BIOLOGY AND PREDATORY POTENTIAL OF *Rhynocoris marginatus* (FAB.) (HEMIPTERA: REDUVIIDAE) ON INSECT PESTS OF COWPEA

By

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(2015 – 11 - 025)

THESIS

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DECLARATION

I, Femi Mohasina M. (2015-11-025), hereby declare that this thesis entitled **"Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea"** is a *bona fide* record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me any degree, diploma, fellowship or other similar title of any other University or Society.

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CERTIFICATE

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

Cowpea *Vigna unguiculata* (L.), is an important leguminous vegetable crop grown in an area of 6750 ha across Kerala with an annual production of 4196 tons. It is a crop bestowed with a series of merits such as rich nutrient composition, multiple uses as vegetable, grain legume and an animal fodder and suitability as an intercrop due to its high nitrogen fixing ability.

Insect pests pose the major threat to cowpea cultivation and the crop is severely attacked at every stage of its growth. The most damaging insect pests are cowpea aphid, *Aphis craccivora* (Koch.), leaf eating caterpillar *Spodoptera litura* (Fab.), legume pod borer, *Maruca vitrata* (Fab.) and pod sucking bug, *Riptortus pedestris* (Fab.). Infestation by these multiple pests in field often causes a reduction in the yield by 30 – 60 per cent. Insecticides are available as a popular solution to manage the insect pests in cowpea. However, these insecticides need to be sprayed from the very beginning of crop stage and need to be continued till crop maturity. Sole dependence on insecticides are not advisable in a crop like cowpea in which the pods are harvested on every alternate day.

A natural enemy that can offer control against a diverse range of insect pests could be a valuable tool in cowpea pest management. Reduviid predators have been reported as potential predators which consume not only more numbers of prey but also a diverse range of prey. Being polyphagous in nature, they can be excellent candidates for augmentation in crops with diverse herbivore fauna such as cowpea. Even though reduviids are generalist predators, reportedly they have preference to lepidopteran caterpillars especially *S. litura* followed by hemipterans. *Rhynocoris marginatus* (Fab.) is a Harpactorine reduviid predator and the potential of reduviids under Harpactorinae subfamily against many economically important insect pests of vegetables, groundnut and cereals in India has been well documented (Ambrose, 2003).

Despite many reduviids identified as preying up on a wide array of insect pests, sufficient and consistent investigation on their distribution and biology have not carried out all over India with few studies in Kerala. Though the efficacy of a natural enemy as augmented biocontrol agent can only be assessed through field evaluation, it is necessary to obtain information on biology and behavior from laboratory experiments. Apart from this, studies under confined condition enable easier and reliable prediction of the field performance of a biocontrol agent in an augmented field situation.

Hence an attempt was made on the study of "Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea" with the following objectives.

1. To study the biology of *R. marginatus* on *S. litura*
2. To evaluate the predatory potential of *R. marginatus* on *S. litura* under laboratory condition.
3. To study the predatory efficacy of *R. marginatus* on cowpea aphid, *A. craccivora* and leaf feeder, *S. litura* under caged condition.
4. To study the field efficacy of *R. marginatus* on insect pests of cowpea.

Review of literature

2. REVIEW OF LITERATURE

Reduviid (Reduviidae: Hemiptera) predators are the largest land heteropterans, consisting of 7000 species and subspecies under 913 genera and 25 subfamilies (Maldonado, 1990). Indian reduviid fauna include 464 species belonging to 144 genera and 14 subfamilies (Ambrose, 2006).

Rhynocoris marginatus (Fab.) is a harpactorine reduviid predator and an effective biocontrol agent against nearly 20 insect pests of many cultivated crops. These reduviid predators, though generalists are useful in a crop ecosystem acting on diverse pest species. Present work is mainly concentrated on successful augmentation methods of these predators especially in legume crops.

The literature on important insect pests of cowpea, biology and predatory potential of *R. marginatus* and other reduviids, and field efficacy of reduviid predators on various insect pests in different crop ecosystems are reviewed here under.

2.1 PESTS OF COWPEA

Cowpea is a leguminous vegetable cultivated throughout Kerala. It is infested by a variety of insect pests at various stages of growth. The major insect pests of cowpea included cowpea aphid, *Aphis craccivora* (Koch), pod bug, *Riptortus pedestris* (Fab), legume pod borer, *Maruca vitrata* (Fab.), pea blue, *Lampides boeticus* (Linnaeus) and cotton boll worm, *Helicoverpa armigera* (Maxwell-Lefroy, 1909). Cotton leaf worm, *Spodoptera litura* (Fab.) is a serious pest of cowpea, which is primarily a defoliator and in large numbers can cause complete crop failure (Singh and Emden, 1979), causing damage 85.5 per cent (Ram *et al.*, 1985).

Many insect pests such as *A. craccivora*, *Empoasca kerri* (Pruthi), *S. litura* and *M. vitrata* attack cowpea causing an overall damage of 65 -100 per cent. Aphids attack the plant at the seedling stage, while the flower thrips, *Megalurothrips sjostedti* (Trybom) at the flowering stage and the pod borer, at the pod formation stage (Taylor, 1981). The most damaging effect of cowpea aphid is the transmission of cowpea mosaic virus which causes mosaic like symptoms and results in high yield loss (Atiri *et al.,* 1984).

Fatokun *et al.,* (2000) reported that the productivity of cowpea inspite of all the improvement brought in cultivation was very less due to the increasing insect pest damage.

Aphids cause significant damage to the crop by sucking the sap and is one of the most important pest of cowpea in terms of economic damage (El – Ghareeb *et al.*, 2002). According to Xue *et al.,* (2009) the larval survival of *S. litura* was more on cowpea plant compared to other hosts like chinese cabbage, sweet potato and tobacco resulting in severe damage in cowpea crop. Recently *S. litura,* was being reported as a major pest in polyhouse cultivation. (Vashisth *et al.*, 2016)

2.2. BIOLOGY AND MORPHOMETRICS OF *Rhynocoris marginatus*

Ambrose and Livingstone (1989) in their observations on the biology of *R. marginatus* reported that the eggs were pale yellow in colour and were laid in batches and glued to each other. The incubation period was 9-13 days and it took 68 – 115 days for total development. Female biased sex ratio was reported and females lived longer than males.

In a laboratory study Ambrose *et al.,* (1990), observed a mean nymphal duration of *R. marginatus* as 84.70 ± 1.01 days when reared singly on *Odentotermes obesus* (Rambur) but when reared singly on grasshopper, the mean nymphal period duration was significantly lesser (46 ± 0.00 days).According to Sahayaraj (1995) the mean adult longevity of female predator was more (69 days) than that of male predator (47 days) when reared on 3 - 4 days old *S. litura* larvae, and the nymphal period was an average of 37.66 days

George (1999a) made a comparative study on the biology of *R. marginatus* on the larvae of three prey such as *Corcyra cephalonica* (Stainton), *S. litura* and *Earias vitella* (Fab.) and reported maximum fecundity and adult longevity as well as minimum developmental period when the predator was reared on the larvae of *S. litura.* The average incubation period recorded was 9 ± 0 days and the nymphal developmental duration was 20.43 ± 2.84 days. The fecundity reported was 191.89 ± 39.69 eggs/ female. When reared on third or fourth instar larvae of *S. litura,* the mean oviposition period of predator was 111.84 days and the mean preoviposition period was 18.64 days.

George (1999b) found that three colour morphs of *R. marginatus*, namely niger, sanguineous and nigro-sanguineous morph had variations in their developmental period and other biological parameters. The mean incubation period of niger morph was 9.17 ± 0.51 days and the mean total nymphal period was 102.08 ± 2.01 days. The mean longevity of an adult female was found to be 43.43 ± 12.84 days and that of an adult male was 19.67 ± 7.17 days. Niger morph had the lowest developmental period among the three morphs. The eggs laid by sanguineous morph of *R. marginatus* hatched in 8.51 days. The life from egg to adult extended to an average of 105.93 ± 1.02 days. The average life period of adult male was 75.29 ± 8.82 and female was 29.71 ± 5.59 days. The mean egg incubation period was the highest for nigrosanguineous morph (9.85 ± 0.72) but it had the shortest stadial period (96.92 ± 0.93). The adult females of nigrosanguineous morph lived longer (45.00 ± 7.14) than their respective males (18.60 ± 5.15). The mean preoviposition period of niger morph of *R. marginatus* was 33.33 ± 2.78 days, sanguineous morph was 45.00 days and nigrosanguineous morph was 33.00 ± 1.47 days. The sanguineous morph of *R. marginatus* laid the highest number of eggs (175.00) followed by niger (154.67 ± 52.82) and nigrosanguineous (101.25 ± 47.04) morphs. Total number of nymphs hatched showed high variation among the three morphs. It was 97.00 ± 00 in case sanguineous morph, 88.33 ± 23.64 in niger morph and 36.50 ± 20.75 in case of nigrosanguineous morph.

Sahayaraj and Paulraj (2001) studied biology of *R. marginatus* on *S. litura* under laboratory where they reported that the total developmental period of *R. marginatus* was 46.71 ± 1.58 days. Preoviposition period lasted for 18.64 ± 0.76 days and oviposition period was 6.31 times longer than preoviposition period. Females had more life span (128. 04 ± 8.48 days) when compared to males (82.84 ± 11.09 days). An adult female laid an average of 405.28 ± 22.15 eggs in its life span. The eggs hatched after 6.81 ± 0.10 days and the 1st, 2nd, 3rd, 4th and 5th instars lived upto (10.54 ± 0.22, 6.53 ± 0.19, 10.45 ± 0.34, 8.83 ± 0.41 and 10.36 ± 0.34 days) respectively when reared together. The females lived longer (128.04 ± 8.48 days) than males (82.84 ± 11.09 days) and during its entire life time adult female preyed upon an average of 234 third and fourth instar larvae of *S. litura*. This reduviid is reported to have a female biased sex ratio (male: female – 0.91:1.0) and the female predator showed paternal care for the eggs. They also reported that the female of *R. marginatus* laid the highest number of eggs (405.28 ± 22.15) when reared on larvae of *S. litura.* The pre oviposition period was 20.43 ± 2.84 days and the oviposition period was six times longer than preoviposition period which is an added advantage while mass rearing a biocontrol agent.

Sahayaraj (2001) observed that when female of *R. marginatus* was reared on the grasshopper *Chrotogonus sp*., had an average length of 1.92 cm. Sahayaraj and Jeyalekshmi (2002) compared the morphometrics of third instar nymph of *R. marginatus* fed with live *Corcyra cephalonica* larvae with that of third instar nymph fed with frozen larvae. The predator when fed with live *C. cephalonica* larvae had a head length 0.44mm, width of 0.15 mm, thoracic length of 0.98 mm, thoracic width of 0.52 mm, abdominal length of 0.78 mm and abdominal width 0.47 mm, as against head length of 0.43 mm, width of 0.15 mm, thoracic length of 0.97 mm, thoracic width of 0.46 mm, abdominal length of 0.78 mm and width of 0.47 mm respectively for nymphs reared on frozen larvae. He also reported that the laboratory rearing of *R. marginatus* was more successful with live *C. cephalonica* larvae than in dead larvae. *R. marginatus* nymphs fed with live larvae of *C. cephalonica* had a developmental period of 48.66 ± 1.6 days which was significantly higher than those fed with frozen larvae (41 ± 0.2 days). Male (141.91 ± 10.87 days) and female (123.5 ± 13.5 days) of *R. marginatus* had the longest adult longevity when reared in live larvae when compared to that in dead larvae.

George *et al.,* (2002) reported that *R. marginatus* had the longest nymphal period when reared on *Raphidopalpa foveicollis* (Lucas) (100.08 ± 9.06 days) than on *Chrotogonus sp.* (85.52 ± 10.14 days) and the minimum developmental period was recorded on *S. litura* (69.36 ± 6.75 days).

R. marginatus when mass reared on *C. cephalonica* larvae fed with four different diets, it was observed that the shortest stadial period was seen in the nymphal instars fed with Jowar Fed Corcyra – JFC(38.5 ± 0.3 days) followed by the nymphs fed with Sorghum Fed Corcyra – SFC (40.1 ± 0.7 days). This reduction in nymphal period in nymphs fed with JFC was mainly as a result of better nutrition obtained by the predator with less expenditure of energy and also because of this, *R. marginatus* male and female fed with JFC had the highest adult longevity when compared to *C. cephalonica* reared in other diets whereas the shortest longevity was recorded on WFC (Wheat Fed Corcyra) i.e. 147.9 ± 6.5 days for female and 135.7 days for male (Sahayaraj and Sathiamoorthi, 2002).

In a recent study, Pravallika (2015) found that adult of *R. marginatus* laid 380 ± 11.92 eggs in its life time. The oviposition started 18.8 ± 0.37 days after adult emergence and continued for a period of 58.5 ± 2.5 days. The nymphal developmental period was 62.3 ± 2.62 days. The life span of adult female and male was 128.04 ± 8.48 days 82.84 ± 11.09 days respectively. She also observed that the female bug had a length of 9.77 ± 0.14 mm and width 3.60 ± 0.08 mm and male bug had a length of 9.61 ± 0.13 mm and width of 3.33 ± 0.02 mm.

2.3 BIOLOGY AND MORPHOMETRICS OF OTHER *Rhynocoris sp.*

In a study on the biology of *Rhynocoris kumarii* Ambrose and Livingstone on *C. cephalonica* Ambrose and Livingstone (1989), reported five nymphal instars with mean durations of 11.73 ± 1, 11.28 ± 0.5, 10.34 ± 0.5, 11.17 ± 0.5 and13.55 ± 0.7 days respectively. Adult longevity was 21.61 ± 0.6 days for female and 21.64 ± 1.3 days for male. The preoviposition period of *R. kumarii* was 26 ± 5 days and the fecundity of females on an average was 29 ± 5 eggs with a hatchability of 37.38 ± 16.79 per cent.

Ambrose and Claver (1997) recorded the fecundity of females of two reduviid predators *R. fuscipes* (61 -101 eggs) and *Cydnocoris gilvus* Brum. (45- 89eggs). The oviposition period was 43- 47 days for *R. fuscipes* and 27 - 43 days for *C. gilvus.*

Ambrose *et al.*, (2003) reared *Rhynocoris longifrons* (Stal.) on four different hosts – *C. cephalonica, O. obesus, Clavigralla gibbosa* Spinola and *H. armigera*. The eggs of adults reared on *H. armigera* larvae had the shortest incubation period (7.8 ± 1.5days) whereas the eggs of adults fed with *O. obesus* had the longest incubation period (8.3 ± 1.1 days). The eclosion of all the eggs took 4 to 7 minutes and only 62.1 ± 6.3 per cent of eggs hatched within this time period when the adults were reared in *C. cephalonica*. The nymphal development duration of *R. longifrons* when reared on *O. obsesus* was the highest (72.7 days) and the lowest was when reared on *H. armigera* larvae (58.4 days). Adults reared on *H. armigera* lived longer (114.9 ± 13.4) and were followed by those on *C. gibbosa* (104. 9 ± 6.9), *O. obesus* (78.6 ± 12.0) and *C. cephalonica* (66.8 ± 10.4). They also reported that the preoviposition period of *R. longifrons* was 14.3 ± 1.9 days while the post oviposition period was 12.6 ± 2.1 days when reared on larvae of *C. cephalonica*. The mean number eggs laid in the life period of a female was the highest when insects was fed with *H. armigera* larvae (159.3 ± 22.4) and significantly shorter when insects were fed with *O. obesus* (41.8 ± 20.9). *R. longifrons* had a slightly female biased sex ratio. He also redescribed the male of *R. longifrons* in which the body length of predator is 9.7 ± 1 mm, width across eyes is 0.7

± 0.1 mm, width across prothorax is 2.9 ± 0.1 mm and the width across the abdomen 2.8 ± 0.3 mm.

The biology of *Rhynocoris fuscipes* (Fab.) was studied by Sahayaraj and Selvaraj (2003) in which he reported that the incubation period was 8.0 ± 1.0 days for eggs. The duration of nymphal stages when reared with *C. cephalonica* was 37.6 days.

According to Ravichandran (2004) the preoviposition period of *R. kumarii* was 54 days while the oviposition period was 53.1 days. The survival rate of immature stage to adult was 0.74 adult/ individual. The adult female laid an average of 133.77 eggs during its entire life time.

Kalidas and Sahayaraj (2012) reported that the eggs of *R. longifrons* hatched in 7 to 8 days when fed with different types of prey, with the highest hatchability on *H. armigera* as compared to other prey species viz., *D. cingulatus A. gossypii* and *Phenococcus solenopsis* Tinsley.

Sahayaraj (2012) attempted to study the effect of artificial rearing media on *Panthose bmaculatus* along with *Sycanus collaris* Fab. and *R. kumarii*. When these predators were reared in meat based artificial diet under laboratory conditions, *R. kumarii* had an incubation period of 10 days, *S. collaris* – 15 days and *P. bmaculatus* – 21 days. *R. kumarii* took 88.30 ±3.60 days to become adult from first instar nymph, while *S. collaris* took 75.67 ± 9.06 days and *P. bimaculatus* took 101.12 ± 2.30 days to become adult. There was an increase in the nymphal period of *R. kumarii* (49.30 ± 1.95), *P. bimaculatus* and *S. collaris* when compared to the duration in previous studies by George *et al.,* (1998). The sex ratio was the lowest for *S. collaris* (1; 0.67), followed by *P. bimaculatus* (1: 0.60) and *R. kumarii* (Sahayaraj, 2012).

Bhat *et al.*, (2013) recorded the biology of *Rihirbus trochantericus* Stal – an indigenous predator of tea mosquito bug *Helopeltis antonii* Signoret. The duration of I, II, III, IV and V nymphal instars were 12.39 ± 1.13, 7.00 ± 0.39, 7.56 ± 0.35, 9.28 ± 0.64 and 12.78 ± 1.27 days respectively. The adult male lived for 107.13 ± 2.70 days while the female predator lived for 117.9 ± 3.3 days. One egg mass contained an average of 26 eggs.

Biology of the predatory reduviid *Panthous bmaculatus* was investigated by Muthupandi *et al.,* (2014) on *C. cephalonica*, artificial diet and *S. litura*. Eggs hatched in 21.3 ± 0.86, 21.00 ± 0.00, 23.00 ± 0.00 days when reared on *C. cephalonica*, artificial diet and *S. litura* respectively. The developmental period of first, second, third, fourth and fifth instars fed with *C. cephalonica* was 13.47 ± 0.44, 11.56 ± 0.34, 16.24 ± 0.77, 15.24 ± 0.96 and 18.57 ± 2.53 days respectively. When reared on artificial diet the duration of instars was 15.76 ± 1.36, 17.00 ± 3.27, 24.25 ± 5.08, 15.00 ± 0.00, 17.20 ± 1.57 days respectively. The developmental period was less when fed with *S. litura* 13.67 ± 0.55, 11.97 ± 0.60, 15.86 ± 1.04, 15.36 ± 1.47, 16.25 ± 1.82 days respectively for first, second, third, fourth and fifth nymphal instars. The sex ratio was 1: 0.71 female: male when reared on *C. cephalonica*.

