymphal instars respectively). Sex ratio was male biased and they lived shorter period (45.33 days) than the females (69.91 days).

Prey Record: *Heliothis armigera* Hubn., Dysdercus cingulatus Distant. (Ambrose, 1985); *C. compressus* (Ambrose, 1980, 1987); *H. armigera, D. cingulatus, M. pustulata, S. litura* (Ambrose and Livingstone, 1990); *P. gossypiella* (Sahayaraj, 1991); *C. cephalonica.*

Ectomocoris vishnu Distant biology was carried out by Vennison and Ambrose (1990). It is an alary polymorphic reduviid. Males are alate and the females are micropterus reduviid. It is a violaceous black and yellow, crepuscular, polyphagous and entomophagous reduviid, mainly present in tropical evergreen forests. It was first described by Distant in 1904 He was collected this reduviid from Mumbai. Vennison and Ambrose (1990) and myself were collected this predators from Azhaharmalai tropical forest in Madurai district, Tamil Nadu, India. Eggs were laid after 15 days of emergence. Eggs are laid deep inside the soil and cover them with small sand particles with the help of the hind legs. It is pale yellow, elongated oval with distinct white operculum. During the lifetime a female can lay 74 eggs in 19 batches. Usually seasonal influence on the oviposition of reduviids was not observed. But such a kind of influence was observed in this species and also in other reduviids like *A. albospilus* (Odhiambo, 1959) and *Zelus* sp. (Ralston, 1977). The eggs hatched in 22 to 122 days. The newly hatched nymphal instar feed only 24 to 48 hours after the eclosion. They took 71 to 88 days (77.5 days) to reached in to adults. But the adults lived very short duration when compared to the adults (28.0 and 48.0 for male and female, respectively). Nymphal survival is lower in the first instar (44%) and followed by second and fifth instar (68 and 67%). The highest survival was observed in fourth instar (87.5%).

Vennision and Ambrose worked out biology of another newly described species ***Ectomocoris xavierei*** Vennison and Ambrose in 1991. It is a polymorphic, crepuscular, entomosuccivorous reduviid. It was collected from Courtallam Tropical rain forest. I have collected this reduviid from Tekkadi, tropical evergreen forest It is mainly present beneath the stones and in litter along with other reduviids like, *Pirates affinis* Serville and *Holoptilus melanosphilus* Walker. A female can lay about 112.83 eggs during its lifetime. Eggs are dull white and elongately oval in nature. They took 23 to 27 days to hatch in to nymphs. Among the eggs alid only 20 per cent eggs were hatched into young ones. The first, second, third, fourth and fifth nymphal instars took 17.7, 13.2, 15.7, 20.4 and 24.4 days, respectively. Total nymphal period is 93.6 days. Females lived longer (42.6 days) than the males (32.62 days).

2.6 Pseudometapterus

Pseudometapterus umbrosus (Blatchley) was described (as *Metapterus umbrosus*) in 1926 from Florida, apparently based on a single non-macropterous male adult. It subsequently was transferred to the new genus *Pseudometapterus* by Wygodzinsky

(1966) in his landmark revision of the emesine reduviids. He reported he had obtained information from R. Hussey who had examined the type and several additional specimens, apparently all from Florida. Hussey expanded Bletchley's description but apparently did not mention wing form. Although Wygodzinsky did not mention wing form specifically in his discussion of the species, he used "micropterous or apterous" as a diagnostic character in his key to separate four species, including *P. umbrosus* , from *P. obtusus* (Piza), which he called "winged." McPherson (1991) reported the presence of *P umbrosus* in southern Illinois based on two male adults who collected from the LaRue-Pine Hills Ecological Area and housed in the Southern Illinois University Entomology Collection (SIUEC), both specimens are micropterous. Subsequently, Hagerty and McPherson (1999) reported that this species apparently is univoltine in southern Illinois and over winters as adults. Further, it occurs on spider webs and plants (*Heuchera parviflora* Bartling) on sandstone bluffs and on spider webs on limestone bluffs. This information was based on 43 adults collected in Jackson and Union countries Bradshaw and McPherson (2001) reported that detailed study of the biology of this emesine was conducted at Little Grand Canyon, Jackson County, including life history, laboratory rearing and descriptions of the immature stages But no details have been mentioned in the paper.

2.7 Reduviinae

***Acanthaspis pedestris* Stal** has been present in semi-arid zones, scrub jungles, tropical rain forests and also in agroecosystems. However, it prefers to live in dry climatic conditions. Both of its nymphs and adults are predaceous in habit Its size is ranged from 18 to 21 mm and micropterous predator. The antennae are straight and shorter than the body. Both fore and hind legs are having tibial pad. It is found uniformly throughout the Tamil Nadu. The peak population of this reduviid was observed in June and July However, it has been observed throughout the year. This reduviid population has been abundant in dry areas where small stones prevail Even in lower rainfall and relative humidity and moderate temperature we can find this insect at any ecosystem The sex ratio was found to be female-biased. Usually they live in groups. Both adults and nymphal instars live together in a microhabitat or niche

Furthermore, large number of males (95 no.) and females (4 no.) of this bug were found together with nymphs and adults of ***Catamiarus brevipennis***. Rearing container space reduces the nymphal development (104 ml capacity) (66.6 days) and very large sized containers (208 ml) enhanced the adult longevity. However, reduction in space increased the reproductive potential and decreased the size of the bug (Vennison and Ambrose, 1989c). Detailed biology was worked out by Livingstone and Ambrose (1978b) on houseflies and ants. Later, Sahayaraj (1991) studied its development (except fecundity and hatchability) by providing them with *C. cephalonica*. The average nymphal period was 70.47 days (68 to 72 days) (12.46, 8.69, 9.23, 13.69 and 24.02 day for first, second, third, fourth and fifth nymphal instars respectively). The survival rate of the nymphal instar was 100 per cent. The adult longevity (34 83 and 56.0 days for male and female respectively) was shorter than the nymphal period. Among the laboratory adults emerged, females were predominant (1.0) than the males (0.85). Recently he observed (unpublished data) the fecundity and hatchability. After attain into adult, female laid its first batch of eggs after 32 days. The eggs are pale yellow in colour and broadly oval in shape. During her lifetime, she laid about 180.3 eggs with 48.5 batches of eggs. In an average each batch consists of 5.0 eggs (3 to 12 eggs). Among the eggs, 60.78 per cent hatched into nymphs and took 16.3 days to hatch. Its biology in relation to different ecotypes was studied by Ambrose and Livingstone.

Prey Record: *Heliothis armigera* Hubn., *Cyrtacanthacris succincta* Kirby, *Patanga succincta* (Linn.) (Ambrose, 1988); *Earias vittella* (Fabricius) (Ambrose *et al.*, 1988b); *E. insulana* Boisd., *Mylabris pustulata* Lefroy (Ambrose, 1985); *Odontotermes assumthi* Holmagren, *O. wallonensis* Wasmann (Rajagopal, 1984), *O. obesus* Rambur (Ambrose, 1985); Chilo partellus (Butani, 1958); *H armigera* (Ambrose, 1987a, 1988); *P. succincta, M. pustulata, M indica, O. assumthi, P. gossypiella* (Sahayaraj, 1991); *A. janata, E insulana, S. litura, C. cephalonica, O. hyalinipennis*.

Acanthaspis quinquespinosa (Fabricius) an alate, warning coloured, crepuscular, entomosuccivorous, polyphagous and multivoltine assassin bug found in the tropical evergreen forests, scrub jungles, semiarid zones and agroecosystems of peninsular India (Sahayaraj, 1991) It was first reported by Distant (1902) from

Assam, Ranchi and Mumbai. Intensive collection in Tamil Nadu, India shows that *A. quinquespinosa* distributed in Tropical rain forests (Keeriparai, Patchaimalai, Surlitheertham), scrub jungles (Marunthuvazhmalai, Sivanthipatti), semiarid zones (Kanyakumari, Pollachi, Tambaram, Usarathukudieruppu) and agroecosystems (cotton and groundnut respectively) It is a recognised predator of larvae and nymphs of many pesti-ferous insects such as *Laphygma exiguae* Hubner (Lepidoptera: Bombycidae) (Butani, 1958), *Mylabris pustulata* (Thunb.) (Coleoptera: Meloidae) (Ambrose, 1988), *Odontotermes wallonensis* (Isoptera : Termitidae) (Rajagopal, 1984), *Dysdercus koenigii* (Fab.), *D. laetus* Kirby (Hemiptera : Pyrrhocoridae) (Lakkundi, 1989), *Helicoverpa armigera* Hubner (American bollworm, Lepidoptera : Noctuidae), *Spodoptera litura* (Fab.) (Lepidoptera : Noctuidae), *Pectinophora gossypiella* Saunders (Lepidoptera Gelechiidae) and *Corcyra cephalonica* Stainton (Rice meal moth, Lepidoptera : Galleriidae) (Sahayaraj, 1991). The bioecology (Ambrose, 1983) and ethology (Ambrose *et al.,* 1986) were studied. Moreover, Lakkundi (1989) and Sahayaraj (1991) developed new methods for mass rearing of this reduviid According to them the highest stadial period was in fifth instar and followed by first instar The least stadial period was recorded in third instar followed by fourth and second stadia. Oviposition period was higher than the pre-oviposition period. The average total stadial period observed was differing in different studies. For instance, Ambrose (1983), Lakkundi (1989) and Sahayaraj (1991) recorded 59.1, 66.89 and 61 03 days respectively Generally the nymphal mortality was less in I instar and II instar with the V instar also recording high mortality.

Prey Record: *O. wallonensis* Wasmann (Rajagopal and Veeresh, 1981); *O. obesus* Rambur (Rajagopal, 1984); *O. assumthi* Holmgren, Bruchus theobromae M (Ambrose, 1983 and 1985); *Mylabris pustulata* Lefroy, *Tribolium castaneum* H *L. exigua* (Butani, 1958); *C. compressus, M. pustulata* (Ambrose, 1980, 1987a, 1988); *D. koengii* (Lakkundi, 1989), *Dysdercus laetus* Kirby, *H. armigera, S. litura* (Sahayaraj, 1991); *P. gossypiella, C. cephalonica.*

Acanthaspis siva Distant is an entomosuccivorous, polyphagous, crepuscular, alate, and black bug with creamy white spots This hunter bugs found in the scrub jungle, semiarid zones and tropical rainforests of Southern India In tropical forests it has been found underneath the loose dry barks of *Eucalyptus globules, Thespesia populanea, Pithecolobium dulce* and *Tamarindus indicus.* It has been either found in groups or in solitary conditions The adults found along with nymphal instars and also with snakes, lizards, calotes and other insects. It is a predator on Indian honeybee, *Apis indica.* In addition to this prey, it also feeds on ants, termites and earwigs. Ambrose and Livingstone (1987c) observed the biology of this bug by using houseflies and camponotine ants. Distant (1902) briefly described this species collected from central province of India. Later Ambrose (1980) recorded four types of morphs in this species such as, unbanded and banded legs without thoracic spots, and banded and unbanded legs with thoracic spots. *A. siva* lays its first batch of eggs 26 days after imaginal moult. Eggs are laid in batches, singly and loosely without any cementing material. The eggs are maroon coloured and spherical in shape. A female can laid 34.33 eggs with a minimum of one and a maximum of 11 eggs in a batch. Under laboratory conditions the eggs hatch in between 13 to 29 days. Only 30.91 per cent of nymphs hatched from the eggs laid. First generation took minimal period to complete its development (72.26 days) whereas the second generation needs 94.31 days for completion The nymphal survival rate is about 40.68 per cent. The life span of the adult female was 95.67 days and that of adult male was 26 days. Sex ratio was female biased

Prey Record: *Apis indica* (Subbiah and Mahadevan, 1957); *Corcyra cephalonica* Stainston, *C compressus* (Ambrose, 1980); *C. cephalonica* (Lakkundi, 1989).

Allaeocranum biannulipes (Montr. Et Singh) was recorded from Egypt by Abdella in 1976 But its detailed biology was carried out by Tawfik *et al.*, (1983a and 1983b). Head is brown, two reddish ocelli and antennae with four segments Its eggs are oval in shape, slightly taper at both edges. Hatching of egg is depends upon the seasons. In summer (20° C and 60.2% RH) they hatched within 11.2 days, while in autumn (24.5° C and 74% RH) they took 12.25 days. It was further increased to 19.42 days in early spring (21.5° C and 61% RH). The first nymphal stadium occupies 9 00 days in summer and 11 2 days in autumn The developmental period was reduced in second instar (2.68 and 9.0 days for summer and autumn, respectively) Third (5 26 and 8 49 days for summer and autumn, respectively), fourth (6 74 and 11.82 days for summer and autumn, respectively) and fifth (12.63 and 22.09 days for summer and autumn, respectively) instars stadium also varies according to the seasons. Mating occurs 1 to 3 days after the emergence of adults and the ovipositions period is last for 6.4 days in summer. This period is increased 109.4 days in females that became sexually quiescent in winter. Accordingly, the egg production was higher in the former group (403.4 eggs/female) than the latter (175.8 eggs/female). Males in summer generation lived shorter (118.22 days) than the females (123.11 days) An opposite trend was observed in another season (235.5 and 220.3 days for males and females, respectively). The biology of an Indian species *A. quadrisignatum* was described by Sahayaraj (1991). *A. quadrisignatum* was collected from the chillies ecosystem where termites are abundant in number. They are small reduviids (5.99 mm), present along with other Acanthaspis species like *A pedestris* and Acanthaspis sp. It was reared under laboratory condition with *O. obsesus* Overall colour of the reduviid is brown. It glued its eggs to the fresh excreta. The preoviposition of the adult is about 12 days Totally a female can lay about 117 eggs with maximum of 10 eggs and minimum of 1 egg on a day. Totally a female laid 32 batches of eggs during its lifetime. Nearly 64 percentages of the eggs were hatched. The average incubation period of the egg is about 12.47 days. Within 65.26 days the newly hatched nymph attained in to adult (12 47, 13.20, 9.69, 11.72 and 15.0 days for first, second, third, fourth and fifth nymphal instars respectively) Nearly 49 per cent of the nymphs survived. Sex ratio was female biased (0.76). As observed in other reduviids females lived longer (96 49 days) than the males (51.30 days) (Sahayaraj and Ambrose, 1992a).

Prey Record: *D. cingulatus, C. cephalonica, O. obesus, O. hyalinipennis* (Sahayaraj, 1991).

Edocla stateri Distant is a dimorphic assassin bug. Male is alate whereas female is micropterous. It is an entomosuccivorous, crepuscular, piceous bug found in semiarid zones, scrub jungles and foothills of tropical rain forests. The biology of this bug was first worked out by Vennison and Ambrose (1986) Eggs are laid in batches each attached to the other and basally glued to the substratum with ash colour cementing material. Eggs are dark brown, elongate and oval with pale yellow operculum. Operculum is transparent and membranous. The total length of egg is 1.28 mm and 0.64 mm width. This predator prefers to glue the eggs to the fresh excreta. During a female lifetime it laid 129 eggs. At 32 ° C it hatched between 15 to 21 days. The developmental period from first instar to the fifth nymphal instar ranges from 44 to 92 days (mean of 62 57 day) (Vennison and Ambrose, 1986). Nymphal mortality is higher during the first nymphal instar and it is mainly due to the cannibalistic tendency of the nymphs. The life time of the male (47.5 days) is shorter than the female (66.5 days).

Prey Record: *H. armigera* Hubn., *Earias vittella* (Fabricius), *E. insulana* Biosd., Camponotine ants (Vennison and Ambrose (1986b); Termites, *C. compressus* (Ambrose, 1980); *H. armigera* (Ambrose, 1987a); *E. insulana.*

Platymerus biguttata (Linn.) is about 1½" long and mainly black in colour with bright yellow legs and two white spots on its wing cases (tegmina). Although possessing wings, the Assassin bug is not capable of flight. It catches its prey by a combination of stalking and ambush (hence the name), it leaps on the prey, grasping it with its two front legs and immediately follows by stabbing it with its sharp, needle-like mouthparts (rostrum) and injecting a venom which paralyses its prey. There is very little difference in appearance between the sexes, with males only being slightly more slender than females. Assassin bugs in captivity will tolerate each other if kept in groups as long as they are of similar size and well fed. Biology of one more *Platymerus* sp. was available in the literature. *Platymerus rhadamanthus* Gerst adults are large black bugs, three to four centimetres long. The head, thorax and forewings are carbon black, except that there is a round patch 2 mm in diameter of orange-red on the anterior end of each forewing The dorsal side of the abdomen is an orange-red to brown anteriorly and black at the posterior. The ventral side is black. The eggs are thimble-shaped, dark brown or black in colour, with a white or grey operculum. The eggs took 28 to 30 days to hatch. However, it prolonged when they were kept in dry conditions. Nymphal development depends up on the amount of food available and prevailing temperature and humidity. If we provided all them in optimum condition first instar took 28 days when reared on aphids. Second instar also took same period but they were provided with small coleoptera, lepidopterous larvae and Hemiptera. The duration of the third (28 to 42), fourth (35 to 42 day) and fifth (56 to 84 day) instar is very longer than other reduviids The preoviposition period is ranging from 168 to 365 days During the adult lifetime each female can lay two to five eggs /day when plenty of food is supplied (Vanderplank, 1958).

Velitra sinensis Walker is an alate, entomosuccivorous, crepuscular, bivoltine hunter reduviid bug. This bug is mainly found in the tropical rain forest Usually it has been found along with the nymphs and adults of other reduviids like, *A. siva, A philomanmariae, Labidocoris* sp. A female laid its first egg 45 67 days after the emergence Eggs are laid singly and they are pale yellowish brown in colour and elongately oval in shape. Eggs are hatched in to nymphs between 20 to 45 days From the first instar to adults, a nymph took 80 to 153 days. The survival rate is 79 per cent The life span of the adult female is 172 7 days and that of the adult male is 201.33 days (Vennison and Ambrose, 1990). Sex ratio was equal for both male and female (1:1).

Prey Record: *Cyrtacanthacris succincta* Kirby (Ambrose, 1985); *Patanga succincta* (Linn) (Ambrose, 1988); *P. succincta* (Ambrose, 1987a).

2.8 Salyavatinae

The only available biology of this genus is the biology of ***Petalochorus brachialis*** (Stal). It inhabited on the surface of the tree bark chiefly on teak wood The camouflaged nymphal instars were found both solitary and in groups and were quite difficult to discern due to their camouflaging. Adults were found along with the nymphal instars. It is found along with the *A. siva.* The brown adults are about 14 mm long (Figure 3). Antenna (except the flagellar segments), legs, apex of spines to pronotum, abdomen, apex of the scutellum is pale brown. Head, prothothrax, eyes, rostrum and abdomen (except in the middle) are dark brown. Throughout the body is covered with fine and long spines. Scape and legs are having annulations and connexivum obscurely spotted with brown. Head oval, transverse groove inbetween the eyes Eyes are laterally protruded. Rostrum strongly curved. The dark brown or black adults are about 10 mm long They have a narrow, flattened body, long legs and a long, narrow head with a stout, curved beak.

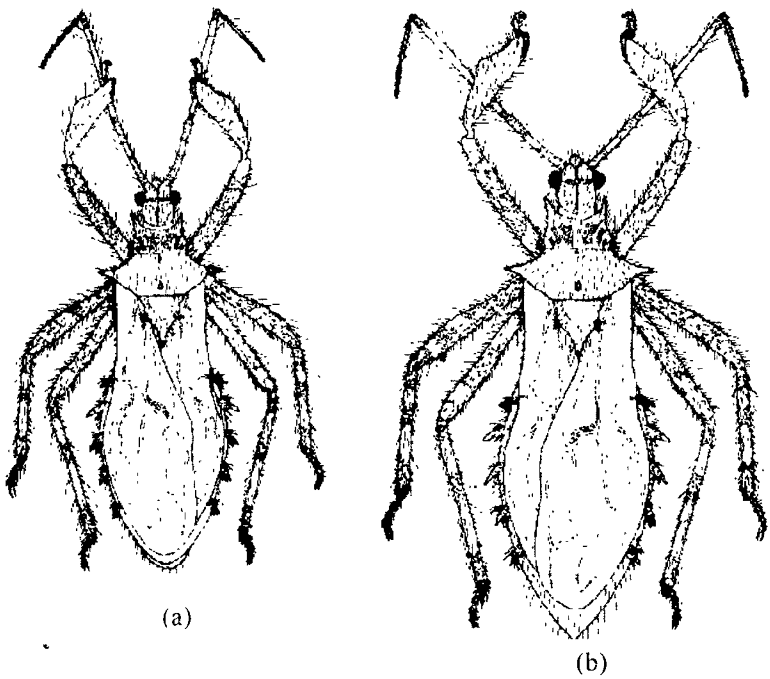


Figure 3 *Petalocheirus brachialis* Male (a) and Female (b)

The beak is held close beneath the body when the bug is at rest. Adults appear during mid summer and deposit eggs in the soil or in crevices in bark. Depending on the species, the winter may be passed in the egg, nymphal or adult stage. There is generally one generation each year Pre and post oviposition periods were 6.70 and 2.50 days respectively. Totally a female can lay 85.3 eggs in her lifetime with a minimum of 2.6 eggs and a maximum of 38.4 eggs in a day They were brown in colour and round shape. Nearly 75 56 per cent of eggs hatched in to nymphs with in 16.41 days. First, second, third, fourth and fifth nymphal instars (Figure 4) took 14.27, 12.62, 21 13, 31.37 and 82 72 days, respectively. The averaged nymphal instar was 173 47 days. Only 33.61 nymphs survived during their nymphal stage. The adult longevity of the both male (8.63 days) and female (12 62 days) were also very low in this predator Among the laboratory emerged adults male population was higher (1 00) than the female population (0.72). I compelled

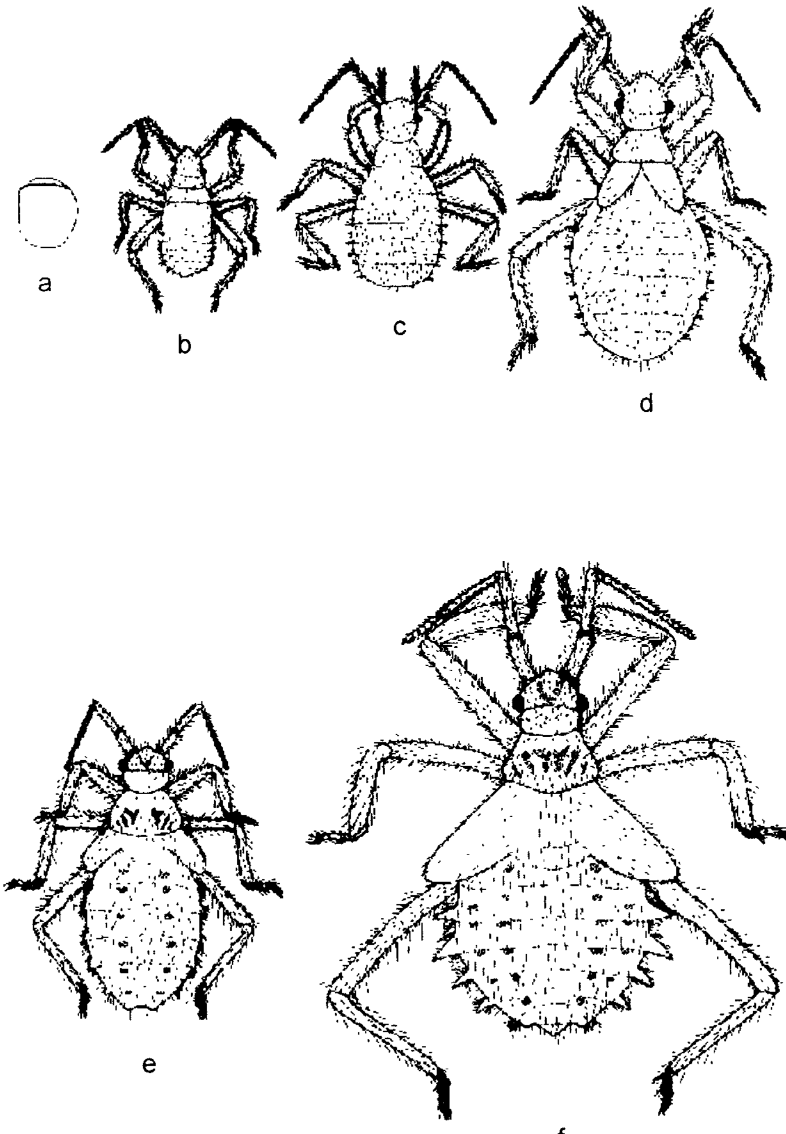


Figure 4 *Petalocheirus brachialis* egg (a) and nymphal instars I-V (b - f)

this bug to feed on much insect and non-insect prey. But it accepts only the termites

Prey Record: *O. obesus* (Sahayaraj, 1991).

2.9 Stenopodinae

Vennison and Ambrose (1989) studied the biology of *Oncocephalus annulipes* Stal on *Trilopidia* sp., *Musca domestica* Linn., *Helicoverpa armigera, E. insulana* and *E. vitella.* The eggs are oval and pale luteous. After emergence, this bug laid its first batch of eggs on 14th day. Eggs are not laid in cluster. Some time the eggs are inserted into the wet cotton swabs and they were hatched in to nymphs after 7 to 24 days. If this bug reared continuously for three generations, first generation took 45.8 days whereas the second and third generations took 100.7 and 69.0 days respectively. Why this kind of waste variations was observed, they won't explain any thing Early instars (first and second) grey and older instars (third to fifth) pale ochraceous Averaged nymphal survival rate was 67.48 per cent. In the laboratory, females were emerged in more number than the males. The males and the females lived 52 and 36.5 days respectively. *O. annulipes* killed 1.8 *H. armigera*, 2.5 *E. insulana* and 2.2 *S. litura* during a day.

Prey Record: *Heliothis armigera* Hubn., *Earias vittella* (Fabricius), *E insulana* Biosd. (Ambrose, 1985); *H. armigera* (Ambrose, 1987a); *E. insulana* (Vennison, 1988); *S. litura, O. obesus*.

2.10 Some tips for rearing the reduviids in groups

2.10.1 Housing

Most of the hunter bugs distributed either in the semiarid zones or in the scrub jungles. So they need a warm at the same time dry environment with a moist area where they can lay their eggs. However, some reduviids prefer to glue their eggs in their faecal matter or on the soil. This is most easily provided by a small glass or plastic aquarium with a well-ventilated lid. Peat substitute, sand, vermiculite, paper strips etc. can be used as a floor covering but the hunter bugs may lay their eggs in this making collection and incubation of eggs awkward. In order to mimic the natural habitats small stones are placed on the floor A more convenient solution is to line the floor with paper; the bugs should then use the tub of moist vermiculite for egg laying. Pieces of wood or plastic plants or real plants can be added to the set-up to give the bugs places to climb and hide and to make the set-up look pretty.

2.10.2 Heating

The set-up is best heated using a small heat mat (as sold in pet shops for reptile heating). This should be positioned behind or upper top of the tank (not underneath), along the back wall and should not cover more than half this area. This arrangement produces a temperature gradient within the set-up and allows the Assassin bugs to choose their own preferred temperature They seem to do best at temperatures around 24 to 30°C. But this device is necessary only in cold countries or regions.

2.10.3 Feeding

Hunter bugs are predators of other insects and will tackle anything they can subdue (up to about their own size) or even bigger preys. They are easily catered for in captivity and can be fed on a diet of live crickets, mealworms, giant mealworms and small locust hoppers. It is advisable to provide pests, which were collected from the agricultural fields Nymphs should be started on smaller prey such as fruit flies, aphids, micro crickets, *Corcyra* and mealworms, and can be offerred larger prey items as they grow. They can be given a light spray of water each evening and will drink from droplets that accumulate. A shallow water dish in the set-up will also allow constant access to water as required. Now it is advisable to provide artificial diets prepared by using insect or meat based diets.

2.10.4 Cleaning

Assassin bugs produce very little waste and no odour so the only routine cleaning that is required is the removal of left over and discarded pieces of food to prevent the growth of any mould. If this process is not done properly, fungal disease occurs to reduviids.

2.10.5 Breeding

Hunter assassin bugs reach sexual maturity, after five moultings at which stage both sexes gain wings in apterous reduviids But don't expect the wings both in brachypterous and apterous reduviids. Differentiating sexes can be difficult with the only real difference being that males are slimmer than females. The abdominal last segment is V shape in males and U shape in female *i.e.* is the easy way to identify the males and females. Mating in reduviid hunter bugs is sexual and as long as you have an adult male and female together (or a group containing adult males and females) and the conditions in the set-up are right they should get on with it without any problems. However, some species immediately after the mating, the mating partners feed each other. In such species the mating partners can be removed immediately after the mating. Once mated the female will soon start laying eggs, they prefer to lay them somewhere moist, and if provided with a tub of slightly dampened vermiculite they should lay them there. Any eggs not laid in the vermiculite should be collected up and placed there otherwise they will dehydrate and collapse. The eggs are ovoid, about 2mm long and shiny dark brown/black in colour with a light cap on top, they turn a reddish brown towards the end of incubation. The eggs can be simply incubated by taking the tub of vermiculite away from the tank, putting a lid on it (with a few small ventilation holes), keeping it somewhere warm at 75°F (the airing cupboard is fine - putting the tub directly on to a heat mat may be too warm!), and making sure it doesn't dry out by giving it regular misting (conditions should not be too wet as this can promote the growth of moulds which can harm the eggs). If all goes well the eggs should start hatching after about 21 days, although in our experience it is not unusual for incubation to take about 4 weeks. To allow the Assassin bugs to continue laying, a new tub should be provided every time one is removed. Ideally this should be every 3 weeks otherwise you may have nymphs hatching out in the adults' tank where they are likely to be eaten.

2.10.6 Nymphs

After their first moult the colour may change. Wings are appeared after the third moult and after the final moult (fifth) into adulthood. This kind of events does not take place in the brachypterous or micropterous reduviids. Nymphs can be raised together, although some are likely to be lost through cannibalism. They are best raised individually in small jars, margarine tubs, or similar for the first couple of instars (moulting stages). They should be given a shallow substrate of vermiculite, which must be sprayed lightly with water every day to maintain the slightly higher humidity that they require at this stage. After about the third moult they are less prone to dehydration (and cannibalism) and so can be kept under the same conditions as the adults. Nymphs should be fed on small prey such as fruit flies, aphids, micro crickets and buffalo worms (tiny mealworms), and can be offered larger prey items as they grow.

2.10.7 Handling

Assassin bugs should not be handled as they can give a very painful bite that feels something like a nasty bee sting. They can also shoot their venom up to a distance of 12" with great accuracy (even backwards over their shoulder), which can cause skin irritation, and even temporary blindness if received in the eye. Fortunately we don't have first hand experience of either, and our assassin bugs have never shown any interest in attacking anything other than their food, but care must be taken while handling the predators very carefully. Usually they attack when they disturbed. Hence it is very essential not to disturb them during rearing

2.11 Recommendations

1. Several collections must be made in to the various agroecosystems and the biology of the collected reduviids will be made.
2. Either non-host like *Corcyra cephalonica* or natural host must be provided and the biology of the reduviids will be carried out
3. Post-embryonic developmental period, survival rate, fecundity and hatchability and age-specific fecundity are worked out for each and every hunter reduviid present in the agroecosystems.
4. In order to utilise these natural enemies in biological control programme pest complex of each and every reduviid present in various ecosystems can be found out.

3

Tropic Interactions

3.1 Introduction

Food webs in any natural ecosystems are very complex and making it difficult to define discrete tropical levels There are two types of interactions takes place in natural ecosystems. They are plant-herbivore and predator-prey interactions It is much more difficult if you consider the annual crop agro-ecosystems which are usually monocultures, relatively few species. In any agro-ecosystem, the interaction between plant, herbivore and the natural enemies is a common phenomenon. The interaction between these three organelles is called ***tritrophic interaction*** The concept of tritrophic interactions implies that evolved plant traits enhance the success of natural enemies as mortality agents of pests. Various scientists worldwide have advocated analyses of the behavioural characters for reduviids and their utilisation in the biological control programme. Recently, ecologists saying that, natural ecosystems involving three or more tropic level interactions. At a time one tropic is affected by the remaining tropics For instance, abundance of the natural enemies in an agro-ecosystem will minimise the herbivore population, and hence both plant and natural enemies can establish themselves. Tropic interaction is mediated by different kinds of chemicals These chemicals and their interactions are listed below (Table 3 1).

Table 3.1. Tropic interactions and their beneficiaries

Chemicals	Tropics involved	Behaviour involved	Beneficiaries
Semiochemicals	Plant & Herbivores	Host seeking	Herbivores Natural enemies
Synomones	Plant & Herbivores Herbivores & Natural enemies	Pollination Predation	Plant & Herbivores Natural enemies
Plant-based kairomones	Plant & Herbivores	Tri-tropic	Natural enemies
Insect-based kairomon	Herbivores & Natural enemies	Host seeking	Natural enemies
Plant allomones	Plant & Herbivores	Repelling & Non-feeding	Plant
Insect allomones	Herbivores & Natural enemies	Repelling & Non-feeding	Herbivores
Antimones	Plant & Herbivores	Detrimental Mating Communication	Plant

Generalist predators like reduviids are frequently the most diverse and abundant members of the insect natural community of the annual crop ecosystems The basic biological control theory for the generalist predators has been based on three discrete tropic level models proposed by Haristone *et al.* (1960). Under this model, individuals occupying the third tropic level (the predator) consume only individuals of the previous tropic level (the herbivores), allowing the plant populations to increase. Polyphagous reduviid predators consume many species that belong to different tropic levels within a community acting as primary predators (consuming herbivores) and as secondary predators (consuming primary predators). In food web, if a predator consumes preys from more than one tropic level it is called omnivores (Pimm, 1982) One form of omnivore is intraglud predation in which two species are competing for the same herbivore prey.

3.2 Tibialorate

Reduviids are present in natural agricultural systems and hence require thorough understanding of their feeding habits. The generalised sequential pattern of feeding behaviour of reduviids is as follows: arousal-approaching-pouncing-rostral probing-piercing–paralysing the prey – sucking the contents of the prey – post-predatory behaviours. However, this kind of pattern is different from tibial pad group (tibialorate) to non-tibial pad group (non-tibialorate). The relative development of the tibial pad has been considered as a visible indication of the predatory efficiency in reduviids (Livingstone and Ambrose, 1978a). The family Reduviidae has stereotyped sequence of prey capture. Nature of rostrum associated with the predatory behaviour, for example reduviids having slightly curved or straight rostrum is associated with pinning and grasping predatory behaviour. Reduviids with acutely curved rostrum pounce over the prey and pin them.

3.2.1 Arousal

Visual stimuli appear to be the primary sensory input for arousal in feeding. In addition prey movement insight initiates arousal response of all hunter reduviids. Reduviids easily locate their preys by their well-developed compound eyes and ocelli. Previously it was reported that the intensity of approach is directly proportional to the agility and size of the prey (Ambrose, 1999). Now it is very clear that reduviids of both tibialorate and non-tibialorate aroused towards the killed or alive or non-prey items (artificial diets or water). Hence, in addition to the visual stimuli, prey or food kairomones also plays an important role in the arousal act. Arousal response was indicated by the unusual posture involving tibial juxtaposition and the extension of antennae towards the prey. In addition to this, intermittent watching of the prey was observed in some predators. The time taken for the arousal act was different for different reduviid species. Generally, the time decreased, as the nymphal instars grew older. Usually the adult female exhibited arousal response with shortest time than the male The expression of arousal response was almost similar in both tibial pad and non-tibial pad groups of reduviids but the subsequent events that follow varied considerable.

3.2.2 Approaching

Tibialorate reduviids approached their prey with jerky movements or running after the prey with their extended antenna If the prey was more agile and tried to move away from the approaching predator this act is intensified.

3.2.3 Pouncing (capturing)

After reaching the closer proximity of the prey, it raised both the fore and mid legs in a swift motion and pounced over the prey. But tibialorate has not pinned the prey. The tibial pads with differential development of hair present in the fore and mid tibiae were employed to hold the prey with powerful grip. The pouncing acts and holding were more powerful when the prey tried to escape from the grip of the predator. When the prey remained motionless, it certifies the worthiness of the prey by touching with the antennae Adhesive secretion of the predator's fore and mid-tibiae facilitated capture of the prey. Predators in starved conditions act quicker in capturing than the non-starved reduviids.

3.2.4 Rostral probing and stylet penetration

Once the prey was firmly held by the predator, it extended its rostrum to probe the various parts of the prey to locate suitable piercing sites such as antennal base, leg joints, junction between head and thorax or between two segments and between thorax and abdomen. When the prey struggled vigorously, the rostrum was usually withdrawn and reinserted in to another region. If the predator is very hungry then it probes more sites. Once the probing was over with precision and deftmarkmanship, the stylets were planted deep into the apparently predetermined sites and the toxic saliva was injected into the prey. Invariably all these events culminated into the total paralysis of the prey. Starved predators quickly paralyse its prey than the non-starved reduviids. First instar nymphs took more time for paralysing their prey and it gradually diminished when the reduviids grew older.

3.2.5 Prey transportation

Transporting the immobilised prey to a safer place for consumption is yet another distinct behaviour of reduviids. By inserting the stylets at suitable places, the predator dragged the prey forward if the prey was smaller and it dragged backward if it was larger

3.2.6 Feeding

Feeding commenced while the prey continued its struggling to escape and stylets were frequently withdrawn and reinserted at different angles. During the act of sucking, some reduviids rotated their prey and selected the various soft cuticle areas of the prey The predators never left the prey half emptied. After sucking the contents of the prey including the brain and digestive system, the predator dropped only the empty cases of the prey.

3.3 Non-Tibialorate

The predatory behaviour sequence of these non-tibial pad reduviids can be summarised as follows: arousal – orientation – antennal extension and pinning – paralysis of the prey – prey transportation – prey sucking – dropping the empty case – post predatory behaviour.

3.3.1 Approaching

Once the arousal was accomplished, the predators oriented towards the prey and remained motionless until the prey approached the predator. If the prey was large and more agile then the predator moved away from the prey after a few minutes of waiting, the predators especially the nymphal instars became restless and raised their legs While Harpactorine reduviids waiting in tibial juxtaposition pin their prey with their already extended rostrum. Long and straight rostrum of harpactorines is well adapted for quicker forward projection that enables efficient pinning. The adults in addition to this behaviour raised their wings and they moved swiftly here and there. If the prey was small and less active, the predator approached the prey with extended rostrum and antennae. However, *Zelus socins* moved slowly holding its antennae in a bent position above the head. Generally females approached the prey more quickly than the male.

3.3.2 Pouncing (Capturing)

After reaching the closer proximity of the prey, the predator pounced over the prey with the help of its fore leg. Nymphal instars took longer time to capture a prey than the adults. Some times the captured prey emits defensive fluid that compelled the predator invariably to leave off the prey and only after some time the predator could again hold the same prey and suck the body fluid This kind of behaviour was observed both in tibialorate (Sahayaraj, 1991) and non-tibialorate (Kumaraswami, 1991 and Sahayaraj *et al.*, 2002a) reduviids.

3.3.3 Pinning

Once the prey was firmly held by the predator, it pinned the prey with the extended rostrum to probe the various parts of the prey to locate suitable piercing sites, such as antennal base, leg joints, junction between head and thorax and abdomen. Once the probing was over, the stylet was planted deep into the apparently predetermined sites and the toxic saliva was injected into the prey. Invariably, all the events culminated into the total paralysis of the prey. The first nymphal instar took more time to paralyse the prey and it gradually diminished when the predator grew older. Among the sexes, the male quickly paralyses the prey than the female

3.3.4 Prey transportation

After the prey was immobilised, the predator released its grip and transported the paralysed prey to a safe and secluded place for feeding. The paralysed prey was kept at the tip of the rostrum and dragged forward when the prey was smaller and dragged backward when it was larger.

3.3.5 Feeding

Once the prey was transported to a safe and secluded place the predator started feeding. The stylets were penetrated deep into the prey and subsequently the internal content of the prey was sucked. During the act of sucking, reduviids pierced and sucked various places and parts of the prey but never rotated the prey. Reduviids suck only the predigested food from the body of the prey and flushed out the watery secretion of the main salivary glands that secretes enzymes for the digestion of the food. Usually females consumed more number of preys than the males. After sucking the contents of the prey including the digestive system, the predator dropped the empty cases of the prey. Among all the five nymphal stages, the fifth nymphal instar was more efficient in predation than the remaining instars. The females were found to be better predators than the males.

3.3.6 Post-predatory behaviours

This act is common in both tibialorate and non-tibialorate reduviids.

As the final act of predation, the empty case of victim was dropped and the satiation was manifested by the antennal and rostral cleaning by the fore tibial pads in the case of tibial pad group and tibial combs in the case of non-tibial pad group. Grooming of the rostrum and antennae was performed by passing them between a set of flattened, flexible bristles located at the tibio-tarsal junction of each foreleg. Early nymphal instars of camouflaging reduviid act very systematically gathered the empty cases of the prey by the cooperative efforts of the hind legs and threw them over their dorsum which was already covered with debris Rearrangement and adjustment of these particles were made by their hind legs in order to maintain the accurate balance. Grooming of antennae and rostrum was observed in the satiated bugs The hind legs also cleaned the hemelytra. The predation frequency and relative duration between successive steps in the predatory behaviour varied between sexes and among the nymphal instars and for the different types of the prey offered. Starvation induced to perform rostral probing on the empty cases of the prey. Spitting behaviour (a drop of saliva was seen at the tip of rostrum) was either present or absent in reduviids. In some reduviids the mating partners were found to predate while they were in copulating. Generally reduviids with fossula spongiosa or tibial pad were considered as better predators than those without tibial pad. Tibial pad can be used for climbing on smooth surface, and also for capturing the preys. The tibial pads of reduviids possess numerous adhesive spines (or) hair. The adhesiveness is produced by the glandular cells present just below the first body layer which produces an oily substance and opens into the spines and presumably discharges at the tips.

3.4 Adaptive features

3.4.1 Group feeding/congregational feeding

So far congregational or group feeding, death feigning and rolling along the prey are the feeding adaptive behaviours reported in reduviids. These kinds of behaviour are species specific. Concerning predatory exploitation, pack hunting among the social mammal, predator is generally recognised as typical examples of the most elaborate forager group predatory behaviour associated with improved capture success With regard to insects, a highly evolved strategy of group raiding has been reported in some group of insects including army ants from the view point that group predation is primarily concerned with specialised feeding on large arthropods and other social insects. Communality in capturing prey item has been well documented among spiders. When every hunter reduviid present in solitary condition, it feed the available prey individually. The congregational feeding was found more common among the nymphal instars of reduviids. It was also reported in some adult reduviids. Congregational feeding behaviour was present up to fifth nymphal instars. In nymphal instars, this behaviour is closely associated with the starvation. It leads to the cannibalism. Cannibalism was common among the nymphal instars than in adults. The efficiency in capturing the prey was significantly higher in the group attacking at any prey size class than the solitary conditions. The kind of group feeding or cooperative predation showed that reduviids are sociality animal. The degrees of this cannibalistic intensity were found to vary considerably among the species. But this intensity of cannibalism was very low in tibialorate reduviids. Generally, both nymphal instars and adult reduviids turned cannibalistic when they were subjected to starvation. However, the cannibalism was totally absent in the adults of reduviids. Inoue (1985) expressed that inclusion of more prey species into the diet initiate the group predatory behaviour of reduviids. Recently Sahayaraj (unpublished data) showed that *R.marginatus* adults expressed group feeding behaviour when they were provided with artificial diet. *A. pdestris, A. siva, A. quadrisignatum, C. nodulosus, E. tibialis, E. umbrinus, E. plagiatus, Haematorrhophus* spp., *R. fusicpes, R. marginatus, S. reclinatus* and *S. signatus* are some of the reduviids which having congregational feeding behaviour.

3.4.2 Death feigning and rolling behaviour

Death feigning is a behaviour when any natural enemy approaches the reduviid it seems to be dead animal. This behaviour was first observed in *Acanthaspis petax*. Ambrose (1980), Vennison (1989) and Sahayaraj (1991) reported the same behaviour in oriental reduviids from India. Nymphal instars were found to feign death when they were confronted with large prey. Only after several minutes (15 to 25 minutes) they resumed their normal activities. When the prey was much larger then the predator, nymphs and adults were found to roll their bodies and fold their legs. This kind of behaviour has been reported in many reduviids However, it was well pronounced in Harpactorine reduviids than other oriental reduviids.

3.4.3 Structural adaptation for feeding

Predatory efficiency and its concurrent prey selection have a very close relationship with structural adaptation for both prey capture and sucking. Both *Echrichodiinae* (except *N. therasii*), and *Reduviinae* (except *P. nigerma*) have well developed tibial pads on both the fore and mid tibia. Non-tibial pad groups are having hair, which are used to hold the prey with powerful grip. The long rostrum of the non-tibial pad reduviid enabled the predator to straighten it out when needed for easy pinning and deep penetration of the prey. Furthermore, it helped the predator to lift the prey and to transport the prey by rostral dragging to secluded place for feeding.

3.5 Insect based kairomones

A number of host-related products have been found to elicit host-seeking behaviour, *e.g.* host faeces, haemolymph, semiochemicals and host artificial diets. Semiochemicals present in an ecosystem influence various organisms at different tropic levels causing dynamic interactions between host plants, their insect pests and natural enemies. These chemicals are otherwise known as "Infochemicals" which mediate direct or indirect interactions between various organisms. These signalling chemicals fall into two categories namely pheromones and allelochemicals. Pheromones are used generally for intra-species communication and allelochemicals are used for inter species communication barring tropic levels. Natural enemies utilise a variety of stimuli to locate and identify their hosts based on chemical cues emanating from the hosts body. Herbivorous prey may influence predators because the herbivores are chemically defended to some degree. These allelochemicals are present in the gut, heamolymph and nutrient storage sites (Duffey, 1980; Haridass and Ananthakrishnan, 1981a). The release of homogenates of lepidopterous larvae has been shown to increase retention of many generalised predators (Gross *et al.*, 1985; Senrayan, 1989) including reduviids (Parker, 1971; Sahayaraj and Paulraj, 2001c). When we offered the kairomones to the reduviids, they orient towards the odor source with antennae facing towards the odour source. After getting a perfect orientation position the reduviids palpate their antennae. Then they aroused and subsequently showed the other behavioural responses. When *Vistula lineaticeps* (Sign.) was tested against the models prepared from cockroaches (given cockroach scent by enclosure in a small glass jar for 24 hours), and placed in front of the reduviid, the predator extended its proboscis and grasped the model. Maran (1999) studied the kairomonal ecology of reduviids in relation to their preys. He studied the Excess Proportion Index (EPI) of life stages of *Rhynocoris fuscipes* and *Rhynocoris kumarii* to hexane extract, 5 per cent ether in hexane fraction and 15 per cent ether in hexane fraction of *Spodoptera litura* caterpillars, *Mylabris pustulata* and *Dysdercus cingulatus* adults, who reported that all these three predators showed positive response to all the tested solvent fraction of *S. litura* and fewer negative responses to *M. pustulata* and still higher negative response to *D. cingulatus* Irrespective of the life stages such as third, fourth and fifth nymphal instars and adults tested, all of them preferred 15 per cent ether in hexane fraction (EPI = 1) followed by 5 per cent and hexane fraction of *S. litura* he added. He concluded that this kind of studies would throw light on the host preference and suppression efficiency of reduviids.