The early nymphal instars of *Rhynocoris albopilosus* Signoret was reared on larvae of eri silk worm, *Samiacynthia ricini* (Drury). The first instar started feeding 6 to 12 hours after hatching and it had a developmental period of 8.67 days. The second and third instar took 8.00 and 6.67 days respectively to complete the instar. The first instar nymph fed maximum number of larvae (0.72 ± 0.05 preys/ day) during the first day, while the second and third instar nymph consumed a maximum of 0.63 ± 0.10 preys on third day and 0.21 preys on third day respectively. (Sahayaraj *et al.,* 2015).

Shanker *et al.,* (2016) studied the biology of *R. fuscipes* on rice leaf folder, *Cnaphalocrocis medinalis* Guenee. Female laid eggs in batches of 6 to 12 and the eggs hatched in 7 to 12 days. In total female predator laid an average of 60.4 ± 20.23 eggs during its life time. Maximum fecundity was seen when fed with lepidopteran larvae (169 eggs/ female). The hatchability of eggs was 94.3 per cent and the preoviposition period extended up to 53.2 ± 10.06 days. They also reported that the total developmental period duration of first generation of *R. fuscipes* was 76.80 ± 11.21 days and it was reduced in the subsequent second (72.50 ± 7.08days) and third generations (67.80 ± 2.04 days). The average life span of male predator was 57.20 ± 16.16 days and that of female predator was 70.30 ± 19.06 days. This predator had a male biased sex ratio (1: 0.83).

2.4 EVALUATION OF PREDATORY PREFERENCE UNDER LABORATORY CONDITIONS

2.4.1 *Rhynocoris marginatus*

Predatory potential and predatory behaviour of *R. marginatus* studied on various insect pests such as lepidopterans and hemipterans are reviewed here under.

Haridass (1985) observed that stimuli response mediated predatory behavior in reduviid began with search for the prey and it was followed by activities like approach and attack of the prey, immobilization of prey, transportation of prey to safe place and consumption of the prey.

Sahayaraj and Sivakumar (1995) stated that preferred life stage of prey *S. litura* (second, third, fourth and fifth-instar larvae) by reduviid predator, *R. marginatus* varied with the life stage of the predator and each stage had its own preference.

Ambrose and Claver (1996) when studied the preference of *R. marginatus* for three pests- *S. litura, Euproctis mollifera* (Thunberg) and *Mylabris pustulata* (Thunberg), the predator preferred *S. litura* over other preys due to the soft cuticle and slow movement of the larvae. *S. litura* larvae of size below 1 cm was preferred by first instar nymph while the second instar fed mostly on 0.1 to 1.0 cm long larvae. Larvae of size 1 to 2.0 cm was preferred by third and fourth instar of the predator. The large sized larvae of 0.6 to 2.5 cm were preferred by fifth nymphal instar, adult male and female. They observed more number of kills by *R. marginatus* at higher prey densities as the prey densities increased from one prey/ predator to 16 prey/ predator thus exhibiting a type II functional response. At prey density of 10 prey/ predator, an adult female of *R. marginatus* attacked 7.33 larvae of *S. litura* while it attacked 13.50 larvae at a prey density of 16 prey/ predator. When predatory potential of *R. marginatus* was studied on *S. litura* larvae a positive correlation was obtained between the prey density and the number of prey killed (log y = 3.53 + 5.17 log x; r = 0.979).

In a comparative study on predatory efficiency of *R. marginatus,* George and Sreenivasagan (1998) reported greater preference of *R. marginatus* to larvae of *S. litura* than to *H. armigera* irrespective of the prey size. First instar of *R. marginatus* consumed 4.00 ± 0.63 larvae of *S. litura* compared to 2.50 ± 0.55 larvae of *H. armigera.* When smaller prey was provided, adult females consumed more than males..

Ambrose (1999) stated that the adults and nymphal instars of *R. marginatus* preferred *H. armigera* over *M. pustulata* and *E. insulana* in a laboratory experiment. He studied the stage preference and capture success of the predator with *H. armigera* as prey and found that adult predator was completely successful in capturing larvae of 5 to 19 mm size. The fifth instar nymph was 95 per cent successful in capturing 20 to 24 mm sized larvae, 90 per cent successful in capturing larvae of 25 to 29 mm and 83 per cent successful in capturing larvae of size 30 to 34 mm. With *S. litura*, *H. armigera* and *E. mollifera* as prey, he reported that adult female was more efficient in catching larger larvae of size 130 – 160 mm (46 %) followed by adult male (45 %) and fifth instar nymph (39 %). He observed that the predatory behaviour in reduviids is mediated by sensory responses and it includes activities in sequence such as arousal, approach, capturing, rostral probing, injection of toxic saliva and paralysing, sucking and post predatory behavior. He also reported that harpactorines pin and jab their prey with their rostrum.

According to Sahayaraj (1999a) the fourth instar nymph of *R. marginatus* accepted fourth instar larvae of the *S. litura* (43.76%) while fifth instar of the predator accepted fifth instar larvae (48.14%) and the adult preferred sixth instar larvae (50.13%) when different instars of larvae were given as prey together. Even though *R. marginatus* were polyphagous predators they had clear preference for lepidopteran pests followed by pests from hemipteran and coleopteran families (Ables, 1978; Sahayaraj, 2008).

Sahayaraj and Balasubramanian (2009) reported that the predator reared on artificial diet fed on greater number of prey than those reared on natural diet. The female of *R. marginatus* reared in artificial diet was efficient in killing S. *litura* larvae (2.40 prey/ predator/ day) than third instar nymph of *D. cingulatus* (1.36 prey/ predator/ day).

Pravallika (2015) reported that the number of third instar larvae of *S. litura* killed by the adult predator at prey densities of 2, 3, 5, 7 and 10 were 1.6, 1.8, 3.0, 3.6, and 3.8 respectively.

2.4.2. Other reduviid predators

Claver and Ambrose (2002) found that the predation rate of *R. fuscipes* on *H. armigera*, *Euproctis subnotata* Walker and *Exelastis atomosa* (Walsingham) increased with the increasing prey density but the highest attack ratio (3.1, 3.3 and 3.0) was observed when the prey density was 1 prey/ predator and the lowest (0.45, 0.43 and 0.46) was found when the prey density was 16 prey/ predator.

In an experiment Ravichandran (2004) studied the prey preference of IV, V instars and adult of *R. kumarii* to different insect pests of cotton such as *S. litura, H. armigera, E. mollifera, D. cingulatus, Riptortus clavatus* (Thunberg), *M. pustulata, Dittopternis venusta* (Walker) by using choice tests. The results obtained showed that fourth nymphal instar preferred lepidopteran larvae like *S. litura* (78.72%) over *D. cingulatus* (17.02%) and *M. pustulata*. The fifth nymphal instar preferred *H. armigera* (70.52%) over *R. clavatus* (17.86%) and *E. mollifera* (11.86%). The adults of *R. kumarii* preferred *H. armigera* (44.5%) to *S. litura* (32.2%) and *D. cingulatus* (18.3%). Preference of predator for different prey sizes were also assessed in laboratory. The preference of first instar nymph for 0.1 – 0.5 cm long *H. armigera* larvae was more when compared to other sizes. The second and third instar nymph preferred 0.1 – 0.5

cm long larvae while the adult male and fourth instar nymph preferred 1.1 – 1.5 cm long larvae. The adult female preferred the largest size larvae given in choice experiments (1.5 – 2.5 cm). The first, second, third, fourth, fifth instars and adults of *R. kumarii* preferred larvae of size < 0.1cm, 0.1- 1.0 cm, 0.1 – 2.0 cm, 0.1 – 2.0 cm, 0.6 – 2.0 cm, 0.6 – 2.5 cm respectively.

The predatory behaviour of adult of *Coranus spiniscutis* (Reuter), an adult reduviid bug was studied on larvae of tomato fruit borer, *H. armigera*, *S. litura* and *D. cingulatus* under laboratory conditions by Claver *et al.,* (2004). According to them the predator preferred third instar nymph of *D. cingulatus* (54.16%) over larvae of *Anomis flava* (37.5%) and third instar larvae of *H. armigera* (8.33%) and it showed Holling's type II functional response curve when the correlation between the prey density and number of prey killed was plotted from the mean of five days observation. The time taken for predation also was noted compared for adults starved for various days and daily fed prey. The adult bug which fed daily took more time for predation than the predator starved for one, two and three days. The five day starved predator took less time for predatory activities (0.08 ± 0.01 min for arousal, 0.05 ± 0.01 min for approaching the prey, 0.16 ± 0.01 minutes for capturing the prey, 2.60 ± 0.21 minutes for paralyzing the prey, 69.16 ± 9.75 minutes for piercing and sucking the prey).

Assessment of predatory potential of *Sphedanolestes variabilis* Distant at various prey densities of *C. cephalonica* under laboratory conditions revealed that the searching efficacy and rate of consumption by the predator were at their maximum at a density of 4 prey/ predator. Moreover the predation rate increased from 1prey/ predator to 4 prey/ predator and a constant rate was maintained at the higher prey densities. (Ambrose *et al.,* 2009).

Sahayaraj *et al.,* (2012) observed that the attack rate by the predator *R. longifrons* increased with the increase in prey density of *D. cingulatus* (1 to 16), *Aphis gossypi* (5 to 40) and *P. solenopsis* (5 to 40).

Bhat *et al.,* (2013) analyzed the predatory potential of *Rihirbus trochantericus* (Stal) - an indigenous predator of tea mosquito bug in laboratory and stated that it exhibited Holling's type II functional response curve.

Sahayaraj *et al.*, (2015) studied the functional response of adults and nymphs of reduviid bug *R. kumarii* to various population densities (1, 2, 4, 6, 8 and 10) of *P. solenopsis* in laboratory. All the life stages of the predator showed a Holling Type II curvilinear functional response. The number of prey consumed by the predator increased gradually from 1st to 3rd instars. However, the fourth and fifth instars consumed similar number of prey. Adult male killed more number of preys than the adult females while out of all the instars fifth instar consumed more number of prey in 24 hours. The number of prey killed by different instars increased with the increase in prey density. Third instar was found to be more aggressive than the other instars and it consumed 55 per cent of the total mealy bugs compared to that of 13 per cent by first, 29 per cent by second, 55 per cent by fourth and 51 per cent by fifth instar. The adult females consumed less percentage of mealy bug (20%) than the adult males (27%). Predator consumed more number of *P. solenopsis* at population density of ten prey/ predator and per day consumption was 0.8, 1.8, 5.0, 5.3, and 5.5 for the first to fifth instars while it was 2.3 for adult male and 0.9 for adult female.

The first instar nymph of *Rhynocoris albopilosus* fed maximum number of larvae (0.72± 0.05 preys/ day) during the first day, while the second and third instar nymph consumed a maximum of (0.63 ± 0.10 preys/ day) and (0.78 ± 0.21 preys/ day) on third and sixth day respectively (Sahayaraj *et al.,* 2015).

2.5 PREDATORY EFFICACY UNDER CAGED CONDITIONS

2.5.1. *Rhynocoris marginatus*

Evaluation under caged conditions is more helpful in assessing the pest and natural enemy populations than the field experiments (Van Lenteren and Woets 1988; Simmons and Minkenberg, 1994).

George and Sreenivasagan (1998) reported that when different life stages of *R. marginatus* were introduced on cotton plants along with *H. armigera* and *S. litura* at 1: 20 ratio in nylon mesh cages they preferred *S. litura* over *H. armigera.* The first instar nymph of the predator consumed 4.00 ± 0.63 and 2.50 ± 0.55 larvae of *S. litura* and *H. armigera* respectively when prey of small size (0.1 – 1 cm) were provided. The female predators killed more prey (9.67 ± 0.82 *S. litura* larvae and 8.33 ± 0.82 *H. armigera* larvae) than males.

In a cotton field cage experiment, Ambrose and Claver (1999) released *R. marginatus* at the rate of 1 predator/ plant and they reported reduction in infestation of *S. litura*, *M. pustulata* and *D. cingulatus* by 57.5 per cent, 52.3 per cent and 45.8 per cent respectively. The leaf, flower and boll damage by *S. litura*, *M. pustulata* and *D. cingulatus* were also less (45.8%) in the predator released field cages. In yet another study made by Ambrose (1999), he reported 61.4 per cent suppression of *S. litura* population.

Ambrose *et al.*, (2000) reported that the fourth instar nymphs of *R. marginatus* exhibited Type II functional response curves when adults of *C. gibbosa* and *Hieroglyphus banian* (Fab.) were given as prey in pigeon pea field cages.

2.5.2. Other reduviid predators

Grene and Shepard (1974) reported that when reduviid bug *Sycanus indigator* Stal was released in cages at the rate of 5 to 20 predator, it reduced the population of cabbage looper in field by 44.3 per cent.

Ambrose and Claver (1995) reported that the predator *R. fuscipes* exhibited a Holling's Type II functional response curve against the bean bug, *Riptortus clavatus* in pigeon pea field cages. This predator attacked a greater number of preys at higher prey density than at a lower prey density.

Wyss *et al.*, (1999) experimented the effect of three native aphidophagus predators – *Adalia bipunctata* Linn. *Aphidoletes aphidimyza* (Rondani), *Episyrphus balteatus* (De Geer), to control the rosy apple aphid, *Dysaphis plantaginea* (Passerini) in laboratory and field cages. In the laboratory, a single second instar larvae of predator killed 50 per cent aphids in apple seedlings after 6 hours of release and 70 per cent of aphids after 48 hours of release. But in field cages the combined release of predators - *A. bipunctata* and *E. balteus* controlled the aphid population to 5 per cent of that in the control.

Claver and Ambrose (2001) observed that adults of *R. kumarii* reduced the *H. armigera* by 49 per cent and that of *S. litura* and *E. mollifera* by 37 per cent when released in cotton field cages at the rate of 1 predator / cage.

Ravichandran (2004) studied the predatory potential of *R. kumarii* against four cotton pests in caged cotton branches. In the functional response study, the adults and fourth nymphal instar responded to increasing prey density of *H. armigera, S. litura, E. mollifera* and *D. cingulatus* by killing more number of prey at higher prey densities compared to that killed at lower prey densities and thus exhibited type II functional response curve. The adult predator significantly reduced the population of *H. armigera* at initial stage of infestation. It also minimized the per cent damage of leaves and bolls by *H. armigera, S. litura, E. mollifera* and *D. cingulatus.* The predator also decreased the loss of seed cotton by 1.52, 1.18, 1.37 and 1.45 times in *H. armigera, S. litura, E. mollifera* and *D. cingulatus* infested field cages respectively.

2.6 FIELD EVALUATION OF REDUVIID PREDATORS

2.6.1 *Rhynocoris marginatus*

Field evaluation is necessary step to assess a natural enemy before it is recommended for augmentation. Sahayaraj (1999b) conducted a field experiment to assess the efficacy of *R. marginatus* and reported that the release of *R. marginatus* @ 2500/ ha in groundnut field reduced the population of *S. litura* and *H. armigera* by 94.9

and 92.7 per cent respectively. According to him, the yield was significantly higher (1867.8 kg/ ha) in the predator released plot compared to control (1022.8 kg/ha).

Ambrose and Claver (1999) reported that *R. marginatus* significantly reduced the artificially released population of *S. litura* ($F = 8.02$: d.f = 1.9; $P< 0.05$), *M. pustulata* ($F = 129.06$, d.f. = 1.7; P, 0.001) and *D. cingulatus* in cotton ($F = 44.47$; d.f. = 1.5; P, 0.001). Release of this predator in field cages reduced the flower damage by *M. pustulata* ($F = 60.43$; d. f. 1.7; $P < 0.001$) and boll damage by *D. cingulatus* ($F = 68.57$: d.f. = 1.5; $P < 0.001$) significantly.

Sahayaraj (2002) compared the effectiveness of combining the release of predator, *R. marginatus* and application of different leaf extracts against *S. litura* and *Aproaerema modicella* (Deventer) in groundnut field. The results showed that the predator was effective against *S. litura* but did not reduce the population of *A. modicella*.

In another experiment Sahayaraj and Martin (2003) released different life stages of *R. marginatus* at the rate of 5000/ ha in groundnut field , which reduced the population of cotton leaf worm, *S. litura* (85.89%), *H. armigera* (67.65%), *A. craccivora* (46.34%), *Atractomorpha crenulata* (Fab.) (42.86 %) and *Chrotogonus trachypterus* (Blanchard) (42.86%).

According to Sahayaraj and Ravi (2007), release of 2000 number of different stages of *R. marginatus* in a groundnut field of 0.405 ha, reduced the incidence of *H. armigera* to a range of 0.77/ plant when compared to control (6.44/ plant). The population of *S. litura* also was less (0.88 number/ plant) when compared to (5.44 /plant) control.

2.6.2 Other reduviid predators

Ravichandran (2004) studied the predatory efficacy of *R. kumarii* by releasing different stages of predator four times in an open cotton field to control pests. The fourth release of the fifth instar nymph of *R. kumarii* reduced the number of *D.*

cingulatus almost two fold less than that in the control field three weeks from release making it as an effective treatment against *D. cingulatus.* The release of the predator did not affected the population of other predators in the field. The release of the predator increased the percentage of good quality cotton by 63.1 per cent than in controlled plots.

Sahayaraj and Ravi (2007) reported that when 360 numbers consisiting of different life stages of *R. kumarii* was released in groundnut plots of 249.26 m^2 size, it reduced the population of *S. litura, Chrotogonus, H. armigera* and *A. craccivora* by 66.66, 40, 56.25 and 51.59 per cent respectively.

Sahayaraj and Asha (2010) found that the first, second, third and fourth instars of *R. kumarii* controlled *A. craccivora* efficiently when they were released at the ratios 1: 24, 1: 47, 1:59 and 1: 75 respectively in ground nut ecosystem and fourth instar when released at the ratio of 1 : 75 was the most efficient among this.

32

Materials and methods

3. MATERIALS AND METHODS

The present study on the "Biology and predatory potential of *Rhynocoris marginatus* (Fabricius) (Hemiptera: Reduviidae) on insect pests of cowpea" was carried out at College of Horticulture, Vellanikkara and Cashew Research Station, Madakkathara, Thrissur during 2015- 2017 period. Laboratory study on predatory potential and the cage evaluation of predatory efficacy on cowpea aphid, *Aphis craccivora* and leaf feeding caterpillar, *Spodoptera litura* were done at Cashew Research Station, Madakkathara. The field experiment to study the efficacy of the predator on insect pests of cowpea was laid out in Exploded Block Design at College of Horticulture, Vellanikkara. The materials used and the methods followed in the laboratory and field experiments are described in this chapter.

3.1 BIOLOGY AND MORPHOMETRICS OF *Rhynocoris marginatus*

3.1.1 Mass culturing of host insects

3.1.1.1 Mass culturing of *Corcyra cephalonica*

The stock culture of the predator, *R. marginatus* was maintained on larvae of *Corcyra cephalonica*. For the purpose, culture of *C. cephalonica* was established in the laboratory. Eggs of *C. cephalonica* were obtained from the laboratory culture maintained at All India Coordinated Research Project on Biocontrol of Crop Pests (AICRP on BCCP), College of Horticulture, Vellanikkara. The culture was established using fortified jowar medium (Table 1) kept in plastic basins of 45 cm diameter and 25 cm height covered with muslin cloth and tied with rubber band.