Recently we found that *R. marginatus* nymphs and adults were found attracted to the solvent extracts (1 portion hexane and 2 portion acetone) of different pest larvae like *A. modicella, H. armigera* and *S. litura* (Sahayaraj and Paulraj, 2001c). The frequency of prey location behaviour was higher to *S. litura* extracts for fourth (10.43 minutes), fifth (12.07 minutes) nymphal instars and adults (15.38 minutes) of this reduviid. Fourth, fifth instars and adults were preferred only fifth instar *A. modicella* larval extract. However, the percentage of preference was lower in adults (API = 0.44) than the nymphal instars (API = 0.56 and 0.57 for fourth and fifth instars, respectively). Similar trend was also observed when *Helicoverpa armigera* (0.79, 0.89 and 0 67 for fourth and fifth nymphal instars and adults, respectively). In contrast, API was higher when *S. litura* was provided to the adults (0.72, 0.78 and 0.80 for fourth and fifth nymphal instars and adults, respectively). They further added that in general, adult predator exhibited high frequency of prey location behaviour for all the tested pests. Later the extract was further divided in to two fractions namely, water and hexane The hexane extracts of *M. pustulata* showed four spots on TLC plates when placed in iodine chamber (Rf = 0.03, 0.10, 0.18 and 0 60) and *S. litura* showed three spots with benzene and dichloromethane solvent system (Rf = 0.03, 0.14 and 0.71). GC-MS studies showed that *H. armigera* contain tridecane, octacosane, 1-iodododecane, octadecane, eicosane, pentacosane, heptacosane and dotriacontane. However, *S. litura* hexane fraction consists of di-n-octylpthalate, 1,2-benzenedicarboxylic acid, di-isooctyl ester, 3,3-dimethyl acetane, 4-methyl decane and bis (2-ethylhexyl) phthalate.

The response of *R. marginatus* to the hexane soluble fractions of *M. pustulata, H. armigera* and *S. litura* is shown in Table 3.2. The approaching response was higher for *S. litura* hexane soluble fraction

Table 3.2. Feeding behaviour of *Rhynocoris marginatus* to hexane soluble fraction of three pests

Responses	Life stages of predator				
	II	III	IV	V	Adult
S. litura					
Positive choice	4	1	3	1	5
Negative choice	2	5	4	3	1
No choice	4	2	1	4	2
χ^2	0.799	3.245	1.746	1.746	3.245
Significance	*	*	*	*	*
M. pustulata					
Positive choice	4	3	2	1	4
Negative choice	5	4	1	2	3
No choice	1	1	5	7	3
χ^2	2.601	1.746	3.245	6.205	0.198
Significance	*	*	*	-	*
H. armigera					
Positive choice	5	7	5	5	6
Negative choice	-	1	2	3	3
No choice	5	2	3	2	1
χ^2	5.004	6.205	2.241	1.4	3.802
Significance	*	-	*	*	*

* not significant at 5% level

Source: Sahayaraj and Delma (2005)

than *M. pustulata* extract (Figure 3.1). When the predators entered the test chamber, they exhibited exploration and probing behaviour by showing rostrum cleaning, antenna cleaning and head lifting. This shows the approaching of the predators towards prey kairomones due to their chemosensory mechanisms. Once the predators came in contact with the filter paper impregnated with the extracts, they inserted their rostrum into it and clumped around it. All the predator stages approached the test chamber faster than the control chamber except the second instar nymphs for *M.pustulata* extract and fourth nymphal instar and adult predators in the case of *S.litura* and adult predators for *H.armigera* extract. However the difference in the approaching time between control and test was statistically insignificant except for III ($t = 2.035$, $df = 4$, $p<0.1$), V ($t = 2.120$, $df = 2$, $p<0.1$) instars and adult ($t = 1\ 622$, $df = 4$, $p<0.1$) with respect to *M.pustulata* extract and III instar ($t = 1.733$, $df = 6$, $p<0.1$) with respect to *H.armigera* extract.

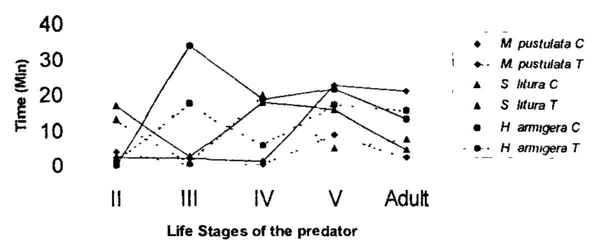


Fig. 3.1 Approaching time of R. marginatus towards the pest extracts

The researcher postulated that chemical cues from the preys attract the predators towards them. Although the reduviids show chemosensory response to the kairomones from the pests, the results tabulated show that they prefer the lepidopteran pests than the coleopteran pest, *M. pustulata*. In this study the second instar nymphs and the adults of *R. marginatus* showed maximum response to the hexane soluble fraction of the pests indicating that these predator stages are active decision-makers as compared to other stages. Among the lepidopteran pests *R. marginatus* preferred *H. armigera* to *S. litura*.

The water-soluble fractions of *H.armigera, S.litura* and *M pustulata* might be presumed to contain the faecal matter of the preys. The prey-seeking behaviour of a pentatomid *E.furcellata* was stimulated by the faeces of *S.litura* (Usha Rani and Wakamura, 1993). Similarly in reduviids, the water-soluble fraction elicited a negative approaching behaviour as shown in Table 3.3. Though higher

Table 3.3. Feeding behaviour of *Rhynocoris marginatus* to water soluble fraction of three pests

Response	Life stages of predator			
	II	III	IV	V
	S. litura			
Positive choice	1	0	0	1
Negative choice	7	4	3	1
No choice	0	2	3	4
X^2	8.092	4	3	3
Significance	-	*	*	*
	M. pustulata			
Positive choice	2	4	2	1
Negative choice	1	1	3	1
No choice	7	5	5	8
X^2	6.205	2.601	1.400	9.809
Significance	-	*	*	-
	H. armigera			
Positive choice	7	8	6	8
Negative choice	1	2	2	1
No choice	2	0	2	1
χ^2	6.206	10.41	3.203	9.809
Significance	-	-	*	-

* not significant at 5% level

Source Sahayaraj and Delma (2004)

attraction and host seeking behaviour was observed on hexane extracts, water extracts do not attract the reduviids significantly. From the results obtained in the present study, it is evident that the kairomones emanating from the pests play an important role in attracting the predator *R. marginatus* towards the preys and therefore these predators can be used in the management of lepidopteran and also coleopteran pests. Further studies are essential to identify the compound present in each fraction.

The feeding behaviour of *Rhynocoris marginatus* (in terms of handling time) on three pest extracts is shown in Table 3.4. Second instar *Rhynocoris marginatus* exhibited maximum handling time in

Table 3.4. Handling time (in minutes) of *Rhynocoris marginatus* (N ± SE) to the water fractions of three pests.

Predator life stages	Handling time					
	M. pustulata		*S. litura*		*H. armigera*	
	Control	Test	Control	Test	Control	Test
I	08.64 ± 0.64	01.30 ± 0.16	5.53 ± 0.18	40.62 ± 0	26.92 ± 0	± 0.85 13.44
III	00.67 ± 0	12.72 ± 2.11	16.84 ± 1.05		12.53 ± 0	06.85 ± 1.24
IV	03.92 ± 1.05	3.71 ± 1.66	03.81 ± 0.26		08.49 ±	17.81 ± 1.77
V	27.69 ± 2.66	10.04 ± 1.08	04.66 ± 0.19	06.25 ± 0	21.76 ±	30.18 ± 2.24

Spodoptera litura extract (40.62 ± 0 min) followed by *Helicoverpa armigera* (13.44 ± 0.85 min) and *Mylaberis pustulata* (1.30 ± 0.16 min). The third instar nymphs spent more time with *Mylaberis pustulata* extract (12.72 ± 2.11 min) when compared to *Helicoverpa armigera* (6.85 ± 1.24 min) extract. However, third and fourth instar nymphs of *Rhynocoris marginatus* showed no response to *S. litura* extract. The fourth and fifth nymphal instars showed maximum handling time (17.81 ± 1.77 min and 30.18 min respectively) towards *H. armigera* extract followed by *Mylaberis pustulata* extract (3.71 ± 1.66 min and 10.04 ± 1.08 min respectively). The comparison between the water fraction of the pest extract and water was found to be significant for third ($P < 0.045$) and ($P < 0.440$) and fifth instar (P <

0.0454) with respect to *Mylaberis pustulata* and *Spodoptrera litura* and *Helicoverpa armigera* extract, respectively (Table 3.4) (Plate 1).

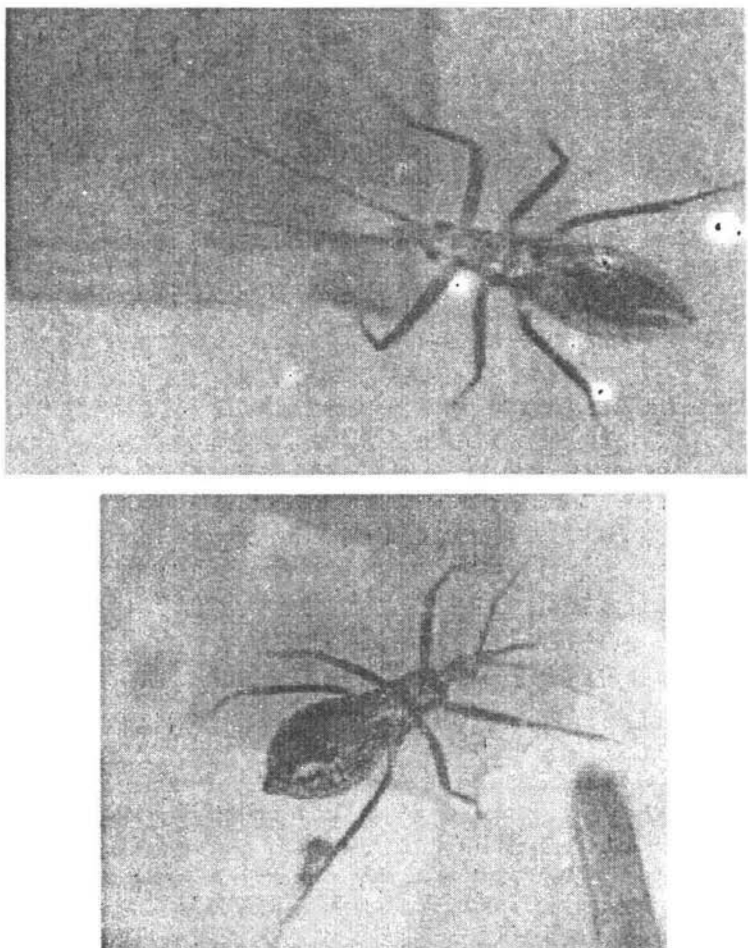


Plate 1. Interaction of *Rhynocoris marginatus* nymphs with its prey kairamone-orientation a) and sucking (b)

Allomones secreted by predators are used in various ways to attract or attack prey. The hunter bug *Ptilacerus ochvaceus* makes available a secretion on its ventral trachoma's that attracts ants, and the ants that feed on the secretion became paralysed and are fed upon by the reduviid (Jacobson, 1911). Another hunter bug *Apiomerus pictipes* attracts certain singles bees by using allomones that mimic the bee pheromones.

3.6 Plant-based kairomones

Plant-based odour plays an important role in the tritrophic interaction. Though many studies are available on parasitoids, little information is available on predators and no information is available for reduviids. It is well known that natural enemies are attracted to tissue wounding response by herbivores through release of synomones. The information on how a reduviid predator locates its prey in relation to presence and absence of plant is not available in the literature except the works of Sahayaraj *et al.* (2002). They studied the biological control potential of *R. fuscipes* in relation to the presence and absence of groundnut leaves (var. TMV 7) under laboratory conditions. *R. fuscipes* adults consumed more number of *A. craccivora* (3.3), *Myllocerus* sp. (3.0) and *S. litura* (2.83) when the predation arena has groundnut leaves. The time taken by *R. fuscipes* to handle *S. litura, Myllocerus* sp., and *A.craccivora* were 0.038, 0.037 and 0.13 days, respectively Some kind of groundnut plant-based and/or other plants kairomones induce and increase the biological control potential of the reduviid More studies are essential to prove this statement.

3.7 Prey stage and prey selection

Almost all the organisms increase their body dimensions from the birth to adulthood which is called ontogenetic change. During this change many insects will undergo extensive shifts in food and also their habits. This behaviour is common in generalist predators. They change their prey preference when they grow older and/or at the time of metamorphosis. Still very little is known of host finding is a complex process, with a hierarchy of successive behaviour. Changes in the feeding preference are associated with: (a) the relative availability of specific types of prey, (b) the foraging behaviour of predators, (c) the suitability of prey, and (d) the risk of predation or other mortality factors associated with obtaining prey, (e) age of both the predator and its prey, (f) shape and texture (*e.g.*, Thompson, 1975, Price 1984, Endler 1991, Begon *et al.* 1996, Lockwood, 1989) and particularly in reduviids (Sahayaraj, 1995a, Sahayaraj and Ambrose, 1997b, Sahayaraj and Paulraj, 2000). Most of the hunter reduviids are stimulated to bite their prey after making contact with their antennal receptors. After 'tasting' the prey, the predator may either accept it or reject it at this point. Three synergistic interactions involving predators are probably the result of an increased rate of discovery of prey by predators due to increased prey movement on antixenotic cultivars. The implications are not applicable for the above said studies. Because all the experiments were carrying out in the laboratory, so there is no possibility of interaction of plant odour here. However, preys have been reared on different varieties of plants and hence there is little possibility for the interference of antixenotic cultivars.

3.7.1 Prey stage selection

Reduviids are much larger in size than other Hemipteran predators like *Nabis* (Nabidae), *Geocoris* (Lygaeidae), *Orius* (Anthacoridae), *Lygus* (Miridae) and *Podisus* (Pentatomidae) and are successfully attacking and consuming larger preys (Schaefer, 1988). The effectiveness of the biological control agent depends upon the number of prey killed, quality of the food, reproductive capacity, searching, discovering, prey handling time, digestion, hunger, prey preference and competition among predators Moreover, before utilising a natural enemy for biological control, it is important to assess its ability to capture and consume relevant stages of the targeted pest insects. Such assessment can identify the limitation of the predator and its potential impact before for the more costly experimentation is considered. Among these factors, prey preference is of prime importance (Ambrose and Sahayaraj, 1993; Sahayaraj, 1994b). Relation's between prey size to predator size of predaceous animals has been reviewed by Hespenheide (1973). The feeding preference was evaluated by both choice and non-choice tests. This kind of tests was conducted in many reduviids such as *Rhinocoris lapidicola* Samuel and Joseph, *R. nysiphagous* Samuel and Joseph and *Coranus* sp. (Joseph, 1959); *Salyavata varigata* Amyst. and Seville (McMahan, 1983a and 1983b), *Agriosphjodus dohrni* (Inoue, 1985), *Rhynocoris fuscipes* (Kumaraswami, 1991), and *A. quadrisignatum* (Ambrose and Sahayaraj, 1993). In general, various instars of hunter reduviids attack different size prey. First three nymphal instars of *R. lapidicola*, *R. nysiphagous* and *Coranus* sp. preferred earlier nymphs of *Nysius inconspicuous* Distant (Joseph, 1959). A choice test was conducted to assess the preference of *R. marginatus* (fourth and fifth nymphal instars and adults) on four groundnut pests in the laboratory by using glass olfactometer (Sahayaraj, 1999b). He proposed that *R. marginatus* preferred fourth (43.76%), fifth (48.14%) and sixth (50.13%) instar larvae of *S. litura*. Second, third and fourth stage larvae of *A. albistriga* were preferred by fourth and fifth nymphal instars and adults of *R. marginatus*, respectively. *R. marginatus* fourth instar preferred fourth instar *Helicoverpa armiger* and both fifth instar and adults preferred fifth instar larvae It also preferred *A. modicella* in similar manner as observed for *Helicoverpa armiger*. All the nymphal instars and adults of *R. kumarii* were killed and consumed more number of small and medium sized larvae of *Spodoptera litura* followed by *Helicoverpa armiger* and *Earias vitella*. Laboratory observations indicated that the attack strategy of *Z. renardii* depends upon the type of the prey encountered; smaller, more mobile preys are usually ambushed whereas larger, less mobile prey is stalked (Ables, 1978). Many scientists made the similar kind of statements (Edwards, 1966; Sahayraj, 1991; Kumaraswami, 1991) for reduviids. Though reduviids preferred all the stages of the preys available in its habitat, some predators preferred only particular stage of the prey. For example, first nymphal instar of *R. fuscipes* preferred only second nymphal instar of *Nezara viridula* Linn , the second nymphal instars preferred second and third instar nymphs whereas third, fourth and fifth instar nymphs preferred only third nymphal instar of *N. viridula* (Singh and Singh, 1987). *E. umbrinus* first (94.44%) and second instars (61.11%) preferred second instar nymphs of *D. cingulatus* whereas the third instar preferred second instar *D. cingulatus* (66.66%) (Sahayaraj, 1991). He also reported that though *N. therasii* was provided with I, II and III nymphal instars of *D. cingulatus* all the life stages of *N. therasii* mainly preferred I instar *D. cingulatus* (92.00, 75.00, 75.00, 55.00, 73.68 and 66.66% for first, second, third, fourth and fifth nymphal instars adults respectively). Similar observation was also observed for *A. quadrisignatum* (100.00, 90.00, 76.66, 70.00 and 63. 33% for first, second, third, fourth and fifth nymphal instars of *A. quadrisignatum*). If the size of the prey is smaller than the predator then some reduviids rejected them. For instance, *A. pedestris* rejects both the *E. insulana* and *P. gossypiella*, which were smaller than their own body size. Under laboratory conditions, Sahayaraj (1991) offered *Earia insulana*, *Helicoverpa armigera*, *O. hyalinipennis*, *P. gossypiella* and *S. litura* to adult *Acanthapis pedestris*; *Dysdercus cingulatus*, *Achea janata*, *Helcoverpa armigera* and *Spodoptera litura* to *E. tibilais*, *Dysdercus cingulatus*, *Achea janata*, *Earia insulana*, *Helicoverpa armigera*, and *Spodoptera litura* to *C. brevipennis*; *Earia insulana*, *Helcoverpa armigera*, *Oxycarenus hyalinipennis*, *P. gossypiella* and *S. litura* to *N. therasii*; different life stages of *Dysdercus cingulatus* to life stages of *N. therasii*, *A. quadrisignatum* and *E. umbrinus* and find out the preferences. Kumaraswami (1991), Sahayaraj (1994a) and Ambrose and Claver (2001b), Sahayaraj and Sivakumar (1995) studied similar experimentation in *Rhynocoris kumarii*, *Rhynocoris fuscipes* and *Rhynocoris marginatus* and Das (1996) on *S. horridae* and *Irantha armipes* and Sahayaraj (1999b) on *Rhynocoris marginatus*. Their conclusions are as follows:

1. Large size predator preferred large size prey and the smaller size predator preferred the smaller size prey.
2. Particular prey could not elicit similar preference on different predators, and
3. Timely release of the predator into the pest infested fields leads to effective controlling.

In addition to the prey type and motion, prey weight and age also play an important role in predation. Knowledge of the nutritional requirements of reduviids may furnish the key to their successful establishment of effective operation. Host preference can still be accurately evaluated by using energetic of predators on different host preys. Even though reports are available on quantity of food consumption and growth of predatory insects, investigations on predatory reduviids are scanty. Hence, the host preference of reduviids has been discussed with three objectives: to assess the host preference by prey type and energetic.

3.7.2 Prey selection

Readio (1927a and 1927b) reported *Melanolestes picipes* as an exclusive predator of scarabaeid grubs, whereas *R. fuscipes* as one on a number of crop pests, belonging to different orders (Rao, 1974, Ambrose, 1999). *Phonoctonus* species like *Phonoctonus* sp. (Stride 1956a) and *Phonoctonus fasciatus* Stal (Evans, 1962) and *Phonoctonus* sp. (Fuseini and Kumar, 1975) studied the prey preference. By choice test Bass and Shepared (1974) also studied the pest preference. They reported that *Sycanus indagator* (Stal), a reduviid predator imported from India preferred greater wax moth, larvae *Galleria mellonella* (Linn.) than the larvae of the fall armyworm, *S. frugiperda* (J.E. Smith). Karsavuran (1989) pointed out that, 91.83 per cent of *Rhynocoris punctiventris* (H.S.) nymphs died during their first three developmental stages when reared on *Dolycoris baccarum*. He concluded that *Dolycoris baccarum* is not the appropriate prey for *R. punctiventris*. In support of his view, the host preference of *Isyndus heros, Coranus* sp., and *Endochus inornatus* were studied on *S. litura, H. armigera, A. janata* and *C. cephalonica* by fixing their anterior potion (head and thorax) using cellotape of 2.5 cm width (Lakkundi, 1989). According to him, the three reduviids studied are not host specific. In contrast Parker (1965a) in *Pisilus tipuliformis*; Abels (1978) in *Zelus renardii* Kolenati; Awadallah *et al.* (1984) in *Peregrinator biannulipes* (Montr.et.Sign) were not specifically preferring any preys. Among the five stages of the life stages (first instar to adults) *I. armipes, S .horrida* and *Sphedanolestes* sp. preferred very small stage (3 to 5 cm) *H. armigera* (Das, 1996). *R. kumarii* fourth instar preferred *S. litura* (78.72%) followed by *D. cingulatus* (17.02%) and *M. fustulata* (4.26%). But both the fifth nymphal (70.52, 17.86 and 11.86% for *H. armigera, R. clavatus* and *E. molligera*, respectively) instar and adults (45.50, 38.20 and 18.30% for *H. armigera, S. litura* and *D. cingulatus*, respectively) preferred another lepidopteran pest *H. armiger* (Ambrose and Claver, 2001b).

Some predators feed on a variety of prey species in proportion to their relative abundance in the environment. For instance, *Oncocephalus annulipes* Stal prefer to feed *E. insulana* (2.5), followed by *E. vitella* (2.2), *S. litura* (2.2) and *H. armigera* (1.8) (Vennison and Ambrose, 1986b). *A. pdestris* preferred *P. gossypiella* (39.92%) followed by *H. armigera* (35.38%), *S. litura* (16.92%) and *E. insulana* (10.77%). Both the *E. tibialis* and *C. brevipennis* were preferred *H. armigera* (Sahayaraj, 1991). *Fitchia aptera* (Stal) both the nymphs and adults won't accept aphids and variety of species of beetles. Similarly *Reduvius personatas* (Linn.) rarely accept weevils *Brachyrhinus sigulatus* (Linn.) (Schdder, 1992). Almost all the reduviids either feed on young ones or adults of other insects. But, *Z. socins* feed on bollworm eggs (Whitecomb and Bell, 1943).

3.7.3 Energy budget is a tool for prey selection

Food intake and utilisation of consumed food are not only crucial for the survival of the insect but are also responsible for the establishment of its population. It has been well understood from the previous section that reduviids preferred particular prey. This may be due to the nutritional quality and quantity of the prey. Moreover, the difference in the food value of preys for the reduviids may be due to the differences found in the food intake of the preys or differences in the nutritive value of the ingested food or both. In this section we deal with the effect of different prey on the consumption and growth of three reduviids. It is considered to be an important tool to prove the prey preference of the reduviids. Hagen (1987) studies the nutritional ecology of reduviids. The only available work in the literature is the work of Ambrose and Kumaraswami (1993) and Sahayaraj (1991). The farmer authors studied the food requirement of *R. fuscipes* by using *C. cephalonica* as prey. Later author studied the pest preference by using energy budget as a tool. Moreover, Kumaraswami (1991) evaluated the total number and amount of prey consumed/predator/day in *R. fuscipes* and *R. marginatus*. Similar kind of study was carried out in *R. kumarii* (Ambrose and Claver, 1995a). In 1996, Sahayaraj and Ambrose (1996b) recorded the quantitative consumption, assimilation and conversion of male and female *N. therasii* on *Dysdercus cingulatus* and *Helicoverpa armigera*. Females consumed more amount of food than the males. Similarly consumption, assimilation, metabolic and conversion rates (mg dry weight/g live weight/day) were higher in females than males. This could be attributed to its higher nutritional requirement of the female for reproduction. *N. therasii* consumed more amounts of *Dysdercus cingulatus* (28.22 and 23.32 mg/dry weight for male and female respectively) than *Helicoverpa armigera* (21.19 and 25 99 mg/dry weight for male and female respectively). Conversion rate of female (0.02 mg dry weight/g live weight/day) was higher than the males (0.01 mg dry weight/g live weight/day) while *Dysdercus cingulatus* was provided as a prey. However, conversion rate of female and males (0.014 mg dry weight/g live weight/day) were same on *Helicoverpa armigera*. Sahayaraj and Ambrose (1996b) concluded from the study that *N. therasii* preferred *Dysdercus cingulatus* than *Helicoverpa armigera* because of the presence more amount of total protein (57 16%) and lipid (12.24%) present in the farmer prey.

Table 3.4. Different pests on the energy budget of *A. pedestris*

Parameters	*E. insulana*	*H. armigera*	*P. gossypiella*
Consumption (mg/dr wt)	43. 92[a]	79.01 [b]	93.96[c]
Assimilation (mg/dr.wt)	36.93 [a]	67.22 [b]	84.20[c]
Conversion (mg/dr.wt)	18.12 [a]	20.15 [ab]	23.85 [bc]
Consumption rate	0.027 [a]	0.043 [b]	0.059[c]
Assimilation rate	0.023 [a]	0.037 [b]	0.053[c]
Conversion rate	0.008 [a]	0.010 [b]	0.014 [bc]
Metabolic rate	0.011 [a]	0.026 [b]	0.075[c]
Assimilation efficiency	82.354 [a]	84.24 [ab]	89.48[c]
Conversion efficiency	50 49 [a]	33.39 [b]	28.48[c]

Source. Sahayaraj (1991)

Mean followed by the same alphabets in the row are not statistically significant at 5 per cent by DMRT The efficiency of utilising prey by terrestrial predaceous insect is best known in a few heteropteran predaceous insects. The pioneering research of Sahayaraj (1991) studying the energetic of the predaceous reduviids *A. pedestris, C. brevipennis* and *E. tibialis* fed with various lepidopteran caterpillars and hemipteran nymphs and provided a foundation for subsequent research in nutritional ecology of hunter reduviids. The food consumption of the adult *A. pedestris* was different for the different preys. The *P. gossypiella* reared reduviids consumed higher amount of food. *A. pedstris* consumed more amount of *P. gossypiella* followed by *H armigera* and *E. insulaana* (Table 3.4). The maximum consumption rate was also observed in *P. gossypiella* prey. The feeding rate was coincided with the food consumption. Though *P. gossypiella* fed predator has statistically significant ($p<0.05$) conversion rate, this group had minimum conversion efficiency (28.48%). *E. insulana* had minimum percentage of protein (20.58%) in its food followed by *H. armigera* (36.15%) and *P. gossypiella* (57.23%). The higher conversion efficiency (50-49%) in the *E. insulana* fed predator shows that all the available protein of *E. insulana* was converted into body, though *A. pedestris* consumed less amount of *E insulana*. This result is in contrast to the visual observation, *i.e., E. insulana* in the least preferred prey (10.77%) of *A. pedestris*. In *C. brevipennis* adults the feeding rate was higher in *H.armigera* (201.74 mg/dry wt) than *D. cingulatus* (168.98 mg/dry wt). It was higher when *E. tibialis* was provided with *D. cingulatus* and it was statistically highly significant. Assimilation (191.51 mg/dry wt), conversion (85.06 mg/dry wt) was also in favour of *H. armigera* than *D. cingulatus* (160.41 and 68.31 mg/dry wt). Both the consumption (0.016) and assimilation (0.015) rates were equal when *C. brevipennis* was provided with these two pests. However, the conversion (0.033) and metabolic (0.012) rates were in favour of *H. armigera*. Similar trend was observed in assimilation and conversion. But similar consumption and assimilation rates were observed in both pests. The food assimilation and its rate were also in favour of those pests which had maximum consumption and consumption rates. The reduviid with higher and lower conversion rates had higher and lowers metabolic rates, respectively.

E. tibilais consumed maximum *D. cingulatus* (204.47 mg) followed by *H. armigera* and *C. cephalonica* (Table 3.5). Assimilation and conversion and their rates were also in favour for the preferred food. However, the efficiency is in favour for *H. armigera* followed by *C. cephalonica*. In general those animals with higher and lower conversion rates had higher and lower metabolic rates respectively. An exactly equal trend was also observed in *E. tibialis* that fed on *H. armigera*. The metabolic rates of *D. cingulatus* fed adult was significantly different from that of *H. armigera* fed group. Increased feeding (high consumption) might have caused dilution of digestive enzyme and increased metabolic rate so that the growth rate was not able to maintain (Scriber and Slansky, 1981). Similar observation was also recorded in *C. brevipennis* fed on *Dysdercus cingulatus* and *Helicoverpa armigera* but in *Acanthapis pedestris* and *Ectomocoris tibialis* increased feeding did not reduce the assimilation rate but increased the metabolic and growth rate. The higher growth rate might be due to the higher assimilation and the conversion efficiency. And hence *Helicoverpa armigera* can be considered as a preferred prey of *E. tibialis*. This result corroborates with the visual observation. The reference study shows that *E. tibialis* significantly preferred *H. armigera* (49.23%). Thus, hunter reduviids are efficient in converting prey to body tissue.

Table 3.5. Different pests on the energy budget of *Ectomocoris tibialis*

Parameters	*C. cephalonica*	*D. cingulatus*	*H. armigera*
Consumption (mg/dr wt)	88.27	204.47	105.52
Assimilation (mg/dr.wt)	85.21	194.73	101.02
Conversion (mg/dr.wt)	20.17	14.46	27.14
Consumption rate	0.051	0.091	0.075
Assimilation rate	0.049	0.082	0.065
Conversion rate	0.011	0.005	0.015
Metabolic rate	0.038	0.045	0.051
Assimilation efficiency	96.47	94.64	95.47
Conversion efficiency	23.79	7.47	31.13

Source: Sahayaraj (1991)

It may be concluded that the differences in growth of reduviids on the preys are due both to the differences in the consumption rate and the nutritive value of these diets. Soo Hoo and Fraenkel (1966) clearly pointed out that the amounts of food consumed, assimilated and converted by polyphagous insects vary with quality of food. Moreover, conversion rate and conversion efficiency of the reduviids determine the growth of the predator. In general if a predator consumed less amount of food, all the consumed food is converted into the body and ultimately enhanced the growth of the predators. So by visual observation we can't predict the prey preference of the reduviids. Ultimately this chapter shows that the information on orientation of a predator to suitable prey would be extremely important in the manipulation of predators in successful pest management strategies. Study of tritrophic interactions between plants, herbivores, and natural enemies, is very much useful to know the integrate host plant resistance and biological control in the pest management of arthropod pests and to understand the relative importance of direct and indirect effects of physical, chemical, and nutritional qualities of plants on the attack rate, survival and reproduction of natural enemies. Furthermore, it also helps to know the abundance and distribution of natural enemies against vulnerable pest populations. Recently Sahayaraj (2006) reported that study of natural behaviours of reduviids are very much useful and helpful to utilise them as an efficient biological control agents in the nature.

3.8 Recommendations

1. Still very little information is known about the host finding behaviour of reduviids and hence more studies are essential to know this complex process.
2. It is essential to study this behaviour based upon the physical characteristics of the host (shape and texture, size, developmental stages and movement).
3 Preference can be assessed in relation to Prey – related substances (regurgitation, digestive tract, haemolymph, integument, faeces and prey's food medium)
4 More energy budget related studies are essential to understand the preference in a better way.
5 Isolation, identification of chemical case of various natural preys of reduviids is necessary.

4

Zoophagy of Reduviids

4.1 Introduction

Before utilising any natural enemy for biological control, their importance to be assessed by recording its ability to capture and consume the relevant targetted insect pest. Such assessment can be useful to identify the limitation of a predator and its impact before and/or furthermore costly experimentation is being commenced. The venom of poisonous predators has been a great source of novel peptide with a notable potential for use in agriculture and in medicine. They have also been valuable biochemical tools for the study of ion channels in animal. Toxic peptides targetting ion channels have been frequently isolated from snakes, scorpions, marine cone snails, spiders and other animals. Toxic peptides from venom of scorpion have been extensively studied and they are considered as a valuable biochemical tools for the study of sodium channels. Scorpion venom is a rich source of polypeptides with diverse physiological and pharmacological activities.

Most of the families belong to the Heteroptera and sub-family reduviidae contains many species of zoophages. Morphological comparisons of both mandibular and maxillary stylets reveal differences between heteropteran phytophages and zoophages Predaceous reduviids inject venom and/or salivary enzymes, via the salivary duct of the maxillary stylets in to the prey where it can liquefy the prey solids. The injection of the saliva causes immobilisation of the prey. However, it is not very clear whether all reduviid predators immediately inject venom into the prey as they penetrate the stylet into the prey cuticle. The salivary system of reduviids confirms to the general heteropterous principal and accessory glands, which are divisible into secretary and conducting parts. Many workers extensively studied the diversity and function of principal salivary gland of various reduviids. The anterior lobe of principal salivary gland of reduviids secretes zootoxic enzymes, which immobilise the prey and digestive enzyme secreted by posterior lobe. In this chapter we provided the information's about the morphology and histology of hunter reduviid salivary glands, venom collection methods, quantity of venom in relation to sex and prey deprivation, zootoxic effects, biochemical composition of venom and therapeutic and paralytic use of venom have been considered.

4.2 Salivary gland Morphology and Anatomy

To isolate the salivary glands, the tergal plates of anaesthetised predators were carefully removed by making a circular lateral incision around the abdomen with a single edge razor blade in saline solution (NaCl – 6.5 gms; KCl – 0.25 gms; $CaCl_2$. 0.25 gms; Na_2CO_3 – 0.25 gms; distilled water 1000 ml). The gut, reproductive, nervous and tracheal systems along with any adhering tissues were carefully removed to fully expose the salivary glands and ducts. The main salivary duct was next detached from the sclerotised mouthparts closer to the salivarium The gland removed from the predator was rinsed and placed in saline, weighed in a precision balance and fixed in Bouins fluid. The morphometry of salivary glands was carried out under microscope with ocular and stage micrometers. The salivary gland comprises of a pair of principal glands and accessory glands. The principal salivary glands (PSG) are located on either side of the anterior midgut and extended into the abdominal cavity. The PSG is elongately bilobed with an anterior lobe (AL) and a posterior lobe (PL). The AL is elliptical with acutely tapering cephalic end and continues as the fine suspensory ligament (SL) into the head capsule running dorsal to the oesophagous and beyond which it could not be traced The transparent caudal end of the anterior lobe is swollen. The junction of anterior and posterior lobes is distinctly constricted, called the hilus (H). The PLs of most of the harpactorine reduviids are elongating slender, but their shape is not consistent. They are swollen anteriorly at the hilus. They are slightly sinuous throughout its length. Often they are found highly enlarged at certain regions indicating secretory activity. Such enlargements are transparent, while the other areas remain opaque. But they slightly tapered and curved at an angle and fastened with the middle of the crop and the posterior mid gut by means of tracheal branches. A nerve that runs along the length of the oesophagous forms a meshwork at the hilus.

The main duct of the principal salivary gland runs forward, usually following the contour of the alimentary canal and from both sides enter the neck and a little distance beyond the 'U' turn of the accessory salivary gland duct, unite to form a common duct that ultimately enters the lumen of the salivary pump. The AL of the principal salivary gland secretes zootoxic enzymes, while the PL secretes digestive enzymes. The accessory salivary system (ASS) is similar in most of the reduviids. The ASS has the vesicular part that remains intimately attached to the anterior half of the crop. Midway it sends the accessory gland duct, that runs anteriorly, parallel to the posterior lobe of the principal salivary gland. It then continues to run parallel to the afferent salivary duct, enters the head capsule and loops around the nypopharyngeotentorial complex near the gena. It then turns back, becomes narrower, runs parallel to the oesophagous as descending limb and opens apparently independent of the afferent duct into the hilus. Thus the duct up to the loop is ascending and slightly broader than the descending duct The ascending and descending ducts are demarcated by a narrow constriction at the hypopharyngeotentorial complex.

The vesicular part of the accessory salivary gland is distinctly glandular and possesses a moniliform tubular secretary appendix and lies closely to the posterior region of the crop and the posterior midgut. Accessory glands are thought to function as water recapturing organs, a function that has been under emphasised in account of feeding by predaceous heteropternas (Miles, 1972). In freshly dissected salivary glands, when the inseparable vesicle is released from the crop, it seems to be formed of an anterior narrow limb that is almost intimately connected to the junction of oesophagous and the crop and a comparatively broader and more saccular posterior limb, which is lying closely, opposed to the crop. Accessory salivary glands are filled with watery fluid, which recirculates water from the gut to ensure a copious flow of watery saliva and helps the predator to flush out the predigested food from the body of the prey. Maran (1999) recorded the morphometry of three reduviids salivary gland (Table 4.1). Our recent studied revealed that weight of the salivary gland was also varied if they were reared on different preys. For instance when *R. marginatus* was reared on *C. cephalonica* (30.72 mg), the entire gland weight was 30.72 and it slightly increased on *S. litura* (31.01 mg) and *P. ricine* (31.05 mg). Furthermore, the entire weigh of *R. marginatus* was increased when the adult female grw older (30.72, 30.98, and 32.08 for one, two and three times egg laid predator). As observed in *R. marginatus, C. brevipennis* total salivary gland weight also varied for different preys (64.40, 65.45 and 65.78 for *C. cephalonica, S. litura* and *M. pustulata*).

Table 4.1. Morphometry of principal salivary gland of three reduviids

Morphometry	Rhynocoris fuscipes	Rhynocoris kumarii	Rhynocoris marginatus
Weight (mg)	1 34	3.54	2.54
Total length (mm)	1.15	1.36	1.98
Total width (mm)	1.10	1.77	1.82
Anterior lobe length (mm)	1.16	3.05	2.83
Anterior lobe width (mm)	0.99	1.28	0.96
Posterior lobe length (mm)	2.67	5.23	4.99
Posterior lobe width (mm)	0.97	1.11	1.02

After Moran (1999)

Observations showed interesting variations in the state of salivary gland activity at different stages of predation. In starved predators, the lobes of the principal and accessory glands were completely filled with secretions. When these predators attacked a prey, the anterior lobes were flaccid. The posterior and accessory gland lobes were filled with their respective secretions. But when these predators completed their feeding events, the anterior lobe, the posterior lobe and the accessory glands seemed empty, suggesting the secretions were spent during feeding The ducts of both principal and accessory glands are having cuticular linings resembles the spiral thickening in tracheal tubes. Recently Sahayaraj and Sangaralingam (unpublished data) observed that total weight of *R. marginatus* salivary galand varied when it was fed with *Corcyra cephalonica* (30.72 mg), *S. litura* (31.01 mg) and *P. ricini* (31.50 mg). Similar weight difference was also observed in another redviid *C. brevipennis* (64.40, 65.45 and 65.78 for *Corcyra cephalonica, S. litura* and *M. pustulata* respectively)

4.3 Histology of the Salivary glands

Very limited work has been available about the histology of reduviid salivary glands. For instance, the histology of 3 salivary glands of *R. fuscipes, R. kumarii* and *R. marginatus* was studied by Maran (1999). According to him, the principal salivary glands of *R. fuscipes, R. kumarii* and *R. marginatus* have single layer of binucleate cells enclosing a spacious cavity for storing their secretions. The cells of anterior lobes of these three predators are smaller and flattened with less viscous cytoplasm having numerous secretory granules. Their nuclei are flattened and elongated. The cells in the anterior lobes of *Rhynocoris fuscipes, Rhynocoris kumarii* and *Rhynocoris marginatus* are 17.93, 21.40 and 14.74 μ wide with nuclei of 8.12, 9.78 and 8.50 μ wide, respectively. In contrast, the cells of the posterior lobes are larger with highly viscous cytoplasm with numerous granules and vacuoles. Each cell has two spherical nuclei with many chromatin granules These cells are 28.58, 37.34 and 31.45 μ wide with nuclei of 15.72, 13.68 and 17.24 μ wide in *R. fuscipes, R. kumarii* and *R. marginatus*, respectively. The wall of accessory salivary gland is made up of extremely flattened syncytial epithelial cells enclosing a wide lumen. The cytoplasm is devoid of secretary granules and vacuoles The ultra structure of the accessory glands of *Zelus renardii* appears to be that of a first stage of ultra filtration system with numerous mitochondria present at possible sites of water-ion transport (Cohen, 1990). The cells in the hilar valve are columnar, uninucleate and without any granules. The ducts of main and accessory glands are made up of a single layer of cuboidal cells. The salivary system was innervated by a complex nervous system from the suboesophageal ganglion and stomatogastric system.

4.4 Venom

Venom is defined as a mixture of substances that are produced in specialised glands of the venomous animal and injected with the aid of a stinging or piercing apparatus into the body of its prey in order to paralyse it. Venomous arthropods possess proper instrumentation for stinging or piercing and direct introduction of toxic substances into the circulation and tissues of their prey. The vast majority of venomous arthropods are predators and they feed exclusively on living prey that comprises other arthropods, especially the insects. In the process of predator—prey interaction, two devices are being used by the predators: one—a physical device, the stinging apparatus enabling the direct introduction of the venom into the circulation or close proximity to the critical target tissues of the prey, and two—the chemical device, in the form of the active substances—the neurotoxins, which possess a unique pharmacologically specific relation to these target tissues. A neurotoxin is defined as a substance that interferes with the functions of excitable tissues. The higher paralytic potency at lowers concentrations, and rapid action within seconds or minutes of neurotoxin is a prerequisite for predators employing venom for prey capture.

4.4.1 Collection methods

4.4.1.1 Milking method

Generally there is few collection methods have been commonly used for collecting venom from venomous arthropods. They are extract the whole body, dissection of venom glands and milking. Venom is probably the most similar to the substance certainly injected by a sting, is obtained by milking. Among the above said three methods, milking is the mostly popular method for obtaining venom from the venomous arthropods. Many procedures of milking venom from the sting have been developed, ranging from freezing to electro stimulus to alarm pheromone stimulus. Here we described the procedure for milking the pure venom from hunter reduviids (Sahayaraj *et al.*, 2006).

To milk venom from the reduviids, several males and females are released onto a clean plastic troughs having wide mouth. Capture and hold the abdomen placing the right hand thumb on the ventral side and second finger on the dorsal side. Then slightly insert the glass capillary tube (2 5 cm height 1mm diameter) on to the rostrum of the reduviid. Gently press both the fingers. This activity stimulates the reduviid to inserting the rostrum deeper into the capillary tube.

During this acts the venom should flow from the tip of the rostrum as a thin drop of water into the capillary tube. But *C. brevippenns* split the saliva before inserting the capillary tube into its beak. A 1.5 cm length effendorf is placed on the other end of capillary tube, where a drop of venom is extrudes and will be collected. The acts of pressing the abdomen can be made two or three times continues, with few seconds interval. Perhaps as a result of either the pull on the capillary tube into the rostrum up to the second segment of the rostrum (or) the contact of finger on abdominal hair. Although the amount obtained from the individual predatory may vary, we have found that we can milk several reduviids at a time by using this simple procedure without killing reduviid. Subsequently 5 ml of phosphate buffer or 1 phospho-2 urate crustal has been added along with the venom and stored in refrigerator for further use.

4.4.1.2 Electric shock method

In electric shock method, instead of holding the animal in hands, the victim has holed with forceps attached with the electric shocker. After the proper set up was over, the electric stimulus (20 - 30 volts) was passed into the last two (or) three ventral abdominal segments. The shock has been passed two (or) three times during a milking. It is very clear from our observation that due to the contraction of muscles that surrounding the venom gland, venom was pressed out and could be collected at the tip of the fangs with a capillary tube. Since, the electric shock is applied at the abdomen, the stimulus has been transferred into the salivary gland through the abdominal segmental neurons.

4.4.1.3 Dissection method

To find out the volume of saliva, the intact salivary glands of anaesthetised reduviids were dissected out in ice-cold saline (0.15M) under stereoscopic microscope. Anterior and posterior lobes of the principal salivary glands were separated and their salivary venom was measured by using the microsyringe (gauge 26) Maran (1999).

Among the three methods, the former method can be used for the frequent collection of venom from reduviid predator. We observed the following demerits in the electric shock as well as dissection methods:

1. It is very difficult to subject the reduviid for electric stimulus.
2 The reduviid was dead or was killed between 24 to72 hours after electric shock.
3. The predator doesn't feed any prey after the electric shock.
4. Scar has been formed at the site of electric shock, and
5 In dissection method large number of animals could be sacrificed.

However, we are recommending reducing the electric shock level (volts) (or) modify the electric shocker (or) change the site and find out the suitable site by trial and error method for electric shock stimulation.

4.4.2 Quantity of Saliva

4.4.2.1 Parts of the Gland

Quantity of the saliva is varied depending upon the position of the various parts of the salivary gland Maran (1999) has studied the volume of saliva in various parts of the salivary gland in normal condition as well as in prey deprived conditions on three harpactorin reduviids. His data is presented here. According to him, the volume of saliva was higher in the posterior lobes than in the anterior lobes. Prey deprivation caused accumulation of saliva in both the lobes. The anterior lobe of prey fed *R. fuscipes* had 2.80 µl of saliva and its posterior lobe contained 4.90 ± 0.433 µl. In *R. kumarii,* the anterior lobe contained 3.40 µl whereas its posterior lobe had 4.90 µl of saliva. *R. marginatus* also exhibited a similar trend, that the anterior lobe had lower volume (3.00µl) than the posterior lobe (4.60 µl). Among these three predators, *R. kumarii* had the highest volume of saliva in the anterior lobe followed by *R. marginatus* and *R. fuscipes,* whereas the posterior lobe of *R. fuscipes* and *R. kumarii* had equal volumes of saliva (4.90 µl) Maran (1999).

Prey deprivation caused accumulation of saliva in both the lobes of principal salivary gland. The accumulation was higher in the anterior lobe of *R. kumarii* followed in *R. marginatus* and *R. fuscipes.* For instance, in the anterior lobe of 8 day prey deprived *R. kumarii,* the volume of saliva increased from 3.40 µl to 8.70 µl whereas it was from 3.00 µl to 7 50 µl in *R marginatus* and from 2.80 µl to 6.90 µl in 4 days prey deprived *R. fuscipes* Regarding the posterior lobes, the increase in the volume of saliva was the highest in *R. marginatus* followed in *R. kumarii* and *R. fuscipes*. For instance, in the posterior lobe of 8 days prey deprived *R. marginatus,* the volume of saliva increased from 4.60 µl to 10.50 µl, whereas it was from 4.90 µl to 9.90 µl in *Rhynocoris kumarii* and from 4.90 µl to 7.80 µl in 4 days prey deprived *R. fuscipes* (Maran, 1999).