Table 1: Composition of fortified jowar medium

Sl.No	Ingredients	Quantity
1	Jowar	2.5 kg
2	Groundnut	200g
3	Yeast	10 g
4	Streptomycin	5 g
5	Wettable Sulphur	5 g
6	Water	5 ml

The ingredients shown in Table 1 except wettable sulphur, were mixed together and taken in plastic basins of 25 cm × 45 cm size, over which the cleaned *C. cephalonica* eggs were uniformly distributed @ 0.5 cc/ basin (Plate 1a). Wettable sulphur was spread along the borders of the basin containing diet to prevent the attack by storage mites. The basin containing culture after covering with muslin cloth was left undisturbed for the emergence of moths. The emerged moths were collected and released in plastic boxes provided with 10 per cent honey solution for mating and oviposition. The eggs were used for establishing and maintaining the culture of *C. cephalonica*.

3.1.1.2 Mass culturing of *Spodoptera litura*

The larvae of *S. litura* were collected from banana plots of Banana Research Station, Kannara, Kerala Agricultural University, Thrissur and the insect culture was established on fresh castor leaves in plastic containers of 8 cm height and 22 cm diameter, lined with filter paper. The castor leaves were replaced with fresh leaves every day (Plate 1b). A square shaped hole of about 7 cm × 7cm was made on the lid of the container for proper ventilation and the hole was covered with muslin cloth to prevent the larvae from escaping.

Plate 1: Stock culture of predator, *Rhynocoris marginatus* and host insects

a) Stock culture of *Corcyra Cephalonica*

b) Stock culture of *Spodoptera litura*

c) Stock culture of *Rhynocoris marginatus*

Sixth instar larvae were transferred to another container with 3 cm thick layer of soil for pupation. After 3 days the pupae were collected and placed in another container for adult emergence. The adults emerged were collected every day and introduced into cylindrical containers of 25 cm height and 16 cm diameter with a piece of cotton soaked in 10 per cent honey solution fortified with few drops of vitamin E. The adults were allowed to mate and lay eggs. Black colored chart strips folded in zig – zag manner were kept inside the boxes for egg laying. The egg masses were collected and placed on fresh castor leaves in clean containers for hatching. After hatching, the neonates were fed with fresh castor leaves after transferring them to another container and the culture was maintained. This larvae reared in laboratory were taken for experimentation on biology and predatory potential.

3.1.2 Mass culturing of *R. marginatus*

Initial culture of *R. marginatus* was obtained from National Institute of Plant Health management (NIPHM), Hyderabad and was maintained on the factitious host, *C. cephalonica* in circular plastic rearing containers of radius 11 cm and 8 cm height in laboratory at 28°C temperature and 85 per cent relative humidity (Plate 1c). The rearing containers were lined with filter paper to absorb moisture from the excreta of the predator and also the body fluids of the prey. Black chart paper strips folded in a zig – zag manner were provided in the rearing containers for egg laying. On hatching of eggs, the nymphs were reared on *C. cephalonica* larvae of proportionate sizes kept in Petri dishes lined with filter paper. Freshly moulted males and females identified based on the abdominal width were introduced into rearing containers lined with filter paper and kept for mating and oviposition. Freshly moulted adults were used for experimentation.

3.1.3 Biology of *R. marginatus*

Biology of *R. marginatus* was studied on *S. litura*. For studying the biology and developmental parameters, ten pairs of freshly emerged males and females were

Plate 2. Experiment set up for studying the biology of *Rhynocoris marginatus*

a) Adult males and females in pairs maintained in Petri dishes

b) *Rhynocoris marginatus* adults feeding on *Spodoptera litura*

c) Nymph feeding on *Spodoptera litura*

c) Twenty five individuals maintained seperately in Petri dishes

selected from the laboratory culture and were maintained in Petri dishes provided with later instar larvae of *S. litura* and observed for mating and oviposition (Plate 2). Strips of black chart paper were provided in petri dishes for egg laying. The egg masses were collected and kept for hatching in Petri dishes lined with tissue paper. On hatching, twenty five freshly emerged nymphs were separated, kept individually in Petri dish and reared to adults for studying the developmental parameters. Each nymphal stage was provided with *S. litura* larvae of appropriate size. Data on number of nymphal instars, duration of each stage, morphological measurements, adult emergence, preoviposition period, fecundity, incubation period and adult longevity were recorded.

3.1.4 Morphometrics of *R. marginatus*

Morphometric measurements of different stages were recorded by observing ten individuals of each stage. Morphometry of egg, 1st, 2nd and 3rd nymphal instars were recorded under a Leica- EZ stereo microscope equipped with Leica Application Suite (LAS) image analyzing software at 8X magnification. Morphometry of adults and later nymphal instars (4th and 5th instars) were recorded by marking the head and tip of abdomen on precalibrated paper and measuring the line joining the points by a ruler in millimeter (Vennison and Ambrose, 1988). Other morphological parameters viz., length and width of abdomen, length and width of thorax, length and width of head, distance between eyes, length of antenna and rostrum of different stages were also measured under stereomicroscope by following standard procedures and recorded.

3.2 LABORATORY EVALUATION OF PREDATORY POTENTIAL OF *R. marginatus* ON *S. litura*

The predatory potential of each nymphal instar (II, III, IV, and V) as well as adult male and female of *R. marginatus* was evaluated on third instar larvae of *S. litura* at different prey densities of 2, 4, 6, 8 and 10, each replicated 15 times. Third instar larvae of *S. litura* were introduced in Petri dishes lined with filter paper and castor

Plate 3. Experimental set up for laboratory evaluation of predatory potential of *R. marginatus* at different prey densities of *S. litura*

2 prey/ predator

4 prey/ predator

6 prey/predator

8 prey/ predator

10 prey/predator

leaves were provided as food for the prey. The predator was starved for 24 h prior to release into each Petri dish at the rate of one/Petri dish to observe the prey consumption, searching time, handling time and attack ratio by the predator (Plate 3). Predatory efficiency was assessed in terms of number of prey killed by the predator in 24 h. The experiment was continued for three days, replenishing the prey at 24 h interval. The functional response was also assessed at different prey densities and expressed using Hollings disc equation (Hollings, 1959). The disc equation

Functional response denoted by $Y' = a\ (Tt - by)\ x$

Where, y = total number of prey killed in given period of time

Tt = total time in days

$b = Tt/k$ = handling time of each prey by the predator

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

Linear correlation and regression analysis was used to study various functional response parameters.

3.3 ASSESSMENT OF PREDATORY EFFICACY ON COWPEA APHID, *A. craccivora* AND LEAF FEEDING CATERPILLAR, *S. litura* ON CAGED COWPEA PLANTS

3.3.1 Mass culturing of host insects

Cowpea aphids collected from field were reared on cowpea plants raised in polybags of size 30 cm ×30 cm and 600 gauge thickness. Polybags were filled with red soil: FYM: coir pith in the ratio of 1:1:1. Cowpea seeds were sown singly in each polybag. Seedlings at four leaf stage were infested with aphids and established the culture for requirement of artificial infestation on cowpea plants for assessment of predatory efficacy under caged plants. The larvae of *S. litura* from stock culture established as detailed under section 3.1.1.2 were taken for experimentation.

Plate 4. Experimental view on cage evaluation of predatory potential of *Rhynocoris marginatus*

Plate 5. Release of *Rhynocoris marginatus*

Plate 6. Recording observation on aphid population

Plate 7. Release of *Spodoptera litura* on cowpea plants in cage

3.3.2 Assessment of predatory efficacy of *R. marginatus* on aphid and *S. litura* under caged condition.

The predatory efficacy of *R. marginatus* was assessed on cowpea aphid, *A. craccivora* and leaf feeder, *S. litura*. Cowpea plants of variety Anaswara were raised in grow bags inside rectangular cages of size 110 cm × 45 cm. Two separate experiments were laid out for *A. craccivora* and *S. litura*. Experiment was laid out in Completely Randomized Design maintaining predator released and control plants each with 12 replications.

Polybags of size 30 cm × 30 cm were filled with potting mixture prepared by mixing of FYM: red soil: coir pith in the ratio of 1:1:1. Then each grow bag with plant was caged by fixing wooden stumps on four sides of the polybag and covering the wooden frame with nylon mesh of size 0.15 mm and the net was tightly fixed over the frame to avoid escape of the released prey and predator (Plate 4).

3.3.2.1 Predatory efficacy of *R. marginatus* on *A. craccivora*

Aphis craccivora were collected from the stock maintained on cowpea plants and released on caged cowpea plants 18 days after sowing at the rate of five/ plant. Third instar nymph of the predator was released at the rate of one predator/ plant on twelve caged plants after assessing the aphid population 2 days after artificial infestation (Plate 5). The release of the predator was repeated at 20 days interval. Twelve caged plants were maintained as control without release of predator. Observation on the aphid population/10 cm twig was recorded at weekly intervals till the completion of the crop (Plate 6).

3.3.2.2 Predatory efficacy of *R. marginatus* on *S. litura* under caged cowpea plants

Laboratory reared second instar larvae of *S. litura* were released on 24 caged cowpea plants at the rate of five larvae per plant 26 days after sowing(Plate 7). Third instar nymph of the predator was released on twelve caged plants at the rate of one

Plate 8. View of the experimental plot

Treated plot

Control plot

predator per cage 48 hours later, after assessing the *S. litura* population. Twelve caged plants were maintained as control without the release of the predator. Observations on the number of live *S. litura* per plant and the number of damaged leaves were taken daily until the *S. litura* population reached zero in the cages with the predator.

3.4 EVALUATION OF FIELD EFFICACY OF *R. marginatus*

Field experiment on the efficiency of predator on insect pests of cowpea was carried out at College of Horticulture, Vellanikkara. The experiment was laid out in Exploded Block Design with two plots of 20 m^2 area (Plate 8). The semi trailing cowpea variety Anaswara was sown in at a spacing of 45 cm × 60 cm. One plot was selected as treated by releasing the predator and the other was kept as control. Three rows of bhendi plants were sown as barrier crop for preventing insect migration between the plots. Apart from this, nylon net was also erected, separating the two plots to prevent the movement of predator from predator released plot to the control plot. Agronomic practices as per the Package of Practices Recommendations, KAU (2011) were followed except for plant protection measures. However, the use of pesticides was avoided. Laboratory reared third instar nymphs of predator were released into the treatment plot @ 1 predator/ m^2 on 30, 50 and 70 days after sowing. Observations were recorded from 20 plants selected at random.

The following observations were recorded before as well as after the release of the predator at weekly intervals.

a. Aphid population/10 cm stem
b. Number of flowers damaged/ plant
c. Number of pods damaged/ plant
d. Number of leaf feeding larvae/ plant ; if any
e. Number of other natural enemies/ plant (coccinellids and spiders)
f. Yield/ plot

3.5 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

The data on the biology and development parameters of *R. marginatus* were analyzed by calculating the mean and standard deviation in SPSS. Hollings disc equation was used to find out the functional response parameters and this data were then subjected to linear regression analysis to study the relationship of prey density with per day consumption, searching time and attack ratio. The per day consumption of different instars and adults were analyzed by using ANOVA. The data on population of insects in cage as well as field data on insect population and damage were recorded at different intervals were subjected to two sample t test to compare the treatments.

Results

4. RESULTS

Studies on the biology and predatory potential of the reduviid predator, *R. marginatus* at different prey densities were carried out at Entomology laboratory, CRS, Madakkathara. The predatory efficiency was assessed against two important insect pests of cowpea *viz*., cowpea aphid, *A. craccivora* and leaf feeding caterpillar, *S. litura* under caged condition and the efficiency of predator against insect pests of cowpea was assessed under open field conditions at College of Horticulture, Vellanikkara. The results of the studies on the biology, predatory potential and efficiency of *R. marginatus* are presented here in.

4.1. BIOLOGY AND MORPHOMETRICS OF *R. marginatus*

The results of the study conducted on the biology, including fecundity, developmental stages and developmental duration, oviposition, adult longevity and survival per cent of the reduviid predator, *R. marginatus* are presented in Tables 2 and 3. The developmental stages of *R. marginatus* are presented in Plate 9.

4.1.1. Morphology and development duration of *R. marginatus*

4.1.1.1. Egg

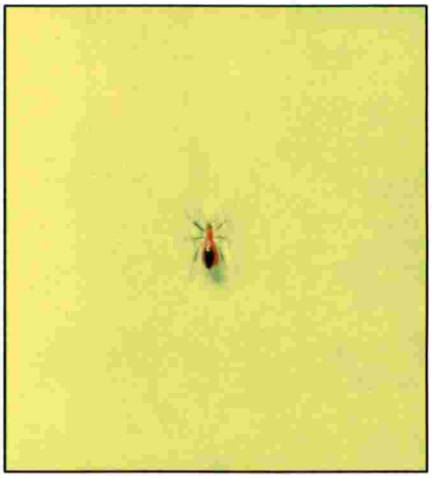
Eggs were elongate oval in shape and yellowish brown in colour with white operculum (Plate 10b). The colour of egg gradually changed to bright red from fourth day of incubation. One day prior to hatching the egg became transparent, translucent, bulged and the black eye spots of the nymph was visible through the chorion (Plate 10c). The eggs hatched on an average of 6.8 ± 0.92 days after laying. During hatching, the nymphs emerged through the split of operculum (Plate 10d).

4.1.1.2. First instar nymph

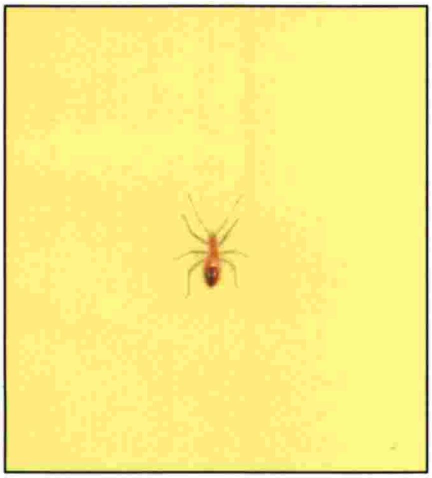
First instar nymph was light orange in colour upon hatching, which turned to dark orange within five to six hours of hatching. Nymph started feeding five to six hours after hatching and by this time a black oval shaped spot had developed on the dorsal side of the abdomen. The mean development duration of first instar was 6.64 ± 0.70 days.

Plate 9. Development stages of *Rhynocoris marginatus*

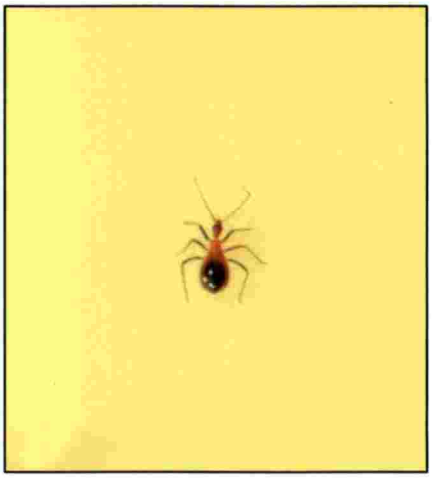
a)Egg mass – 10X



b) First instar nymph – 2X

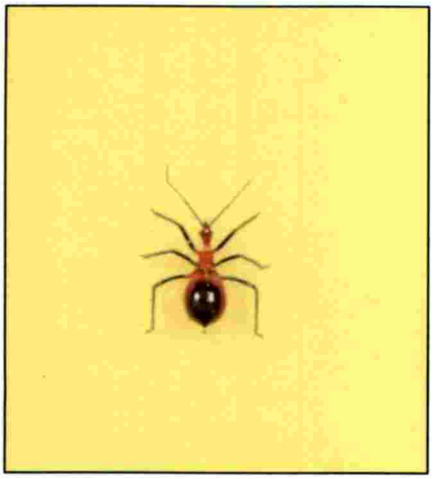


c) Second instar nymph – 2X



d) Third instar nymph – 2X

contd…



e) Fourth instar nymph – 2X

f) Fifth instar nymph -2X

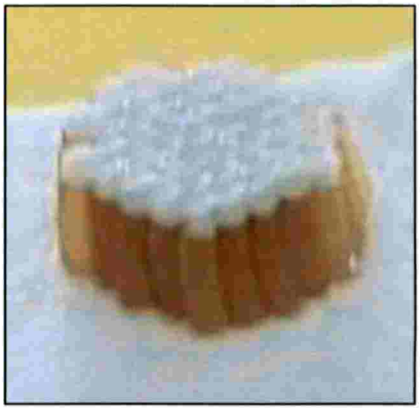
g) Adult male - 2.5 X

h) Adult female – 2.5 X

Plate 10: Egg laying and nymphal emergence of *Rhynocoris marginatus*

a) *Rhynocoris marginatus* female laying eggs

b) Freshly laid eggs



c)Eggs just before hatching

d) *Rhynocoris marginatus* nymph emerging from egg

4.1.1.3. Second instar nymph

Second instar nymph was bright orange with a black oval spot on dorsal abdomen. On an average, the development duration of second instar nymph was 5.68 ± 0.99 days.

4.1.1.4. Third instar nymph

Third instar nymphs were dark orange coloured with black oval spot on abdomen and two small black spots on the dorsal abdominal region adjoining the thorax. The mean development period duration of third instar nymph was 7.08 ± 1.00 days.

4.1.1.5. Fourth instar nymph

The body of fourth instar nymph was dark orange in colour with a large oval black patch on abdomen and two black spots on abdominal region near thorax. The mean duration of development period of fourth instar nymph was 7.48 ± 0.77 days.

4.1.1.6. Fifth instar nymph

There was a drastic increase in body size from fourth to fifth instar. Fifth instar nymphs were bright reddish orange with black patch covering entire abdomen except borders and an orange coloured patch on scutellum. The abdomen was small just after the moulting and it expanded with feeding. In this stage, males and females can be identified by the difference in abdominal width. The female nymph had broader abdomen compared to the male. The mean development duration of fifth instar nymph was 6.10 ± 0.64 days.

4.1.1.7. Adult

Adults were similar in size to fifth instar nymphs. The adult males and females of *R. marginatus* were similar except for the size of the abdomen. Males had slender abdomen compared to females. The pronotum and scutellum were bright red coloured while all the other parts were black in colour. They were initially light orange in colour but turned dark orange and the characteristic black patches on abdomen appeared within an hour from moulting. Adult female was the largest among all the life stages of the predator.

4.1.1.8. Total development of *R. marginatus*

The predator had five nymphal instars in its development and the total nymphal developmental period was 32.96 ± 1.91days. Survival of hatched out nymphs up to adult was 59.33 ± 5.13 per cent (Table 2). The mortality was high (21.5%) during the first instar nymphs which got reduced to 13.5, 10.83, 8.3 and 5.2 per cent respectively during second, third, fourth and fifth instars. Cannibalism was observed at the time of moulting.

First instar nymphs usually fed on prey in group for 8 to 12 h after their emergence. Second instar nymphs were less active and mostly did not attack larger prey. Third instar onwards, the nymphs were highly active and they often followed prey larger than them, attacking them repeatedly until the prey got killed.

The predator stopped feeding one day before moulting. Lightening of colour of exoskeleton was also observed when the nymph was about to moult. Before moulting, the predator moved to a corner of the container and ecdysis started from the head portion of the predator. Just after moulting, body of the predator was soft and light coloured, but within 5 to 6 h after moulting the pigmentation was completed and the predator attained dark orange to red colour.

4.1.1.9 Adult longevity

The adult female predator lived for an average of 84.1 ± 14.81 days where as the average longevity of adult male was 65.73 ± 4.65 days.

Table 2: Duration of developmental stages of *Rhynocoris marginatus*

Sl. No	Life stage **Life stage**	Mean duration in days **in days**
1	Egg	6.80 ± 0.91
2	First instar nymph	6.64 ± 0.70
3	Second instar nymph	5.68 ± 0.99
4	Third instar nymph	6.90 ± 1.00
5	Fourth instar nymph	7.48 ± 0.78
6	Fifth instar nymph	6.20 ± 0.65
7	Total nymphal period	32.96 ± 1.91
8	Total developmental period Male Female	 65.73 ± 4.65 84.10 ± 14.81
9	Adult longevity Male Female	 98.71 ± 4.65 117.00 ± 14.12
10	Survival to adult (per cent)	59.33 ± 5.13

*Figures are mean of 25 observations

4.1.2 Reproductive biology of *R. marginatus*

4.1.2.1 Mating and Oviposition

The predator showed a sequential behaviour for mating. The male predator initiated the mating, and it searched female for 6 to 7 hours after its emergence. Both male and female mated with more than one partner during their life time.

Arousal

Arousal occured when the female was sighted by a male. When the female was initially introduced into a container containing males, the males turned head towards female within 10 – 12 seconds, extended their antenna and rostrum towards the female and started moving towards it.

Approach

When a male approached a receptive female, the female responded by extending its antenna and rostrum towards the male. Then the male touched the antenna of the female with its antenna.

Riding over

The male after approaching kept the legs over the female and then gradually positioned itself above the female while clasping the later with legs. In this riding over position male pressed their rostrum over the pterothorax region of female. This was followed by extension of genitalia and intromission. Copulation lasted from few minutes to 3 h. Once the genitalia got connected, copulation started. Touching each other's antenna and tibia was observed during copulation. The male predator did not feed but the females sometimes chased prey and fed during copulation. At the end of copulation, genitalia got detached and grooming of antenna and tibia was observed. The adults mated more than once in their life.

The adult female started oviposition after 14.00 ± 1.30 days of emergence. Before the beginning of oviposition, the female abstained from feeding and moved to corners or dark secluded areas in the rearing container. After reaching corners, it widened the hind legs and front legs and brought the hind part of the abdomen closer to the surface (Plate 10a). The antennae and rostrum were kept erect downwards and the eggs were laid with the operculum facing the upper side. The egg was placed one after the other by touching the space nearer to previously deposited eggs. The predator laid eggs by its abdominal tip so that each egg was attached to the other and basally to the substratum. The eggs were deposited in a definite pattern in which initially egg mass attained a square shape which later became hexagonal as egg laying progressed. The oviposition lasted from 30 min to two hours, depending upon the size of the egg mass. The female left the last egg on the top of the egg mass. After egg laying, the female stayed over the eggs and remained near the egg mass for one or two days. Parthenogenesis was also observed which produced non-viable eggs that shrivelled later.

4.1.2.2 Fecundity, sex ratio and egg viability of *R. marginatus*

The adult female laid eggs mostly in batches which were glued basally to the substratum and to each other laterally. Sometimes female laid scattered or loosely adhered eggs. An adult female during its entire life period laid an average of 377.2 ± 45.52 eggs in 8.60 ± 0.97 batches (Table 3). The number of eggs in an egg mass varied from 18 to 70, with a mean value of 44.32 ± 4.5. The number of eggs in an egg mass was highest in the 4th, 5th and 6th batch of egg mass which gradually declined afterwards. The mean hatchability of eggs was 98.45 ± 2.02 per cent. The eggs were laid at 4 - 7 days interval initially but the interval increased to 9 to 12 days towards the end of the oviposition period. The preoviposition period of the predator on an average was 14 ± 1.33 days and the mean oviposition period was 66.13 ± 6.27 days. The adult female died 3.20 ± 2.5 days after laying the last batch of egg. . The sex ratio (male: female) was 0.94: 1.

Table 3: Biological parameters of reduviid predator, *Rhynocoris marginatus* reared on *Spodoptera litura*

S. no	Biological parameters	Mean value
1	Number of eggs in a single egg mass	44.33 ± 4.57
2	Number of batches of eggs laid by a female	8.60 ± 0.97*
3	Fecundity (Number of eggs/ female)	377.2 ± 45.52*
4	Incubation period of eggs (days)	6.80 ± 0.91
5	Hatchabilty of eggs (per cent)	98.26 ± 2.73
6	Preoviposition period (days)	14.00 ± 1.30 *
7	Oviposition period (days)	66.13 ± 6.27 *
8	Post oviposition period (days)	3.20 ± 2.5 *

*Figures are mean of 10 observations

4.1.4 Morphometry of developmental stages of *R. marginatus*

The predator showed a gradual increase in size from egg to adult stage except that of fifth instar which showed a sudden increase in size from fourth instar (Table 4). All the eggs in an eggmass were of uniform size and had an average length of 2.47 ± 0.01 mm and width of 0.67 ± 0.22 mm. The mean body length and width of first instar nymph was 3.36 ± 0.13 mm and 1.73 ± 0.20 mm respectively. The second instar measured 4.91 ± 0.13 mm in length and 2.70 ± 0.11 mm in width. The length of third instar nymph was 7.07 ± 0.18 mm while the width in the broadest part of abdomen was 3.49 ± 0.24 mm. The fourth instar nymph had an average length of 10.31 ± 0.34 mm and width of 5.27 ± 0.32 mm. The fifth instar nymph measured 16.01 ± 0.42 mm in length and 8.11 ± 0.39 mm in width. The length and width of adult predator was 17.26 ± 0.35 mm and 9.06 ± 0.25 mm for male and 17.97 ± 0.18 mm and 9.46 ± 0.27 mm for female, respectively.

Table. 4: Morphometrical parameters of developmental stages of *Rhynocoris marginatus*

Morphometrical parameters (mm)	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Adult female	Adult male
Body Length	3.36 ± 0.13	4.91 ± 0.13	7.07 ± 0.18	10.31 ± 0.34	16.01 ± 0.41	17.82 ± 0.18	17.26 ± 0.36
Head length	0.67 ± 0.46	1.67 ± 0.09	1.70 ± 0.13	2.57 ± 0.17	3.48 ± 0.29	3.75 ± 0.09	3.70 ± 0.10
Prothoracic length	0.53 ± 0.03	0.70 ± 0.09	0.91 ± 0.08	1.30 ± 0.10	1.81 ± 0.08	1.86 ± 0.06	1.79 ± 0.10
Length of abdomen	1.73 ± 0.20	2.70 ± 0.11	3.49 ± 0.24	5.27 ± 0.32	8.11 ± 0.39	9.46 ± 0.27	9.06 ± 0.25
Distance between eyes	0.39 ± 0.04	0.41 ± 0.03	0.61 ± 0.02	0.81 ± 0.08	1.09 ± 0.10	1.17 ± 0.04	1.10 ± 0.10
Distance across eyes	0.60 ± 0.04	0.86 ± 0.04	1.09 ± 0.05	1.33 ± 0.09	1.73 ± 0.06	1.90 ± 0.06	1.90 ± 0.06
Width of prothorax	0.52 ± 0.04	0.63 ± 0.04	0.92 ± 0.13	1.41 ± 0.20	2.45 ± 0.12	3.50 ± 0.05	3.27 ± 0.60
Width of abdomen	1.25 ± 0.12	2.12 ± 0.06	3.12 ± 0.04	4.14 ± 0.23	5.75 ± 0.53	6.60 ± 0.12	5.99 ± 0.17
Antennal length	1.26 ± 0.12	3.79 ± 0.14	4.26 ± 0.16	6.57 ± 0.27	8.32 ± 0.61	10.15 ± 0.37	9.69 ± 0.34
Rostral length	1.07 ± 0.05	1.50 ± 0.15	2.32 ± 0.12	2.69 ±0.14	3.58 ± 0.22	4.54 ± 0.25	4.40 ± 0.24

* Figures are mean of 10 observations

57

4.2 LABORATORY EVALUATION OF PREDATORY POTENTIAL OF *R. marginatus*

4.2.1 Predatory behaviour of *R. marginatus*

R. marginatus showed pin and jab mode of predatory behaviour. This mode of predation had sequential steps viz., arousal, approach, capture, pinning and paralysing, sucking and post predatory activities (Plate 11).

4.2.2.1. Arousal

The predator showed an arousal response upon sighting the prey which included turning head and antennae towards prey. This response was faster when the prey was moving.

4.2.2.2. Approach and Capture

The aroused predator started moving towards prey, stood motionless initially and then slowly extended its antennae after reaching its close vivinity. After sensing the prey with antennae, it extended its rostrum and with a sudden forward movement and rostrum protrusion, the predator pinned the prey in its anterior prothoracic region or in the region near the last proleg. At this time when the prey started to wriggle, the predator secured its hold over the prey by holding it with forelegs. When the prey were larger than the predator, the predator attacked the prey three to four times before finally jabbing the prey. But larger predator controlled the wriggling prey by piercing the prey deeper.

4.2.2.3. Pinning, Paralysing and Sucking

Once the predator pinned the prey successfully, it injected its toxic saliva into the prey using the stylet. The predator took 5 ± 0.1 seconds to paralyse the prey. The prey moved its head to both sides, upon paralysis the movement stopped. After this the predator loosened its grip over the prey and removed the forelegs from the body of the prey and started sucking the body fluid with only the tip of the stylet inside the prey. Once the prey was killed, the predator sucked pre-digested fluid from different points of the body.

Plate 11. Predatory behavior of *Rhynocoris marginatus*

Approach

Capture

Paralysing the prey

Sucking the prey

Post predatory activities

When the fluid from the body of the prey was completely sucked out, only the exuvia of the prey was left. *Rhynocoris marginatus* after removing its stylet from the prey, cleaned its rostrum and antennae by rubbing it with fore tibia.

4.2.2 Predatory potential of *R. marginatus*

Predatory potential of each nymphal instar (II, III, IV and V) as well as that of adult female and male of *R. marginatus* was evaluated on third instar larvae of *S. litura.* Predatory potential was studied at different prey densities of 2, 4, 6, 8 and 10 prey/ predator and number of larvae killed per day by the predator was recorded. The first instar nymphs did not attempt to prey upon the third instar larvae of *S. litura*. The lowest per day predation was by second instar nymph which was able to kill less than 2 larvae at all prey densities. The later instar nymphs, adult female and male killed more larvae with an increase in prey density. A gradual increase was also recorded in the number of larvae killed by the predator with the progression of nymphal instars from second to fifth (Table 5).

At a prey density of two prey/predator, the second, third, fourth and fifth instar nymphs, adult female and male killed an average of 1.13 ± 0.18, 1.86 ± 0.23, 2.00 ± 0.00, 2.00 ± 0.00, 2.00 ± 0.00 and 2.00 ± 0.00 larvae per day respectively. There was no significant difference in the number of larvae killed by the fourth and fifth instar nymphs, adult male and female of the predator at lower prey densities of two and four prey/ predator. The per day killing by second to fifth instar nymphs and adult male and female was 1.33 ± 0.00, 3.67 ± 0.30, 3.80 ± 0.18, 4.00 ± 0.00, 4.00 ± 0.00, 4.00 ± 0.00 respectively. But at higher prey densities of six and eight prey/ predator, there was significant difference in the number of larvae killed by the fourth and fifth instar nymphs, adult male and female. The mean number of prey killed by second, third, fourth and fifth instar nymphs, adult male and female was 1.60 ± 0.14, 5.67 ± 0.49, 6.67 ± 0.41, 7.60 ± 0.15, 7.87 ± 0.50 and 8.00 ± 0.23 respectively at a prey density of six prey/ predator. At a prey density of eight prey/ predator, an average of 1.53 ± 0.18, 5.20 ± 0.17, 5.20 ± 0.45, 7.13 ± 0.18, 7.60 ±

0.15 and 7.67 ± 0.23 number of preys were killed respectively by second to fifth instar nymphs, adult male and female of the predator. The mean number of prey killed by second, third, fourth and fifth instar nymphs, adult male and female were maximum at a prey density of ten prey/ predator and were 1.60 ± 0.14, 5.67 ± 0.49, 6.67 ± 0.41, 7.60 ± 0.15, 7.87 ± 0.50 and 8.00 ± 0.23 larvae/day respectively.

4.2.3 Functional response of *R. marginatus*

The functional response of II, III, IV and V nymphal stages and adults of *R. marginatus* was assessed on third instar larvae of *S. litura* at five different prey densities *viz*., 2, 4, 6, 8 and 10 prey/ predator. When the relation between prey density and number of prey killed was defined, it yielded a Hollings type II curvilinear functional response (Fig. 1). The number of prey killed (y) increased with increase in prey density (x). Fourth and fifth instar nymphs and adults of *R. marginatus* killed all the prey provided at lower prey densities, indicating higher attack rate that gradually diminished with increase in prey density. The relation between prey density and number of prey killed exhibited strong positive correlation ($y= 0.767x + 0.893$, $r = 0.970$) for adult female. Similar type of functional response equations were obtained for adult male ($y = 0.783x + .833$, $r = 0.976$), fifth instar nymph ($y = 0.717x + 1.047$, $r = 0.972$) and fourth instar nymph ($y = 0.570x + 1.233$, $r = 0.975$). Third instar nymph ($y = 0.457x + 1.473$, $r = 0.935$) and second instar nymph ($y = 0. 57x +1.060$, $r = 0.530$) attained satiation early and could not kill all the prey given at the lower prey densities, even then a positive correlation was obtained between the number of prey killed and prey density which denoted the increase in the number of prey killed with increase in prey density.

The number of prey killed by second instar nymph did not increase much with the increase in prey density compared to other instars and adults. The adult male killed maximum number of preys than adult female and nymphal instars. The maximum predation rate denoted by 'k' was found at the highest prey density, 10 prey/ predator regardless of stage of the predator. 'k' value was 8.00 ± 0.23, 7.86 ± 0.50, 7.60 ± 0.15, 6.67 ± 0.41, 5.67 ± 0.49, 1.60 ± 0.14 for male, female, fifth instar, fourth instar, third instar and second instar respectively

R. marginatus spent more time for searching at lower prey densities and with the increase in prey density, searching time gradually declined and a negative correlation existed between prey density and searching time (Table 6). Attack ratio (number of prey killed / prey density) was the highest at lower prey density of 2 prey/ predator for all the instars while it reduced with increase in prey density and was least at the prey density of 10 prey/ predator (Table 6). Attack ratio was 1 for fifth instar nymph, adult female and adult male at the prey densities of two, four and six prey/ predator but reduced to 0.76, 0.78 and 0.80 respectively at prey density of 10 prey/ predator. Among all the instars the attack ratio was lower (0.16) for the second instar at a prey density of 10 prey/ predator.

Table 5. Predatory potential of different stages of *R. marginatus* on third instar larvae of *S. litura*

*Mean number of larvae killed by *R. marginatus*/ 24 h						
Prey density	Second instar nymph	Third instar nymph	Fourth instar nymph	Fifth instar nymph	Adult female	Adult male
2	1.13 ± 0.18^{c}	1.86 ± 0.23^{b}	2.00 ± 0.00^{a}	2.00 ± 0.00^{a}	2.00 ± 0.00^{a}	2.00 ± 0.00^{a}
4	1.33 ± 0.00^{c}	3.67 ± 0.30^{b}	3.80 ± 0.18^{a}	4.00 ± 0.00^{a}	4.00 ± 0.00^{a}	4.00 ± 0.00^{a}
6	1.40 ± 0.27^{d}	4.67 ± 0.50^{c}	4.93 ± 0.27^{b}	6.00 ± 0.00^{a}	6.00 ± 0.00^{a}	6.00 ± 0.00^{a}
8	1.53 ± 0.18^{e}	5.20 ± 0.17^{d}	5.20 ± 0.45^{c}	7.13 ± 0.18^{b}	7.67 ± 0.15^{a}	7.67 ± 0.23^{a}
10	1.60 ± 0.14^{d}	5.67 ± 0.49^{c}	6.67 ± 0.41^{b}	7.60 ± 0.15^{a}	7.87 ± 0.50^{a}	8.00 ± 0.23^{a}

*Mean of 15 replications

Figures with same alphabets within a row are not significantly differed from each other by ANOVA

Table 6. Functional response of *Rhynocoris marginatus* predator to third instar *Spodoptera litura* larvae

Stage	Prey density (x)	Prey consumption(y)	Max. Prey consumption	b= (Tt/k)	by	Searching time, Ts = (Tt – by)	Attack ratio (y/x)	(y/x)/Ts = rate of discovery	Functional response Y' = α(Tt – by)x	Correaltion between y and x
II instar	2	1.13	1.6	1.88	2.12	0.97	0.57	0.59	Y' = 0.93(3- 1.88y)x	0.530
	4	1.33			2.5	0.50	0.33	0.66		
	6	1.40			2.63	0.37	0.23	0.62		
	8	1.53			2.87	0.13	0.19	1.46		
	10	1.60			2.88	0.12	0.16	1.33		
III instar	2	1.86	5.67	0.53	0.98	2.02	0.93	0.46	Y' = 0.85(3- 0.45y)x	0.935
	4	3.67			1.06	1.28	0.92	0.72		
	6	4.67			2.47	0.53	0.78	1.47		
	8	5.20			2.75	0.25	0.65	2.60		
	10	5.67			3.00	0.00	0.57	0.00		
IV instar	2	2.00	6.67	0.45	0.9	2.1	1	0.48	Y' = 0.85(3- 0.45y)x	0.975
	4	3.80			1.71	1.29	0.95	0.73		
	6	4.93			2.21	0.79	0.82	1.04		
	8	5.87			2.64	0.36	0.73	2.02		

63

	10	6.67			3	0	0.67	0.00		
Stage	Prey density (x)	Prey consumption(y)	Max. Prey consumption	b= (Tt/k)	by	Searching time, Ts = (Tt – by)	Attack ratio (y/x)	(y/x)/Ts = α	Functional response Y' = α(Tt – by)x	Correaltion between y and x
V instar	2	2.00	7.60	0.39	0.78	2.22	1	0.45	Y' = 1.33(3- 0.39y)x	0.972
	4	4.00			1.56	1.44	1	0.69		
	6	6.00			2.34	0.66	1	1.51		
	8	7.13			2.78	0.22	0.89	4.04		
	10	7.60			3.00	0.00	0.76	0.00		
Adult female	2	2.00	7.86	0.38	0.76	2.24	1	0.45	Y' = 2.63(3- 0.38y)x	0.970
	4	4.00			1.52	1.48	1	0.68		
	6	6.00			2.28	0.72	1	1.39		
	8	7.60			2.91	0.09	0.94	10.44		
	10	7.87			3.00	0.00	0.78	0.00		
Adult male	2	2.00	8.00	0.38	0.75	2.25	1	0.44	Y' = 2.62(3- 0.38y)x	0.976
	4	4.00			1.50	1.50	1	0.66		
	6	6.00			2.25	0.75	1	1.33		
	8	7.67			2.88	0.12	0.96	10.65		
	10	8.00			3.00	0.00	0.80	0.00		

64

4.3 EVALUATION OF PREDATORY EFFICACY OF *R. marginatus* ON *A. craccivora* AND S. *litura* IN CAGES

4.3.1 Predatory efficacy of *R. marginatus* on *A. craccivora*

The predatory efficacy of *R. marginatus* on cowpea aphid *A. craccivora* was assessed by releasing third instar nymph of *R. marginatus* on caged cowpea plants infested with *A. craccivora* artificially (Plate 12). The nymphs were released at the rate of one per plant four times at twenty days interval, starting from eighteen days after sowing. Observations on aphid population at weekly interval revealed a consistent reduction in the number of aphids in cages with predator (Table 7).