4.4.2.2 Sex

Sex also has an influence on the quantity of saliva. Variation has observed according to both size and sex of *R. marginatus* (Sahayaraj and Muthukumar - unpublished data). Male *R. marginatus* (139.50 mg) milked higher quantity of venom (0.39 mg/animal) than male (0.23 mg/209 17 mg body weight). But an opposite trend was observed when stimulating *R. marginatus* collected venom by electric stock (0.70 and 1.53 mg/animal for male and female, respectively). Similar observation has also been observed in *C. brevipennis.* Further studies are essential to know the influence of sex on the venom quantity.

4.4.2.3 Prey deprivation

In general it is essential to select the male and female, which are uniform in size. If so, the quantity of venom milked by both the male and female were also significant However, ANOVA analysis between the animal initial weight and venom milked showed that the male milked significantly more than the female venom This is not same when the reduviids where starved either continuously or discontinuously. Significant difference was observed during in the discontinuous starvation venom quantity, body weight and weight loss. During the initial period of starvation (first day) the female milked more quantity of venom (6.63 mg than the male 4.57) but as the days of starvation prolonged, the quantity of milked venom was drastically reduced, similar observation was also observed in body weight in both sexes (Table 4.2 unpublished data of the author). Ambrose and Maran (1999b) reported that the quantity of saliva present in both anterior and posterior lobe of *A. pedestris* was increased when the predator was subjected to prey deprivation. Furthermore, the saliva accumulated more in the salivary gland during the prey deprivation (Ambrose, 1999). Prey deprivation continuously implies that the animal was not provided with prey as feed throughout the experimental period. Variation could also be found in saliva quantity, body weight according to period of deprivation. In females milking of venom increasingly in relation to the deprivation period as in the case of discontinuous starvation periods. The venom quantity, body weights were also significantly reduced as the period of starvation increased but on third day of starvation, the male milked more amount of venom than the first day starvation. During the sixteenth day of starvation the male didn't milk any venom. In the second category, the body weight decreased as the time period of starvation increased in both sexes of *R. marginatus*. More studies are essential in other hunter reduviids to confirm this hypothesis.

Table 4.2. Prey deprivation (in days) and sex on the animal and venom weight (in mg) milking and survival rate (in%) of *R. marginatus*

Prey deprivation	Sex	Animal weight	Survival rate	Venom milking rate	Venom weight
1	Male	139.51	100	100	0.39
	Female	209.77	100	100	0.23
2	Male	119.15	100	100	0.33
	Female	202.26	100	100	0.29
3	Male	132.84	100	93	0.53
	Female	205.64	100	86	0.46
4	Male	131.40	100	93	0.72
	Female	186.67	100	86	0.59
5	Male	130.02	93	57	0.22
	Female	188.32	73	54	0.11

Source: Sahayaraj and Muthukumar (unpublished data).

During the prey deprivation the body weight was decreased after 48 hours (119.15 and 202.26 mg for male, female respectively). Then the body weight was gradually increased both in male and female for 96 and 72 hrs. respectively. Moreover, there was no correlation between the body weight and the quantity of saliva milked by the reduviid. However the previous study (Ambrose and Maran, 1999b) indicated that quantity of saliva present in both anterior and posterior lobe of *A. pedestris* salivary gland was increased, when the predator was subjected to prey deprivation. The survival rate of both the male and female is 100 per cent up to four-day prey deprivation. Then decreased to 93 per cent and 73 per cent for male and female respectively, on the fifth day of prey deprivation. Venom milking rate was also decreased from the third day to the fifth day of prey deprivation. Ambrose (1999) reported that prey deprivation causes accumulation of toxic saliva in the salivary glands.

The preliminary range finding tests of paralytic units showed that 0.5 and 3.5 µl of saliva of *R. fuscipes, R. kumarii* and *R. marginatus* could cause 0 per cent and 100 per cent mortalities in the test insects *S. litura, M. pustulata* and *D. cingulatus.* Injection of saliva of predators into *S. litura* caterpillars caused body wriggling and caterpillars became flaccid and motionless afterwards. *M. pustulata* and *D. cingulatus* wriggled body and groomed antennae and forelegs with their mouth parts. Initially restless victims fell upside down and motionless. Spreading of wings was also observed in *M. pustulata* and *D. cingulatus.* In another experiment Maran (1999) observed that to paralyse *S. litura* caterpillars, *R. fuscipes* had to inject 0.212 µl of toxin whereas *R. kumarii* and *R. marginatus* could paralyse it with 0.191 µl toxin. *R. fuscipes* had to inject 0.195 µl of toxin to paralyse the coleopteran pest *M. pustulata*, whereas *R. kumarii* and *R. marginatus* could paralyse it with 0.160 µl and 0.199 µl toxin, respectively. *R. fuscipes* could paralyse the hemipteran pest *D. cingulatus* with 0.137 µl of toxin, whereas it was paralysed with 0.141 and 0.165 µl of saliva of *R. kumarii* and *R. marginatus*, respectively.

4.4.2.4 Survival rate and venom milking rate

We have been raising many questions in our minds such as after milking the venom, the venom milked reduviid will die or lose their weight or face stressed etc. There was no significant difference observed in survival rate of *R. marginatus* male and female and the survival rate of both sexes 100 per cent up to four days of starvation but the rate decreased to 93 and 73 per cent in both sexes during the fifth days of starvation (Table 2). Accordingly the venom-milking rate also decreased during the same period (see Table 2). However *C. brevipennis* in alive constion up to sixth day, then the survival rate decreased to 90 per cent during eleventh and sixteenth day of starvation in male and female respectively. The milking rate of venom differs according to sex and starvation period during the first and third day of starvation the milk ingrate of male and female was found to be 90 and 100 per cent respectively. It gradually reduced to 70 to 20 per cent in sixth and eleventh day of starvation respectively; the male didn't milk venom during the sixteenth day. There was no significant difference observed in female when compared to male, but in eleventh and sixteenth day starvation the milking rate was increased from 10 to 20 per cent than male. Survival and venom milking preference of *C. brevipennis* during discontinuous starvation survival and venom milking preference of *C. brevipennis* during this period was recorded. The survival rate of both sexes was 100 per cent throughout the starvation period. The milking rate of venom was also reduced; in contrast the milking rate was not affected in female in different time intervals of starvation. The milking rate was gradually decreased from 80 to 70 per cent in male and sixth day of starvation and it was drastically reduced from 70 to 40 per cent.

4.4.3 Paralytic potential

The paralytic potential of reduviids, such as *L. affinis* and *H. nigroviolaceous* (Haridass and Ananthakrishnan, 1981a), *A. pedestris* (Morrison, 1989; Ambrose and Maran, 1999a), *C. brevipennis* (Maran and Ambrose, 1999a) and *R. fuscipes*, *R. kumarii* and *R. marginatus* Maran (1999) was studied. The research on the venom of reduviids might be limited due to difficulty in getting large amount of venom owing to the smaller gland size. According to Maran (1999) the predation of *R. fuscipes*, *R. kumarii* and *R. marginatus* suggested that the salivary venom is paralytic and toxic to their prey. The knowledge on paralyticotency of these neurotoxins prompted us to estimate their quantity and protein content analyse their protein profile, paralytic dosage and paralytic duration to three pests *viz.*, *Spodoptera litura*, *Mylabris pustulata* and *Dysdercus cingulatus*. These salivary toxins through their selectivity may illustrate certain unique features in the physiology of insect excitable system and thus may be employed as a valuable tool in the study of insect neuropharmacology and as a potential model for the design of selective insecticides in near future.

The paralytic durations for the pests *S. litura, M. pustulata* and *D cingulatus* by the saliva of *R. fuscipes*, *R. kumarii* and *R.*

marginatus. The saliva of prey-deprived predators could paralyse the prey more rapidly than that caused by fed ones Moreover, the saliva in the anterior lobe caused paralysis more rapidly, whereas the saliva in the posterior lobe caused paralysis after a prolonged duration of injection. Saliva from the anterior lobe of fed *R. fuscipes* took 119.50, 121.10 and 96.30 seconds to paralyse *S. litura, M. pustulata* and *D. cingulatus*, respectively. Four-day prey deprivation significantly reduced the paralytic durations for these three pests (63.50, 77.10 and 64.10 seconds for *S. litura, M. pustulata* and *D. cingulatus,* respectively) by the saliva of the anterior lobe. Saliva from the posterior lobe of fed *R. fuscipes* took 402.00, 407.00 seconds to paralyse *S. litura*, *M. pustulata* and *D. cingulatus,* respectively. Four-day prey deprivation significantly reduced the paralytic durations for these three pests (199.20, 229.40 and 174.00 seconds for *S. litura*, *M. pustulata* and *D. cingulatus*, respectively) by the saliva of the posterior lobe (see Maran, 1999).

Saliva from the anterior lobe of fed *R. kumarii* took 86.60, 82.80 and 79.10 seconds to paralyse *S. litura*, *M. pustulata* and *D. cingulatus* , respectively (Maran, 1999). He also stressed that eight-day prey deprivation significantly ($P < 0.001$) reduced the paralytic durations for these three pests (57.20, 55.70 and 50.90 seconds for *S. litura*, *M. pustulata* and *D. cingulatus*, respectively) by the saliva of the anterior lobe. Saliva from the posterior lobe of fed *R. kumarii* took 292.30, 263.90 and 281.00 seconds to paralyse *S. litura*, *M. pustulata* and *cingulatus*, respectively. Eight-day prey deprivation significantly reduced the paralytic durations for these three pests (174.40, 160.40 seconds for *S. litura*, *M. pustulata* and *D. cingulatus*, respectively) by the saliva of the posterior lobe. Saliva from the anterior lobe of fed *R. marginatus* took 84.10, 77.10 and 83.70 seconds to paralyse *S. litura*, *M. pustulata* and *D. cingulatus*, respectively. Eight-day prey deprivation significantly reduced the paralytic durations for these three pests (55.00, 57.80 seconds for *S. litura*, *M. pustulata* and *D. cingulatus*, respectively) by the saliva of the anterior lobe. Similarly, saliva from the posterior lobe of fed *R. marginatus* took 314.50, 304.70 and 281.00 seconds to paralyse *S. litura*, *M. pustulata* and *D. cingulatus*, respectively. Eight-day prey deprivation significantly reduced the paralytic durations for these three pests (*S. litura*, *M. pustulata* and *D. cingulatus*, respectively) by the saliva of the posterior lobe (see Maran, 1999).

Earlier Haridass and Anathakrishnan (1981a) studied the zootoxic effect in the sense of paralytic potential of *Lesttomerus affinis* (Serville) and *H. nigroviolaceous*. Later a similar kind of the zootoxic effect of reduviid saliva was observed both in the concentrated as well as diluted saliva of anterior and posterior lobes separately in *A. pedestris* (Morrison, 1989; Ambrose and Maran, 1999b) and *C brevipennis* (Maran and Ambrose, 2000). However, the volume of saliva was higher in posterior lobe (4.16 ml) than in the anterior lobe (2.66 µl). Reduviids anterior lobe secretion immobilised the test insect (preys) faster than the posterior lobe secretion For instance, anterior lobe secretion of *A. pedestris* immobilises *Oxya nitiduala* (Walker) within 69 seconds than posterior lobe secretion (289 seconds) (Morrison, 1989). Ambrose and Maran (1999) pointed out that 0.4622 and 0.4074 µl/insect is enough to paralyse *Mylabris pustulata* Thunberg and *D. cingulatus* Fabricius, respectively. According to Maran (1999), the paralytic unit (PU = µl/ insect) of *R fuscipes* was 0.212, 0.195 and 0.137 for *S.litura, M. pustulata* and *D. cingulatus*, respectively. It was reduced in *R. marginatus* (0.191, 0.199 and 0.165 for *S. litura, M. pustulata* and *D. cingulatus* respectively) and also in *R. kumarii* (0.191, 0 160 and 0.141 for *S litura, M. pustulata* and *D.cingulatus* respectively). They also observed that the salivary content had been increased in the prey deprivated *A. pedestris* and they took minimum period for paralysing the prey. Similar kind of observation was also made in another reduviid *C. brevipennis.* Moreover, the study of toxic potential of the reduviid saliva also helped us to evaluate the pest suppression efficacy (Ambrose and Maran, 1999b and 2000a and 2000b; Maran, 1999; Maran and Ambrose, 2000). Cohen (1996) showed that the predators *Nabis alternatus* Parshley (Nabidae) and *Sinea confusa* Caudell (Reduviidae) lacked amylase activity in their salivary glands; another reduviid *Zelus renardii,* showed amylase activity in its salivary glands. Recently, Maran and Ambrose (2000) concluded that the venom of reduviid predator possess neurotoxins which represents a chemical adaptation of these bugs to paralyse their prey by altering the structure and functions of the nervous system of the prey. Since the neurotoxins are analogous to the synthetic insecticides, they can be utilised to model efficient bio-insecticides. I suggest further studies are essential on this line. If such a kind of bio-insecticides has been developed from reduviid venom by using biotechnological methods that can be used to eradicate the pest as we have been practising Bt toxins. Corzo *et al.* (2001) developed such a kind of salivary based biopesticides from reduviids.

4.4.4 Immunological effect

Many saying that venom proteins affect on the host physiology and development of preys were studied. Our (unpublished data of the author) results showed that fourth instar *S. litura* larval haemolymph contains more haemolytes (5.16 x 10^4) than *H. armigera* (2.53 x 10^4 cells). The haemocyte number is greatly reduced when the *S. litura* larvae was injected with *C. brevipennis* (3.89 x 10^4 cells). The result showed that *C. brevipennis* venom has the capability to the *S. litura* haemocytis 24.6 times. This impact was lower (22.5 times) when *C. brevipennis* was provided with *H. armigera* larvae (1.96 x 10^4 cells). From the results it is obvious that reduviid venom introduced into *S. litura* and *H. armigera* larvae interfere lost physiology. It was observed that the impact of parasitoid was *Pimpla hypochondriaca* venom haemocyte aggregation. They reported that haemocytes maintained in the absence of venom migrated to form well-defined aggregates. The anti-haemocytic properties of venom are likely to be an important factor in allowing *Pimpla* to exploit the extremely wide host range, which also has been reported for this wasp.

4.5 Venom Biochemistry

Virtually nothing is known about the chemistry of the salivary venom of reduviids except the study of Edwards (1961) in *P. rhadamanthus*, Zerachia *et al.* (1973a and b) in *Holotrichius innesi* Horrvath and Maran (1999) in *R. fuscipes, R. kumarii* and *R. marginatus*. The barbson the mandibular stylets of predacious heteropteran families (*e.g.*, Reduviidae) are more numerous than the barbson the mandibular stylets of phytophagous heteropteran families (*e.g.*, Lygaeidae) (Cohen 1990). Stylets are highly modified mandibles and maxillae and also vary from species to species. Similarly the dentition varies from a very regular saw tooth configuration to dozens of equal-sized tooth (Cohen, 2000). Further, he added that the maxillary stylet contains brush like, filtering structure close to the tips. It is observed that longer stylets with smaller diameter increase the access of the bundle to cryptic prey parts, but requirements for strength of stylets that must pierce cuticle and other parts of prey partas demand strength inherent in some minimal size Then the diluted slurry is removed from the prey, via the food canal, through the buccalcavity and sent into the gut. Generally in reduviids, the digestive tract is straight tube without any complexities. Ingestion of the extra-oral prey fluid depends upon the viscosity of the prey. The viscosity of the prey is exponentially related to the nutrients concentration and is, therefore, one of the most mutable components of the system. The salivary gland complex contributes in two ways to viscosity reduction of prey fluid: one by producing enzymes that reduce the size of macromolecules (Cohen, 1995) and two by secreting copious, dilute saliva (Miles, 1972). Cohen (1998) pointed out that reduction in viscosity that results from hydrolysis of macromolecules might be less consequently than the reduction that result from dilution.

4.5.1 Digestive enzymes

During feeding, the digestive enzymes are delivered into the prey where they kneaded onto the target structure. Proteolytic saliva is pumped into the prey and in a few minutes all proteinaceous tissues are dissolved, including the muscles, and the mid-gut and its contents. The liquified contents are then sucked out at leisure by the reduviid bug; only a chitinous shell remains (Smith, 1966). Digestive enzymes specific for zoophagy include proteases (*e.g.*, trypsin, chymotrypsin, cathepsin), hyaluronidase and phospholipase (Cohen 1998b, 2000). Digestive enzymes of heteroptera include proteinase, lipase, phospholiphase A1, amylase, pectinase, invertase, hyaluronidase and nuclease (Nuorteva, 1958; Miles, 1972; Cohen, 1998). In addition, eleastase like enzyme was also found in the saliva of *Z. renardii* (Cohen, unpublished data). Previously Cohen (1993) found out the proteinases, trypsin-like enzymes in the same reduviid. Proteinases are the most important liquefaction enzyme in reduviids (Cohen, 1993) and also in other heteropteran predators (Miles, 1972; Rees and Offord, 1969). Houseman and Downe (1983) reported Cathepsin D like proteinase in the posterior midgut of *Sinea* sp. *Z. renardii* could liquify and extract all of the nutrients of a prey nearly equal to its own body weight in less than two hours (Cohen and Tang, 1997). Proteinases are classified in to endopeptidases and exopestidases. The endopeptidases are mainly used for cleaving of reducing insoluble protein molecules into water-soluble subunits. Trypsin-like enzymes attack protein at their basic amino acids sites, cleaving the protein at lysine and arginine aromatic residues (Cohen, 1993). Chymotrypsin present in most of the predatory heteropterans was not reported in any of the reduviids studied. These enzymes not only mobilise otherwise intractable nutrients but also reduce the viscosity of the liquified liquids (Edwards, 1961) of *Platymeris rhadamantus* Gaerst. He observed the zootoxic substances both in the anterior and posterior lobes of this reduviid salivary gland. Our recent studied revealed that *R. marginatus* entiere salivary gland enzyme extract showed the presence of amylase, lipase, protease, invertase, trypsin and pepsin. Amylase, lipase, protease, invertase showed maximum activity was Polymorphic diversity of salivary and haemolymph protein and digestive physiology were recorded (Ambrose and Maran, 2000a; Ambrose and Marran, 1999b) have attempted to study the basic biochemical condition and biological activity of *Acanthapis pedestris* Stal, *C. brevipennis* venom. The toxic saliva of the predatory assassin bugs contain a complex mixture of small and large peptide for diverse use such as immobilising and predigesting the prey and defence against competitors and predators (Corzo *et al.*, 2000). They postulated that reduviid venomous saliva as well as the venomous material of other insects has new potential source of peptic material for the study and characterisation of cell receptors, receptor subtypes that could lead to the development of novel agrochemicals and pharmaceuticals.

The major function of the digestive enzymes used in extra-oral digestion is to disintegrate prey tissue before ingestion after which further digestion can take place. Cohen (1998) called this type of digestion as enzymatic tissue maceration and he observed the process in *Z. renardii.* To appreciate the role of macerating enzymes, it is necessary to understand the internal organisation of the prey he added. During feeding, the reduviids not only feed the haemolymph but also the interior contents including the organs (cells, tissues) and their networking macro and micro-molecular complex including proteoglycans, collagens, elastins, etc. The nutrient-rich materials in the prey are packed in a basement membrane that is impermeable to digestive enzyme (Agusti and Cohen, 2000). Now it is very clear that neither trypsin like proteinases nor lipases can attack these substances. The former enzyme (both trypsin and chymotrypsin) is present in the reduviids (Cohen, 1998). He added that hyaluronidase apparently functions as a spreading factor for toxins (Edwards, 1961) by breaking down the ground substance around cells, thus allowing the other venom components to come and attack the substances.

4.5.2 Total protein

The protein content of the *A. pedestris* venom varied from anterior lobe to posterior lobe (Ambrose and Maran, 1999b). Our unpublished results showed that in male *R. marginatus* venom, the total protein contend was 22.9 per cent. It increased in the female (52.84%). Statistical analysis between male and female is significant at the level of 5 per cent. The protein contents of saliva in the anterior and the posterior lobes of *R. fuscipes*, *R. kumarii* and *R. marginatus* revealed that, total protein content was uniformly higher in the anterior lobe than in the posterior lobe, irrespective of their volume Maran (1999). Among these three predators, *R. kumarii* had the highest protein in the anterior lobe (203 80 ± 31.97µg/µl) followed by *R. marginatus* (182.33 ± 15.14 µg/µl) and *R. fuscipes* (166.80 ± 11.81 µg/µl). As observed for the anterior lobe, the posterior lobe of *R. kumarii* also had the highest protein (113.60 ± 10.11 µg/µl) followed by *R. marginatus* (96.80 ± 7.09 µg/µl) and *R. fuscipes* (88.20 ± 8.80 µg/µl) Prey deprivation caused increase in the amount of protein in both the lobes of all of these three predators (Says Maran, 1999). *R. kumarii* showed the highest increase in the protein content followed by *R. marginatus* and *R. fuscipes*. The highest increase of protein content in the posterior lobe as a function of prey deprivation was observed in *R. kumarii* followed in *R. marginatus* and *R. fuscipes*.

4.5.3 Protein profile

Literature about that protein profile of reduviid venom was scanty except the work of Morrison (1989). He analysed the protein profile different parts of *A. pedestris* salivary gland. The study reveals that the protein profile of male and female of *R. marginatus* was varied. Both male and female showed three different molecular weight polypeptides. Among the three molecular weight polypeptide, one protein having the molecular weight of 6.5 KD and it is common in both sexes. Other two polypeptides differ from male to female. Further studies are necessary to conform this profile in future. Our unpublished results of protein profile of male and female *C. brevipennis* varied both in male and female, six different polypeptides were observed in female various it was only two in male venom. Among the six molecular weight polypeptides, two polypeptides that are having the same molecular weight (18 KD and 21 KD) are common in both sexes. Vary in female (33 KD, 30 KD, 25 KD and 23 KD) were observed. Further studies are necessary to confirm this protein profile in future. Total protein content of *C. brevipennis* venom was higher in females (85.17 µg/ml) than the males (26.6 µg/ml) and it was statistically significant at 5 per cent level by DMRT. The densitometric electropherogram indicates that the total number of protein fractions in the principal salivary gland of *R. fuscipes, R kumarii and R. marginatus* were 9,8 and 8, respectively. In *R. fuscipes*, the highest relative area (49.7%) was observed in peak 1 and the lowest (3.10%) in peak 4. *R. kumarii* showed the highest relative area (31.50%) in peak 8 and the lowest (3.60%) in peak 3. *R. marginatus* had the highest relative area of 20.10 per cent in peak 8 and the lowest (5.30%) in peak 4.

4.5.4 Amino acid Profile

Reduviids saliva is mainly used for paralysing its victim. It consists of digestive enzymes. Digestive enzymes are specific for zoophagic that includes proteases, hyaluronidase and phospholipase (Cohen 1998b; 2000). Digestive enzymes of heteroptera include, proteinase, lipase, phospholiphase A1, amylase, pectinase, invertase, hyaluronidase and nuclease (Nuorteva, 1958; Miles, 1972; Cohen, 1998). Enzymes are made up amino acids. Rf values of standard amino acid and also the reduviid venom have been recorded. Our results showed that saliva of *C. brevipennis* consist of seven amino acids such as histidine, glycine, alanine, tyrosine, valine, cystine and leucine. This kind of investigation is a prerequisite for the study of various amino acids present in the salivary enzymes of the reduviids. Previous reports revealed that digestive enzyme was also found in the saliva of *Z. renardii* (Cohen and Brummett unpublished data). Later the similar kind of the Zootoxic effect of reduviid saliva was observed both in the concentrated as well as diluted saliva of anterior and posterior lobes separately in *A. pedestris* (Morrision, 1989; Ambrose and Maran, 1999b) and *C. brevipennis* (Maran and Ambrose, 2000). However, the volume of saliva was higher in posterior lobe (4.16 µml) than in the anterior lobe (2.66 µml). In all the tested reduviids anterior lobe secretion immobilised the test insect (preys) faster than the posterior lobe secretion. For instance, anterior lobe secretions of *A. pedestris* immobilize *Oxfordnitiduala* sp. (Walker) within 69 seconds than the posterior lobe secretion (289 seconds) (Morrision, 1989). Ambrose and Maran (1999b) pointed out that

0 4622 µml/insect and 0.4074 µml/insect are enough to paralyse *Mylabris pustulata* (Thunberg) and *Dysdercus cingulatus* (Fabricious), respectively.

Similar kind of observations was also observed in *C. brevipennis*. Moreover, the study to toxic potential of the reduviid saliva also helps us to evaluate the pest suppression efficacy (Ambrose and Maran, 1999b and 2000; Maran, 1999; Maran and Ambrose, 2000). Cohen (1996) showed that the predators *Nobisalternatus* (Parshley) (Nabidae) and *Sinea confusa* (Caudell) (Reduviidae) lack amylase activity in their salivar glands; another, however it was reported in *Zelus reardii*. Recently Maran and Ambrose (2000) concluded that the venom of reduviid predator possess neurotoxins, which represents a chemical adaptation of these bugs to paralyse their prey by altering the structure and functions of the nervous system of the prey.

4.6 Venom Autothonous Bacteria

A total of 80 different bacterial isolates taken for study. The identification was done as per *Bergey's Manual of Systematic Bacteriology*. Our results showed that the entire total isolates were Gram-negative bacteria were *Pseudomonas aeruginosa* dominated the other bacterium. It is very interesting that the pure saliva of *C. brevipennis* consist of *Pseudomonas aeruginosa* (83%) and *Klebsiella* sp. (17%).

4.7 Pharmaceutical Use

Totally 18 different isolates have been considered for the study. The identification was done as per Bergey's manual. All the total isolates were gram-negative bacteria were *Pseudomonas aeruginosa* dominated the other bacterium. It is very interesting that the pure saliva of *R. marginatus* consists of *Pseudomonas aeruginosa* (83%) and *Escherichia coli* (17%). The table 4.3 clearly shows the antibacterial activity of salivary glands of adult *R. marginatus* venom against ten bacterial pathogens. The higher activity index (AI) was observed on *E. coli* (56.47%). Venom from the endoparasitic wasp *Pimpla hydrochandriaca* (Hymenoptera: Ichneumonidae) showed antibacterial activity against the gram-negative *E. coli*. It is generally associated with urinary tract infection, septicemia and diarrhoea in human beings. The venom of *R. marginatus*, the activity index formed to be 50 per cent, also inhibited the gram-positive bacteria *Streptococcus pyogens* growth. *Stropto-coccus pyogens* associated with post-operative wound infection, *Septicemia rheumatic* fever and Glomerulo nephritis. From the results it is very clear that *R. marginatus* venom has broad-spectrum antibacterial activity. The

Table 4.3. Zone of inhibition (IZ) (in mm) and activity index (AI) of *Rhynocoris marginatus* and *Catamirus brevipennis* venom on selected human pathogens.

Microorganisms used	Standard	*Rhynocoris marginatus*		*Catamirus brevipennis*	
		IZ	AI	IZ	AI
Escherichia coli	17	9.6	0.56	5.5	0.32
Proteus mirabilis	21	-	0.00	10.9	0.52
Pseudomonas aeruginosa	17	7.5	0.44	4.08	0.24
Bacillus subtilis	17	-	0.00	4.25	0.25
Klebsiella pneumoniae	21	-	0.00	4.41	0.21
Proteus vulgaris	22	8.0	0.36	10.86	0.49
Enterobactor aerogenus	18	-	0.00	5.94	0.33
Staphylococcus aureus	18	-	0.00	3.85	0.21
Bacillus sphaericus	17	-	0.00	3.97	0.23
Streptococcus pyogenes	17	8.5	0.50	-	0.00
Salmonella typhimurim	23	7.5	0.33	4.18	0.18

-Indicates activity not observed, IZ–Inhibition zone, and AI–Activity index
Source: Sahayaraj *et al.* (2006)

remaining gram-negative bacteria like *Pseudomonas aeruginosa, Salmonella typhi* and *Proteus vulgarius* were slightly susceptible. *Bacillus spharius, Cellulomonare* sp , *Staphylococcus aureus, Proteus mirabilis* and *Klepsiella pneumoniae* were inert against the venom of *R. marginatus*. *R. marginatus* venom is composed of many protein and the proportion of the proteins and their responsibility for the antibacterial activity is not known at present Corso *et al.* (2001) reported that reduviids are having shortest peptides, like Ptul in their saliva. To the best of our knowledge, this is the first report documenting the presence of antibacterial activity of venom from hunter reduviid bug *R. marginatus*. Predatory reduviid like *R. marginatus* may transfer pathogen to the host through their venom, during feeding. Therefore, it is possible that antibacterial factor, present in the venom may help guard against the pathogens entering the host in the feeding, channel created by the rostrum. In future the protein bioactive components responsible for antibacterial activity will be identified and recommended as therapeutic agents.

4.8 Conclusion

Though enormous amount works on bionomics, biological control potential of reduviids were available in the literature, only few data are available about the zoophagy of reduviids Reduviid venom is a neuro-toxin; it plays an important role in the prey paralytic activity as well as it determines the predatory potential of a reduviid. The morphology, anatomy is varied in different species of reduviids. Venom quantity is related to the size and sex of the reduviid. Furthermore, starvation will enhance the venom quantity. Paralytic activity depends upon the prey and its activity. The above-mentioned data reveal that it is important fields of research that can be strengthen in the near feature.

4.9 Recommendations

1. Paralytic potential of the most of the possible hunter reduviids venom will be undertaken to know the viable reduviid.
2 Venom protein profile and also the novel polypeptide can be determined.
3. Incorporate the novel polypeptide in pest management programme, and
4. Use the novel peptide isolated from the hunter reduviid venom in transgenic crop could be undertaken.

5

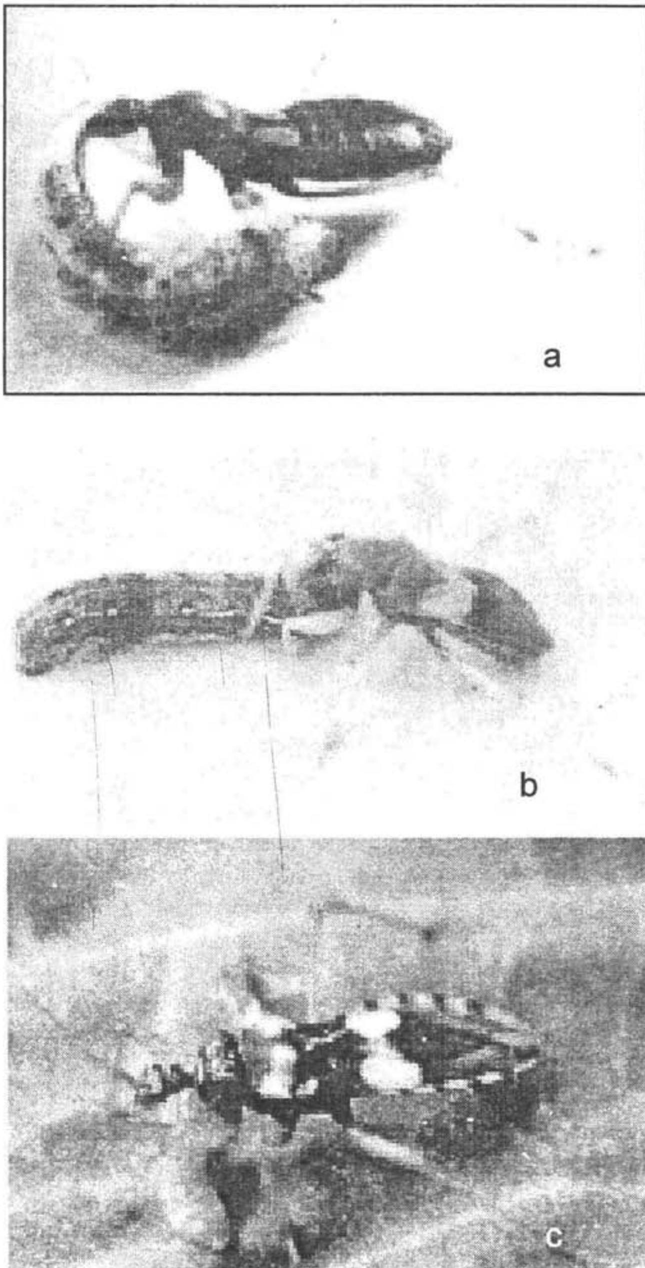
Biological Control Potential

5.1 Introduction

Work on chemical control of phytophagous arthropods has generally been involved in the measurement of pesticide-induced effects on specific target pests reared on key plants. Biological control has been basically studied as an interaction between specific predators and their prey. Many heteropteran predators play an important role in the pest control programme. Of this, reduviids are one of the least researched and most poorly understood families. Before utilising a natural enemy as biological control agent against a particular pest, it is necessary to assess its ability under laboratory conditions (Plate 2). Then it can be assessed under field cage situation and then released into the fields. Field-testing is an important step in evaluating the use of natural enemies as augmented biological control agents.

5.2 Laboratory Evaluation

Both functional and numerical responses are considering as important processes in population interactions. The effectiveness of the biological control agent depends on the number of prey killed or consumed. Hence, many people have discussed the biological control efficacy of reduviids by using these tools.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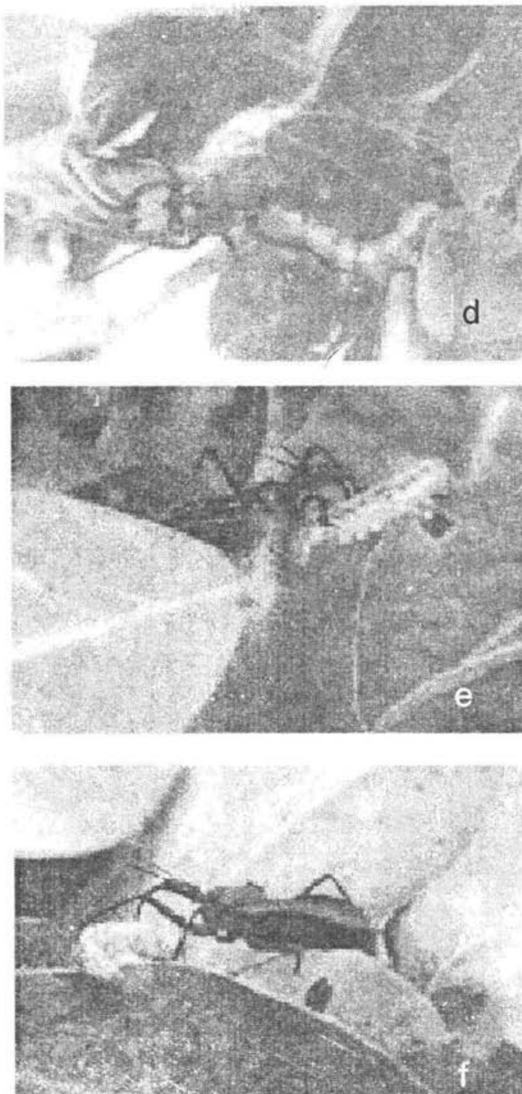


Plate 2. Pest complex of of reduviids. E.tibialis micropterus (a) and alate adult(b), A.quinnquespinosa (c), C.brivipennis (d), R.fuscipes (e) and R.marginatus (f) feeding on Pectinophora gossypiella (c), Helicoverpa armigera (a,d,e&f) and Spodoptera litura (b).

5.2.1 Functional response

Predatory rate of reduviids under laboratory was evaluauve in simple predation arena. The arenas were disposable and/or non-disposable plastic vials or petridishes. They were either covered with muslin cloths or lids having air holes. The predators were placed individually into predation arena, allow them for acclimatisation and then particular prey was released and the prey consumption was observed after a particular period. The feeding rate of an individual predator as a function of prey density is termed as functional response (Solomon, 1949). The response of a predator to prey density can be divided into two types:

(i) the functional response which is related to the number of prey killed by the predator to the prey density, and
(ii) the numerical response which is a change in the prey killed in response to predator density.

The first part of this chapter deals with both the responses.

Several factors have been shown to affect their response curves. They include predator age and sex, prey stage, predation arena and prey and/or predator exposure time. The various parameters followed in the 'disc' equation to describe the functional response of predators at different prey densities are listed below:

X—Prey density
Y—Total number of prey killed in a given predator of given time (Tt)
X/Y—The attack ratio
T—Total time in days when the prey was exposed to the predator
b—Time taken for handling each prey by a predator
a—Rate of discovery per unit of searching time
Ts—Days all searching
Y'—Predicted prey attack ratio
K—Maximum X, and
K/Tt—Maximum number of prey killed during the given period.

Acanthaspis pedestris is a reduviid predominantly found in the semi-arid zones, scrub jungles and on the foothills of forests and their bordering agro-ecosystems. It responded to the increasing prey density by killing higher number of prey than it killed at lower *Pectinophora gossypiella* densities (Ambrose and Sahayaraj, 1996) and exhibiting type II of Holling's (1959) convex curve which is typically density dependent function. The rate of attack was lower at maximum prey density because less time is required to find each prey and more time is spent in non-searching activities at high prey densities. In general, the number of prey killed or consumed (Y) in a given time (Tt) was not significantly from the numbers calculated (Y') on the basis of Holling's 'disc' equation. *Acanthaspis pedestris* Stal is a reduviid predator predominantly found in semi-arid zones and scrub jungles bordering agro-ecosystems of Tamil Nadu, India. Females consumed more number of *Pectinophora gossypiella* (26.45 prey/10days) than the males (23.1 preys/10days). This might be due to the higher nutritional requirement of the females for reproduction. Moreover, it is probably true because the fecundity of a female predator is limited largely by the number and the amount of preys (food) that she can locate and consume. Previously it was reported in one-day observation that both male (3.4 preys/predator/day) and female (3.8 preys/predator/day) *Acanthaspis pedestris* consumed similar number of *Pectinophora gossypiella* (Sahayaraj and Ambrose, 1994c), but the predatory rate was very higher because when we expose the predator to the particular prey continuously, the predator won't consume the prey every day and hence the predatory rate was low in the previous observation It not only feeds on the lepidopteran prey but also isopteran pests like *Odontotermes assumthi.* Very little information was available on the use of natural enemies to control *Odentotermes* spp. Sahayaraj (1995c) studied the biological control potential of this predator on *Odontotermes assumthi* under laboratory conditions. He reported that life stages of this reduviid could consume considerable number of *Odontotermes assumthi.* For instance, *Acanthaspis pedestris* during its nymphal life time consumed 28.77 termites. Its biological control potential was studied on another cotton pest *Earia insulana* (Sahayaraj and Ambrose, 1994). According to them, biological control potential depends upon the prey density, predator sex, prey type and size. If we provide the prey in six densities (1, 2, 3, 4, 5, and 6 preys/predator), and also in two size groups (0.78 mm and 1.32 mm), irrespective of the prey size *Acanthaspis pedestris* consumed maximum number of prey from the higher prey density than the lower density. Along with the *Earia insulana*, they also evaluated the biological control potential on *Oxycarenus hyalinipennis* another pest of cotton in Tamil Nadu. *Acanthapis pedestris* consumed maximum number of female preys

(8.4 preys/day) than the male pest (7.9 preys/day/predator). In 1996 Ambrose and Sahayaraj studied the functional response of this hunter reduviid on *Pectinophora gossypiella.* Male and female *Acanthapis pedestris* responded to the increasing prey density and at the maximum of 13.4 and 14.5 *Pectinophora gossypiella* respectively during five days observation.

A. siva also consumed maximum number of grasshopper *Dittopternis venusta* Walker at higher prey density (11.4 and 8.8 for female and male, respectively) followed by eight, four, two and one prey level (Ambrose *et al.*, 1994b).

In ***Neohaematorrhophus therasii,*** the daily consumption was higher in the IV instar (11.0 and 10.1 for *Dysdercus cingulatus* second instar and *Oxyçarenus hyalinipennis* adults respectively) and increased in the fifth instars (10.1 and 8.0 for *D. cingulatus* and *Oxycarenus hyalinipennis* respectively). Both the nymphal instars did not consume *H. armigera* [II instars] during the nymphal instars. It is a general trend in reduviids that females consumed more number of preys than the males. Same trend was also observed in this reduviid on *H. armigera* (0.33 and 0.43 for male and female, respectively), *Dysdercus cingulatus* (10.33 and 13.16 for male and female, respectively), and *Oxycarenus hyalinipennis* (9.3 and 10.38 for male and female, respectively) (Sahayaraj and Ambrose, 1996a). Later Sahayaraj and Ambrose (1996b) reported that IV instar consumed more number of first instar *Dysdercus cingulatus* (11.0 preys/day) followed by V instar (10.3 preys/day).

Ectomocoris tibialis fifth instars, male and female were provided with IV instar *Dysdercus cingulatus* at six densities (1, 2, 4, 8, 16 and 32). They consumed only 6.5, 4.2 and 5.6 *Dysdercus cingulatus* during the experimental period (Sahayaraj and Ambrose, 1996c). The biological control potential was not changed if the same stages of *Ectomocoris tibialis* were provided with fifth instar *Dysdercus cingulatus* (Sahayaraj, 1995d).

The biological control potential of ***Ponoctonus lutescens*** was studied by Stride (1956b) on *D. voelkeri* and *Odontopus sexpunctalis.* Both male and female consumed more number of female *D. voelkeri* (2.6 and 1.0 for male and female, respectively) than *Odontopus sexpunctalis* (2.6 and 5.3 for male and female, respectively). This trend was changed when *Odontopus sexpunctalis* was provided to male (5.0 and 3.0 for male and female, respectively) and female *Ponoctonus lutescens* (7 0 and 6.6 for male and female, respectively).

The tobacco caterpillar, *Spodoptera litura* is a serious and important polyphagous pest, having a wide host range of 112 species of plants belonging to 44 families (Chari and Patel, 1983). The larvae feed on leaves, flowers, flower buds, fruits, and pods of the crops. In nature these caterpillars are eaten by a number of natural enemies including reduviid like ***Rhynocoris marginatus***. Prey age has an important role in the predatory potential of reduviids. The functional response of ten days old male and female *R. marginatus* to *D cingulatus* was studied by Ambrose and Kumaraswami (1990). They also observed type II functional response curve in this reduviid. The male and the female *Rhynocoris marginatus* consumed 1.7 and 1.9 preys/predator, respectively at two-prey density but consumed more number of bugs (13.16 and 20.0 preys/predator, respectively) at the density of 32 red cotton bugs during the 24 hours observation. Sahayaraj (1994b) reported that *Rhynocoris marginatus* consumed maximum number of *Spodoptera litura* when it was 3 days old (3.50/day) followed by four days (3.20/day) and five days old (3.12/day). However, they were not statistically significant ($P < 0.05$). It is a good biological control agent preying on all stages of *Spodoptera litura* (Sahayaraj, 1994b and 1994c) and *Helicoverpa armigera* (Sahayaraj 1995a) under laboratory condition *Rhynocoris marginatus* first, second, third, fourth and fifth nymphal instar consumed both the third (5.39, 5.03, 2.78, 2.09, and 1 82 larvae/stadium for first, second, third, fourth and fifth instars respectively) and fourth (0.69, 2.13, 3.32, 4.86 and 6.86 larvae/stadium for first, second, third, fourth and fifth instars respectively) instar *Spodoptera litura* (Sahayaraj, 1995a). Similarly, this predator also consumed maximum number of *H. armigera* during the first stadium and it gradually declined when the predator grew older, when it was at one prey (3 0, 3.0, 2.71, 2.0, and 1.86 for first, second, third, fourth and fifth instars respectively) or two prey (5.92, 4.00, 3 75, 3.50, and 2.83 for first, second, third, fourth and fifth instars respectively) density (Sahayaraj, 1995b).

Predator response to prey also varied from the same prey reared on different hosts. *Spodoptera litura* reared on castor, sword bean and cotton and provided to the V instar *Rhynocoris marginatus* (Maran *et al.*, 2002). The results showed that *Rhynocoris marginatus* consumed 14.4, 13.0 and 10.4 preys/predator /day at 16 preys density when it was reared on castor, sword bean and cotton, respectively Furthermore, they suggested that cotton plants possess a lot of phenol compounds and hence *Spodoptera litura* grown very slowly and it moved little slowly. Whereas the prey reared on castor and sword bean grow well and also showed active movement. Since the compounds synthesised from the host plant is incorporates into the body odour of herbivores and this body odour is used as searching cue by enemies (Price, 1984). It also suppresses the pigeonpea pests like *Clavigrralla gibbosa* Spinola (Hemiptera: Coreidae) and *Hieroglyphus banian* (Fab.) (Orthoptera: Acaridae) (Claver and Ambrose, 2003). During the four days observation, *R. marginatus* consumed more or less the same number of *C. gibbosa* at 16-preys density (6.44 preys/predator) and *H. banian* (6.85 preys/predator). When the adults were provided with groundnut pests like *A. albistrigia, A. modicella, H. armigera* and *Spodoptera. litura* at 1, 2, 4, 8, 16 and 32 preys densities, it preferred to feed *A.modicella* (18.37) followed by *H.armigera* (16.93), *S.litura* (16.12) and *A.albistrigia* (4.06) at 32 preys densities (Sahayaraj, 2000). The handling time was also minimum (0.015 days) and maximum (0.029 days) for the preferred and the non-preferred pests respectively. Biological control potential of *R. kumarii* on *D cingulatus, E. mollifera* and *M. pustulata* were studied by Kumaraswami (1991) and Ambrose and Kumaraswami (1990) under laboratory condition. The predator also showed type II functional response curve.

Rhynocoris fuscipes fourth, fifth nymphal instars and adults (both male and female) responded to increasing *Spodoptera litura* density from one to four. Maximum predation was observed in the fifth instar (1.85 prey/day) followed by adults (1.74 prey/day) and fourth nymphal instar (1.71 prey/predator) (Ambrose and Claver. 1997). Previously Ambrose and Claver (1995b) also observed the similar trend when provided with *Riptortus clavatus* Thunberg (Heteroptera: Alydidae) as prey. Though differences were observed among the life stages, they were statistically significant. When *R. fuscipes* was provided with *H. armigera, E. subnotata* and *E. atomosa*, such a kind of difference was not observed. For instance, *R. fuscipes* consumed 7.2 *H. armigera*, 7.0 *E. subnotata* and 7.4 *E. atomosa*/day (Claver and Ambrose, 2002).

Sycanus indagator (Stal) was imported from India to Carolina, USA in 1974. Bass and Shepard (1974) evaluated its biocontrol efficacy under laboratory condition. According to them *Sycanus indagator* gained significantly more weight after feeding for 14 hrs ($P < 0.05$) than for 3 hrs (0.073 mg). The nymphs consumed more number of *G. mellonella* (0.95, 1.50 and 1.50 and 0.75, 1.25, and 0.90 at 1, 2, and 3 prey in nymphs and adults, respectively) than adults. An opposite trend was observed when it was provided with *Spodoptera frugiperda* (0.40, 0.35 and 0.60 and 0.60 and 0.60, 0.75 and 1.70 for nymphs and adults in 1, 2, and 3 prey densities). *S. reclinatus* consumed more number of *E. vitella* (4.0) followed by *E. vitella, Spodoptera litura* (3.0), *Helicoverpa armigera* (2.8), and *D.cingultus* (1.5) (Vennison and Ambrose, 1992). According to Ables (1978), *Z.renardii* also responds positively in relation to the preys offerred.