One week after the first release, the mean aphid density was significantly lower (4.75 aphids/10 cm stem) in predator released cages as against mean population of 29.42 aphids/10 cm stem recorded in control cages. Though there was an increase in aphid population in both the treatments, predator released cage supported significantly less aphid population than that in control at all intervals of observations after the first release of the predator.

The aphid population recorded an increase in mean number in both the cages two weeks after first release of the predator. However, this mean aphid count of 11.00 aphids/ 10 cm stem was significantly lower than the mean value of 39.83 aphids/ 10 cm stem registered in case of cages without predator.

Three weeks after the first release of the predator the mean aphid population was 45.33 and 56.00 aphids/ 10 cm stem in cages with and without predator respectively. The values were on par with each other.

Four weeks after the first release of predator and one week after the second, the control recorded a mean aphid population of 98.58 aphids/ 10 cm stem, which was significantly higher compared to that of predator released cage (16.58 aphids/ 10 cm stem).

The mean aphid population remained constant at 16.57 aphids/ 10 cm stem in the predator released cages five weeks of first release. The mean aphid population in the control cage registered a decrease compared to previous week that still was significantly higher than predator released cage at 57.41/ 10 cm stem.

Plate 12. ***Rhynocoris marginatus*** **feeding on aphids**

The aphid population was reduced after sixth week coinciding with third release of the predator and recorded a mean population of 10.50 aphids/ 10 cm stem in predator released cages, which was significantly less compared to control (62.17 aphids/ 10 cm stem).

Seven weeks after the first release and one week after the third release, the control recorded a mean aphid population of 19.00 aphids/10 cm stem which was on par with the aphid population in predator released plots (9.33 aphids/10 cm stem).

The mean aphid population on eighth week after the release of the predator in cage with and without predator was 5.75 aphids/ 10 cm stem and 16.00 aphids/ 10 cm stem respectively. Though there were no significant difference in the aphid population, the predator released cage had numerically less compared to control.

In the ninth week after the release of the predator, the fourth release of the predator was made and the mean population of aphids in predator released cage (3.83 aphids/ 10 cm stem) was on par with that in control (11.00 aphids/ 10 cm stem).

The mean aphid population in predator released cage (3.00/ 10 cm stem) was statistically significant from control (10.00 aphids/ 10 cm stem) at tenth week after first release coinciding one week after fourth release. In the eleventh week, there was no significant difference in the mean aphid population in predator released (0.92 aphids/ 10 cm) and control (0.92 aphids/ 10 cm stem) cages. However the mean aphid population was numerically less in predator released cages when compared to control.

Table 7: Predatory efficiency of *Rhynocoris marginatus* on aphid, *Aphis craccivora* on cowpea plants under cage

	+Mean aphid population/ 10 cm stem at different weeks after release											
Week / Treatment	0-Ist release	1	2	3-2nd release	4	5	6-3rd release	7	8	5- 4th release	10	11
Predator released	8.17	4.75	11.00	45.33	16.58	16.57	10.50	9.33	5.75	3.83	3.00	0.92
Control	8.92	29.42	39.83	56.00	98.58	57.41	62.17	19.00	16.00	11.00	10.00	2.75
t value	0.645	5.110**	4.96**	1.083	8.266**	4.34**	3.49**	1.30NS	2.16	1.89	2.30*	1.53

+Mean of 12 replications

*Significant at 5% level, **Significant at 1 % level,

Four releases were made at zero, third, sixth and ninth weeks

4.3.1.2 Yield

The yield of green pods was significantly higher (95.58 g/ plant) in predator released cages as against 33.25 g/ plant recorded in the control cages (Table 8). The mean number of aphid infested cowpea pods was also significantly high in control (3.64 pods/ plant) cages compared to predator released cages (1.54 pods/ plant).

Table 8: Mean number of aphid infested pods and pod yield of cowpea in predator released and control cages

Treatments	Yield (g/plant)	Number of aphid infested pods/ plant
Predator released	95.58	1.54
Control	33.25	3.64
t value	08.009**	1.373**

**Significant at 1 % level

Four releases were made at zero, third, sixth and ninth weeks

4.3.2. Predatory efficacy of *R. marginatus* on *S. litura*

Five days old *S. litura* larvae were released at the rate of 5/plant on caged cowpea plants 26 days after sowing of crop. The predatory efficacy of *R. marginatus* on leaf caterpillar, *S. litura* was assessed by releasing third instar nymph of predator on cowpea plants artificially infested with *S. litura*.

The mean number of *S. litura* larvae were 1.5, 1.33, 0.17 and 0.00 at 1, 2, 3 and 4 days after the release of the predator as against a constant and significantly higher value of 5/ plant in control cages (Table 9).

Number of leaves damaged was significantly less on caged cowpea plants harbouring predator compared to control for the entire period of observation (Table 10). On the first day, the number of leaves damaged was 3.4 in predator released cage and 5.2 in plants in control. The corresponding figures for day 2, 3 and 4 were 4.2, 4.3 and 4.3 respectively in cages with predator. In comparison, plants in control cages had 7.2, 8.2 and 8.5 leaves damaged by *S. litura* larvae during the same period, which were significantly higher than the values recorded in case of plants with predators.

Table 9. Predatory efficiency of *Rhynocoris marginatus* on *Spodoptera litura* on cowpea plants under cage

Day	Mean number of *S. litura* larvae / plant		T value	Cumulative number of larvae consumed
	Predator released	Control		
1	1.50	5.00	23.216**	3.50
2	1.33	5.00	16.316**	3.67
3	0.17	5.00	43.014**	4.83
4	0.00	5.00		5.00

** Significant at 1% level

Table 10. Mean number of leaves damaged by *Spodoptera litura* in predator released and control cages

Day	Mean number of leaves damaged / plant		T value
	Predator released	Control	
1	3.40	5.20	4.269**
2	4.20	7.20	6.181**
3	4.30	8.20	9.338**
4	4.30	8.50	10.428**

** - Significant at 1% level

71

4.4 FIELD EVALUATION OF PREDATORY EFFICIENCY OF *R. marginatus* ON INSECT PESTS OF COWPEA

The predator *R. marginatus* was released on cowpea plants at 30 days after sowing with repeated release at 20 days interval as in case of caged conditions. Cowpea aphid, *A. craccivora*, cowpea pod borer, *M. vitrata*, and pod bug, *R. pedestris* were observed in the field during the experiment period. The data recorded on pest population and damage and population of predatory coccinellids are presented here.

4.4.1 Field evaluation of *R. marginatus* on *A. craccivora*

The data on mean population of aphid recorded at weekly intervals are given in Table 11. Similar dynamics with gradual reduction in aphid population was noticed in both control and predator released plots during the experiment. The precount on mean aphid population did not vary significantly among predator released and control plots. In the first week after the first release of the predator, there was a sharp decline in the aphid population in both predator released and control plots. However, the aphid population in predator released plot (20.60 aphids/ 10 cm stem) was significantly less than that in control (51.70 aphids/ 10 cm stem). The mean aphid population in second week after the first release of the predator was 13.55 and 46.70 aphids/ 10 cm stem respectively in the plots with and without predator. In the third week, the mean population of aphids recorded was 12.90 aphids/ 10 cm stem in predator released plot which was significantly less compared to control (33.95 aphids/ 10 cm stem).

Four weeks after the first release of predator and one week after the second, control plot had+00 a mean aphid population of 13.40 aphids/ 10 cm stem which was significantly higher compared to that of predator released cage (8.30 aphids/ 10 cm stem). The mean aphid population steadily declined in the predator released and control plots five weeks after first release. The mean aphid population in the predator released plot was 4.20 aphids/ 10 cm stem which was significantly lesser than 10.60 aphids/ 10 cm stem in control plot.

Six weeks after the first release of the predator, the mean aphid population was 1.05 and 5.75 aphids/ 10 cm stem in plots with and without predator respectively. The values were on par with each other. Same trend was observed in the aphid population in predator released (0.15 aphids/ 10 cm stem) and control (4.35 aphids/ 10 cm stem) plots on seventh week after the first release of the predator coinciding one week after third release.

Table 11. Predatory efficiency of *Rhynocoris marginatus* in insect pests of cowpea

Mean aphid population/10 cm stem								
Week / Treatment	0	1	2	3	4	5	6	7
Predator released	217.75	20.60	13.55	12.90	8.30	4.20	1.05	0.15
Control	208.70	51.70**	46.70**	33.95**	13.40*	10.60*	5.75	4.35

*Significant at 5% level, **Significant at 1% level

Three releases of the predator were made at 30, 50, 70 DAS

4.4.2 Field evaluation of *R. marginatus* on other insect pests of cowpea.

The pod borer and pod bug infestation was very less in experiment plot. The data were not sufficient for statistical comparison. No definite trend was observed with respect to population of pod bug in the treatments.

4.4.2.1 Flower and pod damage

Mean number of flowers and pods damaged by *M. vitrata* was less in the predator released field compared to control field (Table 12). However, there was no significant difference among the predator released and control plots.

Table 12. Number of flowers and pods damaged by *Maruca vitrata* in field

Weeks	Mean number of flowers damaged/ plant		Mean number of pods damaged/ plant	
	Treated	Control	Treated	Control
Zero week - 30DAS*	0.00	0.00	0.00	0.00
First week	0.00	0.00	0.00	0.05
Second week	0.00	0.15	0.00	0.15
Third week– 50 DAS*	0.05	0.15	0.05	0.15
Fourth week	0.15	0.20	0.05	0.05
Fifth week	0.00	0.05	0.00	0.00
Sixth week – 70 DAS*	0.00	0.05	0.00	0.00
Seventh week	0.00	0.00	0.00	0.00
Eighth week	0.00	0.00	0.00	0.00

*Three releases of the predator were made at 30, 50, 70 DAS

Table 13. Infestation of pod bug, *Riptortus pedestris* in field

Week	Population of *R. pedestris* /plot		Mean number of pods damaged/plant	
	Treated	Control	Treated	Control
Zero week– 30DAS*	0.00	0.00	0.00	0.00
First week	2.00	2.00	0.00	0.05
Second week	2.00	4.00	0.00	0.15
Third week–50 DAS*	6.00	5.00	0.05	0.15
Fourth week	0.05	0.00	0.05	0.05
Fifth week	0.00	0.00	0.00	0.00
Sixth week – 70 DAS*	0.00	0.00	0.00	0.00
Seventh week	0.00	0.00	0.00	0.00
Eighth week	0.00	0.00	0.00	0.00

*Three releases of the predator were made at 30, 50, 70 DAS

The pod bug population and damage was very less in the field and no definite trend in population variation was observed among treatments (Table 13).

4.4.3. Influence of predator on natural enemies

The common aphidophagous predator, coccinellids were observed in the experimental plots. The population of coccinellids was very less and a maximum of 0.5/ plant was observed in the experimental field (Table 14). A definite trend in population was not observed in the population of coccinellids in both control and predator released plots.

Table 14. Population of predatory coccinellids in predator released and control plots

Weeks	Mean number of coccinellids/ plant	
	Treated	Control
Zero week – 30 DAS*	0.05	0.45
First week	0.05	0.05
Second week	0.25	0.40
Third week – 50 DAS*	0.35	0.00
Fourth week	0.00	0.00
Fifth week	0.00	0.00
Sixth week – 70 DAS*	0.00	0.00
Seventh week	0.00	0.00
Eighth week	0.00	0.00

Three releases of the predator were made at 30, 50, 70 DAS

Table 15: Mean pod yield of cowpea in predator released and control plots

Treatments	Green pod yield (g/ plant)	Green pod yield (kg/ plot)
Predator released	101.05	18.35
Control	78.05	13.75
t value	2.494*	

*Significant at 5 % level

75

4.4.4. Pod yield

The pod yield of cowpea in the predator released plot was 101.05 g/ plant (Table 15) and it was significantly high compared to that in control (78.05 g/ plant). The plot yield was 18.23 kg and 13.25 kg respectively in predator released and control fields.

Discussion

5. DISCUSSION

Study was carried out on the biology as well as predatory potential of the reduviid bug *R. marginatus* against selected insect pests of cowpea under laboratory as well as caged conditions. The efficacy of *R. marginatus* in regulating pests of cowpea was also evaluated. The results of the above experiments are discussed hereunder.

5.1 BIOLOGY AND MORPHOMETRY OF *R. marginatus*

5.1.1. Morphology and development of *R. marginatus*

In the present study, it was observed that the eggs of *R. marginatus* were elongate oval in shape and yellowish brown in colour. Later the colour changed to reddish brown and the black coloured eyespot of nymph became visible at the time of hatching. This was in confirmity with the findings by Pravallika (2015) who reported that the eggs turned dark brown colour by the time of hatching and eyespots were visible on the anterior side of the egg.

The average incubation period was 6.80 ± 0.91days. The mean development duration of first, second, third, fourth and fifth instar nymphs in the present study were 6.64 ± 0.70, 5.68 ± 0.99, 6.90 ± 1.00, 7.48 ± 0.78 and 6.20 ± 0.65 days respectively, with a total nymphal development period of 32.96 ± 1.96 days on *S. litura*. Similar findings were made by Ambrose (1999), who recorded a nymphal duration of 36.50 ± 20.75 days but when reared on the larvae of *C. cephalonica.* However, the above values varied with earlier records by Ambrose and Livingstone (1989) and Sahayaraj and Paulraj (2001), as well as with the findings of George (1999a) who recorded 89.5 days of nymphal developmental period. A recent study by Pravallika (2015) revealed a total nymphal developmental period of 62.3 ± 2.62 days with 10.2 ± 0.45, 10.8 ± 1.27, 11.4 ± 0.28, 12.2 ± 0.33 and 17.7 ± 0.29 days for first, second, third, fourth and fifth instars respectively when reared on *S. litura*.

Variation in developmental duration of *R. marginatus* depending on the climatic conditions of rearing as well as nutrient condition was reported by

Sahayaraj and Paulraj (2001). Even the diet of the prey insect was reported to influence the biology of *R. marginatus* (Sahayaraj and Sathyamoorthi, 2002).

In the current experiment, the survival per cent of hatched out nymphs to adult was 59.33 ± 5.13 per cent. Mortality was the highest in the first instar, with a gradual reduction as the age advanced. The major causes of nymphal mortality in the initial instars was starvation due to the inability to hunt larger prey or death in fight with prey, abnormalities in moulting and cannibalism under captivity. This predator turned cannibalistic at the time of moulting by feeding on the newly moulted individuals. The new skin after moulting was soft and thus it was easy to pierce and suck through it. George (2000) reported cannibalism as the major factor for nymphal mortality when *R. kumarii* was reared in groups. Cannibalism increased with starvation and was the highest in the first and second nymphal instars. Similar observations were made in the present study as well. Pravallika (2015) also reported that the survival of hatched out nymphs to adult varied from 60 to 100 per cent.

Newly hatched nymphs of *R. marginatus* started feeding 8 to 12 h after their emergence. Sahayaraj *et al.*, (2015) also made similar observations in the case of reduviid predator, *R. albopilosus*.

5.1.1.9 Adult longevity

The adult females had an average life span of 117 ± 14.12 days and males lived for an average of 98.71 ± 4.65 days. Similar findings were recorded by Sahayaraj and Paulraj (2001) as well as Pravallika (2015), who reported that the female predator lived longer (128.04 ± 8.48 days) than males (82.84 ± 11.09 days).

5.1.2. Mating and oviposition

The mating behaviour with the characteristic riding over phenomenon is a typical harpactorine character observed during the present study. Ambrose (1999) also reported similar findings. Mating involved sequential steps such as arousal, approach, riding over, extension of genitalia, copulation, ejection of spermatophore capsule by the female and post mating cleaning. The same series of steps were

79

reported by Ambrose *et al*., (2009) in the case of another reduviid predator *S. variabilis*. Mating was observed to begin one day after moulting as adults and each act lasted for 30 to 45 min. This is in agreement with the findings of Pravallika (2015) who observed that mating happened one day after adult emergence and it extended for 30 to 45 min.

Adult female laid eggs in batches and these eggs were adhered to each other and to the substratum. Before laying egg with the tip of abdominal segments, female positioned the legs wide apart, raised the wings and the scape and pedicel were kept erect. Ambrose and Livingstone (1989) also made similar observations.

5.1.3. Fecundity, sex ratio and egg viability of *R. marginatus*

In the present study, it was observed that an adult female laid eggs 14 ± 1.33 days after emergence. During the oviposition period of 66.13 ± 6.27 days, a single female laid an average of 377.2 ± 45.52 eggs that hatched in 6.8 ± 0.92 days. The average number of eggs in an egg mass was 44.32 ± 4.57 with the number varying from 18 to a maximum of 70. The preoviposition period and incubation period observed in the present study were in agreement with previous findings by George (1999a) who reported that *R. marginatus* had a preoviposition period of 18.64 days. However, the fecundity reported was less (191.89 ± 39.69 eggs/ female) compared to the present findings and according to him, the oviposition period extended for 111.84 days which was comparitively high. Sahayaraj (2002) reported that *R. marginatus* had a preoviposition period of 18.8 ± 0.37 days. The incubation period observed in the present study was very close to the findings of Sahayaraj and Paulraj (2001) who reported an incubation period of 6.8 ± 0.1 days. A high fecundity of 405.2 ± 22.15 eggs/female was also reported in a study made by them.

The present results were in confirmation with the findings of a recent study by Pravallika (2015) in which the predator laid 380 ± 11.92 eggs in its life time with the number of eggs in an egg mass varying from 22.0 ± 4.77 to 65 ± 3.53. According to her, egg laying started 18.8 ± 0.37 days after adult emergence and it extended over a period of 58.5 ± 2.5 days.

80

A sex ratio (male: female) of 0.94: 1.0 was observed in the present study. A female biased sex ratio in *R. marginatus* has been recorded in earlier studies as well. (Ambrose and Livingstone, 1989; Sahayaraj and Paulraj, 2001; Pravallika 2015).

5.1.4 Morphometry of *R. marginatus*

The eggs in an egg mass were of uniform size and measured an average length of 2.47 ± 0.01 mm and width of 0.67 ± 0.22 mm. Similar observations were made by Pravallika (2015) who reported that the egg had a mean length of 2.38 mm and width of 0.76 mm. However, Ambrose and Livingstone (1989) observed that egg had a mean length of 1.01 mm and width of 0.46 mm. Adult female of *R. marginatus* had a length of 17.97 ± 0.18 mm, width of 6.60 ± 0.12 mm while male had a length of 17.26 ± 0.36 mm and width of 5.99 ± 0.70 mm. Sahayaraj (2001) when reared *R. marginatus* on grasshopper, *Chrotogonus sp.* observed that adult female had a length of 19. 20 mm which is very close to the present findings.