McMahan (1983a) studied the bioefficacy and preference of ***Salyavata variegata*** Amyot and Serville, on different castes of *Nasutitermes corniger* (Motschulsky). The study revealed *Salyavata variegata* maximum preys (66.7) during its third instar followed by adults (60.0). *Alleocranum biannulipes* (Montr.et.Singh) varied its predatory potential when the size of the prey differs (Awadallah *et al.*, 1984). He studied the predatory potential of *A. biannulipes* with three preys such as *C. cephalonica, Tribolium confusum* and *Anagaste kuehniella* under four densities (3, 6, 9 and 12). Negative response was observed towards the increase of the initial density of the predators up to 9 pairs/vial on *A. kuehniella*. However, in association with the other two preys, a reverse trend took place. Flower *et al.*, (1987) also studied the functional response of three peiratinae reduviids such as, *Rasahus hamatus* (Fab.), *Sirthenea carinata* (Fab.) and *Sirthenea* sp. on *Scapteriscus* spp. and *H. armigera*. Recently, Grundy and Maelzer (2000) studied the bioefficacy of *Pristhesancus plagipennis* (Walker) on *H. armigera* and *Nezra viridula*. First instars consumed minimum number of preys and the prey consumption was increased when the predator grew older. For instance first, second, third, fourth and fifth nymphal instars of *P. plagipennis* consumed 7.2, 13.2, 28.2, 54.2 and 117.1 first instar *H. armigera* and 5.8, 10.2, 24.4, 49.2, and 94.8 second instar *N.virudula*, respectively. The prey consumption was decreased when the age of the prey increased from I to IV instar (219.9, 161.9, 57.5 and 35.6 preys) of *H. armigera* and II to IV instars of *N. virudula* (184.4, 93.4 and 48.8). They further reported that *P. plagipennis* life stages cumulatively consumed more number of *H. armigera* (219.9, 161.9, 57.5 and 35.6 for first, second, third, fourth and fifth instar larvae, respectively) than the *N. viridula* (184.4, 93.4 and 48.8 for first, second, and third instar, respectively) and these pests possibly reducing population below economic thresholds.

In observations mentioned above, the number of prey killed or consumed (Y) in a given time (Tt) did not differ significantly from the numbers calculated (Y') on the basis of holling 'disc' equation. If any deviation occurs in any reduviid to any prey, it is only neglected value. The relationship between observed and predicted values are analysed by regression, was not significant from 1.00 (r value is ranging from 0.88 to 1.0). The attack rate (Y/X) decreased with the increase of prey density level in nymphal instars and also in adults (both male and female) of reduviids with few exceptions. In general the number of prey killed (Y) by the individual predator increased as the prey density (X) was increased from minimum prey/predator to maximum prey/predator. This was further confirmed by the positive correlation obtained between the prey density and prey killed (r = 0.80 to 1.0). Almost in the entire reduviids, type II functional response curve was observed.

Morris (1963) reported that such type II functional response is typical type for most of the heteropteran predators. 'K' value is higher in female predator and also in higher prey densities. The time taken by the predator to feed the captured prey is estimated as 'b' value or feeding time. Observations of different scientists in different reduviids indicate that all the reduviids modify the extent to which they feed on successive prey under different prey densities, age and sex. They also spent less time for feeding on prey at higher prey densities. Such a kind of feeding behaviour is an adaptive value because the energy return is probably highest in the first phase of feeding on a prey and it is most economical to move to another prey at high prey densities after that phase is over and the marginal costs begin to increase. The value of 'b' was assumed to be constant for all prey density. However, female predator took lesser time to handle the prey than the males. Similarly if the prey is smaller in size then the predator took lesser time. The handling time also decreased when the exposure time increased and also from the nymphal instars to the adult reduviids. The response of the adults on longer exposure was somewhat different from that on one day suggesting that the predatory act of hunter reduviids changes with age and the energy demands. Males spend their energy during mating whereas the females spend by egg production. In another parameter 'a', the rate of discovery was also estimated and it decreased with the increase of prey density level. The 'a' value was higher in males than in the females. Furthermore, the discovering ability was lesser for larger preys than for smaller preys. In general the searching time (Ts) was longer in one prey level and gradually diminished when the prey density increased. Probability of the predator's contact with the prey at higher prey density would have enhanced the searching ability per unit area. It is a general observation in reduviids that if the searching time (Ts) increases automatically the handling time (b) decreases. Nymphal instars took more time to search a prey than adults. Contrasting observation was observed in *N. therasil* adults when provided with first instar *Dysdercus cingulatus* (Sahayaraj, 1991). Among the adults, the females searched the prey quickly than the males. Irrespective of the reduviid stage and sex, the resting time was significantly lower at higher prey density and gradually increased at lower prey density. Furthermore, the resting time was higher in the early nymphal instars than in the adults.

5.2.2 Numerical response

Though many laboratory and field observations were available for functional response, very few studies are available for the numerical response. Kumar (1993) studied the numerical response of *Rhynocoris longifrons* life stages at 1, 2, 4 and 8 densities on *C. compressus*. The completion of the predator decreases with the duration of the predatory act. He concluded that predators without competitors pierced lesser number of sucking sites. The number of sucking sites increased as the number of competitors increased. It was also studied in *S. lorrida* and *I. armipas* life stages on *H. armigera* (9 - 11mm) (Das, 1996). According to him competition decreased the capturing, paralysing and sucking time of these reduviids. Numerical response was studied in *R. fuscipes*, *R. kumarii* and *R. marginatus* (Claver, 1998). They revealed that all the studies on reduviids had a positive numerical response by killing more number of preys in terms of available prey population per predator at a given time. For instance, *R. kumarii* killed 0.23, and 0.88 *M. indica* at one and eight predator densities. The study also indicated that the predatory rate also gradually decreased form 24 hr observation to 96 hr observation (0.84 to 0.48 for 24 and 96 hrs, respectively at 4 predator density). The searching time decreases with the increasing prey density. However, the rate of discovery and attack rate are increased while the predator density increased.

5.3 Field cage/pot evaluation

Laboratory research findings suggest that all the assassin bugs tested were capable of suppressing the increasing pests population and could be employed as biological control agents for suppressing the pest's population. The augmentation of natural enemies for biological control of agricultural pests has long been considered a viable strategy in the field. With the pre-requisite, it is essential to evaluate under controlled field cage before introducing them into the field situation. These kinds of studies were carried out in cotton, potato, soybean, pigeon pea, lady's finger and groundnut.

5.3.1 Cotton

Cotton ecosystem has variety of natural enemies like, Pentatomids, Reduviids, Anthacorids, Spiders, Ants and Coleopterans. Each varying in importance at different times is based upon its specificity. However, even a single well-adapted species like assassin bug is capable of reducing even the well established pest population like red cotton bug (Sahayaraj, 2003). This is clearly indicated by the success that has been achieved by the introduction and the establishment of a wide range of the reduviids for the control of red cotton bug. The investigation on biological control potential of reduviids in the field cage shows that during 14 days observation, both the tibialorate assassin bugs, *Ectomocoris tibialis* Distant (Sahayaraj and Ambrose, 1997c) and *Catamiarus brevipennis* (Sahayaraj, 1991) and non-tibialorate reduviid, *Rhynocoris kumarii* and *R. marginatus* (Kumaraswami, 1991 and Claver and Ambrose, 2001b and 2001c) suppressed more than 50 per cent of both the fifth instar nymphs and adults of red cotton bug. Sahayaraj and Ambrose (1997c) reported that *E. tibialis* suppressed 84 and 80 per cent of nymphs and adults of *D. cingulatus* respectively. They suggested that in the field situation *E. tibialis* adults preferred nymphs than the adults. In contrast, laboratory observations showed that *E. tibialis* adults preferred *D. cingulatus* adults (66.66%) than fifth instar (8.33%) nymphs (Sahayaraj, 1991). Between the tibial pad and non–tibial pad reduviid group of assassin bugs, the former group reduced more number of *Dysdercus cingulatus* than the non–tibial pad reduviids. Adults of *Rhynocoris kumarii* significantly suppressed the *H. armigera* population (49%) during the initial infestation. However, it will cause similar suppression on *S. litura* and *Euproctis mollifera* (Claver and Ambrose, 2001b and 2001c). They further reported that the release of *R. kumarii* in both *Spodoptera litura* and *Euproctis mollifera* infested fields did not significantly increase the cotton yield. So it shows that reduviids play a significant role in the ecological balance and they could be used for the biological control programme on red cotton bug, they added. Recently Ambrose and Claver (1999b) released *R. marginatus* in cotton field cage infected with *Spodoptera litura, M. pustulata* and *D. cingulatus* separately. They recorded that *R. marginatus* greatly reduced the infestation of *Spodoptera litura* (57.5%), followed *M. pustulata* (52.3%) and *D. cingulatus* (45.8%). Further they added that seed-cotton yield loss was higher in *Spodoptera litura* released field (148) followed by *D. cingulatus* (99) and *M. pustulata* (51). According to Ravichandran *et al.* (2003) *R.longifrons* controlled the *H.armigera* in the potted cotton plants. The prey attack was increased from one prey (1.00) to eight preys density (4.30) and it gives type II functional response curve.

In Australia, Grundy and Maelzer (2000) assessed the impact of *P.plagipennis* in cotton against *Helicoverpa* spp. In cotton field cage *P. plagipennis* was released at the rate of 3, 6 and 12 predators/ row. The results revealed that the potential was higher in the latter two densities than the former density during the first week of the reduviid release. Similar trend was also observed during the second release of this reduviid. The boll production was higher in the reduviid-released fields than the control (63.4). However, no significant change was observed among the various densities of the predators released. They concluded that *P. plagipennis* nymphs have the capacity to locate and capture insect prey within the crop canopy. Maran *et al.* (2002) argued that *Spodoptera litura* from cotton field was suppressed by *R. marginatus* fifth nymphal instars more vulnerably (2.0, 3.6, 3.8, 4.4, 10.4 preys/predator for 2, 4, 6, 8 and 16 preys density, respectively) than *Helicoverpa armigera.*

5.3.2 Groundnut

As we have seen in other reduviids, the predatory rate of *R. kumarii* was increased from fourth instar (1.33 preys/day) to fifth instar (1.66 preys/day) and adults (1.83 preys/day) on *Spodoptera litura.* Similar trend was also observed on *Helicoverpa armigera* (1.16, 1.33, and 1.50 preys/day for fourth, fifth nymphal instars and adult respectively) in groundnut grown in pots Life stages of *R marginatus* were released into groundnut separately and evaluated their biological control potential on *A. craccivora* nymphs at 1, 2, 4 and 8 densities. It is clear from the results that the nymphal instars of *R. marginatus* move through the groundnut vegetation in search of their prey and finally find out the clusters of *A. craccivora* easily than the prey present in solitary conditions (Figure 5.1). Once it has learned, the predator easily determines the possible routes to find the aphid. *R. marginatus* nymphs consumed more number of aphids than the adults. Among the nymphal stages second instar is the active stage to predate upon aphids than the other stages. As observed in the laboratory observations the predatory rate is also increased when the prey number increased. And hence the nymphal instars especially the second instar can be utilised in the aphids management in groundnut.

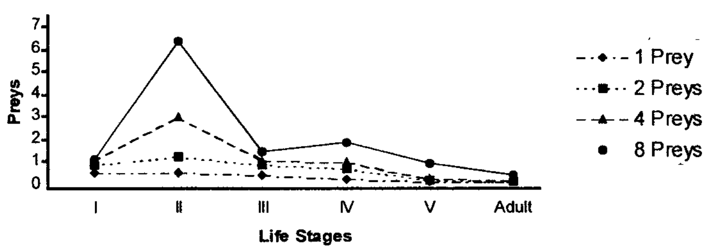


Fig. 5.1. Predatory rate of different life stages of Rhynocoris marginatus on A. craccivora

Very recently Ravi (2004) conducted pot studies and it revealed that at low prey density (one-prey), prey consumption given a uniform prey distribution was higher than that for contagious prey distribution ($P < 0.05$), but no similar prey consumption rates were observed at high prey density for the two prey spatial patterns ($P < 0.05$). *R. longifrons* preferred both *S. litura* and *Helicoverpa armigera* and maximum consumption of 1.66 preys/predator/day for both pests. However, the maximum weight gain was observed in the adult that fed *S lituna* (54 94 ± 5.00 mg). *R. kumarii* adults consumed more *Spodoptera litura* (1.83) than *Helicoverpa armigera* (1.66) but not statistically significant at 5 per cent level. The nymphal instars and the adult predators preferred *S. litura* slightly better than *H. armigera*. As observed in *R. longifrons*, in *R. kumarii* also the maximum weight gain was achieved by the adult fed on *Spodoptera litura* (62.13 ± 3.81 mg). The life stages (fourth, fifth instars and adult) consumed 1.32, 1.5 and 1.83 *Spodoptera litura* and 1.16, 1.32 and 1.66 *Helicoverpa armigera* respectively when two-prey was provided.

5.3.3 Lady's finger

Micro plots of 5" and 6" were demarcated and lady's finger plants were raised in five rows with the interval of 1.2 feet between and each in five row plants with one feet interval. The plots were covered with nylon mesh cage (29 meshes in 1 sq.cm). At the time of fruiting stage third instar larvae of *H. armigera* was introduced and allowed to acclimatize for one day. Next day ten adult *A, pedestris* were released into the field separately. Control plots were devoid of reduviid predators. Observations were made every day. The experiments were made of 10 days. A maximum and minimum predation of 0.062 and 0.013 *H. armigera* larvae per animal per day were recorded on the sixth and fifth day, respectively. On an average a total predation of 0.0064 prey/predator/day was obtained when recovery was made on the tenth day after the reduviid release. Totally all the 10 predators reduced 64.0 per cent *H. armigera*. Only 15 fruits were damaged out of the 44 fruits present in the predator released cage (34.09%). But in the control cages, the damage was too high (90.0%). The difference in fruit damage (66.91%) between the control and the experimental field cages showed the effective biological control potential of *A. pedestris* on *H. armigera* (Sahayaraj and Ambrose, 1997c). Although the results clearly establish the biological control potential of hunter reduviids in the field cage release programme, augmentative release and subsequent monitoring on their synchronisation are required.

5.3.4 Potato

Aphids are cosmopolitan pests of potato and also the vectors of viral diseases. In India one of the important aphid pests in potato is *Myzus persicae* Sulzer. Four species of hunter bugs such as *Coranus* sp., *Aplus mussooriensis*, *Henricohania* sp , and *Sphendanolestes variabilis* were found to predate on this aphid in Simla (reported by Trivedi and Rajagopal, 1988 - Saxena and Singh 1976, Saxena *et al.*, 1980).

5.3.5 Pigeon pea

Pigeon pea, *Cajanus cajan* (Linn.) Millspaugh is an important cash crop grown in many parts of the world. Many natural enemies have been reported in this crop. Minja *et al.* (1999) reported predation of insect pests of pigeon pea by the assassin bugs. Within pigeon pea filed, the relative mix of predaceous reduviids varied with locality and season. One of the most important reduviid predators present in the pigeon pea is *R. fusicpes* (Bhatnagar *et al.*, 1983 and Ambrose and Claver, 1995b). Its biological control potential was evaluated in pots under laboratory condition on three pigeon pea pests such as pod borer, *H. armigera*, tussock defoliator *Euproctis subnotata* Walker and plume moth, *Exelastis atomosa* (Walsingham). *R. fusicpes* consumed 7.2 *H. armigera,* 7.0 *E. subnotata* and 7.4 *E. atomosa* during a day observation Hence, further field studies in larger areas and in different conditions are required before recommending these predators as biological control agents.

5.4 Field evaluation

There are several examples that illustrate the importance of predators in natural communities. Impact studies of indigenous predators on various agricultural pests have been largely based on observed correlations between abundance of predators and population changes of the prey. Goel (1978) collected *T. indica* (121 and 158 during 1975 and 1974, respectively) from rice and other ecosystems. The occurrence of reduviid *R. marginatus* was very low when compared to spider *Lycosa tista* (Sahayaraj and Paulraj, 2003). However, hunter reduviids are distributed in most of the agricultural ecosystems (see chapter 1, refer table 1.1). If the natural enemies are not available in the particular density, then release is essential to check the pest population. Based upon this view chosen hunter reduviids were released into the fields and evaluated their impacts on pest population and crop production.

5.4.1 Cotton

Claver and Ambrose (2001c) released *R. kumarii* at Dhalapathisamudram village, Tirunelveli district, Tamil Nadu, India. One hundred adults, 20 batches of eggs (56.72 eggs/batch), 200 third instar nymph and 100 fifth instars of *R. kumarii* were released in to the cotton field (var. LRA 5) and evaluated its impact on D. cingulatus infestation and also the population. The results revealed that the reduviid reduced *D. cingulatus* population (5.77%) and its defoliation (26.9, 7.10, 8.90, 22.80, 37.21 and 23.57% during the first, second, third, fourth, fifth and sixth sampling time respectively).

5.4.2 Groundnut (Peanut)

Groundnut (*Arachis hypogea* Linn.) (Peanut) is a major oilseed crop in many parts of the world particularly in the semiarid tropics. The major constraint in groundnut production is damage caused by insect pests. In developing countries like India, the average yield is 945 Kg h^{-1} compared with 2500 to 4000 Kg h^{-1} obtained in the developed countries (Dharne and Patel, 2000). Until 1968, there were only four major insect pests like aphids, groundnut leaf miner, red hairy caterpillars and termites (Rai, 1976). Since then, the number of pests affecting groundnut has increased to 125. First time Sahayaraj (1999a) introduced the reduviids in groundnut IPM. He released *R.marginatus* life stages (egg to fifth nymphal instars) at 5000 bugs/ ha at 15 days interval for three times at Trichy district, Tamil Nadu, India. *R. marginatus* life stages highly reduced both *H. armigera* and *S. litura* populations and also enhanced 845 Kg groundnut productions in a hectare land. Later he conducted the same experiment in another area in the same district (Anonymous, 1998). He observed only *A. modicella* in the field during the study time. *R. marginatus* enhanced groundnut production (643 Kg/ha) in nominal level and this reduviid reduced only 12.67 per cent *A.modicella* population. Similar kind of experiment was conducted in Tirunelveli and Thoothukudi districts, Tamil Nadu, India. All the studies indicated that *R. marginatus* has the capability to reduce most of the groundnut pests and increase the production. Unpublished data (Sahayaraj and Ravi) shows that *R. kumarii* also plays an important role in reducing groundnut pests and their infestations and groundnut production. The predator was released in Sakkamalpuram, Thoothukudi district @ 5000 ha. After the first, second and third release *S.litura* (50, 25, and 33%), *H.armigera* (40, 42.8 and 56.25%), *A. craccivora* (16.66, 14.28 and 16.66%), and grasshoppers such as, *Chrotogonus trachypterus* (33.33, 20 and 40%) and *Atractomorpha crenulatata* (25, 40, 25%) were controlled The pod yield was also increased from control (1369 Kg/h) to *R. kumarii* released field (2155 Kg/h). The study also clearly indicates that this reduviid does not affect other natural enemies like *Menochiles sexmaculatus*, *Lycosa tista* and *Oecdsius putus* present in the field. It proved that irrespective of the pest incidence, reduviids have the capability to reduce the pests and their incidence and also enhanced the groundnut production. Recent studies by Sahayaraj and Martin (2003) revealed that *R.marginatus* could be used augmented biological control agent for groundnut. Because they not only suppress the lepidopteran pests populations and their infestations, but also the pests from other orders like Hemiptera (*Aphis craccivora*), Coleoptera (*Mylabris pustulata* and *M.indica*) and Orthopetera (*Atractomorpha crenulata* and *Chrotogonous trachypeterus*) (Table 5.1).

Table 5.1. Impact of *R.marginatus* on the groundnut pest level during different observation period

Days of observation	SLC	SLP	HAC	HAP	GHC	GHP	ACC	ACP	MYC	MYP
26	0.78	0 78	0.64	0 68	0 57	0.56	51 44	51.77	0.16	0.16
34	0.78	0.44	0.68	0 46	0 61	0.49	50.66	48.33	0.25	0.27
46	0 66	0.56	0 70	0 54	0.56	0.50	49.44	49.72	0.26	0.27
54	0 56	0.22	0.62	0 32	0 50	0 47	44.11	37.78	0.26	0.23
66	0.44	0.33	0.58	0.44	0 49	0 43	41.67	40.00	0.28	0.28
74	0.44	0.11	0.56	0.22	0 43	0 32	32.56	27.78	0.31	0.30
Mean	0 61	0.41	0.62	0.44	0 53	0 46	44.98	42.56	0.25	0.25

C—control and P—predator released, SL—*S.litura*, HA—*H.armigera*, GH—Grasshopper, AC-*A.craccivora*, MY—*Mylabris* spp

Source: Sahayaraj and Martin (2003)

5.4.3 Oilseeds

Platymerus plagipennis Walker was mass reared in the laboratory and released into the oil seed crops like sunflower, soybean and cotton crops in Australia (Hassan and Maelzer, 2000) and observed its in IPM. They found that it is an efficient reduviid can be used to control the pests at field situation.

5.4.4 Palm

The assassın bug, ***Platymerus rhadamanthus*** Gerst adults are large black bugs, 3 to 4 cm long. It has been observed frequently in the field by Vanderplank (1958). All stages of this bug found throughout the year at Zanzibar, East Africa. The adults were generally found in pairs hiding near each other in the debris in the axils of leaves of the crown of the coconut palm. The rhinoceros. beetles *Platymeris laevicollis* Distant gravid females and adult males (30 – 40 days), and also third and fourth nymphal instars were released in to three palm growing areas such as Lakshadweep; Pandalam, Alleppey District, Kerala and Vittal, Karnataka. Release of the bugs were made on the crowns of 100 palms each at Pandalam and Vittal and on 200 palms in Androth Island. The number released at each time being 1 to 5 bugs/palm (Antony *et al.,* 1979). In control more than 90 per cent of the total leaves and 40 per cent of the inflorescences and bunches were damaged by *Oryctes* spp. on the fifth day after the release of the bugs, from the leaf axils of 154 palms. Totally 213 dead and 45 live beetles were observed from 32 palms. The annual observations following the release of the bugs showed a gradual decline in the pest population with a remarkable decrease in fresh incidence on spindles as well as on opened inflorescences. Altogether they released 9,100 bugs during 1969 – 74. The leaf attack of 100 palms was reduced from 45.28 to 23.43 per cent, similarly the inflorescences attack was also reduced from 15.49 to 0 per cent.

5.4.5 Soybean

Soybean is an important protein diet crop cultivated throughout the world. Grundy and Maelzer (2000) assessed the impact of *Platymerus plagipennis* third instar nymphs in soybean against green mirids, *Creontidaes dilutus* (Stal), and looper caterpillars, *Chrysodexix* spp. The results showed that the mean number of *C.dilutus* and *Chrysodexix* spp. were significantly lower with two predator nymphs per m row than the control. One nymph per m row caused a significant reduction in the number of *Chrysodexix* spp. larvae for the week following release but, as pest numbers increased, this predator density was not sufficient to provide significant levels of continuing biological control during the proceeding periods of observations. Though the pest populations were decreased, none but the predators' treatment increased the soybean yield.

Table 5.2. *R. marginatus* on the groundnut pests reduction, groundnut production (Kg/ha) and cost benefit ratio

District	Year	Pest observed	Pest reduction (in%)	Production Kg/hec	Cost benefit ratio
Tirunelveli		*E. kerri*	36.36	1225/1085	1:1.62
	2001	A. craccivora	12.15		
		Genocephalun sp.	46.16		
		A. crenulata	25.0		
Tuticorin		*S. litura*	32 78		
	2002	H. armigera	29.03	1480/1104	1:1.8
		A. craccivora	05.38		
		Mylabris spp.	00 00		
Trichy	1997	*A modicella*	12.67	1668/1025	1:1.8
Trichy	1997	*H. armigera*	94.91	1868/1023	1·1.9
		S litura	92.73		

5.5 Role of reduviids in IPM

Adoption of IPM strategies helps to reduce the use of insecticides. These tactics are ecologically sound, economically viable and socially acceptable method. Plant-derived insecticides have the potential for pest management. The cultural control strategy of intercropping also has the potential to reduce the incidence of insect pests and provide higher income. While integrating intercropping, use of plant biopesticide and reduviid predator control strategies have been evaluated individually, their combined impact remains unknown. Benefits may be greatly increased if synergistic effects occur. In this part we discussed the various IPM components in groundnut and pigeon pea pest control and also their productions.

5.5.1 Plant products and reduviids

5.5.1.a Groundnut

In 1996 and 1997 *R. marginatus* was integrated with water extracts of *A. indica*, *V. negundo*, *P. pinnata* and *C. gigantia* separately. All these plant biopesticides were sprayed at 0.3 per cent during the evening hours and the predators were released (all the life stages in equal number) after 12 hrs of plant biopesticides sprayed at the rate of 5000/ha. Results revealed that *R. marginatus* does not reduce the *A. modicella* population (4.11 and 4.22 for control and predator released field respectively). However, while integrating plant biopesticides along with the reduviid both IPM components combinely reduced the pest population (1.33, 2.11, 1.55 and 1.66 for *A. indica, V. negundo, P pinnata and C. gigantia* respectively) and its infestation (6.11, 6.0, 5.0 and 4 22 for *A. indica, V. negundo, P. pinnata and C. gigantia* respectively). Simultaneously the production and cost benefit ratios were also increased (Sahayaraj, 2002).

Table 5.3. Integrated effect of *R.marginatus* and plant biopesticides on the groundnut production and its economics

Treatments	Pod yield (Kg h^{-1})	Cost of Cultivation (Rs /ha)	Net gain (Rs./ha)	Total gain (Rs./ha)	Cost benefit ratio
Groundnut	1246	6470	5280	11750	1.1.82
Groundnut+Vitex + Reduviid	1560	7260	9112	16732	1:2.30
Groundnut+Neem + Reduviid	1685	7260	10442	17702	1.2 44
Groundnut+Calotropis + Reduviid	1539	7260	8902	16162	1 2 23
Groundnut+Pongamia + Reduviid	1613	7260	9672	16932	1.2 33

Source. Sahayaraj (2002)

Later this predator was integrated with the *Pedalium murex* Linn. (Family: Pedaliaceae) a commonly available medicinal plant and find out its role in groundnut pest management. In control plot, the incidence of *E. kerri* were 1.47, 3 5, 2.6 and 2.6 per 10 plants in the first, second, third and fourth counting respectively. In the reduviid and plant biopesticide integrated plot the population was comparatively less than other categories (Table 5.3). As observed in *E. kerri*, *A. crenulata* population was also less in all the treated categories than the control. In control plot, *A. crenulata* incidence was 1.1, 1.3, 0.6 and 1 0, per 10 plant in the first, second, third and fourth count respectively. When *R marginatus* was released in to the plots, *A. crenulata* population was gradually decreased from 1 9 to 0.1 (1.9, 0.4, 0.8 and 0.1/10 plants for first, second, third and fourth count respectively). *Genocephalum* sp. was effectively controlled either by the release of *R. marginatus* or by the spray of *P. murex* and this was clearly exhibited by the incidence of the pest. Similarly, *A. craccivora* population was 45.3 and 27.5/10 plants in the first and second counts respectively. Total number of pod per plant was 12.6 than in the control (11.6/plant). However, they were statistically insignificant. The pod yield obtained from PRE and PE combination was higher (1373 Kg/h^{-1}). When compared to the control it was statistically significant at 5% level. The cost benefit ratio was 1: 1.62 in PRE + RDG and low cost benefit ratio was observed in control (1 : 1.1). The reduction of pest incidence in the PRE + PE is mainly due to the action of either predator or plant products or both. In addition to this fact, the predator may have an impact on pest incidence and infestation. From the present study, it was clear that predator does not directly control all the pest population studied here. The plant products such as *P. murex* were proved to be lethal to all the pests studied here. But it won't cause any side effect to the reduviid. The above-mentioned studies indicated the safety of botanicals to the reduviid predator.

5.5.1.b Pigeon pea

Plots of 3 x 1.5 m were selected from the farmers pigeon pea field. Fifty-five days after the seedling emergence 45 third instar nymphs of *R.fuscipes* were released. In another experiment the fields (3.5 x 7 m) were mulched with sorghum trash, sugarcane trash and palm and banana leaves. In the third category, pigeon pea was combined with chilli, onion, tomato, okra, brinjal, soybean, cotton and groundnut at 0.2 hectare each. During the experimentation the H. armigera infestation was very low in caryota leaf mulched plots (4.72 and 3.92/10 plants for experiment and control, respectively). Similar effect was also observed for *R. clavatus* and *C. gibbosa* infestation. Mulching along with *R.fuscipes* reduces the pod damage (12.18 & 13.30; 12 3 & 10.4; 12.31 and 12.42 and 46 8 & 41.3 for neem, caryota, mixed and control, respectively) Caryota produced 1512 and 1586 Kg/ha followed by control 584 and 437. Predator colonisation was greater in mixture (9.7 and 7.3) whereas in control it was 0.01 and 0.3. Chili and *R. fuscipes* combination reduce *H. armigera* (5.5), *N. viridula* (8.5) and *R. clavatus* (7.2) infestation. The *R. fuscipes* occurrence was also high in this system (16.54) (Claver and Ambrose, 2003).

5.5.2 Integrated effects of plant products, intercrops and reduviids

5.5.2.a *A. modicella* population and infestation

A. modicella incidence was significantly higher in the control crop in both seasons when compared to the treated plots. The grand mean values show that the larval population was the least in T_4 and T_6 in rabi (1.1 larva/plant) (September to February) and T_6 (0.7 larva/plant) in kharif seasons (Table 5.4) (June to August). All treatments in the rabi season were found to be had an impact on

Table 5.4. Plant products and *R.marginatus* on the groundnut pest populations (No/10 plants)

Treatment	Counting schedule				
	I	II	III	IV	Mean
			Empoasca kerri		
Control	1.47	3.5	2.6	2.6	2.75
PRE + PE	0.30	0.8	1.5	0.6	0.78
			Atractromorpha crenulata		
Control	1.1	1.3	0.6	1.0	1.00
PRE + PE	1.9	0.4	0.8	0.4	0.84
			Genocephalum sp.		
Control	1.38	0.62	0.12	0.37	0.62
PRE + PE	0.5	0.25	0.25	0.25	0.31

PRE – Predator and PE – Plant products

pest incidence after the second and the third applications of plant products and predators release. First application reduced the incidence in T_5 and T_6 only In kharif season, third spray was found to be effective in all treatments. In the control plot, the incidence increased dramatically throughout the study period in both seasons, and it was recorded as 1.0, 1.3, 5.0, 7.7, 10.7 and 13.3 larvae per plant in rabi and 4.3, 4.9, 6.3, 6.0, 7.3 and 7.5 larvae per plant in kharif seasons on 26, 34, 41, 49, 56 and 64 DASE respectively. Treatment$_1$ (0.2, 1.0, 2.3, 2.3, 1.6 and 1.0 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and T_2 (1.8, 2.6, 0.5, 0.8, 1.5 and 1.3 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) highly reduce the pest populations. And hence these treatments were identified as the least effective treatments against *A. modicella* incidence in kharif, whereas T_2 (1.3, 3.3, 2.0, 1.3, 1.3 and 1.0 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) treatment was the least effective one in rabi season. *A. modicella* incidence was highly reduced in 1999 than 1998.

In both seasons, *A. modicella* infestation was significantly less in all the treatments when compared to the control. In the control plot, the infestation was recorded as 2.7, 2.7, 10.0, 11.3, 17.0 and 17.0 leaves per plant in rabi and 6.5, 7.4, 7.8, 13.4, 13.7 and 15.8 leaves per plant in the kharif on 26, 34, 41, 49, 56 and 64 DASE respectively (Table 5.5). The most effective treatment was identified

Table 5.5. Different IPM components on *A. modicella* and *S. litura* population reduction in two crop seasons.

Year	Pest	Treatments					
		T_1	T_2	T_3	T_4	T_5	T_6
1998 (rabi)	*A. modicella*	76.92	72.85	76.92	83.07	78.46	83.07
1999 (Kharif)	*A. modicella*	77.05	77.05	83.33	83.60	85.24	88.24
1998 (rabi)	*S. litura*	65.79	65.79	50.00	39.47	39.47	39.47
1999 (Kharif)	*S. litura*	43.48	39.13	43.48	34.79	26.08	13.04

T_1= Castor (CR)+ Predator + Neem (N); T_2 = CR + PR + Calotropis (C); T_3 = CR+ PR + Vitex (V): T_4 = Maize (MZ) + PR + N; T_5 = MZ + PR + C; T_6 = MZ + PR + V

as T_6 in both seasons (7.3, 5.7, 5.7, 6.0, 5.3 and 5.0 leaves per plant in rabi and 2.8, 2.3, 2 6, 1.4, 1.7 and 1 6 leaves per plant in kharif on 26, 34, 41, 49, 56 and 64 DASE respectively). This treatment (T_6) was highly significant ($P < 0.05$) in all the observed periods except on 26 DASE in the kharif season.

Mean values carrying same alphabet *(s)* in a column are not significantly different at 5 per cent level by DMRT

5.5.2.b *S. litura* population and infestation

The larval population of *S. litura* was significantly reduced by all treatments (Table 5.5). Significantly high ($P < 0.05$) *S. litura* population was recorded in control plots in both seasons (1.9, 2.3, 2.3, 4.7, 5.3 and 6.3 larvae per plant in rabi and 1.3, 1.1, 1.4, 2.6, 3.7 and 3.7 larvae per plant in kharif seasons on 26, 34, 41, 49, 56 and 64 DASE respectively) and the population increase continued throughout the study period. The most effective treatments in rabi were T_1 (2.0, 2.3, 1.3, 1.3, 0.5 and 0.3 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and T_2 (1.7, 2.0, 1.7, 1.3, 0.5 and 0.5 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) (Table 5.5). In kharif, least number of larvae was recorded in T_1 (1.4, 1.8, 1.5, 1.1, 1.1 and 0.7 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and T_3 (1.3, 1.7, 1.8, 1.1, 1.0 and 1.0 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) treatments. The first application of the plant products and predator release was found to be not effective except T_4 and T_6 in rabi and T_4 in kharif seasons. But the second and the third applications significantly reduced the pest incidence in all treatments. Results show the effect of various treatments on the mean number of infested leaves per plant on different observation periods in two seasons. The infestation was comparatively severe in control than treated plots. An average of 8.3 and 9.8 infested leaves per plant were recorded in rabi and kharif seasons respectively in control plots and this was significantly higher than T_2 and T_3 treatments (4.0 leaves per plant) in rabi and T_3 (3.6 leaves per plant) in kharif. In rabi 1998, the first treatment reduced the infestation in T_5 only (from 8.3 to 8.0 leaves per plant), but interestingly it was observed that in this same treatment, the infestation increased after second spray but in all other treatments, the infestation decreased Third spray controlled the infestation on 64 DASE in all treatments below the levels recorded on 56 DASE.

5.5.2.c Production and per cent avoidable loss

Table 5.6 shows the production values of both groundnut and intercrops. T_1 harboured the highest groundnut production both in rabi (1017 kg/ha) and kharif (1173 kg/ha) seasons. Yield from the

Table 5.6. Impact of IPM components on groundnut production and economics in two crop seasons

Year and Season	Treatment t	Production (kg/ha) Ground-nut	Inter-crops	Total cost of cultivation (Rs./ha)	Total income (Rs./ha)	Net income (Rs./ha)	Cost-benefit ratio
Rabi, 1998	Control	893	-	9120	10716	1596	1 : 1.2
	T_1	1017	168	9630	13716	4086	1 · 1.4
	T_2	908	157	9630	12309	2679	1 · 1 3
	T_3	1013	169	9630	13677	4047	1 1.4
	T_4	1005	315	9905	16785	6880	1 · 1 7
	T_5	918	327	9905	15921	6016	1 . 1 6
	T_6	1011	312	9905	16812	6907	1 1.7
Kharif, 1999	Control	917	-	8220	11004	2784	1 · 1 3
	T_1	1173	175	8730	15651	6921	1 . 1.8
	T_2	1042	182	8730	14142	5412	1 : 1.6
	T_3	1015	170	8730	13710	4980	1 : 1.6
	T_4	1028	328	9005	17256	8251	1 : 1.9
	T_5	993	343	9005	17061	8056	1 : 1.9
	T_6	1057	325	9005	17559	8554	1 : 1.9

T_1 = Castor (CR) + Predator (PR) + Neem (N); T_2 = CR + PR + Calotropis (C); T_3 = CR + PR + Vitex (V); T_4 = Maize (MZ) + PR + N, T_5 = MZ + PR + C; T_6 = MZ + PR + V.

control plots was comparatively poorer than treatments in both seasons (893 kg/ha in rabi and 917 kg/ha in kharif) The least effective treatments with reference to production were T_2 (908 kg/ha) in rabi and T_5 (993 kg/ha) in kharif seasons. In general, the production of the groundnut as well as intercrop was higher in the kharif than rabi. Castor production was the highest in vitex sprayed field (169 kg/ha) in rabi and calotropis sprayed field (182 kg/ha) in kharif. The avoidable groundnut yield loss was the highest in T_1 (12.2%) followed by T_3 (11 8%), T_6 (11 7%), T_4 (11.1%), T_5 (2.7%) and T_2 (1.7%) in rabi. In kharif season, the highest avoidable loss was recorded in T_1 (21.8%), followed by T_6 (13.2%), T_2 (12.0%), T_4 (10.8%) T_3 (9.7%) and T_5 (7.7%) treatments.

5.5.2.d Cost-benefit ratio

Higher cost-benefit ratio was obtained from maize intercropped field in both seasons when compared to castor intercropped field. In rabi the highest cost-benefit ratio was obtained from T_4 and T_6 and the lowest cost-benefit ratio was obtained from control (1 : 1.2). In kharif, T_4 (1 : 1.9), T_5 (1 : 1.9) and T_6 (1 : 1.9) gave the highest cost-benefit ratios. In this season, the control gave the least (1 : 1.3) cost-benefit ratio.

Biological control of insect pests as a part of IPM has been gaining momentum since it is specific, safer to non-target species, beneficial insects, higher animals and man and has the least effect on the ecosystem and environment. The integrated effect of intercrops, predator and botanicals is significant as evident from the above-mentioned results. The sole crop (control) was severely attacked by the pests whereas treatment plots showed fewer incidences, infestation and gave high production also. An important finding in this study is that the two intercrops are efficacious on controlling two different pest insects. Maize intercropped field controlled *A. modicella* and castor controlled *S. litura* incidence and infestations. *A. indica* was found to be the most effective plant product for both pests. However the effectiveness of this plant product was high to *A. modicella* and *S. litura* when it was acting synergistically with maize and castor respectively. When two or more components are integrated against a pest, their synergistic action is considered as an important factor.

The reduction of pest incidence and their infestation in the main crop in intercropping system is due to the high preference of the pest towards intercrop (Jeyaraj and Santharam, 1985). In the case of sole crop, the pest depends only on the groundnut for food since alternate host plant is not available and this may be the main reason for the high level of pest incidence and infestation in sole crop. In addition to this fact, the predator may have an impact on pest incidence and infestation. General predator like *R. marginatus* is extremely effective at low prey densities, not being completely dependent on populations of target pests in contrast, many parasites function most effectively at much higher pest densities. The predator *R. marginatus* highly prefers to attack *S. litura* and not the *A modicella* larvae, since *A. modicella* larvae hide themselves inside the foldings and tunnellings of the leaflets made by them So the predator can efficiently attack the visible pest like *S. litura*. Laboratory observations of Sahayaraj (1999 b) also support this view. He reported that fourth and fifth nymphal instars and adults of *R. marginatus* preferred *S. litura* followed by *H. armigera, A. modicella* and *A. albistriga*. However, another laboratory study (Sahayaraj, 2000) showed that *R. marginatus* fifth nymphal instar consumed more number of *A. modicella* followed by *H. armigera, S. litura* and *A. albistriga*. From these observations, it was concluded that both in rabi and kharif seasons maize can be intercropped along with the reduviid predator and plant products These IPM components increased the groundnut production, net income, cost-benefit ratio and decreased the pest incidence. Hence, these IPM components can be integrated in the groundnut cultivation.

5.6 Natural Enemies of Reduviids

The main aim of the IPM is to utilise and strengthens the natural enemy complex, by introducing them from elsewhere in the world. Males will release calling pheromones secreted by dorsal abdominal glands (DAG) during mating. In addition to the augmentative release, pheramoes can also be. Most of the reduviids possess two pairs of dorsal abdominal glands (DAG). But *Pristhesancus plagipennis* possess three pairs of glands.

It is a general fact that reduviids are generalist predators and often they may attack beneficial arthropods too. Hairston *et al.* (1960) model on tritropic interaction was recently modified. In the agro-ecosystems the generalist predators not only consume herbivore but also other predators (see the review of Rosenheim *et al.,* 1995). Thus, it is imperative to understand the interaction between reduviid predators, and other generalist predators. Initially, Odhiambo (1959) observed two species of egg-parasites found at Kawanda on egg masses collected on *Stylosanthes* [*Hadronotus abntestiae* Dodd and *Hadronotus* sp. Nr. Hiberus Nixon (Prototrupoidea: Scelionidae)]. Several egg parasites have been reported including the *Ooencyrtus johnsoni* and *Anastatus reduvii* (Howard), and the encyrtids *Ooencyrtus johnsoni* (Howard) (Peck 1963). *O. clisiocampae* (Ashmead) (Swadener and Yonke, 1973a) parasites on *Arilus cristatus* (L.). The eggs of *R. albopunctatus* were mainly parasites;

they belong to the family of Scelionidae (Nyiira, 1970). It included *Hadronotus abntestiae* Dodd and *Hadronotus* sp and *Telenomus* sp. Mineo from University of Palermo reported in his scientific note on studies of the scelionidae (Hymenoptera: Proctoirupoidea) that from the egg cluster of *Rhynocoris costae* Picco *Telenomus* sp. female were emerged. He successfully reared the parasite on the eggs of another reduviid *R. erythropus* Linn. Furthermore, the egg parasitism was more frequent in the larger egg masses and was found only among the outer side rows. Similar kind of parasitism is also observed in *R. marginatus* eggs (Sahayaraj - unpublished) (Plate 3). It was observed that *Trissolcus* sp. (Scelionidae) prefer to attack the *R.marginatus* eggs which are present on the outer side of the egg cluster. Reduviids are not only damaged by insects but also by bacterial diseases. Cherian and Brahmachari (1940) reported that *R. fuscipes* was infected by bacterial diseases, particularly during the rainy season. They added that when affected by the disease, the reduviids refrain from feeding and remain still without any kind of movement. The body rapidly turns black and a bad odour emanates from it. Furthermore, preoviposition and oviposition were also reduced due to the infection of *Aspergillus flavus* Link through it prey *C. cephalonica* (Lakkundi, 1989).

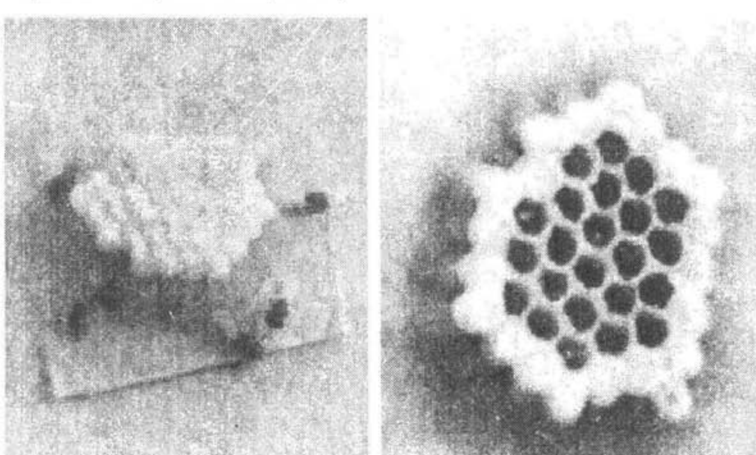


Plate 3. Parasite of *Rhynocoris marginatus* (a- before and b- after parasitism)

5.7 Damage of reduviids

Biological control involves the use of predators, parasitoids and pathogens against their specific preys. The attempts at biocontrol usually involve large scale introduction of single species. The question then arises, "why only a single species?," "why not more than one or a combination of species?." These questions carry weight because indeed as per law of nature, no organism forms an exclusive source of nutrition to another. Since in nature a combination of species feeds on an organism, why not extrapolate that law of nature to biological control. Biological control agent's guild preys or host. In fight of survival both the predators and parasites predates each other so as to garner a major part of the food supply. In this Joint exploitation, they might affect each other's foraging and thus survival success. While competing, the predator might even consume each other in a bid to limit competition; this is intraguild predation (IGP). The aggressor is the intraguild predator, the victim is intraguild prey and the common food is extraguild prey. Furthermore, several predatory insects are commonly found in the same ecosystem and they have common prey. Because of their polyphagous behaviour, these predators not only feed on prey but may feed on each other (*i.e.* called intraguild predation) to varying degrees, depending on predator and prey species density. Whitcomb and Bell (1964) reported that reduviid inhabiting in the Arkanas cotton field feeding on ladybird beetles. Whitcomb and Bell's observation was supported by Rosenheim and Wilhoit (1993), Rosenheim *et al.* (1993) in *Zelus renardii* Stal. *Stenolemus lanipes* present in the dwelling places predate on common household spider *Achaearehea tepidariorum* (C.L.Koch) (Theridiidae) (Hodge, 1984). But the spider developed anti-predatory behaviours. In San Joaquin Valley of California (U.S.A) both the nymphal instars and adults prey upon life stages of *Chrysoperla carnea* (Stephens) and caused heavy mortality. Later this predator was collected from cotton field and its 20.9 per cent of its diet consists of beneficial arthropods (*Hippodamia convergens* Guerin-Meneville, *Chrysopa* larvae, parasitic Hymeoptera and spider). Cisneros and Rosenheim (1997) first time studied the intraguilding behaviour of *Zelus renardii* in North American cotton fields on the lacewings larvae, *C. carnea* Stephens, and the cotton aphid, *A. gossypii* Glover. Their conclusions are as follows:

1. *Z. renardii* and lacewings feed on aphid, thereby acting as potential competitors. In addition, *Z. renardii* feeds on lacewings. Thus, *Z. renardii* is an intraguild predator of lacewing.
2. *Z. renardii* exhibited changes in prey preferences across developmental stages. The older stages of *Z. renardii* exerted greater mortality on lacewing and fed on larger lacewing larvae than did the younger stages.
3. Lacewings suppressed aphid population growth strongly. In contrast, none of the stages of *Z. renardii* was an effective control agent of the cotton aphid.
4. The addition of *Z. renardii* frequently disrupted the effective control of aphids generated by lacewings. In one of the two replicates of the experiment, the disruption increased with the developmental stage of *Z. renardii*, paralleling the increase in lacewings mortality.
5. Although the developmental stages of *Z. renardii* can influence the prevalence of intraguild predation and the intensity of the disruption of the aphid biological control, these experiments have demonstrated that even the youngest instars of *Z. renardii* can cause substantial lacewing mortality and release aphid populations from regulation.

Though many reports were available about the damage of reduviids on other natural enemies, published works are not available from India. We also evaluated the interaction between the reduviids and *Menaculus sexmaculatus* under laboratory situations. The results clearly indicated that *R. marginatus* adults also have the tendency of feeding the lady bird beetle when it was subjected to a very long period of starvation. If the starvation is up to seven days then it won't feed on *M. sexmaculatus*, on the eighth day the reduviid starts to predate upon the ladybirds. However, the predatory rate was very low (0.34/reduviid). Presence of hard cuticle might be the reason for the lower predatory rate. Further studies are essential on this line. Levels of intraguild predation for *R. marginatus* that we determined in the laboratory studies did not reflect those found under natural field conditions. This is because predators were confined with prey, thus magnifying co-occurrence, and presented with higher prey densities which may not occur in the field. I strongly reported here that whenever the pest is available in the field the reduviid won't predate on other predators. But the temptation comes once all the pests are eradicated form the field. Such a kind of situation will occur if the field is sprayed with very high dose of pesticides. We can avoid such a situation, if the pesticides are sprayed block-by-block or compartment-by-compartment. Both laboratory and field studies clearly show that reduviids can reduce the pest infestation and increase the crop production. When it combined with other IPM components the biological control potential has been increased and the production was increased 0 5 to 3 folds.

5.8 Recommendations

1. More field cage evaluations are necessary for most of the major pests.
2. Reduviids could be released in different densities and find out the optimum release rate and also the biological control potential could be found out.
3. Since adults easily migrate from place to place, it is better to avoid them to release in to the field situations.
4. Integration of reduviids with other IPM components result in high yields than they are released alone.
5. It is also essential to know the season impact on the biological control potential of reduviids.
6. Finally, I advise to release more than one species of reduviids and also to know their impact among them and also to other natural enemies in the ecosystem.

6

Mass Production

6.1 Introduction

Mass production of predators is one of the important pre-requisites for the success of biological control programme. Mass rearing is essential to obtain a large number of predators for release in to the field. Currently the reduviids are not commercially available worldwide. However, very little efforts have been made to rear few reduviids in small scale under laboratory conditions. Although the technology required for the large-scale production of reduviids is relatively straightforward, it is not necessarily available to small laboratories and at present it appears that there is little in the literature on small-scale reduviid production. Cohen (1993); James (1994); Ambrose (1995); Schaefer (1988) and Sahayaraj (1999a) felt that there is an urgent need for evolving the strategies to mass rear the potential hunter reduviids. Furthermore, one of the basic requisites for a biological control agent is the availability of a sound, low cost rearing and mass multiplication technique which is not available for the reduviids. Many factors are influencing the mass rearing of the hunter reduviids. They include female parental age, decamouflaging, rearing substrata, type of preys and their food, predator and prey number, age-specific fecundity, temperature thresholds, and artificial diets, etc. Furthermore, nymphal canibolism is a major constrain in the mass multiplication of the reduviids.

6.2 Substrata

Influence of substrata on the mass rearing of reduviids is needed to understand better its efficient mass multiplication strategies. Though it is a known fact that substrata could influence the multiplication of the predator population, information on the role of substrata on the life cycle and the laboratory rearing of hunter reduviid predators on different substrata and predators' substrata preference are scanty except for *R. marginatus*, *R. kumarii* and *R. fuscipes*. Using the following substrata tested all these three reduviids: (1) untreated plastic troughs, (2) tissue and glutting paper (tissue paper was lined to the floor of the troughs and a bit of multi folded glutting paper was placed on the tissue paper for reduviids to hide), (3) dry sand and stone (sand was spread uniformly in the trough upto 2 cm height and stones (approx. 5 x 3 cm size) were placed on it and care was taken for placing concave side of the stone facing the earth to facilitate the hiding of reduviids), (4) dry litter and strips (litter was filled in the troughs up to 4 cm height and some small strips were placed over it for easy movement of reduviids), and (5) green leaves with stem (fresh cotton branch with leaves was placed inside the trough and adequately replaced at regular interval at least once in 2 days to keep the leaves fresh).

Shorter stadial period was observed when *R. marginatus* was reared in the fourth category (59.6 days). But the survival rate of the nymphal instars (72.3%), and fecundity were higher in the fifth category (167.57 eggs/female) (Ambrose and Claver, 1999). Claver (1998) reared *R. kumarii* with substrata like untreated plastic trough, tissue and glutting papers, dry sand and stones, dry plant litter and green plant shoot. He concluded that mass rearing of *R. kumarii* in plastic trough is not advisable and inclusion likes leaves and green stem as substrata could enhance its mass rearing potential. This group had minimum developmental period (51.46 days), maximum nymphal survival rate (61.4%), female biased sex ratio (1:1.3) and maximum egg production (158.9 eggs/female). Recently Claver and Ambrose (2001a) also studied this kind of information for *R. fuscipes*. According to them, the substrata did not influence the incubation period and stadial periods. Green plant shoot supported better survival than did other substrata. This substratum shortens the preoviposition and enhances the fecundity (108.1 eggs/female). From observations made by the both it is very clear that provision of green plants could enhance the mass rearing of the reduviids. Above-mentioned observations clearly indicated that reduviids can easily multiply when they are present in the agricultural fields. Furthermore, presence of green plant in the reduviids rearing arena enhanced the fecundity and reduces the stadial period and nymphal mortality.

6.3 Prey and Predator Density

Food of any animal can influence the development and reproduction. Similar concept is also applicable for the predatory insects including the hunter reduviids. Prey influences the laboratory rearing of reduviids (Ambrose and Subburasu, 1988; Ambrose *et al.*, 1990; Ambrose and Rani, 1991; Sahayaraj and Ambrose, 1994; Tawfik *et al.*, 1983c). Most of the studies show that among the tested preys, *Corcyra cephalonica* Stainton is the most suitable prey and it can be used to rear the hunter reduviids in both small and large-scale manner. So in this section influence of *Corcyra cephalonica* density and reduviid density on the mass-rearing aspects are discussed. Sahayaraj (1991) studied the group rearing of *A. pedestris* and *A.quinquespinosa*. Group rearing reduces the nymphal developmental period (18 and 9 days for *A. quinquespinosa* and *A. pedestris*). It enhances the adult longevity of these reduviids and does not alter the sex ratio apparently. Similar kind of observations was also observed in three *Rhynocoris* spp by Kumaraswami (1991) and Claver *et al.* (1996). In 1995c Sahayaraj recorded the developmental period of *Acanthaspis pedestris* on different densities (one, two and four) of *Odentotermes assumthi. Acanthaspis pedestris* took 121.00, 103.18 and 84.41 day with one, two and four preys respectively. Further he reported that males live shorter (19.66, 25.8 and 37.57 days for one, two and four preys respectively) than the females (22.60, 38.16 and 52.40 days for one, two and four preys respectively). Sahayaraj (2001a) also studied the prey densities (1, 2, 4, and 8 preys/predator) on the development and reproduction of *Neohaemrrhophus therasii* Ambrose and Livingstone. When *N. therasii* was reared on eight preys, the nymphal period was reduced from 73 days to 68 days. This density increased the survival rate of the nymphs (60.0, 73.3, 86.7 and 88 0% for 1, 2, 4, and 8 preys/ predator), adult longevity of both male and female and fecundity and hatchability. They further observed that the predatory rate was increased, as the predator grew older. In the adult, the mean total consumption was 107.11, 117.07, 121.11 and 136.28 for one, two, three, four and eight preys density, respectively. The prey consumption of the adults reflects to their reproduction *i.e.*, female laid maximum eggs in the eight preys density (68.33 eggs/female) followed by four (62.00 eggs/female), two (59.00 eggs/female) and one (40.66 eggs/female) prey level, respectively.

Density of the prey causes cannibalism in the life stages of both nymphs and adults. Cannibalism is a common phenomenon in insects (Lockwood, 1989). Many authors extensively studied nymphal cannibalism of many heteropteran predators. Similarly in reduviids, it is a major constraint in the mass production. Ambrose (2001b) stated that in *R. marginatus* irrespective of their rearing density and whether fed or prey deprived, the first nymphal instars invariably exhibit higher percentage of cannibalism. The rate of cannibalism was found decreasing in the succeeding nymphal instars. He further pointed out that the rate of starvation has also marked influence on the cannibalistic activity. However, cannibalism is not a major limiting factor and *R. marginatus* could be reared successfully at high prey density when provided with adequate food supply (Sahayaraj, 2002). Remarkable cannibalism was also observed in *R. fuscipes* (George, 2002). According to him cannibalism was maximum in the first instar followed by second instar. Lowest cannibalism was observed in the third nymphal instar.

Similar kind of response was also observed in *R. kumarii* and also in *R. longefrons*. In *R. kumarii* shortest nymphal developmental period was observed in both 10 and 15 predator densities and longest was observed in 10, 5 and one predator densities (Figure 2). But the predatory rate was high in both 10 (Q.92 preys/predator) and 15 (0.98 preys/predator) categories. Survival rate was high in 1 predator category (100%) than the other categories. In *R. longifron* shortest nymphal developmental period was observed in 15-predator category (45 days) followed by 10 (47.57 days). But the survival rate was low in this category (78.33%). It was high both in one and five-predator density (100%). Predatory rate was same in one, five and 10 categories (0.88 preys/day) and maximum in 15 predator category (1.0 prey/predator). The later category laid maximum number of eggs (150.4 eggs/female) than the other two categories.

In the adults sex ratio is one of the important factors, which determine the fecundity, and hatchability of any animals. Determining the suitable sex ratio is also a pre-request for the mass production of the natural enemies like reduviids. Very limited studies where undertaken in reduviids. Sahayaraj *et al.* (2003) studied the sex ratio suitability of *R. fuscipes.* According to them 0.6 ratio (three females and two males) was the suitable ratio for this reduviid and this group had longer female adult longevity and fecundity. This group also had maximum gross and net reproductive rates, innate capacity for increases (0.053), corrected r_m (0.05), finite rate of increase (1.054), weekly multiplication (1.449) and hypothetical female in F_2 generation (3286). Similar results were also observed in *R. marginatus,* when reared on the same sex ratio.

Table 6.1. Sex ratios on the life table statistics of *Rhynocoris fuscipes*

Parameters	0.8 (4.1)	7.2 (2.1)	0.6 (3.2)	0.5 (1.1)	0.4 (2.3)	0.3 (1.2)
Gross reproductive rate (GRR)	28 5	36.3	3 7	38.0	76 0	40 0
Net reproductive rate (NRR) (R_o)	24.12	28.75	55 01	38 0	49.75	40.0
Mean length of generation (T_c)	81.477	90.261	821 213	91 32	94.65	90 75
Orbitrary value of innate capacity for increase (r_c)	0 039	0 037	0.049	0.040	0.041	0.041
Corrected r_m	0 043	0.042	0 053	0.041	0.046	0 046
Precise generation time (in days)	74.03	79.98	75.61	88.72	84.94	80 19
Finite rate of increase	1 044	1.043	1.054	1 042	1.047	1 047
Weekly multiplication of population	1.35	1.342	1 449	1.33	1.38	1.38
Doubling time (in days)	16.09	16.45	13.10	16.82	15.13	15 05
Hypothetical females in F_2 generation	582 02	826.56	3026 13	1444	2475 06	1600

Source: Sahayaraj *et al.* (2003)

6.4 Temperature Thresholds

Insects are poikilotherms, so temperature is one of the most important abiotic factors that operates primarily at the physiological level but ultimately affects many aspects of insect ecology. Most of the insect development rates are temperature dependent, with development time approaching a minimum at some optimum temperature (between 25°C and 35°C for most insects) and lengthening within a range of temperatures above or below the optimum The use of entomophagous insects as biological control agents implies the availability of adequate rearing techniques enabling large-scale production at low costs. Besides suitable housing, optimal climatic conditions and adequate nutrition, efficient storage methods are also essential to face problems related to production, planning and the unpredictability of demand. Moreover, the effect of temperature on rate of development, and survivorship is of fundamental importance to understand insect phenology and abundance. Such data is also essential to gain an understanding of interactions between prey and natural enemies in biological control system.

Little has been published on the effect of temperature on development and survivorship in reduviids. Twafik *et al.* (1983b) studied the impact of temperature on the development of *Allaeocranum biannulipes.* Their results showed that the most optimum temperature for rearing this reduviid was 30°C combined with 70 per cent relative humidity. Under this favourable condition *Allaeocranum biannulipes* has 10.71, 74.56 and 130 days for incubation, nymphal developmental periods and adult life span respectively. However, this category of redviids laid 140.27 eggs/ female and it was increased to 202.13 eggs/female when aforementioned temperature is associated with 60 per cent R. H. Similarly, Sahayaraj and Paulraj (2001d) reported that the egg hatching of *R marginatus* and *R fuscipes* in relation to refrigeration Development and survival of *P plagipennis* in relation to different temperature was studied by James (1992) As observed for *Allaeocranum biannulipes, P. plagipennis* also developed very quickly at 30°C (47 days) followed by 27.5 (82.2 days), 25 (78.4 days) and 22.5°C (117 9 days). Nymphal survivorship was higher between 25°C and 30°C and low at 22.5°C. But at 32.5°C none of the nymphs were survived. Previously Tawfik *et al.* (1983b) studied the temperature impact on the stadial period, mortality and fecundity of *Allaeocranum biannulipes*

6.4.1 Cold storage of eggs

Cold storage is a useful technique to ensure the availability of beneficial insects for further research on release without maintaining a continuous rearing. The newly laid egg masses (0 to 24 hr old) were collected from paper towelling from stock rearing and placed in plastic containers (9 x 1.5 cm) with a perforated lid. The eggs were subjected to cold storage in BOD incubator at 25°, 15° and 10° ± 0.1° C and humidity remains (71 and 70% R.H.) for 5, 10 and 15 days respectively. For each treatment, ten egg masses (30 for each egg mass) were maintained. After the stipulated storage period, the eggs were removed from the BOD incubator and transferred to the room temperature (30 ± 2°C) for hatching. The eggs maintained at room temperature were treated as control. The vials were observed daily and the number of eggs hatched was recorded. Incubation period and percentage of egg hatching were calculated. The results presented in Table 6.1 clearly indicate that *R. marginatus* eggs withstand up to 15 days of storage at 25°C, but their hatching was

Table 6.1. Storage of eggs on the incubation period (in days) of *Rhynocoris marginatus* at various temperatures (°C)

Storage period (days)	Temperature (°C)				
	30	25	15	10	Control
5	92.6	87.7	72.7	41.1	96.7
	(7.8)	(9.6)	(10.6)	(11.0)	(8.0)
10	*	75.5	53.4	34.4	88.0
		(12.3)	(14.6)	(15.6)	(7.0)
15	*	67 7	50.4	25.5	90.0
		(14 3)	(18.0)	(18.3)	(7 6)
20	*	-	23.3	17 7	92.2
			(20 0)	(20.6)	(8 0)

-Not observed; *No eggs remain; Figures in the parentheses indicate the incubation period

affected when the storage period was increased (87 7, 75.5 and 67.7% for 5,10 and 15 days respectively). The hatching percentage was gradually decreased when the temperature decreased. At 15°C, 72.7, 53 4, 50.4 and 23 3 per cent of hatching were observed for 5,10,15, and 20 days storage respectively The hatching percentage drastically decreased at 10°C (41.1, 34.4, 25.5 and 17.7% for 5,10,15 and 20 days respectively) (Table 6.2). The results clearly showed that low temperature has a negative effect on the percentage of egg hatching. In *R fuscipes*, hatching was not observed beyond 1 day of cold storage Prolonged storage of eggs strongly reduced the hatching. From this observation, it was clear that prolongation of the period of chilling leads to death of the embryo and non-hatching of the eggs. Furthermore, the gradual decrease in hatching might be due to adverse effect of cold on developing embryos. Similarly, reduction in the incubation period at higher temperature was also observed in another reduviid predator, *A. biannulipes* (Tawfik *et al.*, 1983b). James (1992) also observed similar kind of results in *Pristhesancus plagipennis* Walker.

The age of the eggs as well as the period of refrigeration is the two major factors governing hatching. The percentage of hatching was reduced in *R. marginatus* when the eggs were stored for 10 days and beyond that period. This indicated that the development of the embryo was not completely stopped during the storage period but rather slowed down. Moreover, 5 days storage is the optimum for most of the metabolic processes. When this storage period increased it may either kill the developing embryo or cause abnormalities in the body. The possibility of storing reduviid eggs in the refrigerator for a long period and the subsequent use of the insects as a biological control agent would be a great benefit to the biological control programme. It can be feasible if this predator is used when mass production is required. Hence it is concluded that *R. marginatus* eggs can be stored for five days with minimum reduction in hatchability at 25°C. The studies revealed that there is a possibility of storing reduviid eggs in the refrigerator for a long period and the subsequent use of the insect as a biocontrol agent.

6.4.2 Cold storage of Nymphal instars and adult

Newly hatched first instars of *R. marginatus* were collected from the laboratory culture. The nymphs were fed with fourth and fifth instar *C. cephalonica* larvae in *ad libitum*. Then they were kept in refrigerator (temperature 18°C and 68% RH). In another set of experiment, instead of storing the eggs in the refrigerator, predators were maintained at room temperature and treated as control. The life stages were maintained without providing any food up to their death Observation was made every day and the number of predators died was noted. Similar procedure was followed for the remaining nymphal instars and adults (male and female separately). Thirty predators were maintained in each life stage. At storage regimes, dead individuals were easily differentiated from the live ones. At refrigeration, live predators were mostly immobile, but showed limited movements in response to touching. When there was doubt, the predators were placed at room temperature and survival was recorded after 30 minutes. When the predators were refrigerated, the first instar nymphs with stand very short duration (3.4 ± 0.2 days) followed by second (3.8 ± 0.5 days), third (16.2 ± 1.8 days), fourth (16.4 ± 1.8 days) and fifth instars, (21.8 ± 2.8 days). In the first two instars, the results were statistically significant to control. When the adults were subjected to cold condition, males withstand the cold (20 ± 2.56 days) better than female (17 4 ± 0.94 days). However, the result was statistically insignificant (Table 6.2).

Table 6.2. Impact of cold storage on longevity (in days) of *Rhynocoris marginatus* nymphs and adults

Life Stages	Cold storage	Control
First instar	3.4± 0.2	10.7±0.6
Second instar	3 8± 0.5	14.6±1.4
Third instar	16.2±1.8	18.5± 2.9
Fourth instar	16.4±1.8	19.3±1.9
Fifth instar	21.8±2.9	20.5±3.1
Male	20.0±2.5	21.3±4.5
Female	17.4±0.9	23.1±1.0

Source: Sahayaraj and Paulraj (2001d)

During cold storage, limited movements were observed occasionally. Predators immediately resumed activity when returned to warm conditions or room conditions. The observations indicate that during exposure to low temperatures, the predators were in hibernal quiescence rather than in diapause. Among the life stages of the predator the fifth instars and adults were observed to have a higher tolerance to cold conditions in comparison with first to fourth instars. Previously many scientists worked in reduviids reported that generally reduviid population especially nymphal population was abundant only after the rainfall. For the commercial production of natural enemies, the availability of both short-term and long-term storage methods is desirable. Short-term storage enables the producers to meet weekly differences between supply and demand. Long-term storage lowers the production cost by allowing producers to rear the predators when conditions are favourable. Further, it was observed by many field workers that the efficient storage techniques are vital to deal with problems related to shipment The life stages are more suitable for short-term storage of about 1 week. Under cold storage, the fifth instar and adults of *R. marginatus* could be stored for longer periods (up to 20 days). Further studies on the effect of cold storage on the eggs and biology, fecundity, biological control potential and physical fitness of life stages are necessary. Prolongation of the lifetime reduces the population-increasing rate of the reduviids. However, the delay in time to reproduction may be offset somewhat by the maturation of large, more fecund females from the forth coming seasons. Thus further investigations about the temperature on the fecundity of reduviids are needed.

6.5 Host type

Variation in the quality and quantity of the prey nutrient appears to have considerable effect on the feeding efficiency and the reproduction of the predator. Though *A. siva* is exclusively present in forests, its biology in relation to the economic important pests were carried out by George *et al.* (1998). The total developmental period of *A. siva* was 116.7, 126.4 and 132.0 days when it was provided with *S. litura, E. vittella* and *C cephalonica,* respectively It was also lived maximum days on these pests (66.5, 59.1 and 56 9 days for *S. litura, E vittella* and *C. cephalonica,* respectively) The fecundity was enhanced when this predator predating upon the studied unnatural hosts (114 1, 98.1 and 83.9 eggs/female for *S. litura, E. vittella* and *C. cephalonica,* respectively). Among the prey offered the mean length of generation time was shorter on *S. litura* (152.4 days) followed by *E. vitella* (158.1 days) and *C. cephalonica* (163.2 days). Similar kind of trend was also observed in weekly multiplication rate of *A.siva.* First, second third, fourth and fifth nymphal instars of *Rhynocoris marginatus* took 5.30, 7.22, 7 32, 7.69 and 10.13 days when provided with three and four days old *Spodoptera litura.*

6.6 Host rearing media

In addition to the above-mentioned biotic and abiotic factors, the biology and fecundity of the predator purely depend up on the nature, *i.e.*, both quality and quantity of biochemical constituents of the food. The nature of the food (prey) is influenced by many factors and one among them is the chemical composition of the host in which it has undergone its development If we alter the food of the prey, subsequently the development and fecundity of the predator also varied. Hence this kind of information is very essential for the mass production of any reduviid. Influence of host rearing media on the biology and fecundity was not available in the literature except the work of Sahayaraj and Sathyamoorthy (2002). Their work is described in this section. *C. cephalonica* is a non-host prey for reduviids. Many scientists have used this prey to rear the reduviid including for the mass rearing. Since, *C. cephalonica* causes serious damage to Jawar (JFC), Wheat (WFC), Sorghum (SFC) and Rice (RFC), we selected these grains as source diets. In addition, we added groundnut, multivitamin, streptomycin and some minerals in the diet. These larvae were provided to the reduviid *R.marginatus* and its development and fecundity were observed.

6.6.1 Juvenile development, sex ratio and adult longevity

The shortest total stadial period was observed in the nymphal instars from JFC (38.5 ± 0.3 days) followed by SFC (40 1 ± 0 7 days), RFC (41 0 ± 0.7) and WFC (42.0 ± 0.8 days) respectively However, they were statistically insignificant. The short total developmental period recorded in JFC group might be due to the minimum expenditure of energy obtained as a result of the better nutrition during predation on fewer (19.37 preys/predator) prey individuals. The total average developmental time of *R. marginatus* nymphs in our experiment was about 40 days which is 0.4 times lower value when we compared to the observation of George (1999) in *R. marginatus* nymphs fed on *C. cephalonica* in solitary rearing. The differences are probably due to the differences in experimental set ups and food types. For example, Ambrose *et al* (1990) found that the type of prey had a significant influence on the development time of *R. marginatus.* His study indicates that group rearing was necessary for shortening the nymphal development. Among the five stadia, the shortest stadium was the first except in JFC and the longest was the fifth stadium. Reduviid biologists previously reported that in reduviids the shortest and longest stadia were the second and fifth instars respectively. Male biased sex ratio was observed in both WFC (0.46) and JFC (0.36), whereas in other two media it was female biased (0.59 and 0.61 for SFC and RFC respectively). Ambrose (1989) stated that the members of Harpactorinae were female biased. Hence to understand the sex ratio of *R. marginatus,* further studies are essential. Chi-squire test shows that there is significance between

Table. 6.3. Prey influence on the development, fecundity and life table of reduviids

Prey	TDP	SUR	FAL	FC	HA	NRR	WM	DT	References
					Acanthaspis siva				
S. litura	116.70	-	66.47	114.12	-	33.78	1.23	23.45	George *et al.*, 1998
E. vittella	126.43	-	59.12	098.11	-	29 48	1.21	25.11	- do -
C.cephalonica	132.00	-	56.92	083.87	-	20.62	1.28	29.45	- do -
					A. pedestris				
C. compresus	*122*	*55*	*35*	*07*	*45*	-	-	-	*Ambrose and* Subburasu, 1988
M. domestica	98	78	68	23	44	-	-	-	- do -
O. obesus	97	63	25	09	38	-	-	-	- do
C. cephalonica	70.47	86.00	56.0	173.5	84.3	-	-	-	Sahayaraj, 2004
					Rhynocoris marginatus				
S. litura	46.71	-	128.04	148.6	92.45	292.29	-	11.15	Sahayaraj & Paulraj, *2001d*
H. armigera									*Sahayaraj, 2004*

S litura	70.38	-	79.87	191.89	-	65.95	1.399	14.49	George,1999
E. vittella	76.93	-	68.47	151.44	-	41.35	1.314	17.67	George,1999
C. cephalonica	83.47	-	65.29	121.75	-	27.90	1.278	20.15	George,1999
Rhynocoris fuscipes									
C. cephalonica	-	63.0	43.71	-	-	69 86	6.66	1.109	Sahayaraj, 2004
S. litura	*42.00*	-	*47.17*	*114.34*	-	*32.88*	*1.48*	*12.54*	*George,2000c*
E vittella	48.19	-	42.33	98.49	-	25.05	1.42	13.68	- do -
C. cephalonica	50.02	-	38.11	87.14	-	18.15	1.33	16.72	- do -
R. kumarii									
S. litura	63.45	-	111.46	221.46	-	83.80	1.419	13.87	George,2000b
E. vittella	70.43	-	94.16	207.18	-	66.70	1.342	16.45	George,2000a
C. cephalonica	74.12	-	83.33	186.32	-	56.90	1.314	18.13	George,2000a
Chrotogonus sp.	74.4	70.0	101.5	57.0	87.7	-	-	-	Ambrose and Rani, 1991
O obersus	71.5	20.0	86.5	74 5	93.6	-	-	-	Ambrose and Rani, 1991
Burchus theoromae	97.6	23.3	110.0	91.5	94.4	-	-	-	Ambrose and Rani, 1991

Cydnocoris gilvus									
S.litura	62.33	-	43.00	89.00	-	31.90	1.522	11.58	Venkatesan *et al.*, 1997
Oxya nitidula	65.00	-	39.00	72.00	-	20.94	1 437	13.32	- do -
Odontotesmes obesus	68.00	-	27.00	45.30	-	12.88	1.361	15.72	- do -
Alleocranum biannulipes									
Anagasta kuehniella	75.56	8.7	16.92	140.27	96.0	-	-	-	Tawfik *et al.*, 1983c
Corcyra cephalonica	57.62	-	20.34	247.64	81.97	-	-	-	- do -
Tribolium confusum	39.97	-	21.45	444.75	96.67	-	-	-	- do -

TDP- total devewlopmental period, SUR – survival rate, FAL- female adult longevity, FC - fecundity, HA- hatchability, NRR, WM, DT, - indicates not observed.

male and female sex ratio of all the categories. The male and female of test individuals of JFC had the highest adult longevity (176.4 ± 6.15 and 186.4 ± 4.1 days for female and male respectively). A significant difference was observed between the longevity of male and female ($P < 0.05$) whereas the shortest adult longevity was recorded on WFC (147.9 ± 6 5 and 135.7 ± 6.7 days for male and female respectively) and was not statistically significant. Since rearing medial of the prey place an important role on the life of the predator, more research is essential on this line. Because for the mass multiplication of a potential hunter reduviid, it is advisable to rear them using best medium reared larvae of Corcyra.

6.6.2a Reproduction

The preoviposition period of *R. marginatus* varied with prey rearing media. Among the four media, the shortest pre-oviposition period was observed in JFC (62.7 ± 15 days) followed by RFC (70.8 ± 1.3 days), WFC (73.3 ± 1.6 days) and SFC (68 0 ± 1.2 days). In an average the pre-oviposition period was 63.7 days, which is longer than 41.4 and 38.1 days for *Rhynocoris marginatus*, fed on *S. litura* and *C. cephalonica,* respectively. Further studies are necessary to confirm the results of the above said authors. As observed for the pre-oviposition, the oviposition period was also minimum and maximum in JFC (44.7 days) and SFC (71.6 days) respectively. The variation in the reproductive period among the four categories was due to the variation in the nymphal duration. As observed in pre-oviposition, the fecundity was also higher in JFC group (360.9 ± 13.5) followed by WFC (223.6 ± 5.5) and the minimum was observed in SFC (208.3 ± 3.9) and RFC (208.4 ± 4.4). A diet consists solely by *Corcyra* reared on wheat thus seem to meet the optimal requirements of *R. marginatus* egg-laying female. More number of batches of eggs was recorded in JFC (6.49 ± 1.84) followed by WFC (5.00 ± 1.06). The maximum fecundity of JFC group might be due to the maximum weight of female predator. The reason for the differences in preoviposition and total number of eggs laid per female may be due to the different types of diet provided to the *C. cephalonica*. It may also be due to differences in the experimental setup, in that the female *R marginatus* was present along with a male throughout its lifetime and in the present experiment the females were together with many males. The maximum number nymphs emerged from the *R. marginatus* fed with *C. cephalonica* reared on jower (82.88%) and wheat (82.51%). The minimum number of nymphs emerged from the sorghum (74.33%) category.

6.6.2b Life table

The data on the life table parameters of predator *R. marginatus* revealed that the highest and lowest survival and the female birth was noted in JFC and RFC respectively. In all the four media, the schedules of survival for female (lx) gradually decreased when the predator grew older. The net reproductive rate (NRR) was highest in JFC (490.63) followed by WFC (255.94), SFC (204.8) and RFC (177.31) The intrinsic rate of natural increase was the main focus of life table studies of *R. marginatus* and it was higher on JFC and more or less similar in other three *groups*. The mean length of generation was shorter on JFC (114.87) followed by WFC (116.23) and more or less similar in both SFC and RFC. Doubling time was maximum and minimum on SFC and JFC medium and minimum on SFC and JFC medium respectively. Increased mean length of generation and decreased multiplication were noted on *R. marginatus*. The mean length of generation (Tc) of *R. marginatus* on JFC, SFC, WFC and RFC categories were not higher than the corrected generation time, thus the species had not the capacity to multiply very faster (Sahayaraj and Sathyamoorthi, 2002).

6.6.3 Predatory rate

The predatory rate of *R. marginatus* was maximum and minimum in RFC group (28.79) and JFC group (19.37) respectively. The results show that the predatory rate gradually increased from the first instar to the fourth instar and decreased in fifth instar except WFC group. Lakkundi and Parshad (1987) reported that the feeding rate was higher in immature stages than adults.

6.6.4 Biometrics (Weight)

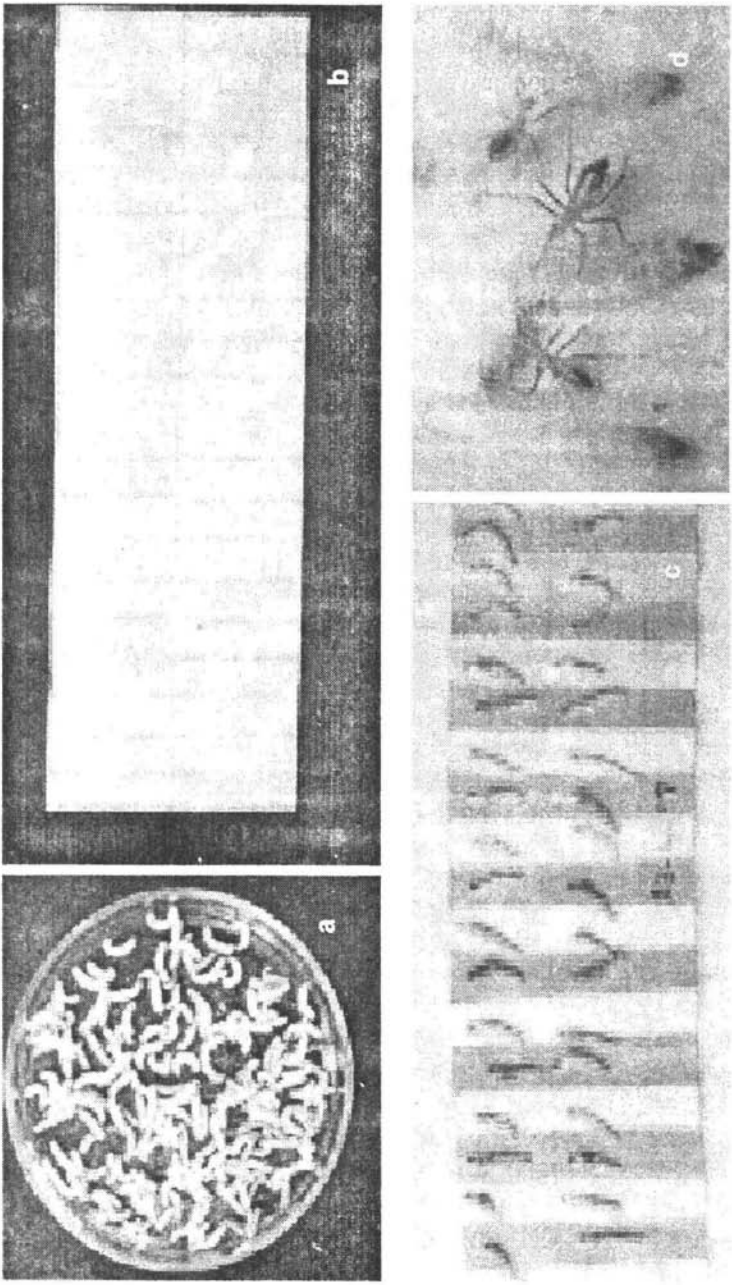
It is a well known fact that the type of food may have a substantial effect on the growth of the organisms. In addition to differences in chemical composition, preys differ in their capacity as phagostimulants. The heaviest female was observed on JFC group followed by WFC group (242 1 and 231.8 mg/female respectively). The lightest female was noted in SFC group (229.3). This result shows that the predatory rate of JFC group was very low when compared with other group. Previous studies showed that type of the prey has no great influence on the development and weight of the reduviids. Further studies are essential to know the impact of prey type on the weight of the predators.

6.7 Technique

C. cephalonica has been used as a laboratory host for rearing reduviids for a long time. Joseph (1959) used *Corcyra* larvae as food for the reduviid bugs by releasing them on filter paper in a glass jar. Sahayaraj (1991) and Kumaraswamy (1991) also used *C. cephalonica* larvae to rear nearly 15 reduviids. Later Lakkundi and Parshad (1987) and Lakkundi and Parshad (1987) used the same prey, but he encountered many disadvantages: the *Corcyra* larvae spun webs and remained hidden under them and hence the bugs were unable to attack and feed on them; often they themselves got entangled in the webs and died; some larvae escaped through the muslin cover, thus making it difficult for quantitative studies. Hence recently I developed a method called "larval card method" and later it was modified (Sahayaraj, 1997). He described the way of preparing the larval card as follows:

6.7.1 Preparation of larval card strips

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 freezing chamber of the refrigerator to immobilise them. The weight of each larva was ranged from 30 - 50 mg (mean 41.02 mg). After immobilisation, the larval head and thorax were stuck on the larval card strips with the help of cellotape stripes of about one centimeter breadth, leaving rest of the larval body free. A total of 50 larvae were stuck on a single strip in two rows (Plate 4). Number of such LCs 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 alive condition provided no fungi or any disease sets in. By using this procedure Sahayaraj (2002) reared *R. marginatus* at four densities (25, 50, 75 and 100 predators/rearing container), the results are presented here.


a
b
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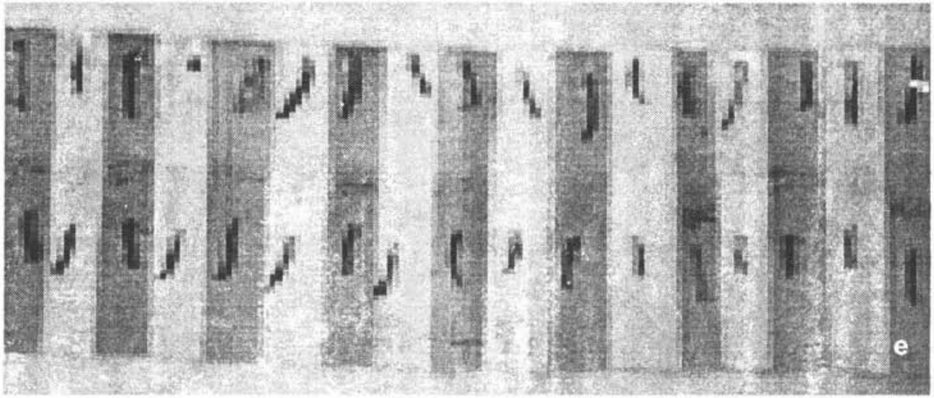


Plate 4. Preparation of larval card (a - collection of *Corcyra* larvae; b - larval card; c - larval card with larvae; d - feeding of larvae by reduviid nymphs and e- larval card after feeding.

6.7.2 Biology

In all the four predator densities tested, the shortest total developmental period (44.23 days) was observed in 50 predator group 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 more suitable for *R. marginatus* (Table 6.4). 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. 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.

Table 6.4. Effect of predator density on developmental period 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	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

Values in the row with same letters are not significantly different at p = 0.05 using the DMRT.
Source: Sahayaraj (2002)

Nymphal survival rate decreased as the predator density increased. In 25 and 50 predator groups, the total nymphal survival was 92 per cent and 90 per cent respectively. In 75 and 100 predator groups, the survival was 70 and 67 5 per cent respectively. Statistical analysis showed that mortality data were highly significant ($p < 0.05$). These decreases in survival rates at high predator densities occurred because all the prey was not equally available to each predator and those predators fed less tend to become cannibalistic. But cannibalistic behaviour was not observed among the immatured stages of *R. marginatus*. In the present study, the nymphal mortality at 25 and 50 predator categories were very low when compared to that in higher density categories.

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 ($P < 0.05$). Since many reduviid predators, including *R. marginatus*, have a similar haplodiploid method of sex determination, higher predator population may also affect their sex ratios in the same manner. The effect of crowding on the sex ratio has not been clearly understood in many reduviid studied. So further detailed studies are necessary to find out the relationship between crowding and sex ratio. Females emerged from 50 individual category lived longer (148.4±8.5 days) than males (132.2± 11.9 days) and the statistical comparison between the groups was significant ($P < 0.05$). The longevity of females is higher than that of the males in many reduviids. Contrarily, it was found that except in the 50 predator category in other three categories it was *vice-versa*. Among the four predator densities tested, the males from the 25 predator category lived shorter than other categories, even though, the statistical significance ($P < 0.05$) was observed only between 25 to 50 and 25 to 100 for males and females respectively. The co-presence of male with the female appeared to have some influence on the survivorship of the female predator. How the presence of male affects the physiology of ageing of female predator is not explainable at present. Female longevity is an important factor for determination of the reproductive period and the rate of oviposition. In all the categories the females lived longer than the males.

6.7.3a Fecundity

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 point of view of biological control. The shortest pre-oviposition period (28.95 ± 1.1 days) was observed in 50 predators group followed by 25 (38.40 ± 1.186 days), 75 (41.05 ± 3.096) and 100 (45.4 ± 2.092) predator categories. All the pre-oviposition data were statistically significant ($P < 0.05$), except between the 25 to the 75 predators density. Total number of eggs per female was the highest in 50 predators group (770.03 ± 69.6 eggs) followed by 25 (632.10 ± 87.9 eggs), 75 (470.6 ± 61.2 eggs) and 100 (391.46 ± 57.0 eggs) predator groups (Table 6.5). The comparison between the different predator densities were statistically significant ($P < 0.05$) The total eggs per female in 50 predator category was nearly two-fold higher than 100 predator category. Among the four densities tested, the average number of eggs per batch was the highest and lowest in 50 (42.8 eggs) and 25 (31.3 eggs) predator category respectively and the results were statistically significant ($P < 0.05$). Incubation period was comparatively lower in the 50 predator group (6.32 ± 0.1 days) and was not significantly different from the other categories. Hatching per cent was the highest in the 50 predators category (88.8 ± 1.1 per cent) and the lowest in 75 predator category (82 6 ± 2.1 per cent) and the data were not statistically significant.

Table 6.5. 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	$38.4 \pm 1\ 2^{a}$	$29.0 \pm 1\ 0^{b}$	$41\ 1 \pm 3\ 1^{c}$	$45\ 4 \pm 2.1^{c}$
Oviposition period	$127\ 1 \pm 6\ 5^{a}$	114.4 ± 7.7^{b}	$122\ 1 \pm 9\ 0^{ac}$	95.7 ± 11.1^{d}
Total number of eggs/female	$632\ 1 \pm 88\ 0^{a}$	$770.0 \pm 69\ 6^{b}$	$470\ 6 \pm 61.2^{c}$	$391.5 \pm 57\ 0^{d}$
Incubation period	6.5 ± 0.1^{a}	$6.3 \pm 0\ 1^{ab}$	$6\ 8 \pm 0\ 03^{abc}$	$7.0 \pm 0\ 1^{bc}$
Hatchability (%)	$86\ 4 \pm 1\ 5^{a}$	$88.8 \pm 1\ 1^{ab}$	$82\ 6 \pm 2\ 1^{ac}$	$86.6 \pm 3\ 4^{abc}$
Average number of eggs/batch	$31\ 3 \pm 6\ 31^{a}$	$42\ 8 \pm 7.2^{b}$	34.7 ± 5.4^{ac}	$33.5 \pm 6\ 4^{acd}$

Source Sahayraj (2002)

Values in the row with same letters are not significantly different at p = 0.05 using the DMRT.

6.7.3b Life table

The life table parameters of *R. marginatus* on the four predator densities is given in Table 6.6. 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 categories, respectively. The corrected mean generation time (T) was more or less equal in 25, 50 and 75 categories in the laboratory. The true intrinsic rate of natural increase (rm) was calculated graphically and it came to nearly 0.053 for 25 and 50 predator categories and 0.047 for 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 having overlapping generations. 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 same in the former two (25 and 50 predator/container) and later two predator categories. Furthermore, the time required to double the population was increased as the predator density was increased. The weekly multiplication rate of *R. marginatus* was the same in 25 and 50 predator categories and 75 and 100 predator categories. This predator had quicker rate of multiplication than other reduviids such as *A. siva*, *C. gilvus*, and *A. pedestris*. 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.

6.7.4 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

Table 6.6. Life table parameters of *R. marginatus* by larval card method

Demographic parameters	Predator density			
	25	**50**	**75**	**100**
Net reproductive rate, Ro = Σ 1xmx	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 numbers(rc)	0.043	0.042	0.038	0.387
Corrected rm	0.0517	0.0518	0.047	0.046
Corrected generation time (T)	109.28	109.942	109.83	106.989
Finite rate or increase in numbers (λ)	1.053	1.053	1.048	1.047
Rate of weekly multiplication (RWM) of the population	7.371	7.371	7.336	7.332
Doubling time (DT) (Days)	13.437	13.68	14.827	14.975

Source: Sahayraj (2002)

levels (14.3, 14.9, 15.6 and 16.6 for 25, 50, 75 and 100 predator densities respectively) However, the difference was very low and not statistically significant. The total number of prey consumed by each stadium was gradually increased from first nymphal instar to the fifth nymphal instar. 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, lower and higher rate of feeding per individual per day was observed during the nymphal period (0.31, 0.34, 0.33 and 0.33 for 25, 50, 75 and 100 predator / container) and adult stage (0.92, 0.94, 0.85 and 0.95 for 25, 50, 75 and 100 predator density) respectively. Lakkundi and Parshad [1987] 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 predator. During the entire life time, a minimum number of preys 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 ($P < 0.05$).

6.7.5 Larval cord Production Cost

Considering the higher fecundity, shorter nymphal development, pre-oviposition and incubation periods and female biased sex ratio obtained in the treatment with 50 predators/rearing container it may be concluded that the optimum density for rearing *R. marginatus* is 50 predator/container. Rearing 4167 nymphal instars of *R. marginatus* required 12,441 *Corcyra* larva (525, 1166, 2083, 3192 and 5475 larvae separately for first, second, third, fourth and fifth instars respectively). Since we were accommodating 50 larvae in an LC, 249 larval cards were necessary for rearing 4167 *R. marginatus* nymphs. The cost of production of 5000 reduviids came to around 410 rupees (See Table 6.7.). The newly formulated culture medium was enough to rear the *Corcyra* larva for three generations consequently. In such a situation, the cost of *R marginatus* production could be reduced to 350 rupees.

Table 6.7. Budget for rearing 5000 *R. marginatus* on *C. cephalonica* larvae by larval card method

Ingredients/materials	Quantity	Amount Rs. P.
Jowar	4 kg	24.00
Groundnut	1 kg	26.00
Ricebran	2 kg	04.00
Streptomycin	15 mg	00.60
Multivitamin 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
Workers salary (@ Rs.30/manual day)	8 days	240.00
Total cost		408.10
Rounded off amount @		Rs.410.00
@		$ = 9.53

6.7.6 Advantages of LC

The system described is a simple, easily managed production programme for producing relatively small numbers of reduviids. It uses materials that are available in most of the laboratories (including labour), which means that many of the costs outlined in the tables are overstated. By using this method we produced nearly 5000 reduviids per generation. 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 to 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 is remanded from the classical work about the role of hormones for moulting by Kopec [1922] 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 LCs gave the reduviids more surface area for movement and resting. Remaining 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 in the quality of food for the reduviids. From the results, he 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 number 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* NPVs (Rs 1800 or $ 41.86).