Length and width of first instar nymph of *R. marginatus* was 3.36 ± 0.13 mm and 1.73 ± 0.20 mm respectively. The respective figures for second, third, fourth and fifth instar nymphs 4.91 ± 0.13mm; 7.07 ± 0.18mm; 10.31 ± 0.34mm and 16.01 ± 0.41mm. However, Pravallika (2015) recorded that the body length of first, second, third, fourth and fifth instar nymphs were 5.46 ± 0.20, 6.06 ± 0.22, 7.86 ± 0.04, 8.54 ± 0.20, 8.93 ± 0.11 respectively and the width of the abdomen of first to fifth instar were 1.69 ± 0.10, 1.85 ± 0.99, 2.44 ± 0.0 ± 1, 2.71 ± 0.13 and 2.97 ± 0.02 respectively. According to her adult female had a length of 9.77 ± 0.14 mm and width of 3.60 ± 0.08 mm and male bug had a length of 9.61 ± 0.13 mm and width of 3.33 ± 0.02 mm.

5.2 LABORATORY EVALUATION OF PREDATORY POTENTIAL OF *R. marginatus*

5.2.1 Predatory behaviour of *R. marginatus*

In the present study, it was observed that *R. marginatus* showed predatory behaviour in a sequential manner. The steps included arousal at the sight of prey, approach, capture, paralysing and sucking the prey. Similar predatory behaviour was recorded earlier by various scientists. Haridass (1985) observed that stimuli response mediated predatory behaviour in reduviids began with search for the prey and it was followed by activities like approach and attack of the prey, immobilisation, transportation of prey to safe place and consumption. This transportation of prey to safe place was observed in the case of rearing in group. Haridass *et al*., (1988) reported that *R. marginatus* got excited when the prey was sighted and the movement of the prey made the predator more active. They also observed that when the predator reached the proximity of prey, it pinned down the prey with the tibial pads of the fore legs, and then jabbed the prey with rostrum and quickly injected the toxic saliva, resulting in death of the prey within 30 – 50 seconds. Ambrose (1999) also observed that the predatory behaviour in reduviids is mediated by sensory responses and it includes activities in sequence such as arousal, approach, capturing, stylet probing, injection of toxic saliva and paralysing, sucking and post predatory behaviour. He also reported that harpactorines pin and jab their prey with their rostrum.

5.2.2 Predatory potential of *R. marginatus*

The first instar nymphs of the predator did not attempt to prey upon third instar larvae of *S. litura* because of the larger size of the prey compared to the predator. The preference of small sized prey by early instar nymphs of *R. marginatus* have been reported earlier by several workers (Sahayaraj, 1994; Pravallika, 2015). In the present study, gradual increase in the number of prey killed was observed with progression of nymphal instars and with increase in prey densities. Fifth instar nymph, adult male and female of *R. marginatus* killed the preys completely at prey densities of 2, 4 and 6 prey/predator. However at prey density of 8 prey/ predator, fifth instar nymph killed 7.13 larvae whereas adult female and male killed 7.67 larvae each. At the prey density of 10 prey/ predator 7.60, 7.87 and 8.00 numbers of larvae where killed by fifth instar nymph, adult female and male respectively. Per day killing by the adults were on par with that by fifth instar nymph at all the given prey density except for the prey density of 8 prey/ predator.

Sahayaraj (1994) and George and Sreenivasagan (1998) also reported a gradual increase in the number of larvae killed by the predator with the progression of nymphal instars. Ambrose and Claver (1996) also reported that the number of prey killed increased as the prey density increased from 1 to 16 prey/ predator with per day killing of 13.50 larvae at a prey density of 16 prey/predator.

According to Ambrose and Sahayaraj (1994) and George and Sreenivasagan (1998) the increase in consumption with progression of nymphal instars was due to their increased nutritional requirement. They also reported that at higher prey density, the predator did not feed all the larvae killed and that the predator continued to kill the prey even after attaining satiation but with decreased rate of attack.

In the present study at a prey density of 10 prey/ predator, an adult female killed an average of 7.87 third instar larvae of *S. litura* per day. However, Pravallika (2015) reported a lower per day killing in the case of adults of *R. marginatus* with 3.8 third instar larvae of *S. litura* per day at the prey density of 10 prey/ predator.

5.2.3 Functional response of *R. marginatus*

Functional response is important for assessing the biocontrol efficiency of a predator. When the relation between prey density and the number of prey killed was assessed at five different prey densities, Hollings type II curvelinear functional response curve was obtained (Fig. 1). At lower prey densities such as 2- 6 prey/ predator, the number of prey killed by the predator increased with the increase in prey density but at higher prey densities of 8-10 prey/ predator, proportional increase in predation was not observed. A positive correlation ($y = 0.767\ x + 0.893$

83

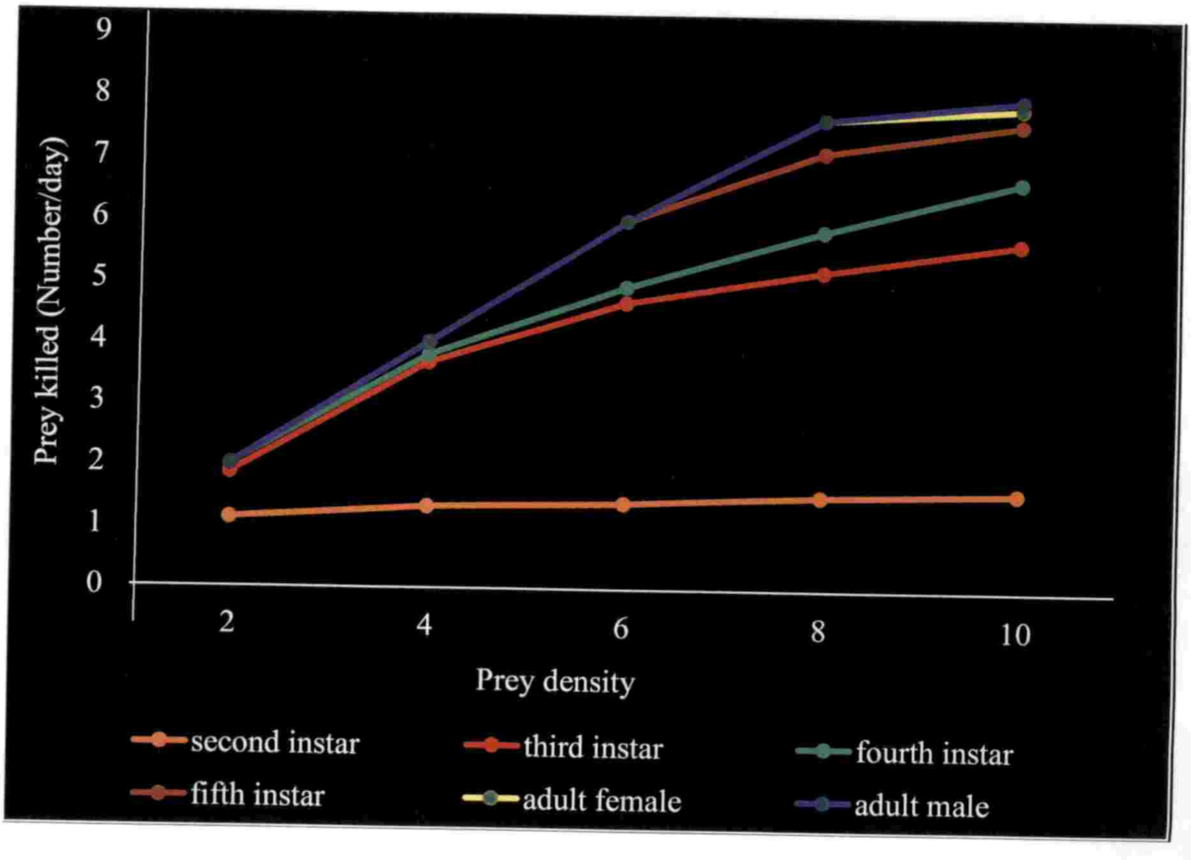
r = 0.970) was found to exist between prey density and the number of prey killed. Ambrose and Claver (1996) also had reported that the predator showed type II functional response curve when observed at different densities of *S. litura* larvae with positive relation between prey density and per day killing. He obtained a correlation of log y = 3.53 + 5.17 log x; r = 0.979 between the prey density and number of prey killed. Pravallika (2015), also observed a positive correlation (Y = 0.2981 x + 1.1505 r = 0.8901) between prey density and number of prey killed. However, the maximum predation or the highest value of 'k' was obtained at highest prey density of 10 prey/predator. Similar observations where the 'k' value was the highest at the highest prey density have been reported earlier by George and Sreenivasagan (1998), Pravallika (2015) and Sahayaraj *et al.,* (2015).

The existence of Type II functional response curve was also reported by Sahayaraj *et al.,* (2015) in the case of *R. kumarii* to various densities (1, 2, 4, 6, 8, and 10) of *Phenococcus solenopsis* under laboratory condition. Ambrose (1995) has reported that reduviid predators killed more number of preys at higher prey density than at lower prey density. Claver and Ambrose (2002) also found that the predation rate of *R. fuscipes* on larvae of *H. armigera*, *Euproctis subnotata* and *Exelastis atomosa* was increased with the increase in prey density. Same was the case with another reduviid predator *S. variabilis* in which the predation rate increased with increase in prey density from 1 prey/ predator to 4 prey/ predator and above this a constant rate was attained (Ambrose *et al.*, 2009).

The attack ratio (y/x) of *R. marginatus* was highest at prey density of 2 prey/ predator with values 0.57, 0.93,1, 1, 1, 1 respectively for second to fifth instars, adult male and female. But at prey density of 10 prey/ predator the respective figures were 0.16, 0.57, 0.67, 0.76, 0.78 and 0.80 .Similar observations were made by Claver and Ambrose (2002) with attack ratio of 3.1, 3.3 and 3.0 for *R. fuscipes* on *H. armigera*, *E. subnotata* and *E. atomosa* respectively at a prey density of 1 prey/ predator, which reduced to 0.45, 0.43 and 0.46 at the highest density of 16 prey/ predator. Pravallika (2015) also observed a decrease in attack ratio with increase in prey density and recorded an attack ratio of 0.8 at a prey density of two prey/predator while it reduced to 0.4 when the prey density was increased to 10 prey/predator in the case of *R. marginatus* on *S. litura*. On the contrary, Sahayaraj *et al.*, (2012) stated that the attack rate of reduviid predator, *R. longifrons* increased with the increase in prey density of *D. cingulatus, A. gossypi,* and *P. solenopsis*.

The searching time of the predator decreased with the increase in prey density. At higher prey density, the predator spent more time for feeding rather than searching for the prey. With the increase in prey density, the time spend for searching the prey decreased and the predator spent more time in killing and feeding thus leading to high 'k' value at the highest prey density. The number of unsuccessful attempts made by the predator was also less at the higher prey densities. Sahayaraj (1991) stated that the searching time for predators of reduviidae family reduced with increase in prey density.

Fig 1: Functional response to different stages of *R. marginatus* on third instar larvae of *S. litura*



5.3 CAGE EVALUATION OF PREDATORY EFFICACY OF *R. marginatus* on *A. craccivora* and *S. litura*

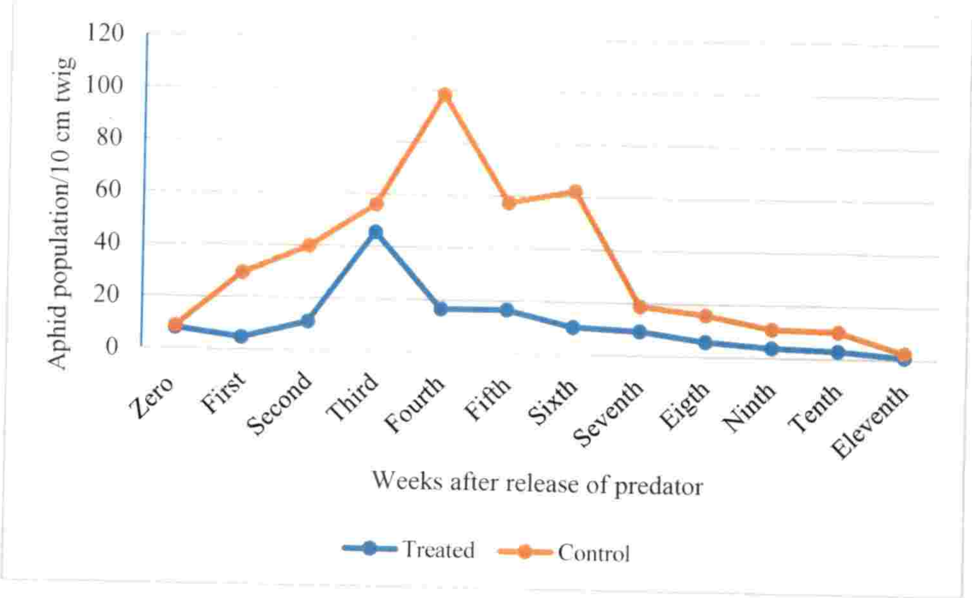
5.3.1 Predatory efficacy of *R. marginatus* on *A. craccivora*

In the present study, release of third instar nymph of *R. marginatus* @ 1 predator/ cage on caged cowpea plants at 20 days interval starting from 20 days after sowing suppressed the establishment of *A. craccivora.* The mean aphid population in predator released cage was significantly lower when compared to control cage throughout the study period from first to sixth week after the first release of predator except for third week (Fig. 2) A drastic increase in aphid population was observed from second to third week and because of this reason the predator was not able to bring significant reduction in aphid population.

The reports available in the literature on the predatory efficacy of *R. marginatus* on aphids under caged or potted condition is very limited and an earlier report by Sahayaraj and Martin (2003) in groundnut ecosystem is presented here for comparison. They studied the bioefficacy of different life stages of *R. marginatus* against *A. craccivora* artificially infested on 25 days old groundnut plants cultivated under nylon mesh cages. The first instar of the predator fed on a maximum of 6.47 aphids/ day and the per day killing decreased to 6.21, 1.68, 1.29, 0.79, 0.26 aphids/ day with the progression of life stages from second to successive nymphal instars and to adults.

The biocontrol efficacy of another predator *R. fuscipes* was studied by Thomson *et al.,* (2017) against mealy bug, *P. solenopsis* on cotton under potted conditions. In the said experiment, they opined that the adult stage of *R. fuscipes* was found to be effective against mealybug.

Figure 2: Trend of aphid population on control and predator released plants in cage



Four release of predator were made at zero, third, sixth and ninth weeks

5.3.2 Predatory efficacy of *R. marginatus* on *S. litura*

The release of *R. marginatus* @ of 1 predator/ cage significantly reduced the population of artificially established *S. litura.* The mean number of larvae remained in the predator released cages were 1.5, 1.33, 0.17 on 1st, 2nd and 3rd day respectively. Number of released larvae reached to zero level within four days of release of the predator (Fig. 3).

There was significant difference in leaf damage between predator released (6.30) and control plants (8.50) after four days (Fig. 4). In a study, Ambrose and Claver (1996) reported 50 per cent suppression in population of *S. litura* through the release of *R. marginatus* in cotton field cages. In another field cage experiment designed by Ambrose and Claver (1999), 57.5 per cent reduction of *S. litura* with significant reduction in leaf damage was reported through the release of *R. marginatus* on cotton.

Figure 3: Population of *Spodoptera litura* in predator released and control cowpea plants in cage

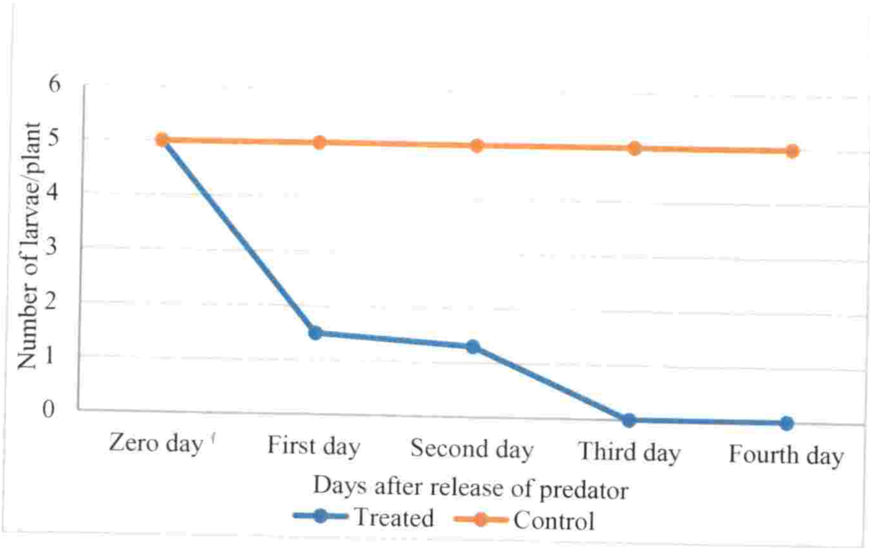
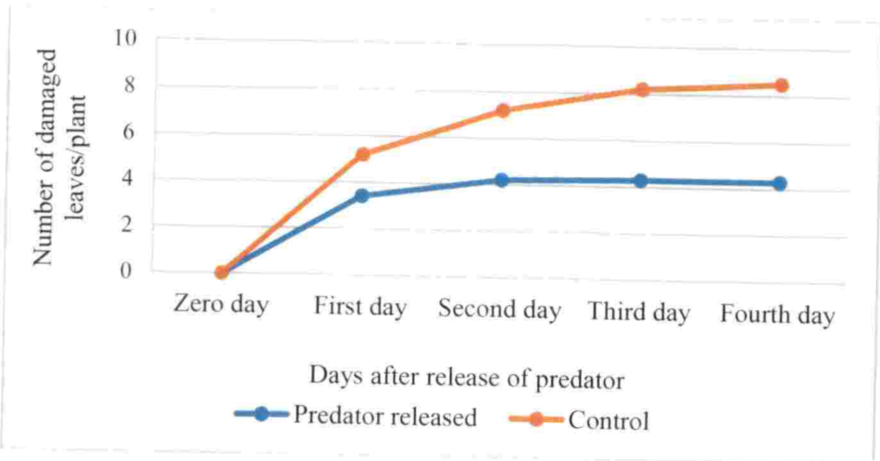


Figure 4: Number of damaged leaves in predator released and control cowpea plants in cage



5. 4 Field evaluation of *R. marginatus* on insect pests of cowpea

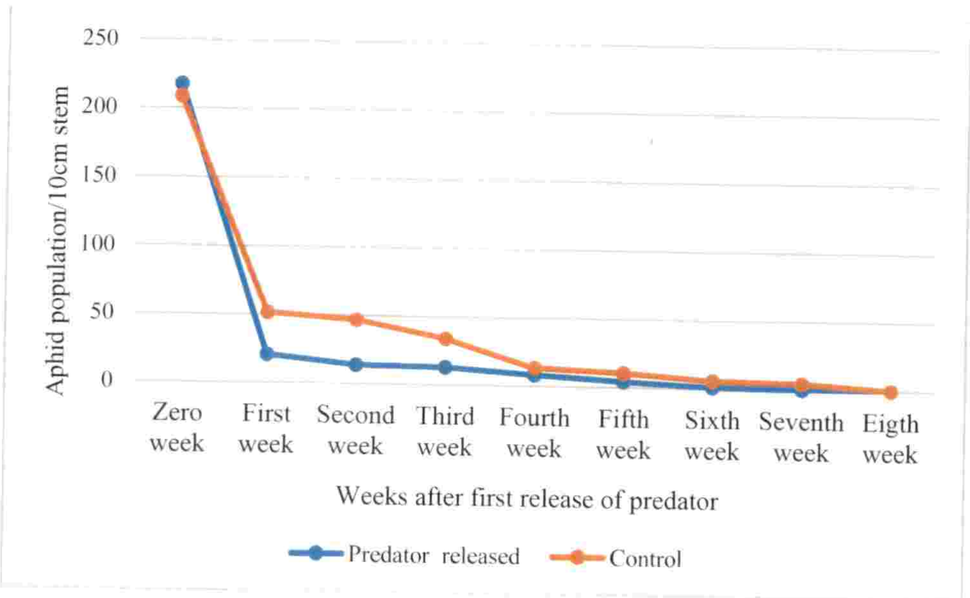
Similar dynamics in aphid population was noticed with sharp decline in first week after the release of predator and gradually towards seventh week (Fig. 5). However, the aphid population in the predator released plot was significantly less compared to control at all intervals of observation starting from first to fifth week accomplishing two releases of the predator at twenty days interval. Even though reduction in population was observed in both the plots, the aphid population was significantly higher in control plot when compared to the predator released plot at every week of observation. After sixth week, though the aphid population was less in the predator released plot compared to control, significant difference was not observed among the two. Same trend was observed in seventh week also. The number of aphid damaged pods was also less in the predator released plot (Fig. 6).