6.8 Frozen Larvae

Many reduviid biologists reported previously that reduviids feed only on live and agile preys. Since reduviids feeding both alive and non-alive preys, the idea has been changed during the course of time. Suitability of dead larvae of *Bombyx mori* and frozen larvae of *Psorocampa denticulate* to reduviid predator like *Apomerus* sp. and *Montina confusa* and hot-water killed larvae of *Tenebrio molitor* (Linn.) and *H. armigera* to another reduviid, *Pristhesancus molitor* (Walker) (Grundy *et al.*, 2000) were studied. Sahayaraj and Jeyalekshimi (2002) compared the effectiveness of alive and cold-killed *C. cephalonica* on the development, fecundity and hatchability and predatory behaviour of *R. marginatus*. Nymphs supplied with an AL (Alive larvae) throughout development had a mean developmental period of 41.00 ± 0.2 days, which was significantly shorter ($P < 0.05$) than those nymphs reared on the FL (48.66 ± 1 6 days). Among the five instars, the shortest instar was the second except the FL (frozen larvae) fed instars, and the longest was the fifth instar (Table 6.8) (Figure 6.1). Nymphal mortality within type of the prey was higher during the early developmental stages which suggested that cannibalistic behaviour (observed usually among older instars) was not the primary cause of mortality. Moreover, type of larvae had significant impacts ($p< 0.05$) on the mean total nymphal survival rate of the predator (82.8 and 92.2% for AL and FL, respectively). Male biased sex ratio was observed in *R marginatus*, which were reared on AL and FL (0.418 and 0.459). Chi square test shows that the result is significant between male and female sex ratio of these two categories. Irrespective of the larval nature, both in the AL and FL categories, the male predators lived longer than the females Both the male (141.91 ± 10.87) and female (123 5 ± 13.5 days) of test individuals fed with AL had the longest adult longevity. A significant difference was present between groups reared on AL and FL respectively (P<0.05). Similarly statistical significance (P<0 05) was observed between male and female adult longevities

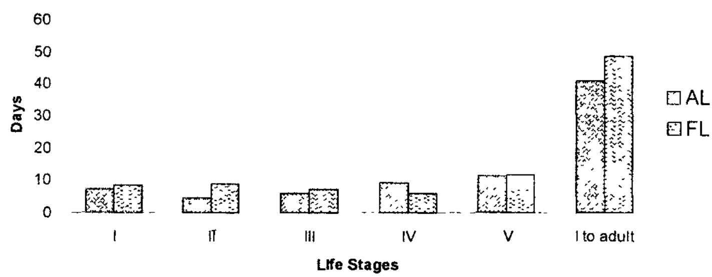


Fig. 6.1. Impact of alive (AL) and frozen larvae (FL) on the developmental period (in days) of Rhynocoris marginatus

The shortest pre-oviposition period was observed among the females fed with the AL (20.4 ± 1.01 days) than the FL category (29.8 ± 2.2 days) (Table 6.8). Furthermore, the AL fed group had relatively longer life span and had shorter pre-oviposition period. The maximum fecundity (266.5 ± 80.77 eggs/female) was recorded among the females fed with AL than FL (235.5 ± 80.77 eggs/female). More number of batches of eggs (6.8 ± 2.15), highest average number of eggs per batch (39.1 ± 4.75), and maximum number of eggs per batch (71.2 ± 3 18) were recorded among the females fed with AL. The maximum number of nymphs emerged from the *R marginatus* in AL (77.1%) than FL (68.69%).

Table 6.8. Alive (AL) and frozen (FL) *C. cephalonica* larvae on the fecundity and hatchability of *R. marginatus*

Parameters	AL	FL
Pre-oviposition period (in days)	20.4 ± 1.0 [a]	29.8 ± 2.2 [b]
Number of batches of eggs/Female	6.8 ± 2.2 [a]	6.1 ± 1.9 [a]
Total number of eggs laid/Female	266.5 ± 84.2 [a]	235.5 ± 7.4 [b]
Average number of egg/batch	39.19 ±4.8 [a]	38.60 ± 4.9 [a]
Minimum number of egg/batch	14.66 ± 4.63 [a]	10.1 ± 3.2 [b]
Maximum number of egg/batch	71.2 ± 3.2 [a]	61.2 ± 2.7 [b]
Hatching percentage	87.15 [a]	68.69 [b]
Post oviposition period (in days)	27.5 ± 2.01 [a]	16.0 ± 5.1 [b]

Values followed by same letters between rows are not statistically significant at 5% by DMRT
Source: Sahayaraj & Jeyalakshmi (2002)

When we provided the frozen larvae, both the approaching and arousal behaviours are delayed (Figures 6.2 and 6.3). Furthermore, the number of larvae consumed by a *R. marginatus* during its immature stage shows that the total predatory rate was maximum and minimum in AL (49.63) and FL (43.56) respectively. All the nymphal instars of *R. marginatus* except first instars fed on FL had lowest predatory rate. Similarly, all instars of the predators except the fifth instar fed on frozen larva had the highest prey consumption. The heaviest adult was observed in the test individuals fed with AL (154.6 ±7.37mg) than FL (151.5 ±7.91mg).

The data on age specific fecundity and the life table parameters of the predator *R. marginatus* are presented in the Tables 6.8 and 6.9. The results indicate that both the survival and the female birth of *R. marginatus* varied when reared on *C. cephalonica* in two different conditions (AL and FL). The highest survival and the female birth were noted on *R. marginatus* fed with AL. The schedules of survival for female (lx) were gradually decreased when the predator grew older. The net reproductive rate (R_0) of *R. marginatus* fed with AL was higher (205.48) than on FL (156.7) The intrinsic rate of population increase (r_m) was more or less similar in both AL and FL The mean length of generation was shorter on FL (84.95). The doubling time

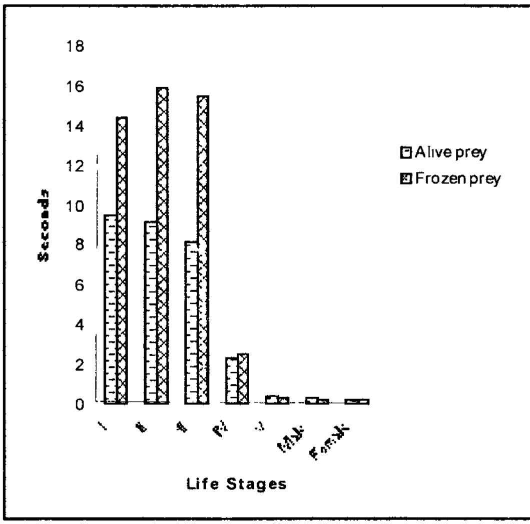


Fig. 6.2. Approach behaviour (in sec) of R. marginatus on alive and frozen prey (n = 20; X)

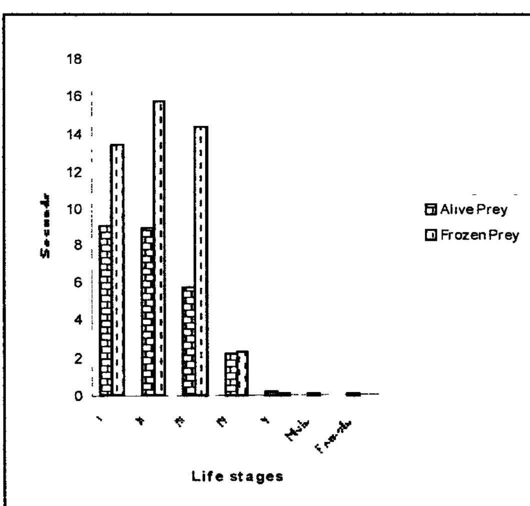


Fig. 6.3. Impact of the (AP) and Frozen prey (FP) on the arousal behaviour or R. marginatus

was more or less similar on AL and FL (Table 6.9). The present study has showed that *R. marginatus* can develop and reproduce on both AL and also on FL. Shorter developmental time, pre-oviposition period, and heaviest adults, highest hatching percentage was observed on AL. This group also had maximum egg production and hatchability. Hence, thyroxin can be incorporated in the *C. cephalonica* rearing medium. Similarly FL also makes an ideal prey for the mass rearing of *R. marginatus*. Hence, FL will be useful tools for mass rearing of reduviids.

The morphometric data show the maximum head (0.44 and 0.15 mm for length and width respectively), thorax (0.98 and 0.52 mm for length and width respectively) and abdominal length (0.81 and 0.49 mm for length and width respectively) are observed in *R. marginatus* fed with AL. This was reduced in FL category *R. marginatus* head (0.43 and 0.15 mm for length and width respectively), thorax (0.97 and 0.46 mm for length and width respectively) and abdominal length (0.78 and 0.47 mm for length and width respectively). However, the statistical analysis showed that AL was significant to the FL. As observed for the various parts of the body the total body length of AL was longer (1.79 cm) than the FL (1.68 cm).

Under natural as well as in the laboratory condition, *R. marginatus* feed on many agricultural and forest pests. Predatory behaviour of *R. marginatus* is observed in sequential patterns as follows: arousal – approach – pouncing – rostral probings – paralysing the prey – piercing and sucking and post predatory behaviour. In the capturing response, the early nymphal instars took less time when they are provided with AL (18.45, 17.21 and 13.80 seconds for first, second and thirst instars respectively), than the FL (37.7,30.16, and 29.8 seconds for first, second and third instars respectively) and the data were statistically significant ($P<0.05$). The time was further reduced in the fourth, fifth instars and adults when they were provided with AL and FL. After the third instar the capturing time was lesser in FL than the AL. However, they were statistically insignificant. Among the adults, female took less time for capturing than the male.

Table 6.9. Influence of live (AL) and frozen (FL) larvae of *C. cephalonica* on the life table parameters of *R. marginatus*

Demographic Parameters	AL	FL
Net reproductive rate ($R_o = \in lx.mx$)	205.48	156.7
Mean length of a generation ($T_C = \in lx.mx$)	90.43	84.95
Innate capacity for increase in numbers ($r_c = \log_e R_o/T_c$)	0.058	0.059
Corrected r_m ($r_m = \in C^{7-mx}.lxmx$)	0.069	0.067
Corrected generation time ($T = \log_e R_o/r_m$)	77.17	75.43
Finite rate of increases in numbers ($\lambda = e^{rm}$)	1.07	1.06
Rate of weekly multiplication (RWM) of the population (e^{rm7})	7.49	7.48
Doubling time (Dt) days ($\log e^2/r_m$)	10.13	10.41

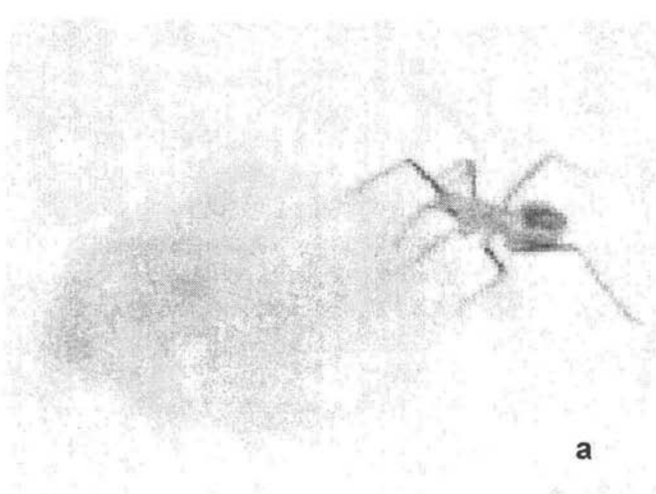
From this observation we conclude that it is feasible to use the frozen larva for fourth and fifth instars and adults respectively. Weight was not significantly different from the AL (154. 6 mg/adult) to FL (151.5 mg/adult). Our experiments demonstrate that *R. marginatus* nymphs and adults have the capacity to consume large number of the cold-killed immature stages of *C. cephalonica*. The developmental time, nymphal and adult survival, size and weight of the adults, fecundity and hatchability, predatory behaviour and predatory rate in relation to that of its prey nature appeared to be the major factor determining success in the rearing. Such observations suggest that cold-killed larvae of *C. cephalonica* can be used for rearing this predator. The study will provide a basis for the further research focusing on its characteristics and its potential as a pest control agent in IPM.

6.9 Artificial diets on reduviids behaviour and biology

A key goal for the successful biocontrol programme is to produce the biocontrol agent in large number with effective and economically profitable technique in mass rearing. Successful development of such technologies based on artificial media or ligidic diets. This requires through knowledge of entomophage behaviour, biology and physiology. Though some promising results obtained in the development of artificial diets for entomophages, the use of artificial diets in mass propagation programmes are very limited to only a few heteropteran predators like pentatomids, anthocorids, and geocorids. Two types of oligidic diets can be used in the field of predators rearing, one is an oligidic diet free of insect components and another one is oligidic diets insect components. Since reduviids use chemical cues for prey search and acceptance, artificial diets can be used for rearing them in mass (see chapter 3). So far none of the reduviid was reported to feed on artificial diets. For the first time the author took some effects to rear the reduviids by artificial diets. Both insect based and meat based artificial diets have been tried by the author to rear the four reduviids from *Rhynocoris* genous (Plate 5). As an initial step Edwards (1962b) tested the water drinking behaviour of Rhynocoris carmelita, Platymeris rhadamanthus and reduviiud personatus.

6.9.1 Artificial Diet Preparation

The artificial diet was prepared following the method used by Cohen with some modifications 100 grams each of *Bombyx mori* pupa, *Coracyra cephalonica* larva, *Egocera venulea* larva, pig liver and pig blood were dried in hot air oven at 60°C for 24 hours. After drying they were ground well by using morter and pestle and stored in refrigerator for further use. They were considered as source



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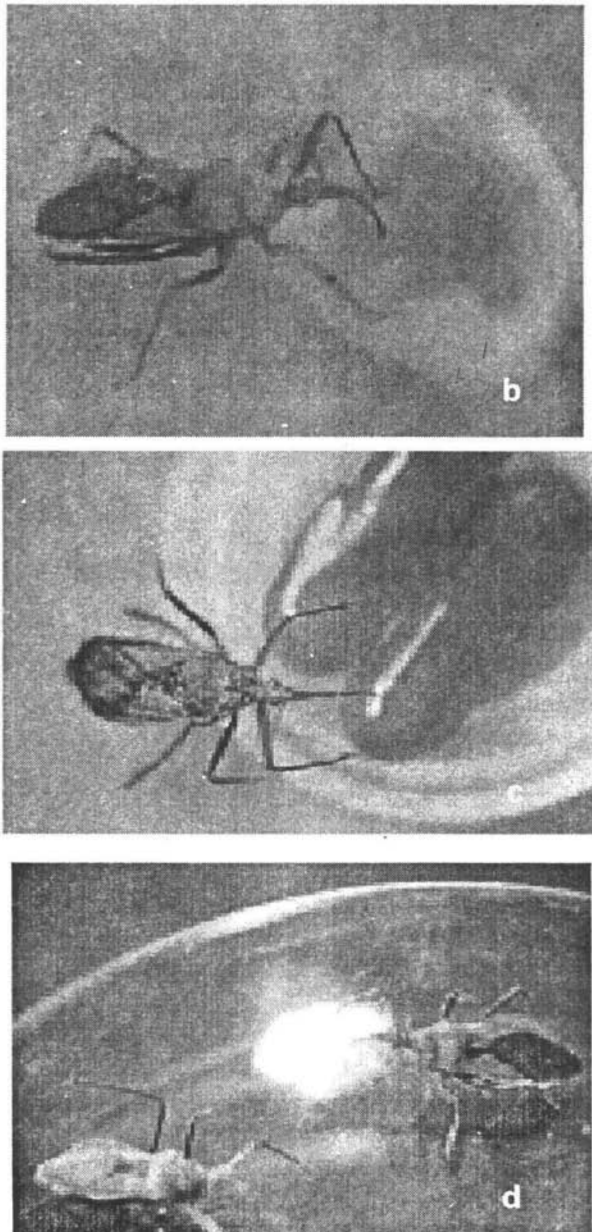
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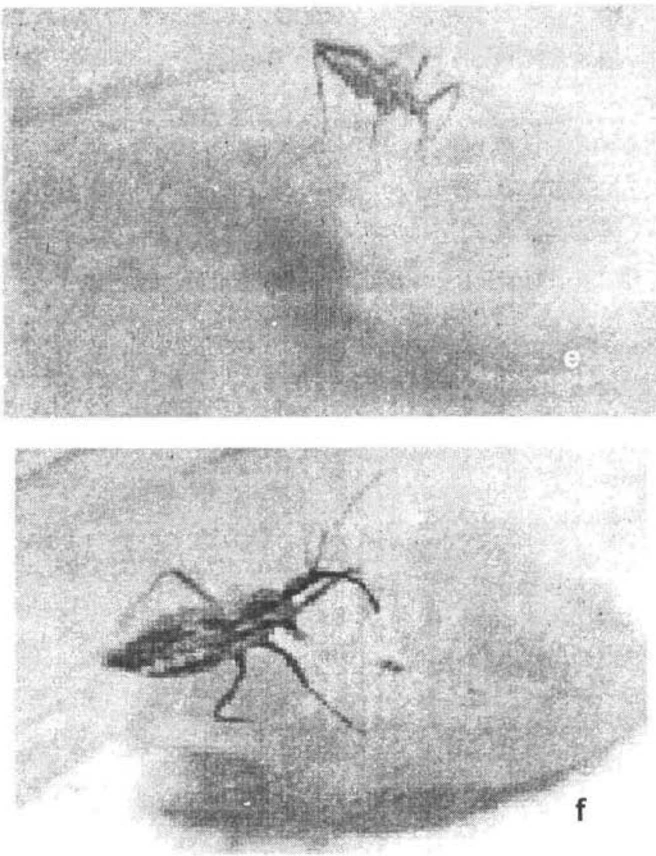

Plate 5. ***Rhynocoris marginatus*** **(a-d),** ***R. fuscipes*** **(e) and** ***R. kumarii*** **feeding on artificial diets and water (d)**

ingredient. Hundred millilitres of distilled water was taken in 500 ml glass beaker and it was boiled at 100°C for 20 minutes. Ten millilitres of the boiled water was taken for dissolving the milk powder (Lactogen, Nestle, Mumbai) and it was allowed to cool. Beef extract, dried egg yolk, honey (Dabur Narendrapur, West Bengal), acetic acid, NaCl and KCl (Glaxo, Gujarat) were added to the remaining 90 ml water and again it was boiled at 100°C. After 10 minutes the temperature was reduced to 40°C and then the source ingredient (BMP, CCL, EVL, PL or PB), vitamin and streptomycin (Sarabairaman, Vadodara) were added and stirred for thorough mixing. Then the milk powder solution was added and stirred well. After the thorough mixing the prepared diet was allowed to cool at room temperature and then it was filtered through Whatmann No.1 filter paper. Filtered liquid diet was stored in 125ml reagent bottles in refrigerator for the future use (Table 6.10) .

Table 6.10. Ingredients of Artificial Diets (100 ml.)

Components (in mg/ml)	F_1	F_2	F_3	F_4
Source ingredient (mg)				
BMP,CCL,EVL,PL,PB	500	1000	2000	4000
Beef extract (mg)	750'	1500	3000	6000
Milk Powder (mg)	500	1000	2000	4000
Egg yolk (mg)	500	1000	2000	4000
Honey (ml)	5	10	15	20
Vitamin (multivit mg)	10	20	40	80
Acetic Acid (ml)	3.7	3.7	3.7	3.7
NaCl (mg)	5	5	5	5
KCl (mg)	5	5	5	5
Streptromycin (mg)	75	75	75	75

6.9.2 Object Preference Test

Before providing the artificial diet it is essential to know the object through which the diet has been provided to the reduviid. Four types of objects such as cotton, foam, paraffin capsule and cavity slide with diet have been tried. Among the four objects tested, *R. marginatus* preferred cotton and it was the suitable object for providing the liquid artificial diet because artificial diet soaked in cotton has the minimum approaching time and maximum feeding time than the other three objects. Fifth, first nymphal instars and adult approached the cotton within 3.3 min., 5.15 min and 7.26 min, respectively. Adult, fifth and first instars consumed the artificial diet more time in cotton and it was recorded as 7.09, 4.86, 3.13 min respectively. Thus the result suggested that cotton was the suitable object because the reduviid inserted its rostrum and sucked the content easier than from other object. Furthermore, the cotton was the cheapest one. A successful diet must utilise inexpensive source of these substances.

6.9.3 Preference of *R. marginatus* on protein-x fortified artificial diet

In order to increase the nutritional quality, protein-x was fortified with the SL based artificial diet. The tested first and third nymphal instars highly preferred the 5 per cent protein fortified diet and they took 16.59 min, 22.24 min respectively for consuming the diet. The same trend was observed when the adults were tested on artificial diet, their consumption time was 16.24 min

6.9.3 Feeding behaviours

6.9.3a Approaching Time

Previously it was reported that reduviids eat only living and moving preys. In contrast, Edwards (1962b) studied the drinking behaviour of Rhynocoris carmelita, and Platymeris rhadamanthus and found that drinking was stimulated by contact between water and the tibial pads of the forelegs and midlegs, the tips of antennae or rostrum. Similarly, irrespective of the diet as well as their concentration tested all the reduviid predators approached the artificial diets including the control soaked with water (Plate 5). All the animals expressed a quicker response towards at least any one of the concentration of insect based diets. For instance, *R. marginatus* at F_4 of EVL; *R. fuscipes* at F_1 of CCL and F_2 of EVL; *R. kumarii* at F_3 and F_4 of SWP and F_2 of CCL and *R. longifron* at F_4 of CCL. All the reduviids immediately approached insect-based diet but no such quicker response was not observed in the meat-based PL and PB diets. Among the meat-based diets PL recorded optimum time (1.67-22.016) for triggering the response, while the control set recorded minimum time for approaching (0.54-6 83%).

6.9.3b Consumption Time

Even if the control (water soaked) diet recorded minimum approaching time, the feeding time was also higher (0 11 to 6.42%). Even though the maximum feeding time of 32.2 per cent was recorded by *R* *fuscipes* on the F_2 of PL; *R marginatus* recorded more time in all the four formulations of PL diet with the time ranging from 15.01 to18.58 per cent and a cumulative of 65.49 per cent whereas *R.longifron* recorded an optimum of 20.77 to 14.15 per cent time on PL diet and the *R. kumarii* recorded the lowest (3.76 – 14.77%) values. Among the insect-based diets, CCL recorded highest feeding time by all the reduviid predators, of which *R. marginatus* recorded a maximum of 29.58 per cent time in the fourth formulation and a cumulative of 52.94 per cent followed by BMP (20.09 and 36.23%). EVL recorded lowest feeding time followed by meat-based PB diet with no feeding or below the control diet This observation suggested that drinking of artificial diet is a common phenomenon of reduviids, and therefore nymphs and adults derive some benefit from the diet

6.9.3c Access Proportion Index (API)

The calculated API values showed all the reduviid predators responded positively towards PL diet in which *R. marginatus* and *R. fuscipes* preferred F_2 (+0 63 and +0 88 respectively), whereas *R. kumarii* (+0.70) and *R. longifron* (+0.82) preferred F_4. Irrespective of the insect-based diets, all the predators preferred F_3 of BMP. However, *R. marginatus* and *R. fuscipes* preferred F_3, *R. kumarii* preferred F_2 and *R. longifron* preferred F_1 of CCL. The F_4 of EVL was preferred by all the predator except *R.marginatus* (Table 6.11).

6.9.3d Food Preference Index (FPI)

Among the experimental animals, *R. marginatus* recorded the highest FPI value (+0.63) followed by *R. longifron* (+0.47) and *R. fuscipes* (+0.45) in the meat-based PL diet. While we consider the insect-based diets, the highest FPI (+.0.24) was recorded by *R. longifron* at EVL followed *R. marginatus* at CCL (+0.24). All other diets showed negative values. All the experimental predators preferred meat-based PL diet with the rank I followed by CCL with two 2nd ranks and two 3rd ranks; BMP with one 2nd, two 3rd and one 4th rank; EVL with one 2nd, two 4th and one 5th rank and PB with one 4th and three 5th.

and it was declined when we compare *R. longifron* to *R. marginatus* and *R longifron* to *R. kumarii* (+0.7). The similarity was further decreased between *R. longifron* and *R. kumarii* (+0.3), and no negative similarities were observed among the predators. These results also coincide with the rank correlation values obtained for.

Table 6.11. Cumulative Approaching and Consumption Time (in percentage) and Food Preference Index (FPI) and Ranking of Reduviids on Artificial Diets

Species	Diet	Approaching Time (percentage)	Cunsumption (percentage)	Food preference index	Rank
Rhynocoris	BMP	41.96	36.23	-0.07	3
marginatus	CCL	32.33	52.94	+0.24	2
	EVL	28 08	12.50	-0.38	4
	PL	14 85	65.49	+0.63	1
	PB	56.24	3.07	-0.89	5
Rhynocoris	BMP	36.17	18.58	-0.32	2
fuscipes	CCL	40 13	8.17	-0.66	3
	EVL	39.00	2.03	-0 90	5
	PL	25.54	65.14	+0.45	1
	PB	14.61	2.11	-0 75	4
Rhynocoris	BMP	28.24	6.78	-0.61	3
kumarii	CCL	38.35	13.30	-0.48	2
	EVL	53.51	11.08	-0.66	4
	PL	56 36	34.32	-0.24	1
	PB	27.25	2.86	-0.81	5
Rhynocoris	BMP	13.09	0.83	-0.88	4
longifron	CCL	44.00	14.31	-0.51	3
	EVL	17.57	30.18	+0.26	2
	PL	20.21	55.50	+0 47	1
	PB	30.07	1.67	-0.89	5

BMP – *Bombyx mori* pupa; CCL – *Corcyra cepalonica* larva; EVL– *Egocera venulea* larva; PB – Pig blood.; PL– Pig Liver

the feeding behaviour of reduviid predators on different artificial diets. All the predators showed highest similarity in their feeding behaviours on PL and PB diets (+1). In which all the animals were attracted and consumed at the highest degrees in PL and neglected or less fed on PB diet While all other comparisons except CCL Vs PB, BMP Vs EVL, PB Vs EVL and EVL Vs PL showed optimum positive similarities on feeding behaviour of predators (+0.4). Among those exceptions the latter two categories showed highly negative values (-1). Furthermore, while we comparing EVL with the meat-based diets the rank correlation were highly negative (–1)

API value was further changed if we provided *R. marginatus* with PL based oligidic diet. For instance, the API values were higher for first (0.67, 1, 1, 0.74), second (0.77, 1, 1, 0.71) and third (1, 1, 1, 0.72) instars as compared to fourth (0.66, 1, 1, 0.66) and fifth (1, 1, 0.5, 1) instars in the diet A maintained insects. For diet B maintained nymphs, higher (1, 1, 0.2, 1) and lower (0.2, 0.5, 1, 0.66) API values were observed for first and second instar nymphs respectively. However, in the diet C developed category, higher API values (0.71, 0.77, 0.77, 1) were observed for second instar and lower (0.75, 0.72, 0.6, 0.71) for V instar nymphs (Sahayaraj, 2005).

6.9.4 Feeding Behaviour

R marginatus nymphs and adult were found feed on the artificial diet as well as water (Plate 5). Generally, reduviid feed on a live prey. However, they attacked heat killed or frozen larvae of *Corcyra cephalonica* and other prey offered to them. When *R. marginatus* was provided with artificial diet, the predatory behaviour was similar to that of live or dead insect preys they encountered. The feeding of reduviid takes place in three phases such as injection of venoms and/or digestive enzymes, pause or mechanical action and sucking the liquefied materials. During predatory behaviour the predator injects the toxic venom, then removes the prey's haemolymph and body content. During paralysing the hemipteran predators injected the saliva (Miles, 1972) into the prey where it can affect liquefaction of a patch of prey solids. The liquefaction of body parts by the saliva, reduces the viscosity of the slurry. Then diluted slurry which is removed from the prey and then ingest into the gut of the predator. Hence we have prepared liquid artificial diet for this reduviid However, semi-solid form of artificial diet has been practised for rearing other hemipteran predators. Once the predator approached the cotton impregnated with synthetic diet or water, it protruded and inserted its rostrum into the cotton and sucked the content (water and artificial diet) This observation suggested that synthetic artificial diet as well as water attracted the bugs and stimulated them to arouse and approached This act is similar to the prey location behaviour of *R. marginatus* (Sahayaraj and Paulraj, 2001c) Reduviids not only feed the live and/or dead preys But also ingest water and artificial diets. Edwards (1962) studied the drinking behaviour of *R. carmelita*, *P. rhadamanthus* and *R. personatus* and found that drinking was stimulated by contact between water and the tibial pads of the forelegs and midlegs. Similar drinking behaviour was also observed in *S. diadema* (Taylor and Schmidt, 1996) and *R. marginatus* (Sahayraj *et al.*, 2003).

Table 6.12. Diets on the feeding behaviour, food preference index (FPI) and ranking by non- choice test

Diet	Approaching time (in percentage)	Consumption time (in percentage)	Food Preference Index	Rank
BMP	41.96	36.23	-0.07	3
CCL	32.33	52.94	+0 24	2
EVL	28.08	12.50	-0.38	4
PL	14.85	65.49	+0.63	1
PB	56.24	3.07	-0.89	5

BMP – *Bombyx mori* pupa; CCL – *Corcyra cephalonica* larvae; EVL - ; PL – Pig liver; PB – Pig blood

In general, the approaching time decreased when the predator grew older. Irrespective of the artificial diet tested in this study, *R marginatus* adult took more time to approach the artificial diet than the nymphal instars. Furthermore, *R. marginatus* was also approached the water source However, they are not statistically significant (P>0.05). Karl Pearson's Correlation coefficient showed that, the approaching time of *R marginatus* life stages in artificial diet with water showed high coefficient correlation (0.78). Harpactorine reduviids pins the prey by its rostrum and holds the prey by its legs (Ambrose, 1999), such a holding behaviour was observed when *R. marginatus* life stages provided with artificial diet. All the life stages of *R marginatus* consumed more amount of artificial diet than the water. Available literatures indicate that many insects drinks water both in natural and laboratory condition When we compare the feeding time on artificial diet with water, it showed positive correlation coefficient (0.68). First instar spends less time on feeding and it was increased when the predator grew older. Nymphs spent more time for feeding the artificial diet than the adults. Studies on food consumption and optimal foraging strategy often proceed under the assumption that all the extractable parts of the prey (artificial diet) are of equal value, generally in terms of energy reward Positive correlation was observed when comparison was made between the feeding times of water with S.L (0.68). During feeding *R. marginatus* try to deepen its rostrum into the cotton. This kind of activity was well pronounced in the later instars and adults than the early nymphal instars. Furthermore, *R. marginatus* pierced and ingested at various places. These are the peculiar behaviour patterns of harpactorine reduviid (Ambrose, 1999). *R. marginatus* life stages spend more time for resting than the approaching and feeding time. No definite pattern of resting was observed among the life stages of *R. marginatus*. Usually harpactorine reduviid does not show the resting act during feeding.

6.9.5 Super strain selection

First, second, third, fourth and fifth nymphal instars and adults of *R. marginatus* were collected from laboratory stock culture and were used for the strain selection studies. It is clear from the observations that 54.6 per cent of the first nymphal instars preferred artificial diet and it was increased to second (57.7%), third (60.6%), fourth (64.3%) and fifth nymphal instars (65%). The preference reached peak value (72%) when adults were provided with the artificial diet containing *S. litura* as source ingredient. When a statistical analysis was made between first and other nymphal instars and adults, except the second nymphal instars all other stages are significant at 5 per cent level. Later artificial diet was prepared by using beef liver as source ingredient and tested for strain selection. Nearly 70 per cent of the first instar nymphs preferred the diet. But the consumption time was very low when compared to *S.litura* diet. When the oligidic diet contain PL, 74 per cent, 50 per cent, 60 per cent, 70 per cent and 50 per cent of I, II, III, IV and V nymphal instars preferred diet 30 g/100 lm whereas 61 25 per cent 70 per cent 50 per cent, 60 per cent and 60 per cent of I, II, III, IV and V instars preferred diet 60 g/ 100 ml. Adults also preferred 30 g/100ml diet (80%) followed by 30 g/100 ml diet (70%).

6.9.6 Biology and survival rate

When *R. marginatus* was provided with PL based oligidic diets, the total nymphal period lasted for 147.8 days. First, second, third, fourth and fifth took 23.3, 16 2, 20.7, 35.3 and 52.5 days, respectively for completing their life. Shortest and longest nymphal developmental period were observed in the second instar and fifth instar, respectively. Generally in harpactorine reduviid the second and fifth nymphal instars are having shortest and longest developmental period respectively. However, it is essential to analyse the chemical composition of its natural prey and incorporate all the ingredients in to the artificial diet which may increase the dietary quality and subsequently reduce the developmental time and increase the percentage of adult emergence Maximum survival rate was observed in first nymphal instar (74.76%) and which was almost equal in the fourth (47.5%) and total (45.5%) nymphal instars survival rates. Minimum survival rate was observed in the second nymphal instar (40.1%). Though 210 *R.marginatus* were subjected to raise them in the laboratory on artificial diet only ten adults were emerged. The artificial diet containing all the required nutrients must be present. These nutrients must be properly proportioned in order to stimulate the normal life cycle of the insect. Recently, we (Sahayaraj and Sujatha, 2003 – unpublished data) reared this predator on PL based oligidic diets with three-concentration *viz.*, 15, 30 and 60 mg/100 ml liquid diet. The nymphs do not proceed their development for the 35 days. However, 30 and 60 diets categories were developed into adults. The developmental period of I, II, III, IV, V instar nymphs of *R. marginatus* were 14.05, 19.3, 24.27, 30.22 and 36.37 days respectively. In 60 gm, total nymphal period lasted for 143.6 ± 9.15 days. The developmental period observed in I, II, III, IV, V instar nymphs were 15.1, 22.15, 28.16, 34.5 and 41.28 days respectively. The total nymphal period lasted for 123.0 and days for 30g developed *R. marginatus*. The survival rate was maximum in *R. marginatus* reared on diet – B second instar (52.63%) which was almost equal to that of III instar (52.38%). Minimum survival rate was observed for

I instar (3.33%). In diet – C maintained *R. marginatus*, minimum survival rate was observed in I – instar (7.77%) and maximum for II instar nymphs (42.86%). The survival rate for III, IV and V instars were found to be 38.46 per cent, 40.00 per cent, and 33.33 per cent respectively.

6.9.7 Predatory potential

After feeding on artificial diet for about 30 days, adults of *R. marginatus* readily attacked active prey. The maintenance of the predator for 30 days on artificial diet did not affect the predation capacity of this reduviid. The current results corroborate the findings of other authors in heteropteran predators. In the laboratory, adult fed on artificial diet were more aggressive (consumed 6 0 fifth instar larvae of *C. cephalonica*/predator/day) than those reared on *C. cephalonica* (4.3 larvae/predator/day). Reduviid reared on artificial diet can also be incorporated in to the IPM programme

6.9.8 Deformities

Deformities were observed mainly in the cephalic appendages of fore, mid and hind legs of the adults maintained with 30g and 60g oligidic diets. Among the nymphal stages the deformities were observed only in the fifth instar nymphs. The fifth instar and adults fed with diet B had long and bent hind legs. Wing deformities and short legs were also observed in one of the 30g developed adults. Deformities in the fore, mid and hind legs were observed in the 60g developed adults.

6.9.9 Weight gain and size

In the experimental group the weight gain was maximum for the predators maintained on diet C (2.41, 6.65, 12.90, 18.38, 32.40, 68.33 for I to adult respectively) than those fed with diet B (2.1, 3.32, 11.25, 14.84, 22.78, 74.4). However, the weight gain was significantly higher in the control category (6.43, 11.55, 21.33, 34.78, 48.60 and 107.00 for I, II, III, IV, V and Adult respectively). There is a positive correlation was observed between the developmental period and the weight of the insects. Morphometry analysis revealed that in both categories (30 and 60 g/100 ml PL diet), the females were slightly larger than the males. While considering the total length of the adult insects maintained on 30 gm (diet B), they are slightly higher than the 60 gm (diet - C) maintained animals. However, they were not statistically significant. At the same time, length of the head and forelegs of II instar *R. marginatus* did not differ significantly in both of these diets.

6.9.10 Adult longevity, sex ratio and reproduction

Female biased sex ratio was observed in diet (B) 0.25 male, 0.75 female and also in diet C (0.57% Female) (0.43% Male). In both the categories, the males lived longer than the females. The adults of R. marginatus emerged from diet B fed group survived for a period longer (33 and 35 days for male and female respectively) than those fed with diet C (30 and 27 days for male and female respectively). However, control maintained predators longevity is higher (41 to 43 days) than these two oligidic (30, 60 gm) diets. Oviposition was not observed in the adults emerged from the two categories that were fed with both of the oligidic diet.

6.9.11 Biochemical analysis

In biochemical analysis of the oligidic diets (A & B) shows that the 15 gm artificial diet consists of 0.46g/ml, 0.34g/ml and 0.23g/ml of carbohydrate, protein and lipid respectively. Similarly carbohydrate, protein and lipid contents of diet B were found to be 0.6g/ml, 0.46g/ml and 0.29g/ml respectively.

6.9.12 Protein profile

The protein profile of the haemolymph of IV, V instar nymphs and adult *R. marginatus* reared on artificial diet 30g (diet B) and 60g (diet C) and factitious host, *C. cephalonica* (control) was studied. Rearing in different media resulted in qualitative changes in the various proteins in the haemolymph. The haemolymph of IV instar *R. marginatus* reared on *C. cephalonica* revealed 12 polypeptides in total of which three bands are overlapping with the haemolymph of IV instar *R. marginatus* reared on 30g and 60g artificial diet (Rf : 0.520, 0.740 and 0.840). One polypeptide (0.180) was shared between 30g and 60g maintained *R. marginatus*. Seven bands were found specific for control (0.140, 0.240, 0.460, 0.560, 0.580, 0.680, 1.06) and none for 30g developed *R. marginatus* respectively. Four polypeptides of Rf values 0.700, 0.760, 0.780 and 0.880 were found specific for *R. marginatus* reared on 60g artificial diet.

As many as 18, 16 and 19 polypeptides were found in the V instar *R. marginatus* reared on *C. cephalonica*, 30g and 60g artificial diet respectively. Six bands (0.260, 0.520, 0.580, 0.620, 0.660 and 0.740) were found similar in all the three. Four bands (0.040, 0.100, 0.180 and 1.000) were found common in 30g and 60 g developed insects. Three polypeptides (0.320, 0.420 and 0.880) between control and 30g developed nymphs and two polypeptides (0.800 and 0.940) between 60g and control nymphs were found common respectively. Seven specific polypeptides (0.080, 0.40, 0.200, 0.300, 0.560, 0.680 and 0.780) were observed in control animals. Only three bands (0.220, 0.440 and 0.820) were found specific in 30g developed nymphs against seven (0.240, 0.380, 0.480, 0.540, 0.840, 0.980 and 1.040) in those reared on 60 g artificial diet. Similarly, of the 24 polypeptides observed in control, eleven bands (0.108. 1.129, 0.172, 0.323, 0.473, 0.602, 0.839, 0.903, 0.968, 1.032 and 1.161) were found specific with seven bands (0.151, 0.215, 0.301, 0.581, 0.731, 0.860 and 1.118) overlapping with 30 g and 60 g developed animals. Five polypeptides (0.279, 0.559, 0.624, 0.817 and 0.882) were found common between control and 30 g developed adults. However, only one (0.796) was found common between adults reared on *C. cephalonica* and 60g artificial diet. Three bands (0.387, 0.495 and 0.538) were shared between 30g and 60g developed insects. Nine polypeptides (0.043, 0.086, 0.194, 0.237, 0.344, 0.516, 0.774, 0.946 and 1.011) and five bands (0.065, 0.258, 0.688, 0.925 and 0.989) were found specific for *R. marginatus* reared on 30g and 60g artificial diet respectively.

6.10 Recommendations

1. Instead of using alive larvae either heat or cold killed lepidopteran larvae having high protein level can be used for rearing the reduviids both in small and large scale.
2. It is essential to analyse the biochemical composition of the natural and factitious host and use them for preparing the artificial diets.
3. Suitable artificial diets which made either from insects or meat based can be incorporated in the field of reduviid mass production.

4. By using the artificial diet the mass production can be brought out at market level and also available to the farmers at low cost.
5. Oligidic diets will be tested and find out the suitable diet which could reduce the developmental times and increase the reproduction.
6. If oligidic diets could fail, then faciated and natural hosts will be recommended for the mass production of these fascinated insects.

7

Bio-safety of Pesticides and Biopesticides

7.1 Introduction

Insect pests were identified as a limiting factor in the sustainable development of agriculture. Biopesticides are target-specific and eco-friendly, in contrast to chemical pesticides and have the potential to revolutionise agriculture around the world. The group felt the need for research in the area of product development and technology transfer. The technology should be efficient, economical and accessible. The group expressed the need for the government, industries and NGOs to participate in training programmes for farmers and distributors of biopesticides. A multi-faceted approach and well-packaged technology and assured marketing were cited as being very important, and the state government and policy makers were urged to come forward. Some policy initiatives to facilitate the registration of biopesticides were discussed. The group felt that research on *neem* had grown in the last two decades and very useful products had been developed, but different combinations were needed to enhance the efficacy of *neem* products. The term 'biopesticides' needed more precise definition in view of the inclusion of GMOs, botanicals, biocontrol agents, plants etc. The need to establish a Neem Research Institute was also felt. No commercial sale of biopesticides without registration was recommended. The group also felt the need to include biopesticides in the package of crop practices distributed by state agriculture universities and state departments of agriculture/horticulture.

Presence of natural enemies including predators in any ecosystem is the crucial factor of pest management. While we spray the insecticide or biopesticides, most of the pests' populations are eliminated from the crop. Continuous and indiscriminate use of these pesticides in plant protection has resulted in toxicity to non-target beneficial organisms like reduviid predators. Realising the adverse effects of chemical insecticides, attention is now diverted in favour of non-chemical methods of pest management. Several scientists have already reported the safety of these biopesticides to non-target organisms over conventional pesticides. But reports on safety of botanical mixtures and microbial pesticides mixtures to non-target insects are lacking. Here we include different solvent extracts of plants, plant based and micro-organism-based insecticides as biopesticides. At the same time phytophagous insects are continually exposed to these kinds of toxins and they may be better insecticide detoxifiers. Generally, the predators and parasites are more susceptible to the pesticides. If all the preys are eliminated, the surviving predators will soon leave from the field or die. Hence, it is necessary to use the selective pesticide to eradicate the pests that would have low toxicity to the natural enemies and their non-pest prey. Furthermore, the degree of pesticidal effects varies according to their chemical composition. In order to develop a sound integrated pest management programme, it is quite necessary to have some knowledge on the safety of different pesticides and biopesticides to the natural enemy complex occurring in a given crop complex. Although many field and laboratory experiments have been carried out successfully to study the effect of pesticides on a variety of beneficial organisms, very little information is available for the reduviid predators.

7.2 Synthetic Pesticides

Vanderplank (1958) first reported that all the life stages of *P. rhadamanthus* are sensitive to various insecticides and although they take up to a week to die, they succumb to very minute dosages of D.D.T. lindane, dielldrin, chlordane and endrin. Martinez and Pienkowshi (1982) first initiated this work on *Raduviolus amaricoferus* Carayon. Martin and Brown (1984) studied the impact of acephate (O, S-dimethyl acetylphosphoramido thioate) a systemic insecticide on *Pristhesancus papuensis* (Walker) They reported that acephate was nine fold toxic to the reduviid than to its prey *Pseudoplusia includens* (Lepidoptera. Noctuidae). It inhibits the acetycholenestrase activity, rapidly converts the acephate to methamidophos, and decreases the overall rate of penetration, metabolism, and excretion. Furthermore, they reported that acephate was nine-fold more toxic to the reduviid than its prey soybean looper. The activation and accumulation steps are apparently the major reason for this effect they added.

In India, enormous amount of work was available about the impact of synthetic insecticides on predatory insects, mites and spiders. However, very little information was available for the reduviid hunter bugs. Sahayaraj (1991) first initiated this kind of work on reduviids. He studied the impact of three commonly used insecticides (rogor, fenvelorate and decamethrin) in cotton ecosystems on *Acanthaspis pesdestris* Stal. It is a common reduviid predator present throughout Tamil Nadu in all ecosystems like agroecosystems, semi-arid zones, scrub jungles and forest. All the three pesticides were found to be significantly toxic to the predator. Effect of these pesticides on behaviour was observed during the acute toxicity tests (96 hrs. exposure). The pesticide-test-individuals moved haphazardly, loosing their orientation, removed their camouflaging materials from the body, spitted saliva and often rubbed the rostrum in the prosternal groove indicating their resistances. These behavioural aspects were less pronounced in the test individuals exposed to lower concentrations (0.0028 and 0.0042%) of the pesticides. Initially the pesticide-exposed individuals showed faster movements and all these activities gradually diminished as the treatment was prolonged. Among the three pesticides tested, rogor was found to be more toxic and fenvalerate was less toxic to *Acanthaspis pesdestris* nymphs. The data on the mortality of the nymphal instars of *A. pesdestris* revealed that in the first nymphal instar, rogor 0.06 per cent caused 73.33 per cent mortality 24 hrs. after application which was followed by fenvalerate 0.04 per cent which gave 46.66 per cent mortality. Lower percentage of mortality was found in the low concentrations of all the three pesticides which increased when the concentration level was increased. He further pointed out that fifth instar *A. pedestris* was highly sensitive to both decis and rogor than to fenvalerate (Table 7.1).

Table 7.1. Ninety-four hours LD $_{50}$ values (in%) of three pesticides on life stages of *A. pedestris*.

Pesticides	First instar	Second instar	Third instar	Fourth instar	Fifth instar
Decis	0.003	0.030	0.043	0.043	0.014
Fenvalerate	0.015	0.060	0.054	0.054	0.078
Rogar	0.003	0.051	0.060	0.060	0.010

Source: Sahayaraj, 1991

Recently it was reported that cypermethrin affect the feeding behaviour by increasing the arousal, approach, capturing and sucking act of this predator (Claver *et al.*, 2003). They further reported that cypermethrin negatively affect the functional response and predatory efficiency of *A. pedestris.* As the result the type II (decelerating curve) of functional response was altered into a type IV (dome-shaped curve). Mundiwale *et al.* (1989) reported that fenvalerate was more toxic to *Chilo pastellus* Swinhoe. Fenevalerate is used to control insect pests which are resistant to chlorinated hydrocarbon (CH), organo phosphate (OP) and carbonate (CB). Even though it was reported as more toxic than CH, OP and CB, it was less toxic and safe to *A. pedestris* nymphal instars. So this pesticide can be integrated in IPM where *A. pedestris* is employed as predator. Similar trend was also observed in the remaining instars (I, II, III and IV instars) of A. *pesdestris.* Recently, Ambrose (2001a) pointed out that cypermethrin was also toxic to this reduviid. Ambrose and George (1995, 1996a, 1996b, 1998), George and Ambrose (1996, 1997, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d, 1999e, 2000) reported the impact of monocrotophos, quinalphos, dimethoate, endosulfan on the LC_{50}, stadial period, body weight, fecundity and hatchability, adult longevity, morphometry, predatory potential, haemogram and macromolecular compositions of three harpactorine reduviids such as, *Rhynocoris fuscipes, R. kumarii* and *R. marginatus.* They reported that all the pesticides prolong the post-embryonic development, alter the sex ratio, reduce the size and weight of the life stages, fecundity and the longevity, predatory rate, carbohydrate, protein, lipid and water content and alter the haemocyte count (increase the total and alter the differential count). While we consider the post-embryonic development, except the endosulfan all other insecticides significantly prolong the nymphal developmental period and also delay the adult emergence (Figure 7.1).

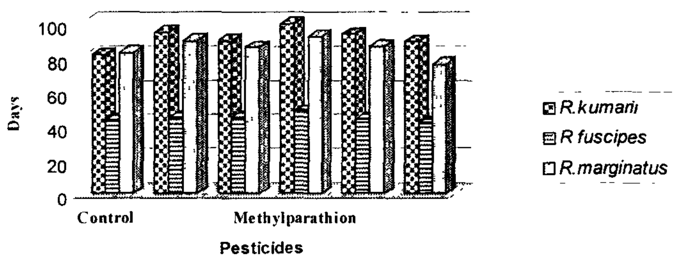

Figure 7.1. Impact of pesticides on nymphal development of three reduviids

Furthermore, they reported that these insecticides disintegrate the alimentary canal, testis and ovary and reduce sperm count and also distort sperms. For the better understanding of these aspects, kindly see Ambrose (2001a) review article. Recently Grundy *et al.* (2000a) evaluated the acute and residual effect of 11 commonly used insecticides on nymphs of *Pristhesancus plagipennis* (Walker) under laboratory and field conditions. Results suggested that carbaryl, esfenvalerate, endosulfan, and deltamethrin had low residual and acute toxicity to *P. plagipennis*, whereas chlorpyrifos, methomyl, and monocrotophos were highly toxic at low concentrations and left persistent harmful residues. Hence carbaryl, fenvalerate, endosulfan and deltamethrin may be suitable for integration with *Pristhesancus plagipennis* in biological control programme. All these results generally agree with published assessments of the effects of insecticides on other heteropteran and hemipteran predators.

7.3 Plant Based and Other Bio-pesticides

In recent years, IPM has gained increased attention as a potential means of reducing reliance on chemical pest control and thereby fostering the long-term sustainability of agricultural systems. Awareness has been created on the botanical pesticides as they have fewer side effects and more insect control property and prosperity through multifacious functions. Nowadays many plant-based insectides have been tested and practised by the researchers and farmers. Botanical insecticides are promising alternatives for use in insect management. However, like conventional synthetic insecticides, botanicals insecticidal have advantages and disadvantages and should be judged accordingly. Each compound must be evaluated in terms of toxicity, effectiveness, environmental impacts and costs. Even though botanicals insecticidal are naturally derived and are relatively safe if used properly, they are poisons and should be handled with the same caution as synthetic insecticides. What are botanical insecticides? Botanicals are naturally occurring insecticidal compounds derived from plants. They are processed into various forms which include: preparations of crude plant material; plant extracts or resins; and pure chemicals isolated from plants.

Subramanian (1993) documented the insecticidal plants in India. Jacobsen and Crosby (1971) reported more than 2000 plant species with insecticidal properties. Recently, Swaminathan and Jeyaraj (2002) explored the possibilities of utilising the plants in the pest management programme. Botanical pesticides do not kill the pest immediately and it leaves the vulnerable population to the natural enemies and keeps the continuous presence of the natural enemies, which take care of the residual population that is an important step in IPM. Though the impact of plant based pesticides on the insect predators were available, very little work is available on reduviids. Moreover, Biopesticides constitute a small but rapidly growing sector of the agrochemical industry.

As an initial step Sahayaraj and Paulraj (1999a) studied the impact of water extracts of *Azadirachta indica*, A. Juss., *Vitex negundo* Linn., *Pongamia pinnata* Vent., and *Calotropis gigantia* Linn. at 0.5, 1, 2, 4 and 6 per cent on *R. marginatus*. The eggs of the reduviid were dipped and immersed in 1 ml of each concentration separately in a Petri dish for 15 minutes then they were incubated on moist cotton swabs in plastic vials of 30 ml capacity. The results revealed that on an average, the incubation period was seven days for all the concentrations of the tested plants as well as control. All these plant extracts did not affect the incubation period of the *R. marginatus*. However, the tested plants affected the egg hatchability. Among the four plants, *C. gigantia* highly reduced the hatchability (19.60%) followed by *A. indica* (14.18%). Both the *V negundo* (5.22%) and *Pongamia pinnata* (4.98%) had similar impact Similar impact was observed when these plants were treated on nymphs and adults of *R.marginatus* (Sahayaraj and Paulraj. 1999b) They reported that nymphal instars were more susceptible to plant extracts than adults. Similarly, Sahayaraj *et al.* (2002c) observed that 0.25, 0.5 and 1.0 per cent water extract of *Coleus aromaticus* Benth (= *ambonicus* Lour) (family Laminaceae) did not cause any mortality to *R. marginatus*. However, 2, 4, and 8 per cent were significantly toxic to this predator. Among the life stages tested, first instar was 6.7 times less resistant than the fifth instar predator. *Pedalium murex* (Linn.) (Family: Pedaliaceae) caused minimum mortality when *R.marginatus* first instars was exposed by leaf dip method (Sahayaraj and Sathyamoorthy unpublished data). However, no mortality was observed in the remaining life stages. Phytoecdysone containing ferns such as *Christella parasitica* (Linn.) H.Lev., *Pteridium aquilinum* (Linn.) Khun and *Heminitis arifolia* (Burn) (Family: Pteridophytes) (Selvaraj and Sahayaraj, 2005) were tested against the life stages of *R.marginatus* (unpublished data). The results showed that none of these ferns caused mortality to this reduviid (Table 7.2).

Table 7.2. Plant extracts, Plant-based and microbe-based (*) commercial insecticides on the Mortality (in%) of *R. marginatus* life stages

Biopesticide	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Adult instar
C. parasitica	0	0	0	0	0	0
P. aqulinum	0	0	0	0	0	0
H. arifolia	0	0	0	0	0	0
C. aromaticus	9.11	3.33	3.33	3.33	2.22	0
P. murex	3.33	0	0	0	0	0
Nimall-300	1.30	0	0	0	0	0
Nivaar	5.31	1.32	0.67	0.21	0	0
Nimbicidine	13.465	13.3	3.32	1.27	0.58	0
Vijayneem	6.61	6.56	3.32	1.43	0	0
NPV (S)*	10.08	5.25	2.50	1.35	0	0
Exodus	60.00	53.00	46.66	26.00	20.68	20.00
Xerion	80.00	60.00	40.00	20.00	13.30	13.33
XLNC	53.30	26.63	-	-	-	-
Biotos	20.00	20.00	-	-	-	-
Phytoporot	20.00	13.30	13.00	-	-	-
Monocrotophas	80.00	86.66	60.00	46.67	40.00	20.00

* Microbial insecticide.

Though many plants have been identified as insecticidal plants, *neem A. indica* has been chosen for the commercial preparation worldwide. Furthermore, *neem* in several cases has shown better activity than synthetic insecticides. To make it more versatile, it should have as many formulations too including synergised formulation. Several *neem* formulations have been available in the market. Many researchers have pointed out that neem formulations are harmless to coccinellids, mirids, predatory mites, spiders and syrphids and also to many parasitoids. Impact of nimbicidine (0.03%) and Nivar (0.03%) was evaluated on the incubation period, egg hatching, nymphal development and life stages mortality of *R. marginatus*. The results showed that these two biopesticides have no impact on incubation period. However, they affect the nymphal hatching percentage; prolong the developmental period and cause moderate mortality. Between the two neem-based pesticides the nimbicidine has more impact on this reduviid than the nivaar. Though the neem-based insecticides have caused minimal mortality in the nymphal instars, they reduce the egg hatching of *R. marginatus* (46 and 40% for nivaar and azadirachtin respectively) (Sahayaraj and Karthick, 2003). They further reported that these biopesticides reduce the predatory potential of this bug when provided with *A. gossypii*. Similar kind of results was observed when *R. marginatus* was provided with *S. litura* (Sahayaraj, 2001b) as prey. In another study (Sahayaraj unpublished data), it was noted that both the nimall-300 and nivaar at field concentration (0.03%) did not affect the incubation period and hatching percentage of *R. marginatus*. From the studies so far carried out, it is very clear that plant based insecticides or plant extracts or microorganism-based insecticides do not cause any mortality in adult stage (Sahayaraj, 2001b).

7.4 Microorganisms Based Insecticides

7.4.1 Entomopathogenice viruses

Entomopathogen like NPV has been used for the control of many insect pest worldwide. In such a situation it is also necessary to assess its impact on the non-target beneficial insects like predators and parasites. Sajap *et al.* (1999) evaluated the impact of nuclear polyhedrosis virus (NPV) on *Sycanus leucomesus* Walker under laboratory situation. The impact depended on the exposure time They provided NPV infected *S. litura* to the reduviid and evaluated the biological impacts. During the nymphal period, 85 and 96.3 per cent of the nymphs were survived when they were fed with infected and healthy larvae respectively. NPV did not show any detrimental effect on the developmental time of the surviving nymphs. However, NPV infected larvae reduce the pre-ovoposition period (3 to 6 days), fecundity (273 and 162 eggs/female for healthy and infected larvae fed predator respectively), and adult longevity (35 and 56 and 10 and 19 days for healthy and infected larvae for male and female respectively). Furthermore, they reported that feeding of *S. leucomesus* on infected host did not cause any morphological abnormalities, however, the size of the predator was significantly ($P < 0.05$) reduced. Recent (Sahayaraj *et al.* unpublished data) observations showed that NPV did not cause any significant impact on incubation periods in *R. marginatus* (8.3 and 8.0 days for control and NPV's treatment). Hatching percentage increases in the NPV treated *R. marginatus* eggs (75.12 and 90.10% for control and NPV treatment respectively). However, it was highly reduced when the age of the egg was increased to six days (70.22 and 55.12% for control and NPV treatment respectively). Furthermore, dermal application of NPV increased nymphal lifetime of *R. marginatus.* If the NPV was applied in the first instar then the nymphal period was slightly increased (38.4, 38.6 and 38.8 days for control first, second and third instars and 49.8, 50.5 and 51.7 for NPV treated first, second and third instars respectively). The nymphal period was more pronounced when NPV was applied in fourth (39.0 and 52.0 for control and NPV treatments respectively) and fifth (39.6 and 52.2 for control and NPV treatments respectively) instars respectively. Survival rate was maximum and minimum when NPV was applied in the early and later instars respectively.

7.4.2 Entomopathogenic Fungus

Deuteromycotina (fungi imperfect - Hyphomycetes) most of the entomopathogenic fungi belongs to Deuteromycetes. About 30 genera have been reported to contain one or more species that infect insects. Imperfect fungi are mycelial fungi that reproduce by means of conidia that are generally produced on free or aggregated conidiophores on the substrate surface. Since these fungi lack apparently a sexual or perfect stage, they are known as imperfect fungi. They have been developing by parasexual reproduction in which nuclear fusion occur. The parasexual process provides a mechanism for genetic exchange among imperfect fungi. Fungi that produce conidia or more or less loose, cottony hyphae are often termed as hyphomycetes. Number of fungi belonging to this class causes muscardine diseases in insects. The term was first applied to the white muscardian of the silkworm caused by *Beauvaria bassiana* (Balsamo) Vuillemin. *Beauvaria bassiana* is a common soil borne fungus that occurs worldwide and has been reported as a suppressive agent for several insect species. *Paecilomyces fumosoroseus* (Wize) Brown et smith *Verticillium lecanii* (Zimm.) Viegas is a hypomycete soil saphrophytic fungi that attacks many insects and is effective in greenhouse against aphids, whitefly and thrips. Due to the increasing awareness about the use of entomopathogenic microorganisms, it is important to determine the effect of entomopathogenic fungi on other IPM components. It was also considered worthwhile to test the pathogeniciy of beneficial non-target species. Moreover, safety to non-target species is an important criterion for the integration of *B. bassiana*, *P. fumosoroseus* and *V. lecanii* in IPM. With this view, we (Sahayaraj and Karthick Raja – unpublished data) evaluated the effect of these fungus on *Rhynocoris marginatus*.

For pathogenicity test, healthy insects adult of *R. fuscipes*, all the instars of *R. marginatus* and *P. viridiana* of same age group (> 48 hours) were inoculated with the spore suspensions containing 1×10^6, 1×10^7 and 1×10^8 spores/ml by dipping and agitating them for 30 seconds. They were allowed to dry on filter paper and transferred to sterile petriplates. Control insects were treated with sterile distilled water with 0.01 per cent between 80. Fifteen predators were taken for each treatment and were maintained at 26 ± 0.1^0 C in an incubator. Mortality was recorded daily and fresh food was supplied. Mortality and time taken for killing the test organisms were recorded. To obtain infected larvae, third instar *S. litura* larvae were sprayed with their respective LC_{50} concentration (fungal spore of each fungi) separately. Larvae were then transferred to a clean plastic container (25 × 14 mm) and maintained on fresh groundnut leaves at room temperature (28 ± 1^0 C). After 8 hrs of fungal inoculation the larvae were provided to the predators. Fifty individual reduviids and spiders were maintained. The nymphal mortality, developmental days and weight of each instar were recorded. Control was maintained with the *S. litura* without the fungal treatment.

R. fuscipes was also found to be susceptible to *B. bassiana* which exhibited 70.0, 63.5 and 51.5 per cent mortality at 10^8, 10^7 and 10^6 spores/ml respectively. Only 5 per cent mortality was observed in *R. marginatus* and the other two fungi did not cause any mortality to this reduviid predator. In general the time taken for killing also increased when the spore concentration decreased.

The results of the study (Table 7.3) revealed that the mortality of *R. marginatus* nymphal instars varied from 21.0 to 14.7, 19.0 to 10.0, 19.0 to 7.8, 10.0 to 5.0 and 7.1 to 3.6 per cent for first, second, third, fourth and fifth instars respectively at the concentration ranged

Table 7.3. Effect of *B. bassiana* (Bb), *P. fumosoroseus* (Pf) and *V. lecancii* (Vl) on mortality (in%) of *R. marginatus*

Conidial Concentrations	Instars	Mortality			
		Bb	Pf	Vl	Control
10^8	I	21.0	19.0	5.0	0.0
	II	19.0	17.3	0.0	0.0
	III	19.0	16.1	0.0	0.0
	IV	10.0	8.7	0.0	0.0
	V	7.1	6.0	0.0	0.0
10^7	I	19.6	17.6	0.0	0.0
	II	17.7	14.2	0.0	0.0
	III	12.4	9.2	0.0	0.0
	IV	9.0	6.3	0.0	0.0
	V	5.7	4.1	0.0	0.0
10^6	I	14.7	12.4	0.0	0.0
	II	10.0	9.1	0.0	0.0
	III	7.8	6.0	0.0	0.0
	IV	5.0	4.1	0.0	0.0
	V	3.6	2.1	0.0	0.0

from 10^8 to 10^6 spores/ml respectively. *B. bassiana* and *P. fumosoroseus* caused higher mortality in first instar and gradually declined when the nymphs grew older. The mortality rate ranged from 19.0 to 12.4, 17.3 to 9.1, 16.1 to 8.0, 8.7 to 4.1 and 6.0 to 2.1 for first, second, third, fourth and fifth instars. But *V. lecanii* caused only 5 per cent mortality in first instar at 10^8, 10^7 and 10^6 spores/ml *P. viridiana* was found to be less susceptible to all the tested fungal pathogens. The mortality decreased from 12.0 to 5.0, 10.0 to 3.5, 7.0 to 3.0 per cent in first, second and third instars when subjected to the spore concentrations that ranged from 10^8 to 10^6 spores/ml of *B. bassiana*. *P. fumosoroseus* recorded only 5 per cent mortality in first instars at 10^8 and 10^7 spores/ml. All the tested fungal pathogens did not cause any mortality to fourth, fifth, sixth and seventh instars. *V. lecanii* at any spore concentration recorded nil mortality to any instars.

In *R. marginatus*, the nymphal developmental period was generally reduced when they were provided with the fungi treated *S. litura*. The development time was found to be 26 4, 27.1 and 27 1 in *B. bassiana*, *P. fumosoroseus* and *V. lecanii* treatment respectively. Mortality was not recorded in second, third, fourth and fifth instars and 7 0 and 5.0 per cent mortality was observed in first instars when they were treated with *B. bassiana* and *P. fumosoroseus* treated *S. litura*. But the weights of the instars were reduced when compared to the control. The pathogens showed detrimental effect on the developmental time and the survival rate of *P. viridiana* nymphs. The average developmental times of nymphs were recorded as 83.3, 87.1 and 87.6 days when they were provided with *B. bassiana*, *P. fumosoroseus* and *V. lecanii* treated *S. litura* larvae. Only 7, 5 and 3 per cent mortality was recorded in the first instar of *P. viridians* fed with *B. bassiana*, *P fumosoroseus*, and *V. lecanii* respectively. Mortality was not recorded in the subsequent instars of any treatment. Distinct effect on weight of the instars was observed on both the predators in all treatment. As observed in *R. marginatus*, reduction of weight of instars was also observed in *P. viridicana*.

It is well understood from the above said account that synthetic insecticides altered the biology (nymphal developmental period, sex ratio, fecundity, incubation period, egg hatching, and adult longevity) and physiology (haemogram, macromolecular compositions and cellular constitutions) of reduviids Hence, it is very essential to screen the synthetic insecticides before integrating them in the pest management Since the biopesticides are very safer to the studied reduviids, such incorporation could be effectively enhanced in the IPM. However, the impact of various pesticides and biopesticides on more reduviids will be studied in the laboratory and/or controlled field cages before recommending them for the pest management.

7.5 Recommendations

1. Toxicological effect of commonly used synthetic pesticides against most efficient biological control reduviids will be carried out in the laboratory and field cage level
2. Combatable synthetic, plant based and microbial insecticides will be combined with reduviids and integrate them in crop pest management.
3. Toxicological, biological, physiological, biochemical, immunological and molecular level studies should be done on the effectiveness of many neem formulations to reduviids. This would be of help in developing more effective *neem* formulations
4. Since, botanical pesticides have anti-feedant, anti-ovipositional, IGR (insect growth regulators), toxic and anti-ecdysobionts effects on pests, it is recommended to evaluate their impacts on reduviids too.
5. Combined effects of synthetic pesticides, plant based and microorganism-based pesticides on reduviids are also essential in near feature, and
6. It is recommended to spray the synthetic pesticides and biopesticides in black wish manner in order to protect the natural enemies including the reduviid predators from them.

8

Source and References

Abdella, M.M.H. 1976. Entomophagous insects attacking *Anagasta kuehniells* Zell. In Alexandria mills and silos with particular reference to the morphological, biological and ecological aspects of *Allaeocranum biannulipes* (Montrouzier et Signoret) under laboratory conditions (M.Sc. Thesis, Fac. Of Agric., Alex. Univ.).

Ables, J R. 1978. Feeding behaviour of an assassin bug, *Zelus renardii. Ann. Ent. Soc. Amer*, 71: 476-478.

Agusti, N and A.C. Cohen. 2000. *Lygus Hesperus* and *L. lineolaris* (Hemiptera: Miridae), phytophages, zoophages or omnivores: evidence of feeding adaptations suggested by the salivary and midgut digestive enzymes. *J Entomol. Sci.* 35: 176-186.

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.

— — — 1983. Bioecology of an alate assassin bug, *Acanthaspis quinquespinosa* (L) Fabr. (Heteroptera: Reduviidae). In *Proc. Symp Ins. Ecol.* And Resource Manage, S.C. Goel (Ed.), Muzaffarnagar, India pp. 107-115.

— — — 1985. Assassin bugs of Tamil Nadu and their role in biological control (Insecta, Heteroptera; Reduviidae); *In Advance in biological control research in India* (Eds.) Joseph, K.J. and Abdurahiman, U.C. Calicut, pp. 16-28.

— — — 1987. Assassin bugs of Tamil Nadu and their role in biological control (Insecta Heteropter: Reduviidae). In *Advances in biologicl control research in India*, K.J. Joseph and U.C. Abdurahiman (Ed.), (Calicut: M/S printex Ltd), pp. 16-28.

— — — 1988. Biological control of insect pests by augmenting assassin bugs (Insecta: Heteroptera: Reduviidae). In *Bicovas*, K.S. Ananthasubramanian, P. Venkatesan and S. Sivaraman (Eds.), Loyola College, Madras,India. 2: 25-40.

— — — 1989. Ecotypic diversity of *Acanthaspis siva* (Heteroptera: Reduviidae) in two habitats in southern India. *Colemania*' 5: 35-39.

— — — 1995 Reduviids as predators Their role in biological control. In *Biological control of social forests and plantation crops insects*, T.N. Ananthakrishnan (Ed.) (New Delhi: Oxford & IBH Publishing Co. Ltd.,) pp 153-170.

— — — 1999. Assassin Bugs. Science Publishers.New Hampshire, U.S.A. pp. 337.

— — — 2001a. Friendly insecticides to conserve beneficial insects. *Zoos' print Journal.* 16(8) : 561-572.

— — — 2001b. Assassin Bugs (Heteroptera: Reduviidae) in Integrated Pest Management Programme: Success and Strategies. In: Strategies in Integrated Pest Management, (Eds.) Ignacimuthu, S. and Alok Sen, Phoenix Publishing House Pvt. Ltd., New Delhi, pp 73-85.

— — — and Claver, M.A. 1995a. Food requirement of *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera: Reduviidae). *J. Boil. Control*, 9(1): 47-50.

Ambrose, D.P. and Claver, M.A. 1995b. Functional response of *Rhynocoris fuscipes* Fabricius (Heteroptera: Reduviidae) to *Riptortus clavatus* Thunberg (Heteroptera: Alydidae). *J. Biol. Control*, 9(2): 74-77.

— — — 1997. Functional and numerical responses of the reduviid predator *Rhynocoris fuscipes* (F.) (Het., Reduviidae) to control leafworm *Spodoptera litura* (F.) (Lep., Noctuidae). *J. Appl. Entomol.* 121: 331-336.

— — — 1999. Suppression of cotton leaf worm *Spodoptera litura*, flower beetle *Mylabris pustulata* and red cotton bug *Dysdercus cingulatus* by *Rhynocoris marginatus* (Fabr.) (Het , Reduviidae) in cotton field cages. *J. Appl Entomol.* 123: 225-229.

——— 2001a. Survey of Reduviid Predators in Seven Pigeonpea Agroecosystems in Tirunelveli, Tamil Nadu, India. *International Chickpea and Pigeonpea Newsletter*, No. 8: 44-45.

——— 2001b. Prey preference of the predator *Rhynocoris kumarii* (Heteroptera: Reduviidae) to seven cotton insect pests. *Journal of Applied Zoological Research* 12(2 & 3): 129-132.

Ambrose, D.P. and George, P.J.E. 1995. Relative toxicity of three insecticides to *Acanthaspis pedestris* Stal a potential predator of insect pests (Insecta: Heteroptera: Reduviidae). *J. Adv. Zool.*, 16(2): 88-91.

——— 1996a. Impact of flooding on hatching in three *Rhynocoris* reduviid predators (Insecta: Heteroptera: Reduviidae). *Fresenius Envir. Bull.*, 5: 185-189.

——— 1996b. Effect of monocrotophos, dimethoate and methylparathion on the differential and the total haemocyta counts of *Acanthaspis pedestris* Stal (Insecta: Heteroptera: Reduviidae). *Ibid.*, 5: 190-195.

——— 1998. Comparative toxicological effects of monocrotophos to the third nymphal instars and the adults of *Acanthaspis pedestris* Stal, a potential biocontrol agent (Insecta: Heteroptera: Reduviidae). *Indian Journal of Environmental Sciences*. 2(2): 105-111.

Ambrose, D.P. and Kumaraswami, N.S. 1990. Functional response of the reduviid predator *Rhynocoris marginatus* on the cotton stainer *Dysdercus cingulatus* Fabr.; *J. Biol. Control*, 4: 22-25.

——— 1993. Food requirement of *Rhynocoris fuscipes* Fabr. (Heteroptera: Reduviidae); *J. Biol. Control*, 7: 102-104.

Ambrose, D.P. and Livingstone, D. 1985b. Impact of mating on adult longevity oviposition pattern, hatchability and incubation period in *Rhynocoris marginatus*; *Environment & Ecology*, 3: 99-102.

——— 1986a. A new species of *Rhynocoris* (Fabricius) from southern India; (Heteroptera: Reduviidae: Harpactorinae). *J. Bombay Nat. Hist. Soc.*, 83: 173-177.

——— 1986b. Bioecology of *Sphedanolestes aterrimus* Distant (Heteroptera: Reduviicdae). *Ibid*, 83: 248-252.

——— 1986c. A new genus of *Ectrichodiinae* from southern India (Insecta: Heteroptera: Reduviidae). *Ibid.*, 83: 401-406.

——— 1986d. Bioecology of *Rhynocoris fuscipes* Fabr.

(Reduviidae) a potential predator on insect pests. *Uttar Pradesh J. Zool.*, 6: 36-39

— — — 1987a. Biology of a new harpactorine assassin bug *Rhynocoris kumarii* (Hemiptera: Reduviidae) in south India. *J. Soil Biol. & Ecol.*, 7: 48-58.

— — — 1987b. Ecotypic diversity in a micropterous reduviid *Acanthaspis pedestris* from peninsular India. *Environment & Ecology*, 5: 456-463.

— — — 1987c Biology of *Acanthaspis siva* Distant, a polymorphic assassin bug (Insecta· Heteroptera: Reduviidae). *Mitt. Zool. Mus. Berl.*, 63: 321-330.

— — — 1988. Polymorphism in *Rhynocoris marginatus* Fabricius (Insecta: Heteroptera. Reduviidae). *Mitt. Zool. Mus. Berl.*, 64: 343-348.

— — — 1989d. Biosystematics of *Ectomocoris tibialis* Distant (Insecta: Heteroptera : Reduviidae) a predator of insect pests; *Arquivos Do museu Bocage,* 1 : 281-291.

— — — 1990. Polymorphism in *Acanthaspis siva* Distant (Insecta: Heteroptera: Reduviidae). A predator of the Indian Honey bee; *J. Bombay Nat. Hist. Soc.*, 87(2): 218-222.

— — — 1991. Biology of *Neohaematorrhophus therasii* (Hemiptera: Reduviidae); *Colemania (Insect Biosystematics and Ecology)* 1: 5-9.

Ambrose, D.P. and Maran, S.P.M. 1999a. Substrata impact on mass rearing of the reduviid predator *Rhynocoris marginatus* (Fabricius) (Insecta: Heteroptera: Reduviidae). *Pakistan Journal of Biological Sciences.* 2(4): 1088-1091.

— — — 1999b. Quantification, protein content and paralitic potential of saliva of fed and prey deprived reduviid *Acanthaspis pedestris* Stål (Heteroptera: Reduviidae: Reduviinae). *Indian Journal of Environmental Sciences.* 3(1): 11-16.

— — — 2000a. Polymorphic diversity in salivary and haemolymph proteins and digestive physiology of assassin bug *Rhynocoris marginatus* (Fab.) (Het., Reduviidae). *Journal of Applied Entomology*, 124: 315-317.

— — — 2000b. Haemogram and Haemolymph protein of male and female (mated and oviposited) *Rhynocoris fuscipes* (Fabricius) (Heteroptera: Reduviidae. Harpactorinae). *Advances in Biosciences*, 19(II) . 39-46.

Ambrose, D.P. and Paniadima, A. 1988 Biology and behaviour of a harpactorine assassin bug *Sycanus pyrrhomelas* Walker (Hemiptera: Reduviidae) from south India; *J. Soil Biol & Ecol.*, 8(1): 37-58.

Ambrose, D.P. and Rani, M.R.S. 1991. Prey influence on the laboratory mass rearing of *Rhynocoris kumarii* Ambrose and Livingstone, a potential biological control agent (Insecta: Heteroptera: Reduviidae). Mitt. Zoo. Mes. Berl., 67: 339-349.

Ambrose, D.P. and Sahayaraj, K. 1993. Predatory potential and stage preference of reduviid predatoor, *Allaeocranum quadrisignatum* (Reuter) on *Dysdercus cingulatus* Fabricious *J. Bio.cont.* 7(1): 12-14.

— — — 1996. Longterm functional response of the reduviid predator *Acanthaspis pedestris* Stal in relation to its prey, *Pectinophora gossypiella* Saunders density. *Hexapoda*. 8(2): 77-84

Ambrose, D.P. and Subburasu, P.A. 1988. Prey influence on the development, reproduction and size of assassin bug *Acanthaspis pedestris; Environment & Ecology*, 6: 948-955.

Ambrose, D.P. and Vennison, S.J. 1989a. A new species of *Coranus* from Southern India (Heteroptera: Reduviidae: Harpactorinae); *Acta. Entomologica Bohemoslove*, 86: 67-71.

— — — 1989b. Biology of a migratory assassin bug *Polididus armatissimus* Stal (Insecta: Heteroptera: Reduviidae); *Arquivos Do Museu Bocage*, 1: 271-280.

— — — 1990. Diversity of spermatophore capsules in reduviids (Insecta: Heteroptera: Reduviidae); *Mitt. Zool. Mus. Berl.*, 66: 309-317.

Ambrose, D.P., George, P.J.E. and Kalidoss, N. 1994b. Functional response of the reduviid predator *Acanthaspis siva* Distant (Heteroptera: Reduviidae) to *Camponotus compressus* Fabricius and *Ditopternis venusta* Walker; Environment & Ecology, 12: 877-879.

Ambrose, D.P., Gunaseeli, M. and Vennison, S.J. 1988b. Impact of female parental age on the development and size of offsprings of assassin bug *Rhynocoris kumarii*; *Environment & Ecology*, 6: 938-942.

Ambrose, D.P., Kennedy, I J.J. and Vennison, S.J. 1986. Impact of blocking sensory inputs on the predatory behaviour of assassin bug *Acanthaspis quinquespinosa*; *Ibid* , 4. 469-474.

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.

Ambrose, D.P., Solomon, K. and Vennison, S.J. 1985. Effect of competition, space and starvation on the predatory behaviour of the bug *Rhynocoris marginatus; Environment & Ecology*, 3: 280-285.

Anonymous, 1998. Integration of biocontrol agent, plant products and intercrops for chosen groundnut pesy management. Department of science and technology, Young scientist project (Sahayaraj, K.), Govt. of. India. 19 pp.

Antony, M., Daniel, J., Kurian, C. and Pillai, G.B. 1979. Attempts in introduction and colonization of the exotic reduviid predator *Platymeris laevicollis* Distant for the biological suppression of the coconut rhinocerous beetle, Oryctes rhinocerous; *Proc. Plant. Crops. Symp.*, II: 445-454.

Ashmead, W.H. 1895. Notes on cotton insects found in Mississippi; *Insect life*, VII: 320.

Awadallah, K.T., Tawfik, M.F.S., and Abdellah, M.M.H. 1984. Suppression effect of the reduviid predator, *Allaoeocranum blannulipes* (Montr. Et Sign.) on populations of some stored product insect pests; *Z. Ang. Ent.*, 97: 249-253.

Babu, A., Seenivasagam, R. and Karuppasamy, C. 1995. Biological control resources in social forest stands; In *Biological control of social forest and plantation crops insects*, T.N. Ananthakrishnan (Ed.) (New Delhi: Oxford & IBH Publishing Co. Ltd.,), pp. 7-24.

Barrion, A.T., Anguda, R.M. and Litsinger, J.A. 1987. The natural enemies and chemical control of the Leucaena psyllid *Heteropsyila cubana* Crawford in the Phillipines; *Leucaena Research Report*, 7(2): 45-49.

Bass, J.A. and Shepard, M. 1974. Predation by Sycanus indagator on larvae of *Galleria melleria* and *S. frugiperda; Ent. Exp. & appl.*, 17: 143-148.

Beeson, C.F.G. 1941. Ecology and control of forest insect pests of India and neighbouring countries; *1961 Reprint; Government of India*, pp. 67.

Begon, M., J. L. Haper and C. R. Townsend. 1996. Ecology, 3rd ed. Blackwell Science Ltd. Oxford. Bioscience June 1996 Vol. 46 No. 6 pp. 401-453

Bhatnagar, V.S., Sithanantham, S.S., Pawar, C.S. Jadhav, D., Rao, V.R. and Reed, W. 1983. Conservation and augmentation of natural enemies with reference to integrated pest managements in chickpea (Cicer arietinum L.) and pigeonpea (Cajanus cajan L.) *Millsp; Proc. Int.* Workshop on Integrated pest control for grain legumes, Goiani a, oia's Brazil eds. pp. 157-180.

Blatchley, W.S. 1926. Heteroptera or true bugs of eastern North America with especial reference to the faunas of Indiana and Florida. Nature Pub. Co., Indianapolis. pp 1-116 .

Blinn, R.L. 1994. Synopsis of the saicinae (Heteroptera: Reduviidae) of America north of Mexico, with the description of a new species of *Saica* from the eastern united states; *J. New York Entomol. Soc.* 102(1): 62-66.

Bosch, R.V.D. and Hagen, K.S. 1966. Predaceous and parasitic arthropods in California cotton fields. *Calif. Agric. Exp. Stn. Bull.* 133: 12.

Bose, M. 1949. On the biology of *Coranus spiniscutis* Reuter, an assassin bug (Heteroptera: Reduviidae); *Indian J. Ent.*, 11: 203-208.

Bradshaw, J.D. and McPherson, J.E. 2001. Life history and laboratory rearing of *Pseudometaptrus umbrosus* (Heteroptera: Reduviidae) with discriptions of immature stages. *Annals of the Entomological Society of America.* 95(2): 192-200.

Britton, W.E. 1917. The fall webworm. *Conn. Bull.* 203: 323.

Brown, H.P., and D. W. Lollis. 1963. Observations on the life history and behavior of the threead-legged bug *Emesaya b. brevipennis* (Say), (Hemiptera: Ploiariidae). Proc. Oklanhoma Acad. Sci. 43: 88-90.

Butani, D.K. 1958. Parasites and predator recorded on sugarcane pests in India; *Indian J. Ent.,* 20: 270-282.

——— 1985. Parasites and predator recorded on sugarcane pests in India; *Indian J. Ent.*, 20: 270-282.

Butler, E.A., 1918. Note on the *Coranus subapterus* DeGeer; *Entomologist Monthly Mag. London*, 644: 16-17.

Caffrey, D.T. and Barber, G.W. 1919 The grain bug Zelus renardii. *Bull.* U.S.D.A. 799:35.

Capriles, J.M. 1990. *Systematic catalogue of the Reduviidae of the world (Insecta: Heteroptera),* University of Puerto Rico (Mayaguez). Pp. 694.

Carayon, J. 1950. Caracteres anagomiques et position systematique des Hemipteres Nabidae *Bull. Mus. Paris.*, 22: 95-101.

Cheri, M.S. and Patel, N.G. 1983. Cotton leafworm *Spodoptera litura* (Fab.) its biology and integrated control measures. *Cotton development*. 13: 7-8.

Cherian, M.S. and Brahmachari, 1941. Notes on three predatory hemipteran from south India; *Indian J. Ent.*, 3: 115-118.

China, W.E. and Miller, N.C.E. 1959. Check list and keys to the families and subfamilies of the Hemiptera: Heteroptera; *Bull. British Mus. (Nat. Hist.) Ent.*, 8: 1-45.

Chittenden, F.H. 1905. The corn rootworm; *U.S. Dept. Agr. Circ.*, 59:5.

— — — 1907. The Colarado potato beetle; *U.S.D.A. Bull. Ent.*, 87:11.

— — — 1916. The common cabbage worm; *U.S.D.A. Farmer's Bull.*, 766: 9.

Cisneros, J. J. and Rosenheim. J.A. 1997. Ontogenetic change of prey preference in the generalist predator *Zelus renardii* and its influence on predator-predator interactions; *Ecological Entomology*, 22: 399-407.

Claver, M. A. and Ambrose, D. P. 2001b. Evaluation of *Rhynocoris kumarii* Ambrose & Livingstone (Hemiptera: Reduviidae) as a potential predator of some lepidopteran pests of cotton. *Journal of Biological Control* 15(1): 15-20.

Claver, M.A. 1998. Biocontrol potential evaluation of a reduviid predator *Rhynocoris kumarii* Ambrose and Livingstone (Insecta: Heteroptdra: Reduvuiidae) against three cotton insect pests. Ph.D. thesis, manaonmaniam Sundaran University, Tirnelveli.

— — — 2001c. Impact of augmentative release of *Rhynocoris kumarii* Ambrose & Livingstone (Heteroptera: Reduviidae) on *Dysdercus cingulatus* (Fabricius) (Hemiptera: Pyrrhocoridae) population and damage on cotton. *Journal of Biological Control* 15(2): 119-125.

— — — 2001a. Suitability of substrata for the mass rearing of *Rhynocoris fuscipes* (Heteroptera: Reduviidae), a key predator of pod borer *Helicoverpa armigera* (Hubn.); *Entomon*, 26(2): 141-146.

— — — 2002. Functional response of the predator, *Rhynocoris* *fuscipes* (Heteroptera: Reduviidae) to three pests of pigeionpea (Cajanus cajan); *Shashpa*, 9(1): 47-51.

— — — 2003. Influence of mulching & intercropping on the abundence of the reduviid predator *Rhynocoris fuscipes*. In Biological control of insect pests. (Eds. Ignacimuthu, S & Jeyaraj, S).

Claver, M.A., Rajan, K. and Ambrose, D.P. 1996. Impact of mass rearing in the postembryonic development of *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera: Reduviidae); In *Biological and cultural control of insect pests an Indian scenario*. D.P. Ambrose, (Ed.) (Tirunelveli, India: Adeline Publishers), pp. 216-219.

Claver, M.A., Ravichandran, M., Khan, M and. Ambrose, D.P. 2003. Impact of cypermethrin on the fuctional response, predatory and mating behaviour of a non-target potential biological control agent *Acanthaspis pedestris* (Stal). *J.Applied Entomology*. 127: 18-22.

Cobben, R.H. and Wygodzinsky, P. 1975. The Heteroptera of the Netherlands Antillex-IX reduviidae (assassin bugs); *Studies on the Yauha of Curacao and other Caribbiean island*, 48: 1-62.

Cohen, A.C. 1990. Feeding adaptations of some predacious Heteroptera. Ann. Entomol. Soc. Am.83: 1215-1223.

— — — 1995. Extra-oral digestion in predatory Arthropoda. Annu. Rev. Entomol. 40: 85-103.

— — — 1996. Plant feeding by predaceous heteeroptera: evolutionaly and adatational aspects of tropic switching. In Implication for life history and IPM (Alomar, O. and R.N. Wiedenmann eds.). Thomas say Pub. Entomol. Entomol.Soc.America, USA. 202 pp.

— — — 2000. How carnivorousbugsfeed. In C.W. Schaefer and A. R. Panizzi (eds.), Heteroptera of economic importance. CRC, Boca Raton, FL. P 563.

— — — 1993. Organization of digestion and preliminary characterization of salivary trypsin-like enzymes in predaceous heteropteran, *Zelus renardii; J Insect Physiol.*, 39(10): 823-829.

— — — 1998 Biochemical and morphological dynamics and predatory feeding habits in terrestrial Heteroptera. Pp. 21-32 in M Coll and J R. Ruberson [eds.], Predatory Heteroptera in

Agroecosystems. Their Ecology and Use in Biocontrol. Thomas Say Publ. *Entomol.*: Entomological Society of America, Lanham, Maryland, U.S.A. 233 pp.

Cohen, A.C. and Tang, R. 1997. Relative prey weight influences handling time and extracted biomass in predatory heteropterans *Environ. Entomol.* 26: 559-565.

Corbett, G.H. and Pagden, H.T. 1941. A review of some recent entomological investigations and observations; *Malaya Agri.* J., 29: 347-375.

Corzo, G., Adachi-Akahane, S; Nago, T. Kusui, Y. and Nakajima, T. 2001. Novel pesticides from assassin bugs: isolation, chemical and biology characterization. *FEBS.* 499: 256-261.

Das, S.S.M. 1996. Biology and behaviour of chosen predatory hemipterans; Ph.D thesis, Madurai Kamaraj University, Madurai, India

David, B.V. and Kumaraswami, T, 1978. *Elements of Economic Entomology;* (Madras, India; Popular Book department), pp. 103-115.

Dharne, P.K. and Patel, S.K., 2000. Screening of promising groundnut genotypes for their reaction to *Spodoptera litura* Int. Arach. Newslet. 20: 67-69.

Distant, W L. 1902. *The fauna of British India including Ceylon and Burma, Rhynchota Vol. II* (Heteroptera); (London: Taylor and Francis Ltd.,) pp. 1-503.

— — — 1904. Fauna of British India. Rhynchota Vol II & Heteroptera. *Taylor & Francis. Red Lion Court Fleet, London.* Pp. 254-344.

— — — 1910. *The fauna of British India including Ceylon and Burma, Rhynchota Vol. V* (Heteroptera: Appendix) (London: Taylor and Francis Ltd.,) pp. 1-362.

Duffey, S. S. 1980. Sequestration of plant natural products by insects. *Annu. Rev. Entomol.* 25: 447-477.

Easwaramoorthy, S., Kurup, N.K. and Santhalakshmi, G. 1998. New records and population dynamics of minor arthropod predators in sugarcane ecosystem *Insect Environemnt*, 4 (3): 98-99

Edwards, J S. 1962. Observations on the development and predatory habits of two reduviids (Heteroptera). *Rhynocoris carmelita* Stal and *Platymeris rhadamanthus* Gerst; *Proc. R Ent Soc Lond*, (A) 37. 89-98.

— — — 1962b Observations on the development and predatory habits of two reduviids (Heteroptera), *Rhynocoris carmelita* Stal and *Platymeris rhadamanthus* Gerst; *Proc. R. Ent. Soc. Lond.*, (A) 37: 89-98

— — — 1966. Observation on the life history and predatory behaviour of *Zelus exsanguis* (Heteroptera: Reduviidae); *Ibid.* (A) 41: 21-24.

Elkins, J.C. 1951. The Reduviidae of Texas. Texas J. Sci. 3: 407-412.

Endler, J.A. 1991. Interactions between predators and prey, pp. 169-196. In J.R. Krebs and N.B. Davies [eds], Behavioral ecology, 3rd ed. Blackwell Scientific Pubs, Oxford.

Evans, D.E. 1962. The food requirement of *Phonoctonus nigrofasciatus* Stal (Hemiptera: Reduviidae); *Entmol. Exp. Appl.*, 5: 33-39.

Flower, H.G.,Crestana, L. Camargode, M.T.V., Junior, J.J., Costa, M.M.L., Saes, N.E., Camargo, D. and Pinto,J.C.A. 1987. Functional respose of the most prevalent potential predators to variation in the density of mole crickets (Orthoptera, Gryllotalpidae . *Scapterisces borelli*). *Naturalia* 11/12 : 47-52.

Froeschner, R.C. 1944. Contributions to a synopsis of the Hemiptera of Missouri, Pt. III. Lygaeidae, Pyrrhocoridae, Piesmidae, Tingididae, Enicocephalidae, Phymatidae, Ploiariidae, Reduviidae, Nabidae. Am. Midland Nat. 31: 638-683.

— — — 1988a. Family Reduviidae Latreille, 1807. The assassin bugs, pp. 616-651. In T.J. Henry and R.C. Froeschner (eds.), Catalog of the Heteroptera, or true bugs, of Canada and the continental United States. E.J. Brill, New York, NY. 958 pp.

— — — 1988b. The family Reduviidae. pp. 616-651 *in* Henry, T.J. & R.C. Froeschner, Catalog of the Heteroptera, or true bug, of Canada and the continental United States E.J Brill, Leiden. 968p

Fuseini, B.A. and Kumar, R. 1975. Biology and immature stage of cotton stainers (Heteroptera Pyrrhocoridae) found in Ghana; *Biol. J. Linn. Soc* , 7: 83-111.

Garman, H. 1916 The locust borer (Cyllene robiniae) and other insect enemies of the black walnut. Kentucky Agric Exp Stn. Bull 200: 97-135.

George, P.J.E. 1999. Biology and life table of *Rhynocoris marginatus* (Fabricius) (Heteroptera: Reduviidae) on three lepidopteran insect pests; *J. Biol. Control,* 13: 33-38.

— — — 2000a. Impact of antennectomy on the predatory efficiency of *Rhynocoris marginatus* fabricius (Insecta: Heteroptera: Reduviidae); *Ad. Bios. Vol.* 19(II): 133-140.

— — — and Ambrose, D.P. 1998c. Effect of insecticides on the Post-embryonic development in *Rhynocoris marginatus* (Fabricius) (Heteroptera: Reduviidae). *Journal of Biological Control* 12(2): 113-118.

— — — 2000b. Polymorphic adaptation in biology and life-table studies of *Rhynocoris marginatus* (Fabricius) on Earias vittella (Fabricius); *J. Biol. Control,* 14(2): 35-39.

— — — 2000c. Reproductive performance of a Harpactorine reduviid *Rhynocoris fuscipes* (Fabricius) (Heteroptera: Reduviidae) on three lepidopteran insect pests; *Insect Sci. Applic. Vol. 20, No. 4,* pp. 269-273.

— — — 2002 Effect of starvation and density on the nymphal cannibalism of *Rhynocoris fuscipes* Fab. (Heteroptera: Reduviidae). *Entomon.*, 27 (2): 215-218.

George, P.J.E. and Ambrose, D.P. 1996.Adaptive polymorphism in *Rhynocoris marginatus* (Fabricius) to two insecticides, a non target biocontrol agent (Insecta: Heteroptera: Reduviidae); In Biological and cultural control of insects pests in Indian senario, Ambrose, D.P. (Ed) Adeline Publishers, Tirunelveli, India

— — — 1997. Relative toxicity of five insecticides to the predator *Rhynocoris kumarii* Ambrose and Livingstone (Insecta: Heteroptera: Reduviidae). *Indian Journal of Environment and Toxicology* 8(1): 35-36.

— — — 1998a. Relative toxicity of five insecticides to *Rhynocoris marginatus* (Fabricius), a potential predator of insect pests (Insecta: Heteroptera: Reduviidae). *Fresenius Environmental Bulletin.* 7: 7-8.

— — — 1998b. Relative toxicity of five insecticides to *Rhynocoris fuscipes* (Fabricius), a potential predator of insect pests (Insecta: Heteroptera: Reduviidae). *Shaspa* 5(2): 197-202

— — — 1998d Total and differential count of haemocytes in the life stages and adult haemocyte morphology in *Acanthaspis pedestris* Stal; *Indian J Ent.,* 60(3). 228-232

— — — 1999a. Impact of insecticides on the biochemical constituents in a non- target harpactorine reduviid, *Rhynocoris fuscipes* (Fabricius) (Heteroptera: Reduviidae). *Shashpa*, 6(2) 167-172.

——— 1999b. Biochemical modulations by insecticides in a non-target harpactorine reduviid *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera. Reduviidae). *Entomon*. 24(1): 61-66.

——— 1999c. Insecticidal impact on the post-embryonic development of *Rhynocoris kumarii* Ambrose and Livingstone (Het., Reduviidae). *Journal of Applied Entomology* 123: 509-512.

——— 1999d. Biochemical changes by inscticides in a non-target Harpactorine reduviid *Rhynocoris marginatus* (Fabricius). *Indian Journal of Environment and Toxicology* 9(2): 78-80.

——— 1999e. Post-embryonic developmental changes in non-target *Rhynocoris fuscipes* (Fabricius) (Insecta: Heteroptera: Reduviidae) by insecticides in cotton agroecosystem. *Journal of Advanced Zoology* 20(1). 12-16.

——— 2000. Impact of five insecticides on the differentiala and the total haemocyte counts of *Rhynocoris marginatus* (Fabricius) (Insecta: Heteroptera: Reduviidae). *Indian Journal of Environmental Sciences*, 4(2): 169-173.

George, P.J E. Seenivasagan, R. and Kannan, S. 1998. Influence of prey species on the development and reproduction of *Acanthaspis siva* Distant (Heteroptera: Reduviidae); *Entomon.*, 23(4): 313-319.

George, P.J.E., Claver, M.A. and Ambrose, D.P. 2000. Life table of *Rhynocoris fuscipes* (Fabricius) (Heteroptera. Reduviidae) reared on *Corcyra cephalonica* (Stainton); *Pest Management and Economic Zoology,* 8(1): 57-63.