The pod and flower damage due to pod borer, *M. vitrata* were also less in predator released field compared to control (Fig.7 and 8). No significant difference in pod bug population was observed among the predator released and control plots (Fig. 9 and 10). However, the number of pods damaged by pod bugs were numerically less in predator released plot compared to control. Per plant yield of green pods in the predator released plot was significantly high compared to control. There was no definite variation in the population of predatory coccinellids in both control and predator released plot (Fig 11.).

The field efficacy of *R. marginatus* on important crop pests was reported earlier by many workers. Ambrose and Claver (1999) reported that release of *R. marginatus* significantly reduced the artificially released population of *S. litura*, *M. pustulata* and *D. cingulatus* in cotton along with significant reduction in flower damage by *M. pustulata* and boll damage by *D. cingulatus*. According to Sahayaraj (1999b), release of *R. marginatus* @ 5000/ ha in groundnut field, reduced the number of *H. armigera* larvae from 6.55 to 0.77 per plant and *S. litura* from 5.66 to 0.88/ plant with high yield (1867.77 kg/ ha) in predator released plot compared to control (1023 kg/ ha).

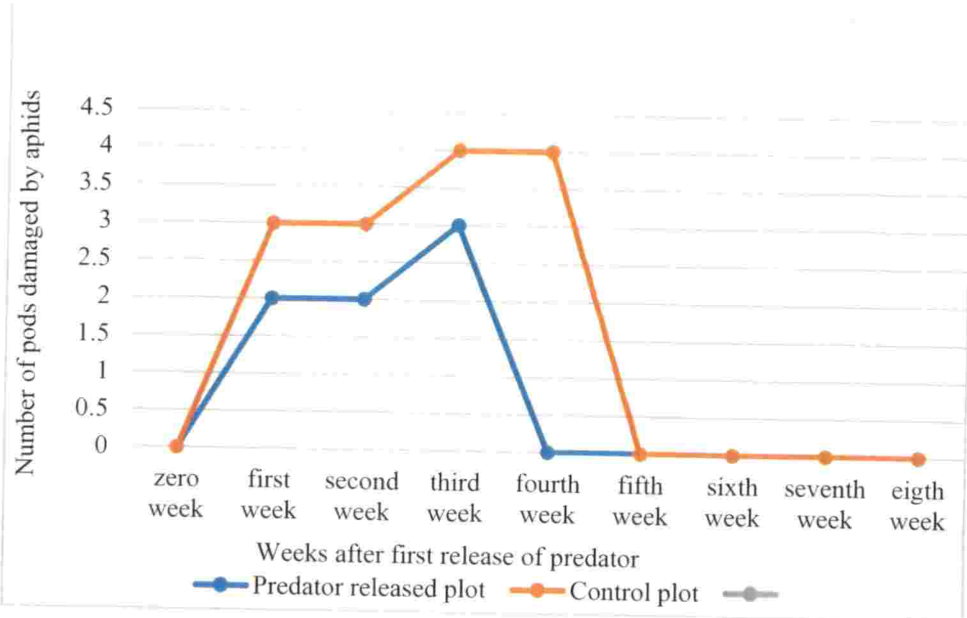
Sahayaraj and Martin (2003) reported that the multiple release of different life stages of *R. marginatus* in groundnut field decreased the infestation of *S. litura* by 85.89 per cent, *H. armigera* by 67.75 per cent and grasshopper by 42.86 per cent. Significant reduction (46.34 %) in the population of aphids was also reported following the release of the predator. Yield in the predator released plot was significantly higher than that in control. Release of *R. marginatus* also resulted in reduction in the number of leaves damaged by *S. litura* (6.61 to 1.78), *H. armigera* (5.84 to 2.24) and grasshopper (5.17 to 2.24). But no impact was reported on the infestation of *Mylabris spp.* and at the same time, the release of the predator had no impact on the population of predatory coccinellids such as *Menochilus sexmaculatus* and *Coccinella septumpunctata*. Similar observations without any definite variation in population of coccinellids among the predator released and control plots were made in the present experiment.

Figure 5: Mean aphid population at weekly intervals in predator released and control cowpea fields



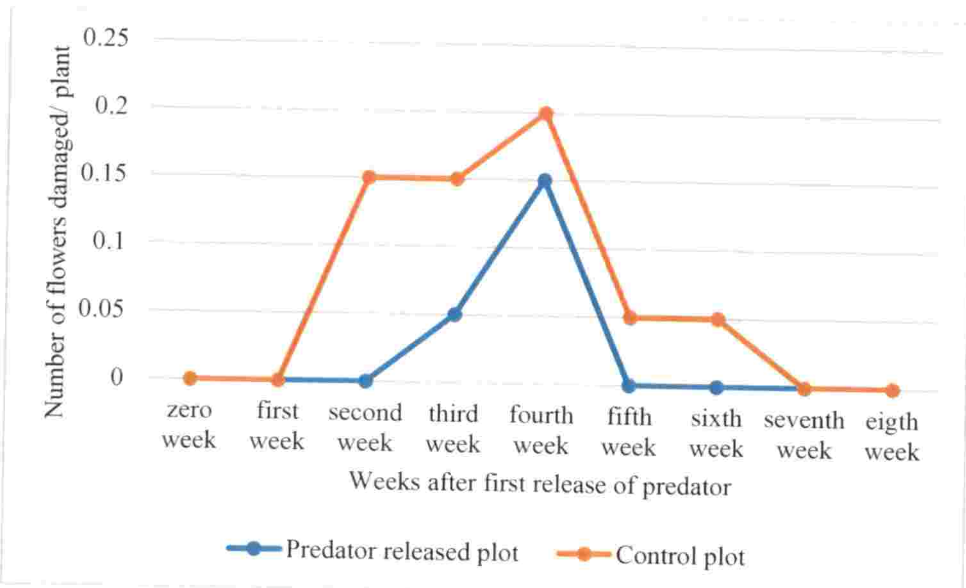
- Three releases of predator were made at zero, third and sixth weeks

Figure 6: Mean number of pods damaged by aphids in predator released and control cowpea fields



- Three releases of predator were made at zero, third and sixth weeks

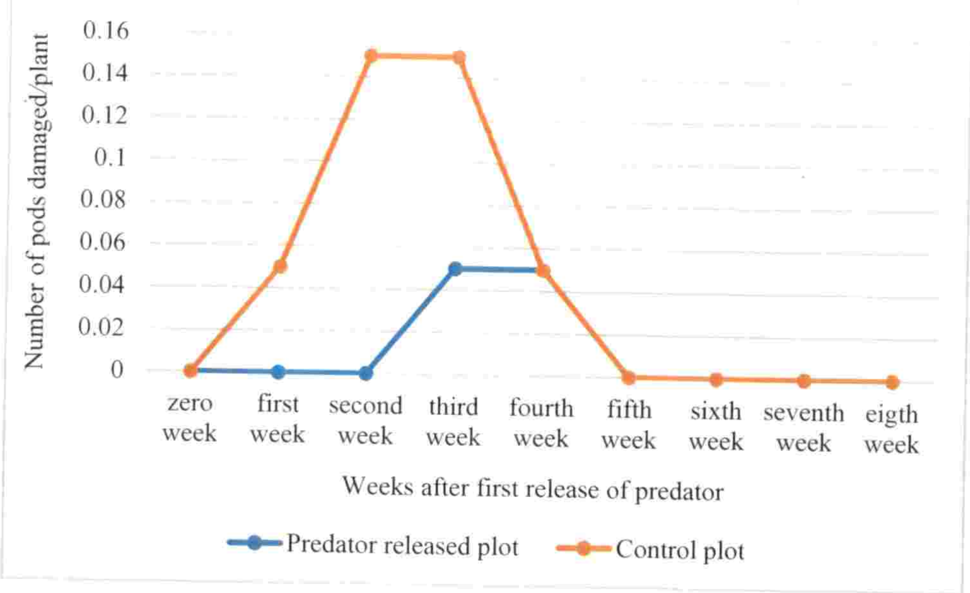
Figure 7: Mean number of flowers damaged in predator released and control cowpea field



- Three releases of predator were made at zero, third and sixth week

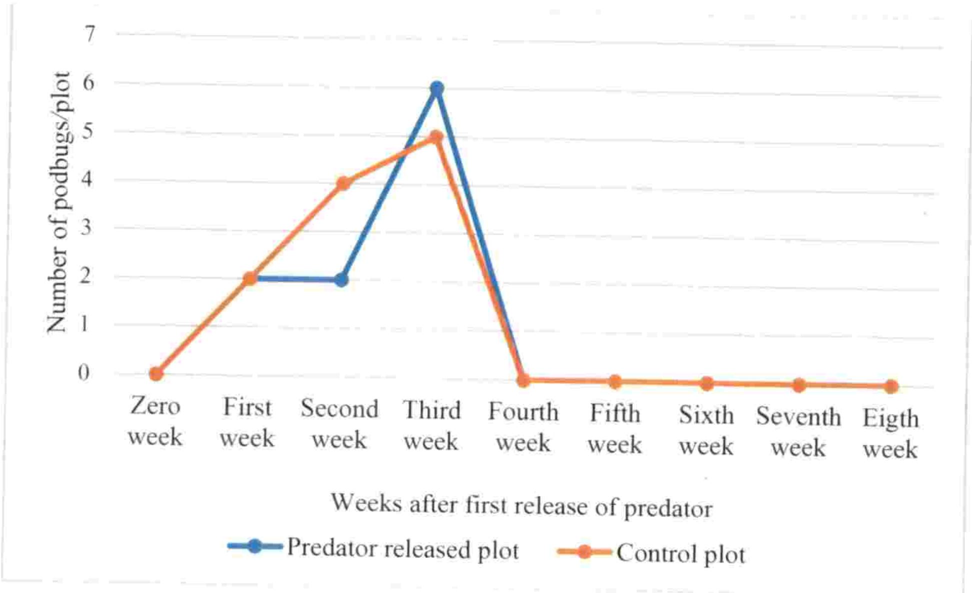
91

Figure 8: Mean number of pods damaged by *Maruca vitrata* in predator released and control cowpea fields



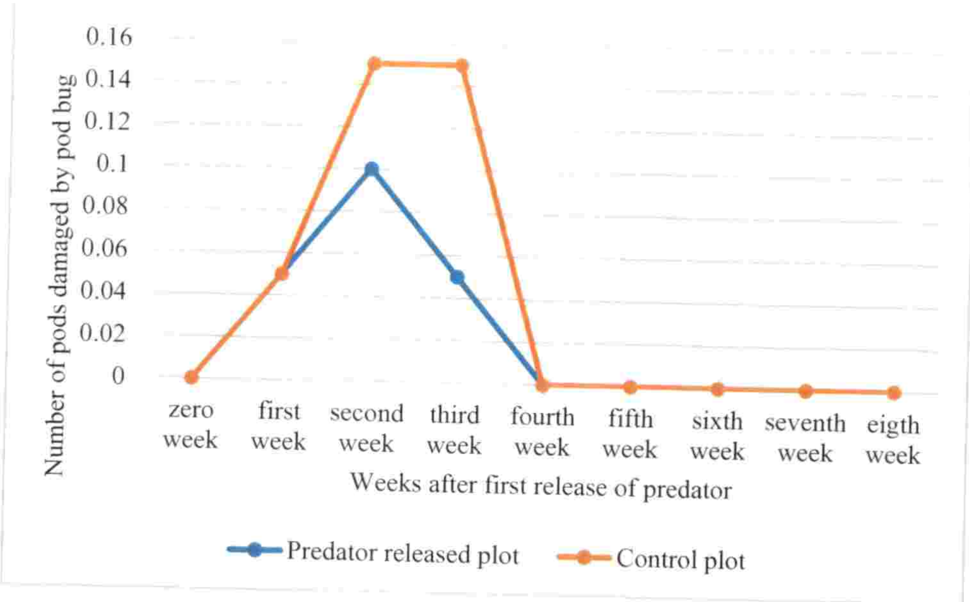
- Three releases of predator were made at zero, third and sixth weeks

Figure 9: Mean population of *Riptortus pedestris* in predator released and control cowpea fields



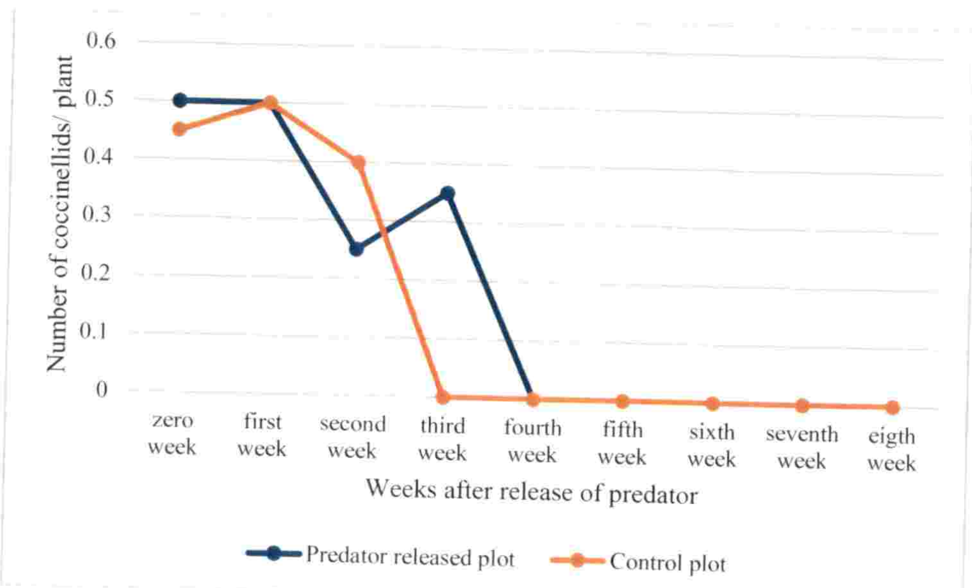
- Three releases of predator were made at zero, third and sixth weeks

Figure 10: Mean number of pods damaged by pod bug in predator released and control cowpea fields



- Three releases of predator were made at zero, third and sixth weeks

Figure 11: Mean population of coccinellids in predator released and control cowpea field



- Three releases of predator were made at zero, third and sixth weeks

Summary

6. SUMMARY

The present study titled "Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea" was carried out at the Department of Agricultural Entomology, College of Horticulture, Vellanikkara, Thrissur from November 2015 to March 2017. The objectives of the experiment were to study the biology and predatory potential of *Rhynocoris marginatus* on *Spodoptera litura* as well as to evaluate its predatory efficacy on cowpea aphid, *Aphis craccivora* and leaf caterpillar, *S. litura* in caged conditions and also field evaluation of *R. marginatus* on insect pests of cowpea.

Different biological parameters such as developmental stages, duration and number of nymphal instars, adult longevity, oviposition behaviour, fecundity and morphometry were recorded. The eggs were elongate oval in shape and yellowish brown in color with an average incubation period of 6.80 ± 0.91 days. It took 32.96 ± 1.81 days to complete nymphal development in five instars. Adult female lived longer than male. The preoviposition period was 14 ± 1.30 days and during the oviposition period of 66.13 ± 6.27 days, it laid 8.60 ± 0.97 batches of egg mass with mean fecundity of 377.20 ± 45.52 eggs/ female.

The predatory potential of second, third, fourth and fifth nymphal instars and adults were studied on third instar larvae of *S. litura* at prey densities, 2, 4, 6, 8 and 10 prey/ predator. Per day predation had strong correlation with the prey density. When the number of prey killed by the predator was plotted against the prey density a Holling's type II functional response curve was obtained.

Per day consumption of adult males and females was on par at all the prey densities. Adult male and female consumed 2, 4, 6, and 7.67 preys at prey densities of 2, 4, 6 and 8 prey / predator. But at the prey density of 10 prey/predator adult female killed 7.87 ± 0.50 preys while the male killed 8.00 ± 0.23 preys. The number of prey killed by the predator increased with increase in prey density and also with the progression of nymphal instars.

The predatory potential of *R. marginatus* on cowpea aphid, *A. craccivora* and leaf caterpillar, *S. litura* was assessed by releasing third instar nymph of *R. marginatus* on caged cowpea plants infested with *A. craccivora* and *S. litura* artificially. Aphid population in predator released cages showed consistent reduction. There was significant reduction in aphid population in predator released cages upto sixth week after the first release of the predator except for the third week. After seventh week even though no significant difference was observed in aphid population in predator released and control cages, the aphid population was numerically less in predator released cages when compared to control. In cages artificially infested with third instar larvae of *S. litura* the predator was able to kill all the released larvae within four days. The leaf damage by *S. litura* was also significantly less in predator released cages compared to control.

Evaluation of predatory efficacy was carried out by releasing the third instar nymph of the predator at the rate of $1/m^2$ in predator released and control plots. The release of the predator significantly reduced the aphid population on cowpea. The infestation by pod borer *Maruca vitrata* and pod bug, *Riptortus pedestris* were negligible and the number of pod borer and pod bug were numerically less in predator released field when compared to control. However, the number of pods damaged by pod bug was comparatively less in predator released field. At the same time, the predator had no impact on the population of coccinellid predators in the field.

The present study clearly indicates the importance of *R. marginatus* as an efficient predator to be considered for augmentation against leaf eating caterpillar, *S. litura* on cowpea. Further studies by with early stage nymphal instars have to be carried out to exploit the potential of this predator on cowpea aphids since the nymphal instars exhibit preference to proportionate size of the prey.

In future, works can be taken up on the prey preference of *R. marginatus* on insect pests of cowpea. Stage preference studies can be done for standardizing augmentative release of the predator. The predatory potential of early instars on aphids at various prey- predator ratios can also be worked out to evaluate the efficacy of predator against aphids. Efficiency of *R. marginatus* against pod borers can also be taken up for future studies.