Godfrey, K.E., Whitcomb, W H and Stimae, J.L. 1989. Arthropod predators of velvetbean caterpillar, *Anticarsia gemmatalis* Hubner (Lepidoptera. Noctuidae) egg and larvae, *Environ. Ent.* 18: 118-123.

Goel, S.C 1978. Bioecological studies on two years capture of hemipteran in western uttar pradesh, Vol. 12(3) 369 – 376

Gravana, S. and Sterling, W L. 1983 Natural predation of the cotton leaf worm (Lepidoptera Noctuidae): *J Econ Ent.*, 76. 779-784

Green. G.L. 1973 Biological studies of a predator *Sycanus indagator* (Heteroptera. Reduviidae) I Life history and feeding habits; *G.L.Fla. Entomol.*, 56(3)· 120-258.

Gross, H.R. Jr., Pair, S D. and Jackson, R.D. 1985. Behavioural responses of primary entomophagous predators to larval homogenates of *Heliothis zea* and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in whorled-stage corn. *Environmental Entomology*, 14: 360-364.

Grundy, P. and Maelzer, D 2000. Predation by the assassin bug *Pristhesancus plagipennis* (Walker) (Hemiptera: Reduviidae) of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and *Nezara viridula* (L.) (Hemiptera: Pentatomidae) in the laboratory; *Australian Journal of Entomology,* 39: 280-282

Grundy, R.P, Maelzer, D., Collins, P.J and Erol Hassan. 2000 Potential for integrating eleven agricultural insecticides with the predatory bug *Pristhesancus plagipennis* (Hemiptera· Reduviidae); *J. Econ. Entomol.* 93(3): 584-589.

Guerra, S.L. and Rodriguez, A.J. 1976. Biologra of otras observations del ciclo biologico de dos chinches asesinas (*Zelus exsanguis* (Fab.) y *Sinea diadema* Kol.) en la Comarca Lagunera; *Invest. Agric. Noreste*, 2(7): 133-138.

Hagen, K.S. 1987. Nutritional ecology of Terrestrial insect predators. In: *Nutritional ecology of insects, mites, spiders and related invertebrates,* F. Slansky Jr. and J.G. Rodriguez (Ed) (New York· John Wiley & Sons) pp. 533-577.

Hagerty, A.M. and McPherson, J.E. 1999. Life history and laboratory rearing of *Arilus cristatus* (Heteroptera: Reduviidae) in southern Illinois. *Florida Entomologist.* 83(1): 58-63.

Hagerty, A.M., Ecpherson, J.E. and Bradshaw, J.D. 2001. Life history and laboratory rearing of *Emesaya brevipennis* (Heteroptera: Reduviidae) in southern Illinois. *Florida Entomologist.* 84(3). 410-414.

Hairston, N.G , Smith, F E and Slobodkin, L.B. 1960. Community structure, population control, and composition. *American Naturalist.* 94: 421-425.

Haridass, E T. 1986a. Ultrastructure of the eggs of Reduviidae: II Eggs of Harpactorinae. (Insecta: Heteroptera);. *Proc. Indian Acad. Sci (Ani.)*. 95: 237-246.

— — — 1986b Ultrastructure of the eggs of Reduviidae; III Eggs of Triatominae and Ectrichodiinae (Insecta· Heteroptera); *Ibid.*, 95(4). 447-456

Haridass, E.T. and Ananthakrishnan, T.N. 1981a. Functional morphology of the salivary system in some Reduviidae (Insecta-Heteroptera); *Ibid.*, 90(2): 145-160.

Hassan, E. and Maelzer, D 2000. The augmentation of predacious reduviids into oil seed integrated pest management systems, Web: http://www.aghort.uq edu.au/icm/.

Henneberry T.J. and Clayton, T.E. 1985 Consumption of pink bollworm (Lepidoptera. Gelechiidae) and Tobacco budworm (Lepidoptera: Noctuidae) eggs by some predators commonly found in cotton fields *Environ Ent.* 14: 416-419.

Hespenheide, H.A. 1973. Ecological inference from morphological data. *Annu. Rev. Ecol Syst* 4. 213-229.

Hiremath, I.G. and Thontadarya, T.S. 1983. Natural enemies of sorghum earhead bug *Calocoris angustatus* Lethierry (Hemiptera: Miridae), *Curr. Res*, 2. 10-11

Hodge, M. 1984. Antipredator behaviour of *Achaearanea tepidariorum* (Theridiidae) towards Stenolemus lampes (Reduviidae); Preliminary observations; *J. Arachnol.*, 12. 369-370.

Holling, C.S. 1959. Some characteristic of simple type of predation and parasitism; *Can Ent*, 91 385-395.

Houseman, J.G., Downe, A E R 1983. Cathepsin-D-like activity in the posterior midget of haempteran insects. *Com. Bioch. Phy.* 75B(3): 509-512.

Illingworth, J.F. 1921. The linear bug *Phaenacantha australica* Kifkaldy; A new pest of sugar cane in Queenland. *Bulletin, Division of Entomology, Bureau of Sugar Experiment Stations, Queensland,* No 14

Imms. A.D. 1965. *A general text book of Entomology*. (London: The English Language Book Society and Methuen company Limited). Pp. 459-460

Inoue, H. 1985. Group predatory behaviour by the assassin bug. *Agriosphodrus dohrni* Signorest (Hemiptera. Reduviidae); *Res. Popul. Ecol.*, 27: 255-264

Irwin, M.E. and Shephard, M 1980. Sampling predacerus Hemeptera on soybean Pp 505-531 In M. Kogan and D. Herzog (Eds.) Sampling methods in soybean entomology. *Springer verlag, New York.*

Jacobson, E 1911 Biological notes on the hemipteran *Ptilocerus ochraceus*. *Tidschr Entomol.* 54: 175-179.

Jacobson, M. and Crosdy, D.G. 1971. Naturally Occurring Insecticides. Marcel Deker, Newyork. pp. 585.

Jalai, S.K. and Singh, S.P. 2002. Seasonal activity of stem borers and their natural enemies on fodde5r maize. *Entomon.*, 27 (2): 137-146.

James, D.G. 1992. Effect of temperature on development and survival of *Pristhesancus plagipennis* (Hemiptera: Reduviidae); *Entomophaga*, 37: 259-264.

— — — 1994. Prey consumption by *Pristhesancus plagipennis* Walker (Hemiptera: Reduviidae) during development; *Aust. Ent.*, 21(2): 43-47.

Jeyaraj, S., Santharam, G., 1985. Ecology-based integrated control of *Spodoptera litura* (F.) on cotton. In : Integrated pest and diseases management (ed. S. Jeyaraj), Tamil Nadu Agricultural University, Coimbatore, pp. 319-336.

Joseph, M.T. 1959. Biology binomics and economic importance of some reduviids collected from Delhi; *Indian J. Ent.*, 21: 46-58.

Karsavuran, Y. 1989. *Rhynocoris punctiventris* (H.-S.) (Het., Reduviidae) in laboratuvarda uretilmesinde besinin uygunlugu uzerinde bir arastirma, *Turk. Entomol. Derg.*, 13(4): 239-243.

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

Krishnaswamy, N., Chowhan, O.P. and Das. R.K. 1984. Some common predators of rice pests in Assam, India; *Indian rice research News letter.* 9: 15-16.

Kumar, S.P. 1993. Biology and behaviour of chosen assassin bugs, *(Insecta: Heteroptera: Reduviidae);* Ph.D. thesis, Madurai Kamaraj University, Madurai, India.

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.

Kuppusamy, A. and Kannan, S. 1995. Biological control of bagworm (Lepidoptera: Prychidae) in social forest stands; In *Biological control of social forests and plantation crop insects*, T N Ananthakrishnan (Ed) (New Delhi. Oxford & IBH Publishing Co. Ltd). pp 25-41

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.

Lakkundi, N.H. and Parshad, B 1987. A techinique for mass multiplication of predator with sucking type of mouth parts with special reference to reduviids; *J. Soil Boil. & Ecol.,* 7: 65-69.

Livingstone, D. and Ambrose, D.P. 1978a. Feeding behaviour and predatory efficiency of some reduviids from the Palghat gap India; *J. Madras University*, B 41: 1-25.

— — — 1978b. Bioeclogy, Ecophysiology and Ethology of the Reduviids of the scrub jungles of the Palghat gap, Part VII: Bioecology of *Acanthaspis pedestris* Stal (Reduviidae: Acanthaspidinae) a micropterous, entomophagous species; *Ibid.*, B 41(3): 97-118

Livingstone, D. and Ravichandran, G. 1988a. Two new species of Polididusaria from southern India (Heteroptera: Reduviidae: Harpactorinae); *J. Soil Biol. & Ecol.*, 8(2): 117-121.

— — — 1988b. A new genus and a new species of Stenopodainae Stal from southern India (Heteroptera: Reduviidae); *Sep. Garcia de Orta, ser. Zoo.*, 15(1): 145-148.

— — — 1988c. A new species of *Tribelocephala* (Heteroptera: Reduviidae) from Western Ghats; *Uttar Pradesh J. Zool.*, 8(1) 100-102.

— — — 1989a. Two new species of *Stenopodainae* Stal from Palghat gap (Heteroptera: Reduviidae); *Hexapoda,* 1: 41-44.

— — — 1989b. Three new species of Harpactorinae from southern India (Heteroptera. Reduviidae: Harpactorinae); *J. Bombay. Nat. Hist. Soc.*, 86. 422-424.

— — — 1989c. Three new species of Harpactorinae from Southern India (Heteroptera: Reduvidae. Harpactorinae); *Environment & Ecology*, 7(1): 228-231.

— — — 1990a. A new species of *Euagoras* (Heteroptera: Reduviidae: Harpactorinae) from Western ghats, India; *J. Bombay Nat. Hist. Soc* , 87. 279-280.

— — — 1990b. Three new species of *Oncocephalus* Klug (Heteroptera: Reduviidae: Stenopodainae) from Western Ghats, India; *Hexapoda*, 2: 57-64.

— — — 1991. A new species of Platerus Distant (Heteroptera. Reduviidae: Harpactorinae) from southern India: *J. Ent. Res.,* 15(4): 274-276.

— — — 1992. A new genus of Ectrichodiinae from the Coromande coast, India (Heteroptera. Reduviidae); *Hexapoda*, 4(2): 167-169.

Livingstone, D. and Yacoob, M.H.S 1986. Natural enemies and biologies of the egg parasitoids of Tingidae of southern India; *Uttar Pradesh J. Zool.*, 6-12.

Lockwood, J.A. 1989. Ontogeny of cannibalism in rangeland grasshoppers (Orthoptera: Acrididae). *Journal of the Kansas Entomological Society*. 62: 534-541.

Maran, S.P.M. 1999. Chosen reduviid predators- prey interaction, Nutritional and Kairamonal Chemical Ecology. Ph.D Thesis. Manonmaniam Sundaranar University. pp. 111.

Maran, S.P.M. and Ambrose, D.P. 2000. Paralytic Potential of *Catamiarus brevipennis* (Serville), a potential Biological control agent (Insecta: Heteroptera: Reduviidae). In: *Biotechnological applications for Integrated Pest Management*, Ignacimuth, S., Sen, A., Janarthanan, S., (eds), Oxford Publishing Co. Pvt. Ltd., New Delhi, pp. 125-131.

Maran, S P.M., Babu, A. and Ignacimuthu, S. 2002. Functional response of *Rhynocoris marginatus* (Fab.) (Heteroptera: Reduviidae) on *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). Proc. of the Vistas of Entomological Research for the New Millennium. G.S.Gill Research Institute, Guru Nanak College Chennai. (Eds. K.P. Sanjayan, V. Mahalingam and M.C. Muralirangan.). pp.112-115.

Martin, W.R.J.R. and Brown, J.M. 1984. The action of acephate in *Pseudoplusia includens* (Lepidoptera: Noctuidae) and *Pristhesancus papuensis* (Hemiptera: Reduviidae); *Entomol. Exp. Appl*, 35: 3-9.

Martinez, D.G. and Pienkowski, R.N. 1982. Laboratory studies on insect predators of potato leafhopper eggs, nymphs and adults; *Environ. Ent.*, 11: 361-362.

McAtee, W.L. & J.R. Malloch. 1925. Revision of bugs of the family Cryptostemmatidae in the collection of the United States National Museum. Proceedings of the United States National Museum 67:1-42.

McMahan, E.A. 1983a. Adaptations, feeding preference and biometric of a termite baiting assassin bug (Hemiptera: Reduviidae); *Ann. Ent. Soc. Amer.*, 76: 483-486.

— — — 1983b Bugs angle for termites with stealth and artifice, the assassin bug lures termites out of their well-guarded nests; *Nat Hist.*, 92(5) 40-46

McPherson, A.J.E. 2000. Life History and Laboratory Rearing of *Arilus Cristatus* (Heteroptera: Reduviidae) in Southern Illinois. Florida Entomologist . 83: (1)· 58-67.

McPherson, J.E. 1991. Noteworthy range extensions of three emesine species (Heteroptera : Reduviidae). Great Lakes Entomol. 24: 263-264.

Mead, F. W. 1974. The wheel bug, *Arilus cristatus* (Linnaeus) (Hemiptera: Reduviidae). Florida Dep. Agric., Div. Plant Industry, *Entomol. Circ.* 143: 1-2.

Miles, P.W. 1972. The saliva of Hemiptera; *Adv. Ins. Physiol,* 9: 183-255.

Miller, N.C.E. 1953. Notes on the biology of the Reduviidae of Southern Rhodesia; *Trans, Zool. Soc. Lond.*, 27: 541 – 562.

— — — 1956. *The Biology of Heteroptera*; (London: Leonard Hill Books Ltd), pp. 79-116.

Minja, E.M., Shanower, T.G., Ong'uro, J.M., Nderitu, J. and Songa, J.M. 1999. Natural enemies associated with arthropod pests of pigeonpea in Eastern Africa International Chickpea and Pigeonpea Newsletter; 6: 47-50

Misra, R.M. 1975. Notes on *Anthis sexguttae* Fabr. (Caranidae: Coleoptera) a new predator of *Pyrausta machaeralis* Walker and *Hybies puera* Crammer Indian Forester. 101: 6504.

Mohanadas, K. 1996. New records of some natural enemies of the teak defoliator *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae) from Kerala, India; *Entomon*, 21(3&4): 251-253.

Morgan, A.C. 1907. A predatory bug (*Apiomerus spissipes* Say) reported as an enemy of the cotton bollweevil; *Bull. U.S.D.A. Bur. Ent.*, 63: 1-54.

Morris, R.F. 1963. The effect of predator age and prey defence on the functional response of *Podisus maculiventris* Say to the density of *Hypbantris cunea* Drury *Canad. Ent.* 95: 1009-1020

Morrison, M.N. 1989. Gel electrophoretic studies with reference to functional morphology of the salivary glands of *Acanthaspis pedestris* Stal (Insecta: Heteroptera: Reduviidae); *Proc. Indian Acad. Sci.* (Anim. Sci.), 98(3) 167-173.

Mundiwale, S.K , Patel, J.D , Men V B. and Kandalkar, H.G. 1989. Efficacy of synthetic pyrethroids against sorghum pests, *Indian J. Ent* , 51(2)· 172-176.

Murray, B. (Ed) 1987. Protect Your Citrus Department of Primary Industries, Brisbane, Queensland Information series· Q18701.

Murugan, C. 1988. Biosystematics and Ecophysiology of the tibiarolite assassin bugs (Heteroptera Reduviidae) of southern India; Ph.D. thesis, Bharathiar University, Coimbatore, India.

Murugan, C. and Livingstone, D. 1995a Keys to south Indian species of Tibiaroliate assassin bugs (Heteroptera: Reduviidae); *J. Ent. Res.*, 19(3): 265-275.

——— 1995b. Description of a new genus of Ectrichodiinae and two new species of the genus *Haematorrhophus* Stal from south India (Heteroptera: Reduviidae); *J. Bombay Nat. Hist. Soc.*, 92(3): 386-389

Nagarkatti, S. 1982. The utilization of biological control of Heliothis management in India; In *Proc. Int. Workshop on Heliothis management,* ICRISAT, Patencheru, Andhra Pradesh, pp. 159-167.

Navarajanpaul, A.V. 2003. Biological control of lepidopteran pests using important predators. In Biological control of lepidopteran pests (Eds. Tandon, P.I., Ballal, C.R , Jalali, S.K. and Rabindra, E.J.). Society for Biological control advancement. PP. 19-28.

Nayar, K K., Ananthakrishnan, T.N and David, B.V. 1976. *General and Applied Entomology*; (New Delhi. Tata Mc-Graw Hill Publishing Company), pp. 169-170.

Nuorteva, P. 1958. On the occurrence of proteases and amylases in the salivary glands of *Cinarapiceae* (Panz.) (Hom.: Aphididae). *Suom. Hyont. Aikak.* 24: 89.

Nyiira, Z.M. 1970. The biology and behaviour of *Rhynocoris albopunctatus* (Hemiptera: Reduviidae); *Ann. Ent. Soc. Amer.*, 63: 1224-1227.

Odhiambo, T.R. 1959. An account of parental care in *Rhynocoris albospilus* Signoret (Hemiptera: Heteroptera: Reduviidae) with notes on its history; *Proc. R. Ent. Soc. Lond.,* (A) 34: 175-185

Parker, A.H. 1965a. The predatory behaviour and life history of *Pisilus tipuliformis* Fabr. (Hemiptera: Reduviidae); *Ent. Exp. Appl.*, 8: 1-12.

——— 1971. The predatory and reproductive behaviour of *Vestula lineaticeps* (Sign.) (Hemiptera: Reduviidae); *Bull. Ent. Res.*, 61: 119-124.

——— 1972. The predatory and sexual behaviour of *Phonoctonus fasciatus* (P. de B.) and *P. subimpictus* Stal (Hem., Reduviidae); *Bull. Ent. Res.* 62 139-150

Patil, B.V and Thontadraya, T.S 1983 Natural enemy complex of the teak skeletonizer *Pyrausta mechaeralis* Walker (Lepidoptera: Pyralididae) in Karnataka; *Entomon*, 8: 249-255.

Pawar, C.S., Bhatnagar, V.S. and Jadhav. D.R. 1986. *Heliothis* species and their natural enemies, with their potential in biological control; *Proc. Indian Acad. Sci.* (Anim. Sci.), 95: 695–703.

Peck, O. 1963. A catalogue of the Nearctic Chalcidoidea (Insecta: Hymenoptera). Can. Entomol. Suppl.: 1-1092.

Pillai, G.B. 1988. Biological control of pests of plantation crops; In *Summar institute on techniques of mass production of biological agents for management of pest and diseases;* Centre for plant protection studies. TNAU, Coimbatore pp. 102-111.

Pimm, S.L. 1982. *Food Webs*. Chapman and Hall, London.

Ponnamma, K.N., Kurin, C. and Koya, K.M.A. 1979. Record of *Rhynocoris fuscipes* (Fabr.) (Heteroptera: Reduviidae) as a predator of *Myllocerus curicornis* (F.) (Coleoptera: Curculionidae) the ash weevil, pest of the coconut plam; *Agri. Res.J. Kerala*, 17: 91-92.

Price, P.W. 1984. Insect ecology, 2nd ed. John Wiley & Sons, New York.

Pyke, B.A. and Brown, E.H. 1996. The cotton pest and beneficial guide. GoPrint, Woolloongabba, Queensland.

Rachel, A.S, and McPherson, J.E. 2005. Life history and laboratory rearing of *Sinea spinipes* (Heteroptera: Reduviidae) with discriptions of immature stages. *Annals of the Entomological Society of America*. 98(1): 18-36.

Ragupathy, E. and Sahayaraj, K. 2002. Biodiversity of reduviid predators in the semi-arid zones of three southern districts of Tamil Nadu. In Proceedings of Vistas of Entomological Research for the New Millenium (Eds. K.P. Sanjayan, V. Mahalingam and M.C. Muralirangan). Pp. 31-36.

Rai, B.K. 1976. *Pests of oilseed crops in India and their control.* Indian council of Agricultural Research Report, New Delhi, pp. 121.

Rajagopal, D. 1984. Observation on the natural enemies of *Odontotermes wallonensis* (Wasssmann) (Isoptera: Termitidae) in South India; *J. Soil Biol. & Ecol.*, 4: 102-107.

Ralston, J.S. 1977. Egg guarding by male assassin bugs of the genus Zelus (Hemiptera. Reduviidae); *Psyche.*, 84(1): 103-106.

Rao, R.S.N., Satyanarayana, S.V.V. and Soundarajan, V. 1981 Notes on new addition to the natural enemies of *Spodoptera litura* F. and *Myzus persicae* Suiz. On fine cored tobacco in Andhra pradesh; *Sci. & Cul.*, 47: 98- 99.

Rao, V.P. 1974. *Biology and breeding techniques for parasites and predators of Ostrina sp. and Heliothis sp.;* CIBC final technical report PL 480 project, Bangalore, India, pp. 86.

Ravi, C. 2004. Integration of selected reduviids and botanicals in groundnut pest mangement. Manonmanium Sundaranar University, Tirunelveli, India.

Ravichandran, B., Claver, M.A. and . Ambrose, D.P. 2003. Functional response of the assassin bug *Rhynocirs longifrons* (Stal) to ctton bollworm *Helicoverpa armigera* (Hubner). In Biological control of insect pests. (eds. Ignacimuthu, S & Jeyaraj, S). PP. 155-159.

Ravichandran, G. 1988. *Biosystematics and ecophysiology of the non tibiaroliate assassin bugs (Heteroptera: Reduviidae) of southern India;* Ph.D. thesis, Bharathiar University, Coimbatore, India.

Readio, P.A. 1926. Studies of the eggs of some Reduviidae (Heteroptera); *Univ. Kans. Sci. Bull.*, 16: 159-179.

— — — 1927a. Studies on the Biology of the Reduviidae, of America north of Mexico; *Ibid.*, 17: 5-29.

— — — 1927b. Studies on the biology of the Reduviidae of America north of Mexico. University of Kansas Science Bulletin, 17: 5-291.

Rees, A.R., Offord, R.E. 1969. Studies on the protease and other enzymes from the venom of *Lethocerus cordofanus*. *Nature.* 221: 665-667.

Rosenheim, J.A., Wilhoit, L.R. and Armer, C.A. 1993. Influence of intraguild predation among generalist predators on the suppression of an herbivore population; *Oecologia,* 96(3): 439-449.

Rosenheim, J.A. and Wilhoit, L.R. 1993. Predators that eat other predators disrupt cotton aphid control; *Calif. Agric.*, 47(5): 7-9.

Rosenheim, J.A., Kaya, H.K., Ehler, L.E., Maris, J.J. and Jaffee, B.A. 1995. Intraguild predation among biological control agents: theory and evidence. *Biol. Control,* 5. 303-335.

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.

— — — 1994a. Capturing success by reduviid predators *Rhynocoris kumarii* and *Rhynocoris marginatus* on different age groups of *Spodoptera litura*, a polyphagous pest (Heteroptera: Reduviidae); *J. Ecobiol.*, 6(3): 221-224.

— — — 1994b. Biocontrol potential evaluation of the reduviid predator *Rhynocoris marginatus* (Fabricius) to the serious groundnut pest *Spodoptera litura* (Fabricius) by functional response study; *Fresenius Envir. Bull.*, 3: 546-550.

— — — 1994c. Capturing success by reduviid predators *Rinocoris kumarii* and *R. marginatus* on different age groups of *Spodoptera litura*, a polyphagous pest. *Journal of Ecobiology*, 6(3): 221-224.

— — — 1995a. Bioefficiacy and prey size suitability of *Rhynocoris marginatus* Fabricius to *Helicoverpa armigera* Hubner of groundnut (Insecta: Heteroptera: Reduviidae); *Fresenis Envir. Bull.*, 4: 270-278.

— — — 1995b. Bio-efficacy and development of a reduviid predator, *Rhinocoris marginatus, on Spodoptera litura. International Arachis Newsletter,* 15: 56-57.

— — — 1995c. Developmental stages and biocontrol potential of a reduviid predator, *Acanthaspis pedestris* Stal against termites on groundnut. *Int.Ara.News.*, 15: 57-59.

— — — 1995d. Functional response of the reduviid predator *Ectomocoris tibialis* Distant of the cotton stainer *Dysderus cingulatus* Fabri. *J. Int. Stu. & Rese.* 4(2): 65-68.

— — — 1997. Laboratory rearing of predaceous bugs with special reference to reduviids (Insecta. Hemiptera: Reduvidae). *Zoo's Print* 13(5): 17-18.

— — — 1999a. Field evaluation of *Rhynocoris marginatus* (Fab.) against two groundnut defoliators. *International Arachis Newsletter,* 19:41-42.

— — — 1999b. Effect of prey and their age on the feeding preference of *Rhinocoris marginatus* Fab *International Arachis Newsletter.* 19: 39–40.

— — — 2000. Evaluation of Biological control potential of *Rhynocoris marginatus* on four groundnut pests under laboratory conditions. *Int. Arach. News let.* 20 . 72-74.

— — — 2001a. A qualitative study of food consumption, growth and fecundity of a reduviid predator in relation to prey density. *Entomologica Croatica*. 5(1 & 2) : 19-30.

— — — 2001b. Biopesticidal impacts on the biocontrol potential and behaviour of *Rhinocoris marginatus* (Fab.) (Hemiptera: Reduviidae) to groundnut pest *Spodoptera litura* (Fab.). *International Arachis News Letter.* 21:46-48.

— — — 2002. Small-scale laboratory rearing of reduviid predator *Rhinocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on *Corcyra cephalonica* Stainton larvae by larval card method. *Journal of Central Europian Agriculture*. 3(2): 137-148.

— — — 2003. Hunter reduviids in cotton bug control. *Agrobios.* 1(12): 9-11.

— — — 2004. Indian Insect Predators in Biological control. (Editor) *Dayas Publication,* New Delhi. pp. 400.

— — — 2006. Ecological adaptive featurs of Hunter Reduviids (Heteroptera: Reduviidae: Reduviinae) and their biological contro In: *Perspective in animal ecology and reproduction* (Volume 3) (Guptha, VK and Verma AK eds.). Daya Publishing House, New Delhi. pp 22-49.

Sahayaraj, K. and Ambrose, D.P. 1992a. Biology, redescription and predatory behaviour of an assassin bug *Allaeocranum quadrisignatum* (Reuter) (Heteroptera: Reduviidae). *J.Soil Biology & Ecology*, 12(2) 120-133.

— — — 1992b. Biology and predatory potential of *Endochus umbrinus* Reuter (Heteroptera: Reduviidae) from South India. *Bulletin of Entomology* 33(1-2): 42-55.

— — — 1993a. Biology and predatory potential of *Coranus nodulosus* Ambrose & Sahayaraj on *Dysdercus cingulatus* Fabricius and *Oxycarenus hyalinipennis* Costa (Heteroptera: Reduviidae). *Hexapoda*, 5(1): 16-22.

— — — 1994. Functional response of a reduviid predator to two pests; *Biology Education,* 11(2): 114-118.

— — — 1996a. Biocontrol potential of the reduviid predator *Neohaematorrhophus therasii* Ambrose and Livingstone (Heteroptera: Reduviidae); *J. Adv. Zool.,* 17(1): 49-53.

— — — 1996b. Functional response of the reduviid predator *Neohamatorrhophus therasii* Ambrose and Livingstone to the cotton stainer *Dysdercus cingulatus* Fabricius; In *Biological and cultural control of insect pests, an Indian scenario,* D.P

Ambrose (Ed.) (Tirunelveli, India: Adeline Publishers), pp. 328-331.

— — — 1996c. Short term functional response and stage preference of the reduviid predator *Ectomocoris tibialis* Distant on the cotton stainer *Dysdercus cingulatus* Fab.; *German J. App. Zool.,* 81: 219- 225.

— — — 1997b. Colour polymorphism in assassin bug *Neo-haematorrhophus therassi* Ambrose & Livingstone. *J. Soil Biology and Ecology.* 17(1) : 58-64

— — — 1997c. Field cage evaluation of the predator *Ectomocoris tibials* Distant to control *Dysdercus cingulatus* Fabricius. *Journal of Insect Science.* 10(1): 65-66.

Sahayaraj, K. and Delma, J.C.R 2004. Chemically mediated behaviour of the predator *Rhynocoris marginatus* (Fab.) (Heteroptera: Reduviidae) searching insect prey *Belgium Journal of Entomology.,* 6: 75-81

Sahayaraj, K. and Jeyalekshimi, T. 2002. Mass rearing of *Rhyno-coris marginatus* Fab on live and frozen larvae of *Corcyra cephalonica* biology. *Entomologica Croatica.* 6(1-2) : 35-49.

Sahayaraj, K. and Karthikraja, S. 2003. Effect of biopesticides on the mortality and biocontrol potential of *Rhynocoris marginatus* Fab. to *Aphis gossypii. Journal of biological control.* (in press).

Sahayaraj, K. and Martin, P. 2003 Assessment of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) as augmented control in groundnut pests. *Journal of Central Europian Agriculture.* 4 (2): 103-110.

Sahayaraj, K. and Paulraj, M.G. 1999a. Effect of plant products on the eggs of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae). *Insect Environment.* 5(1) : 23-24.

— — — 2001d. Effect of cold storage on egg hatching in two reduviid predators, *Rhynocoris marginatus* Fab. and *R. fuscipes* Fab. *Belgium Journal of Entomology 3: 1-7.*

— — — 1999b. Toxicity of some plant extracts against the life stages of a reduviid predator *Rhynocoris marginatus* (Fab.) *Indian Journal of Entomology* 61(4): 342-344.

— — — 2000. Impact of some plant products on the behavior of *Tribolium castaneum* Herbst in groundnut seeds *International Arachis Newsletter.* 20 (1): 75-76

— — — 2001c Effect of cold storage on egg hatching in two reduviid predators *Rhynocoris marginatus* Fab and *R. fuscipes* Fab (Hemiptera Reduviidae). *Belgian Journal of Entomology* 3: 201-207.

——— 2003. Insect pests and beneficial arthropods of groungnut in relation to wind velocity; *Asian Jr. of Microbiol. Biotech. Env. Sc.* Vol. 5, No.(2) : 101-103.

Sahayaraj, K. and Raju, G. 2003. Pest and Natural enemy complex of groundnut in Tuticorin and Tirunelveli districts of Tamil Nadu. *International Arachis News Letter.* 23: 25-29.

Sahayaraj, K. and Sathyamoorthy, P. 2002. Influence of different diets of *Corchyra cephalonica* on life history of a reduviid predator Rhynocoris marginatus (Fab.). J.Centr.Euro agric. 3 (1): 53-61.

Sahayaraj, K. and Sivakumar, K. 1995. Groundnut pest and pest stage preference of a reduviid predator *Rhynocoris Kumarii* Ambrose and Livingstone (Heteroptera: Reduviidae). *Fresnius Environmental Bulletin*, 4(5): 263-269.

Sahayaraj, K., Martin, P. and Karthikraja, S. 2003. Suitable sex ratio for the mass rearing of reduviid predator *Rhynocoris marginatus* (Fab.). *Journal of Applied Zoological Research.* 14(1): 34-37.

Sahayaraj, K., Martin, P., Irudayaraj, V. and Selvaraj, C. 2002. Predatory behaviour of *Rhynocoris marginatus* Fab. on *Papilio polytes polytes* caterpillar, a serious pest of citrus. *Insect Environment.* 8(1): 22-23.

Sahayaraj, K., Raju, G. and Francis Borgio, J. 2006. Space, prey feed modulation, reduviid predator and its prey density on on the reproductive potential of *Acanthaspis pedestris* Stal. In: *Perspective in animal ecology and reproduction* (Volume 3) (Guptha, VK and Verma AK eds.). Daya Publishing House, New Delhi. pp 289-309.

Sahayaraj, K., Subasini, M. and Ravi, C. 2002c. Influence of biorational insecticide *Coleus ambonicus* Lour (= *aromaticus* Benth) to *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) and its predator *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) in laboratory conditions. *Journal of Nature Conservation* 14(1): 113-122.

Sailer, R I. 1957. Proc. Entomol. Soc. Washington 59: 203. Surface, H. A 1906 Order X. The Hemiptera: the bugs, lice, aphids, scale insects, cicadas and others. Pennsylvania Dep. Agric., Div Zool., Mon. Bull. 4: 48-75.

Sajap, A.S., Kotulai, J.R., Kadir, H.A. and Hussein, M.Y. 1999. Impact of prey infected by nuclear polyhedrosis virus on a predator, *Sycanus leucomesus* Walk. (Hem., Reduviidae); *J. Appl. Ent.* 123, 93-97.

Saminathan, V.R. and Jayaraj, S. 2002. Exploring an effective botanical formulation for sustainable crop protection- a review. Proceedings of the Vistas of Entomological Research for the New Millennium. (Eds. K.P. Sanjayan, V. Mahalingam and M.C. Muralirangan.) pp. 72-79

Satpathi, C.R. 2001. Record of predaceous bugs in rainfed rice agroecosystem of West Bengal. *Insect Invironment.* 6 (4): 174-175.

Saxena, A.P. and Singh, V. 1976. Studies on parasites and predators of potato pests. *Ann.Scientific Report. CPRI. Simfa.* pp. 97-100.

Saxena, R.C., Liquido, N.J. and Justo, Jr., H.D. 1980. *Proceedings of First International Neem Conference. Rottach-Egern.* Pp. 171-188.

Schaefer, C.W. 1988. Reduviidae (Hemiptera: Heteroptera) as agents of biological control; In *Bicovas,* K.S. Ananthasubramanian, P. Venkatesan and S. Sivaraman (Eds.), Loyola College., Madras. 1: 27-33.

Scriber, J.M. and Slansky, P.J. 1981. The nutritional ecology of immature insects; *Ann. Rev. Ent.*, 26: 183-211.

Scudder, G.G.E. 1992. The distribution and life cycle of *Reduvius personatus* (L.) (Hemiptera: Reduviidae) in Canada. *J. Ent. Soc. Brit. Columbia,* 89: 38-42.

Selvaraj, P. and Sahayaraj, K. 2005. Effect of chosen fern leaf extract on the development of *Spodoptera litura.* Pp 81-90. In: Green Pesticides for Insect Pest Managemant Ignacimuthu, S and Jeyaraj, S. (eds). *Narosa Publishing House, New Delhi, India.*

Senrayan, R. 1988. Functional response of *Eocanthecona furcellata* (Wolff) (Heteroptera: Pentatomidae) in relation to prey density and defence with reference to its prey *Latola lepida* (Cramer) (Lepidoptera: Lemacodidae); *Proc. Indian Acad. Sci. (Anim. Sci).* 97(4): 339-345.

Severein, H.H.P. 1924. Natural enemies of beet leaf hopper (Eutettix tenella Baker); *J.Econ. Ent.*, 17: 369-377.

Shannon, V.C. and McPherson, J.E 2003. Life history and laboratory rearing of *Sinea spinipes* (Heteroptera: Reduviidae) with discriptions of ımmature stages. *Annals of the Entomological Society of America.* 96(6): 776-792.

Shepard, M., McWhorter, R.E. and King, E.W. 1982. Life history and illustrations of *Pristhesancus papuensis* (Hemiptera: Reduviidae); *Can. Ent.,* 114: 1089-1092.

Singh, G. 1992. Management of oil palm pests and diseases in Malaysia in 2000, In *Pest management and the environment in 2000,* A. Aziz, S.A. Kadar, and H.S. Barlon (Eds.) (UK: CAB Internation, Wallingfood Oxan) pp. 195-212.

Singh, J., Arora, R. and Singh, A.S. 1987. First record of predators of cotton pests in the Punjab; *J. Bombay Nat. Hist. Soc.,* 84: 456.

Singh, O.P. 1985. New record of *Rhynocoris fuscipes* Fabr. as a predator of *Dicladispa armigera* (Oliver); *Agri. Sci. Digest,* 5: 179-180.

Singh, O.P. and Gangrade, G.A. 1975. Parasites, predator and diseases of larvae of *Diacrisia oblique* Walker (Lepidoptera: Arctiidae) on soyabean; *Curr. Sci.,* 44: 481-482.

——— 1976. Biology of a reduviid predator, *Rhynocoris fuscipes* Fabricius on the larvae of *Diacrisia oblique* Walker (Lepidoptera. Noctuidae); *JNKVV Res. J.,* 10: 148-160.

Singh, O.P. and Singh, K.J. 1987. Record of *Rhynocoris fuscipes* Fabricius as a predator of Green stinkbug, *Nezara viridula* Linn. Infesting soyabean in India; *J. Biol. Control,* 1: 143-146.

Singh, S.P. 1994. Fifteen years of AICRP on biological control; Technical Bulletin No.8. *Project Directorate of Biological Control, Bangalore, India.*

Singh, S P., Rao, N.S. and Henneberry, T.J. 1993. Leafhoppers and their natural enemies; *Technical Bulletin No.6, Project Directorate of Biological Control, Indian Council of Agricultural Research, Bellary Road, Bangalore.*

Singh, V., Dubey, O.P., Radhakrishnan Nair, C.P. and Pillai, G.B. 1978. Biology and bionomics of insect pests of cinnamon; *Journal of Plantation Crops.* 6(1): 24-27.

Singh, V., Naik, B.C. and Sundararaju, D. 1982. *CPCRI Annual report for 1979* Central plantation Crops Research Institute, Kasargod, India; 132-134

Sitaramaiah, S. and Satyanarayana, S.V.V. 1976. Biology of *Harpactor costalis* Stal (Heteroptera: Reduviidae) on tobacco caterpillar *Spodoptera litura* F.; *Tobacco Research,* 2: 134-136.

Sitaramaiah, S., Joshi, B.G. Prasad, G.R., and Satyanarayana, S.V.V. 1975. *Harpactor costalis* Stal (Reduviidae: Heteroptera) new predator of the tobacco caterpillar (*Spodoptera litura* Fabr.); *Sci. and Cult.*: 41: 545-546.

Slater, J.A. and R.M Baranowski. 1978. How to know the true bugs (Hemiptera-Heteroptera). W.C. Brown Co., Dubuque. 256p.

Smith, C.N. 1966. Insect colonization and mass production. *Academic press, New York*. P. 198.

Smith, D., Beattie, G.A.C. and Broadley, R (eds). 1997. *Citrus Pests and Their Natural Enemies*. Department of Primary Industries, Brisbane.

Solomon, M.E. 1949. The natural control of animal population; J. *Anim. Ecol.,* 18: 1-35.

Soo Hoo, C.F. and Fraenkel, G. 1996. Selection of food plants in a polyphagous insect *Prodaeaia eridaenia*, *J. Insect. Physiol* 12: 693-709.

Stride, G.O. 1956a. On the mimetic association between certain species of *Phonoctonus* (Hemiptera. Reduviidae) and the Pyrrhocoridae: *J. Ent. Society, South Afr.,* 19: 12-27.

— — — 1956b. On the biology of certain West African species of *Phonoctonus* (Hemiptera: Reduviidae) mimetic predator of the Pyrrhocoridae; *Ibid ,* 19: 52- 69.

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 J. Vet. Sci.,* 27: 117-122.

Subramanian, B. 1993. Potential pesticidal plants of India. In: Botanical and biopesticides. Eds B.S. Parmar and C. Devakumar. S.P.S. Publications No.4 Society of pesticide Science, India and Westvill Publishing house New Delhi.pp.74-100.

Sundararaju, D. 1984 Cashew pests and their natural enemies in Goa; *J. Plant. Crops,* 12: 38-48.

Swadener, S.O., and Yonke, T.R. 1973a. Immature stages and biology of Sinea complexa with notes on four additional reduviids (Hemiptera: Reduviidae). J. Kansas Entomol. Soc. 46: 123-136.

— — — 1973b. Immature stages and biology of *Apiomerus crassipes* (Hemiptera: Reduviidae) *Ann Ent. Soc. Amer.,* 66 188-196.

— — — 1973c. Immature stages and biology of *Zelus socius* (Hemiptera: Reduviidae); *Can. Ent.,* 105: 231-238.

— — — 1975. Immature stage and biology of *Pselliopus cinctus* and *Pselliopus barberi* (Hemiptera: Reduviidae); *Ibid.,* 48: 472-492.

Tawfik, M.F.S., Awadallah, K.T. and Abdellah, M.M.H. 1983a. The biology of the reduviid *Allaeocranum biannulipes* (Montrouzier & Signoret), a predator of stored product insects; *Bull. Soc. Ent. Egypt.*, 64: 231-237.

— — — 1983b. Effect of temperature and relative humidity on the various stages of the predator *Allacocranum bianulipes* (Montrouzier Signoret); *Bull. Soc. Ent. Egypt.*, 64: 239-250

— — — 1983c. Effect of prey on various stages of the predator, *Alloeocranum biannulipes* (Montr. et Sig.) (Hemiptera: Reduvidae); *Bull. Soc. Ent. Egypt,* 64: 251-258.

Taylor, E.J. 1949. Biology of the damsel bug, *Nabis alternatus; Prof. Utah. Acad. Sci.,* 6. 132-133.

Taylor, J.S. 1932. Report on cotton insect and disease investigations part II. Notes on the American boll worm (*Heliothis obsolete* Fabr.) on cotton, and on its parasite, *Microbracoss brevicornis Western; Sci. Bull. Dept. Afri. S. Agri.,* 113: 18.

Thompson, D.J. 1975. Towards a predator-prey model incorporating age structure: the effects of predator and prey size on the predation of *Daphnia magna* by *Ischnura elegans. Journal of Animal Ecology.* 44: 907-916.

Thompson, W.R. and Simmonds, F.J. 1964. A catalogue parasites and predators of insect pests. Sect: 3 Predator Host catalogue Common wealth Agri. Bureaue Books, England. 2048.

Todd, J. N. 1937. Life history of the wheel-bug, *Arilus cristatus* (Linn.) (Hemiptera: Reduviidae). *Entomol. News* 48: 226-228.

Trivedi, T.P. and Rajagopal, O. 1988. Natural enemies of potato aphids, *Myzus persicae* Sulzer and *Apis gossypii* Glover (Hemoptera: Aphididae) in India; *Bicovas.* 2: 173-177.

Usha Rani, P. and Wakamura, S. 1993. Host acceptance behaviour of a predatory pentatomid, *eocanthecona furcellata* (Wolff) (Heteroptera. Pentatomidae) towards larvae of *Spodoptera litura* (Lepidoptera: Noctuidae); *Insect Sci. Applic. Vol. 14, No. 2,* pp. 141-147.

Usinger, R.L 1956. Hemiptera, pp. 182-228 *in* Aquatic insects of

California, R L Usinger (ed.), University of California Press, Berkeley. 508 p

Uthamasamy, S. 1995. Biological control of the introduced psyllid, *Heteropsylla cubana* Crawford (Homoptera: Psyllidae) Infesting subabul *Leucaena leueocephala* (Lam.) de Wit. Progress and Prospects. In Biological control of social forest and plantation crops insects, T.N. Ananthakrishnan (Ed.). (New Delhi: Oxford & IBH Publishing Co. Ltd.), pp. 65-75.

Vanderplai,k, F.L. 1958. The assassin bug *Platymeris rhadamanthus* Gerst. (Hemiptera: Reduviidae) a useful predator of the Rhinoceros beetles *Oryctes boas* F. and *Oryctes moneros* (Oliv); *R. Ent Soc. S. Afr.*, 21: 309-314.

Varma, R.V. 1989. New record of *Panthous bimaculatus* (Hemiptera: Reduviidae) as a predator of pests of *Alantha triphysa; Entomon.*14: 357-358.

Veeresh, G.K. and Puttarudriah, M. 1970. Studies on the morphology and biology of the assassin bug, *Isyndus heros* Fabricius (Hemiptera: Reduviidae); *Mysore J. Agri. Sci.*, 4: 285-295.

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.

Vennison, S.J. 1988. Bioecology and Ethology of assassin bugs *(Insecta: Heteroptera. Reduviidae);* Ph D. thesis, Madurai Kamaraj University, Madurai, India.

Vennison, S.J., and Ambrose, D.P. 1986. Impact of mating on oviposition pattern and hatchability in *Rhynocoris fuscipes* (Heteroptera: Reduviidae) a potential predator of *Heliothis armigera*; *J. Soil Biol. Ecol*, 6(1): 57- 61.

— — — 1986b. Impact of mating on oviposition pattern and hatchability in *Rhynocoris fuscipes* (Heteroptera: Reduviidae), potential predator of *Heliothis armigera;* J. Soil Biol. & Ecol., 6: 57-61.

— — — 1988a. 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.

— — — 1988b. Two new species of *Acanthaspis* (Heteroptera. Reduviidae: Acanthaspidinae) from southern India. *J. Bombay Nat. Hist. Soc.*, 85: 383-390

——— 1989 Biology and predatory potential of a reduviid predator *Oncocephalus annulipes* Stal (Hemiptera: Reduviidae); *J. Biol. Control,* 3. 24-27.

——— 1990. Biology of an assasin bug *Velitra sinensis* walker (Insecta: Heteroptera: Reduviidae) from south India. *Indian J. Ent.,* 52: 310-319.

——— 1991 Biology and behaviour of *Ectomocoris xavierei* Vennison and Ambrose 1990 (Heteroptera: Reduviidae: Peiratinae); *Tropical Zool.,* 4: 251-258.

——— 1992. Biology behaviour and biocontrol efficiency of a reduviid predator *Sycanus reclinatus* Dohrn (Heteroptera: Reduviidae) from southern India; *Mitt. Zool. Mus. Berl.,* 68: 143-156

Wallace, H.R. 1953. Notes on the biology of *Coranus subapterus* DeGeer (Hemiptera: Reduviidae); *Proc. R. Ent. Soc. Lond.,* (A), 28: 100-110.

Watson, T.R. 1918. Insects of citrus grove *Univ. Fl. Agr. Exp. Stat. Bull.* 144: 261.

Weaver, E.C., Clarke, E.T. and Weaver, W. 1975. Attractiveness of an assassin bug to stingless bees. *J. Kanas. Entomol. Soc.,* 48: 17-18

Webster, F M. 1907. The chinch bug, *Pselliopus cinctus; Bull. U.S.D.A. Bur. Ent.,* 69: 95.

Webster, R.L. 1912. The peral slug, *Sinera diadema; Iowa Bull.,* 130: 190.

Whitcomb, W.H. and Bell, K. 1964. Predaceous insects, spiders and mites and Arkansas cotton fields; *Bull. Ark. Agric. Exp. Stn.,* 690: 1-84

Wygodzinsky, P. 1966. A monograph of the Emesinae (Reduviidae, Hemiptera); *Bull. Am. Mus. Nat. Hist.,* 133: 1-614.

Zerachia, T., Bergmann, F. and Shulov, A. 1973a. Pharmacological activities of the venom of the predaceous bug *Holotrichius innesi* (Het. Reduviidae). In animal and plant toxins (ed) Kaiser, E. pp. 143-146.

Zerachia, T., Shulov, A and Bergmann, F. 1973b. Haemolysis induced by the venom of the Predaceous bug *Holotrichius innesi* (Het. Reduviidae) In, Animal and Plant toxins (ed.) Kaiser, E pp. 147-150

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