References

REFERENCES

Ables, J. R. 1978. Feeding behavior of an assassin bug, *Zelus renardii*. *An. Entomol. Soc. Am.* **71**(4): 476-478.

Ambrose, D. P. 1999. *Assassin Bugs*. Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi, India and Science Publishers, New Hampshire, U. S.A., 337p.

Ambrose, D. P. 2003. Biocontrol potential of assassin bugs (Hemiptera: Reduviidae). *J. Exp. Zool.* **6**(1): 1-44.

Ambrose, D.P. 2006. A checklist of Indian assassin bugs (Insecta: Hemiptera: Reduviidae) with taxonomic status, distribution and diagnostic morphological characteristics. *Zoos' Print J.* **21**(9): 2388-2406.

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

Ambrose, D. P. and Claver, M. A. 1996. Size preference and functional response of the reduviid predator *Rhynocoris marginatus* Fabricius (Heteroptera: Reduviidae) to its prey *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *J. Biol. Control* **10**(1/2): 29-37.

Ambrose, D. P. and Claver, M. A. 1997. Functional and numerical responses of the reduviid predator, *Rhynocoris fuscipes* F. (Het. Reduviidae) to cotton leafworm *Spodoptera litura* F. (Lep. Noctuidae). *J. Appl. Entomol.* **121**(1): 331-336.

Ambrose, D. P. and Claver, M. A. 1999. Suppression of cotton leafworm *Spodoptera litura*, flower beetle *Mylabris pustulata* and red cotton bug *Dysdercus*

99

cingulatus by *Rhynocoris marginatus* (Fabr.)(Het. Reduviidae) in cotton field cages. *J. Appl. Entomol.* **123**(4): 225-230.

Ambrose, D. P. and Livingstone, D. 1989. Biology of the predaceous bug *Rhynocoris marginatus* Fabr. (*Insecta: Heteroptera: Reduviidae*). *J. Bombay Nat. Hist. Soc.* **86**(2): 155-160.

Ambrose, D.P. and Sahayaraj, K. 1994. Stage and host preference and functional response of a reduviid predator *Acanthaspis pedestris* Stal to four cotton pests. *J. Biol. Control* **8(**1): 23-26.

Ambrose, D. P., Saju, T. and Sahayaraj, K. 1990. Prey influence on the development, reproduction and size of assassin bug, *Rhynocoris marginatus. Environ. Ecol.* **12**(1): 37-44.

Ambrose, D. P., Claver, M. A. and Mariappan, P. 2000. Functional response of *Rhynocoris marginatus* (Fab.) (Heteroptera: Reduviidae) to two pests of pigeonpea (C*ajanus cajan*). *Indian J. Agri. Sci.* **70**(9): 630-632.

Ambrose, D. P., Kumar, S. P., Subbu, G. R. and Claver, M. A. 2003. Biology and Prey influence on the postembryonic development of *Rhynocoris longifrons* (Stal) (Hemiptera: Reduvidae), a potential biological control agent. *J. Biol. Control.* 17: 113-119.

Ambrose, D. P., Rajan, S., Justin, X., Nagarajan, K., Jeba Singh, V. and Krishnan, S. S. 2009. Biology, behaviour and functional response of *Sphedanolestes variabilis* Distant (Insecta: Hemiptera: Reduviidae: Harpactorinae), a potential predator of lepidopteran pests. *Entomol. Croatica*, **13**(2): 33-44.

Atiri, G. I., Ekpo, E. J. A. and Thottappilly, G. 1984. The effect of aphid-resistance in cowpea on infestation and development of *Aphis craccivora* and the

100

transmission of cowpea aphid-borne mosaic virus. *An. Appl. Biol.* **104**(2): 339-346.

Bhat, P. S., Srikumar, K. K., Raviprasad, T. N., Vanitha, K., Rebijith, K. B. and Asokan, R. 2013. Biology, behavior, functional response and molecular characterization of *Rihirbus trochantericus* Stal var. *luteous* (Hemiptera: Reduviidae: Harpactorinae) a potential predator of *Helopeltis Spp.* (Hemiptera: Miridae). *Entomol. News.* **123**(4): 264-277.

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

Claver, A. M. and Ambrose, D. P. 2002. Functional response of the predator, *Rhynocoris fuscipes* (Heteroptera: Reduviidae) to three pests of pigeonpea (*Cajanus cajan*). *Shaspa.* **9**(10): 47 – 51.

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

Claver, M. A., Muthu, M. S. A., Ravichandran, B., and Ambrose, D. P. 2004. Behaviour, prey preference and functional response of *Coranus spiniscutis* (Renter), a potential predator of tomato insect pests. *Pest Manag. Hortic. Ecosyst.* **10**(1): 19-27.

El-Ghareeb, A. M., Nasser, M. A. K., El-Sayed, A. M. K. and Mohamed, G. A. 2002. Possible mechanisms of insecticide resistance in the cowpea aphid, *Aphis craccivora* (Koch). The role of general esterase and oxidase enzymes in insecticide resistance of cowpea aphid. In: *Proceedings of the First Conference*

101

of the Central Agricicultural Pesticide Laboratory, 3-5 September 2002, Agricultural Research Center, Giza, Egypt: pp. 635-649.

Fatokun, C. A., Tarawali, S. A., Singh, B. B., Kormawa, P. M. and Tamo, M. (eds.). 2000 Challenges and opportunities for enhancing sustainable cowpea production. In: *Proceedings of the World Cowpea Conference III,* 4-8 september 2000, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, pp: 4-8.

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

George, P.J.E., 1999b. Development, life table and intrinsic rate of natural increase of three morphs of *Rhynocoris marginatus* Fab. (Heteroptera: Reduviidae) on cotton leaf worm *Spodoptera litura* Fab. (Lepidoptera: Noctuidae). *Entomon.* **24**(4): 339-344.

George, P. J. E. 2000. Nymphal cannibalistic behaviour of *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera: Reduviidae) to prey deprivation and mass rearing conditions. *J. Biol. Control* **14**(1):1-3.

George, P. J. E. and Sreenivasagan, R. 1998. Predatory efficiency of *Rhynocoris marginatus* (Fabricius) (Heteroptera: Reduviidae) on *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *J. Biol. Control* **12**(2): 25-59.

George, P. J. E., Kannagi, J. and Ambrose, D. P. 2002. Nutritional influence of prey on the biology and biochemistry of *Rhynocoris marginatus* (Fabricius) (Heteroptera: Reduviidae). *J. Biol. Control* **16**(1): 1-4.

George, P. J. E., Seenivasagan, R. and Karuppasamy, G., 1998. Life table and intrinsic rate of increase of *Sycanus collaris* (Fabricius) (Heteroptera: Reduviidae), a predator of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *J. Biol. control*, **12**(2), pp.107-111.

Greene, G. L. and Shepard, M. 1974. Biological studies of a predator *Sycanus indagator*. II. Field survival and predation potential. *Florida Entomol.* 57: 33–38.

Haridass, E. T. 1985. Feeding and ovipositional behaviour in some reduviids (Insecta-Heteroptera). In: *Proceedings of Indian Academy Sciences, Bangalore* **94**(3): 239-247.

Haridass, E. T., Morrison, M. N., and Balu, A. 1988. Predatory behaviour of Rhynocoris marginatus Fabricius (Harpactorinae—Reduviidae—Heteroptera—Insecta). In: *Proceedings of Indian Academy of Animal Sciences, Bangalore,* **97**(1): 41-48.

Holling, C. S. 1959. Some characteristics of simple types of predation and parasitism. *Can. Entomol.* **91**(7): 385-398.

Kalidas, S. and Sahayaraj, K., 2012. Comparative biology and life stable traits of *Rhynocoris longifrons* Stal (Hemiptera: Reduviidae) on factitious host and natural cotton pests. In. *Proceedings of International Conference Science and Technology for Clean and Green Environment*, Annamalai University, Tamil Nadu, pp. 142-149.

Maldonado, J. 1990. Systematic catalogue of the Reduviidae of the world (Insecta: Heteroptera). *Caribbean J. Sci.* **1**(2): 694 p.

Maxwell-Lefroy, H. 1909. *Indian Insect Life*. W. Thakers and Co., London, 1023p.

Muthupandi, M., Evangelin, G., Horne, B. and William, S. J. 2014. Biology of the harpactorine assassin bug, *Panthous bimaculatus* Distant (Hemiptera: Reduviidae) on three different diets. *Halteres*, **5**: 11-16.

Pravallika, K. 2015. Studies on biology, predator – prey interaction, predatory efficacy of *Rhynocoris marginatus* Fabricius (Hemiptera: Reduviidae). M. Sc. (Ag) thesis, Professor Jayashankar Telangana State Agricultural University, Hyderabad, 122p.

Ram, S., Gupta, M. P. and Patil, B. D. 1989. Pest management in fodder cowpea (*Vigna unguiculata* L. Walp.) through mixed-and inter-cropping in India. *Int. J. Pest Manag.* **35**(4): 345-347.

Ravichandran, B. 2004. Biocontrol potential evaluation of a reduviid predator *Rhynocoris kumarii* Ambrose and Livingstone (Insecta Heteroptera: Reduviidae) against three chosen insect pests. Ph. D thesis, Manonmaniam Sundaranar University, 101p.

Sahayaraj, K. 1991. Bioecology, ecophysiology and ethology of chosen predatory Hemiptera and their potential in biological control (Insecta: Heteroptera: Reduviidae). Ph. D. thesis, Madurai Kamaraj University, Madurai, 154p.

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

Sahayaraj, K. 1995. Bio-efficacy and development of a reduviid predator, *Rhinocoris marginatus,* on *Spodoptera litura. Int. Arachis Newsl.* 19:41 – 42.

104

Sahayaraj, K. 1999a. Effect of prey and their ages on the feeding preference of *Rhynocoris marginatus* (Fab.). *Int. Arachis Newsl.* 19: 39-40.

Sahayaraj, K., 1999b. Field evaluation of the predator, *Rhynocoris marginatus* (Fab.) on two groundnut defoliators. *Int. Arachis Newsl.* 20: 72-73.

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

Sahayaraj, K., 2002. Field bio-efficacy of a reduviid predator *Rhynocoris marginatus* (Fab.) and plant products against *Aproaerema modicella* Dev. and *Spodoptera litura* (Fab.) of groundnut. *Indian J. of Entomol.* **64** (3): 292–300.

Sahayaraj, K. 2008. Approaching and rostrum protrusion behaviours of *Rhynocoris marginatus* on three prey chemical cues. *Bull. Insectol.* **61**(2): 233–237.

Sahayaraj, K. 2012. Artificial rearing on the nymphal developmental time and survival of three reduviid predators of Western Ghats, Tamil Nadu. *J. Bio pesticides.* **5**: 218-221.

Sahayaraj, K., and Asha, A. 2010. Biological control potential evaluation of *Rhynocoris kumarii* Ambrose and Livingstone (Hemiptera: Reduviidae) on *Aphis craccivora* (Koch.)(Hemiptera: Aphididae). *Indian J. Agric. Res.* **44**(4): 281-287.

Sahayaraj, K. and Balasubramanian, R. 2009. Biological control potential of artificial diet and insect hosts reared *Rhynocoris marginatus* (Fab.) on three pests. *Arch. Phytopathol. Plant Prot.* **42**(3): 238-247.

105

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

Sahayaraj, K. and Martin, P. 2003. Assessment of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) as augmented control in groundnut pests. *J. Cent. Eur. Agric*. **4**(2): 103–110.

Sahayaraj, K. and Paulraj, M. G. 2001. Rearing and life table of reduviid predator *Rhynocoris marginatus* Fab. (Het. Reduviidae) on *Spodoptera litura* Fab. (Lep. Noctuidae) larvae. *J. Appl. Entomol*. **125**(6): 321-325.

Sahayaraj, K. and Ravi, C. 2007. Evaluation of reduviid predators and plant products against chosen groundnut pests. *Arch. Phytopathol. Plant Prot.* **40** (4): 281-290

Sahayaraj, K. and Sathiamoorthi, P. 2002. Influence of different diets of *Corcyra cephalonica* on life history of a reduviid predator *Rhynocoris marginatus* (Fab.). *J. Cent. Eur. Agric.* **3**(1): 53-62.

Sahayaraj, K. and Selvaraj, P. 2003. Life Table Characteristics of *Rhynocoris fuscipes* Fabricius in Relation to Sex Ratios. *Ecol. Environ. Conserv.* **9**(2): 115-119.

Sahayaraj, K. and Sivakumar, K. 1995. Groundnut pest and pest stage preference of a reduviid predator *Rhinocoris kumarii* Ambrose and Livingstone (Heteroptera, Reduviidae). *Fresenius Environ. Bull.* **4**(5): 263-269.

Sahayaraj, K., Kalidas, S. and Tomson, M. 2012. Stage preference and functional response of *Rhynocoris longifrons* (Stål) (Hemiptera: Reduviidae) on three hemipteran cotton pests. *Brazilian Arch. of Biol. and Technol.* **55**(5): 733-740.

106

Sahayaraj, K., Kumar, V. and Avery, P. B. 2015. Functional response of *Rhynocoris kumarii* (Hemiptera: Reduviidae) to different population densities of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) recorded in the laboratory. *Eur. J. Entomol.* **112**(1): 69 -74.

Sahayaraj, K., Natarajan, S., Chelladurai, K., Jayaseeli, P. R. and Sundaram, A. R. S. 2015. Laboratory culture of early life stages of *Rhynocoris albopilosus* (F.) (Hemiptera: Reduviidae) using early life stages of eri silkworm (Lepidoptera: Saturniidae). *Faunistic Entomol.* **68**:141-147.

Shanker, C., Lydia, Ch., Sampathkumar, M., Sunil, V. and Gururaj, K. 2016 Biology and predatory potential of *Rhynocoris fuscipes* (Fabricius) (Hemiptera: Reduviidae) on the Rice Leaf folder *Cnaphalocrocis medinalis* (Guenee). *J. Rice Res.* **9**(1):47-49.

Simmons, G. S. and Minkenberg, O. P. 1994. Field-cage evaluation of augmentative biological control of *Bemisia argentifolii* (Homoptera: Aleyrodidae) in Southern California cotton with the parasitoid *Eretmocerus nr. californicus* (Hymenoptera: Aphelinidae). *Environ. Entomol.* **23**(6): 1552-1557.

Singh, S. R. and Emden, H. V. 1979. Insect pests of grain legumes. *Annu. Rev. Entomol.* **24**(1): 255-278.

Taylor, T. A. 1981. Distribution, ecology and importance of bruchids attacking grain legumes and pulses in Africa. **In**: Labeyrie, W., Junk (eds), *The ecology of bruchids attacking legumes (pulses)*. The Hague, Netherlands, pp. 199-203.

Thomson, M., Sahayaraj, K., Kumar, V., Avery, P. B., McKenzie, C. L. and Osborne, L. S. 2017. Mass rearing and augmentative biological control evaluation of *Rhynocoris fuscipes* (Hemiptera: Reduviidae) against multiple pests of cotton. *Pest Manag. Sci*. 73(8): 1743-1752.

Van Lenteren, J. C., and Woets, J. V. 1988. Biological and integrated pest control in greenhouses. *Annu. Rev. Entomol.* **33**(1): 239-269.

Vashisth, S., Chandel, Y. and Chandel, R. 2016. Biological Control Potential of Himalayan Strains of Entomopathogenic Nematodes against Lepidopteran Insects Infesting Cole Crops under Screen House Conditions. *Biopestic. Int.* **12**(1). 53-59.

Vennison, S. J. and Ambrose, D. P. 1988. Impact of Space on Stadial Period, Adult Longevity, Morphometry, Oviposition, Hatching, and Prey Capturing in *Rhinocoris marginatus* Fabricius (Insecta, Heteroptera, Reduviidae). *Zoosyst. Evol.* **64**(2):349-355.

Wyss, E., Villiger, M. and Müller-Scharer, H. 1999. The potential of three native insect predators to control the rosy apple aphid, *Dysaphis plantaginea. BioControl.* **44**(2): 171-182.

Xue, M., Pang, Y. H., Wang, H. T., Li, Q. L. and Liu, T. X. 2010. Effects of four host plants on biology and food utilization of the cutworm, *Spodoptera litura. J. Insect Sci.* **10**(1): 22.

BIOLOGY AND PREDATORY POTENTIAL OF *Rhynocoris marginatus* (FAB.) (HEMIPTERA: REDUVIIDAE) ON INSECT PESTS OF COWPEA

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ABSTRACT OF THE THESIS

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ABSTRACT

Insect pests form major threat to cowpea cultivation often causing a yield loss of 30 – 60 per cent. Even though insecticides are the most popular tools for pest management in cowpea their application throughout the crop period is not economically, socially and ecologically advisable. Biological control methods could be an option to reduce the insecticide load on the crop that is often constrained by lack of natural enemies that can effectively control several pests at a time. Members of the predatory family Reduviidae are gaining increased attention due to their broad host range as well as high density responsiveness. *Rhynocoris marginatus* belonging to the subfamily Harpactorinae of the family Reduviidae (Order: Hemiptera) has been found promising in managing a wide range of insect pests in various legume crop ecosystems. This predator reportedly has preference to lepidopteran caterpillars followed by nymphs and adults of hemipterans, two major insect groups regularly occurring in cowpea.

In this context, the work on "Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea" was carried out in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara. The project aimed to study the biology and predatory potential of *R. marginatus* on leaf eating caterpillar of cowpea, *Spodoptera litura* (Fab.); to evaluate the predatory potential of *R. marginatus* on *Aphis craccivora* (Koch) and *S. litura* under caged condition and to study the field efficiency of *R. marginatus* against insect pests of cowpea.

The egg stage recorded an average incubation period of 6.80 ± 0.91 days. It took 32.90 ± 1.81 days to complete nymphal development in five instars. Adult female lived longer than male. The preoviposition period was 14 ± 1.30 days and

during the oviposition period of 66.13 ± 6.27 days, it laid 8.60 ± 0.97 batches of egg mass with mean fecundity of 377.20 ± 45.52 eggs.

The predatory potential of second, third, fourth and fifth nymphal instars and adult were studied on third instar larvae of *S. litura* at prey densities, 2, 4, 6, 8 and 10 prey/ predator. Predation had strong correlation with the prey density and stage of the predator. When the number of prey killed by the predator was plotted against the prey density a Holling's type II functional response curve was obtained.

The predatory potential was also assessed against cowpea aphid, *A. craccivora* and leaf eating caterpillar, *S. litura* on caged cowpea plants. The third instar nymph of *R. marginatus* was released on cowpea plants in cages artificially infested with aphid and compared with control. Aphid population in predator released cages were significantly less than that in control. The predator was able to kill all the released third instar larvae of *S. litura* completely within four days.

Field evaluation was carried out by releasing the predator at 30, 50 and 70 days after sowing of the crop. The release of the predator significantly reduced the aphid population on cowpea. The infestation by pod borer *Maruca vitrata* (Fab.) and pod bug, *Riptortus pedestris* (Fab.) were negligible. However, the number of pods damaged by pod bug was comparatively less in predator released field. At the same time, the predator had no impact on the population of coccinellid predators in the field.