BIOECOLOGY AND MANAGEMENT OF POD BUGS INFESTING VEGETABLE COWPEA, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt

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DECLARATION

I hereby declare that this thesis entitled **"Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt"** is a record of research work done independently by Miss. Bharathi Meena, T. (2004-11-02) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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To

Anbu,

Tumbo

and

Sundu

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" The lark's on the wing;
The snail's on the thorn;
God's in His heaven --
All's right with the world ! "
- Robert Browning

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T.Bharathi Meena

T.Bharathi Meena

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1. INTRODUCTION

The role played by insects, the most successful group of all organisms, in crop production is undisputable. Since neolithic times, the battle to combat these tiny creatures was ever changing with newer and newer weapons. The advances made in pesticide research during the last millennium, infact showered the fields with broad spectrum insecticides. The impact was the upsurge of many insects earlier known innocuous as major pests. Flare up of sucking pests in many agro ecosystems has been documented (Patel and Patel, 1998; Mohan and Katiyar, 2000). The status of sucking pests in vegetable cowpea ecosystems of Kerala is also following a similar trend recently.

Vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt also known as yard long bean is a nutritionally rich and highly priced vegetable in the domestic markets of Kerala, besides being a foreign exchange earner. Though the crop invites an array of pests, the pod bugs which appear in the reproductive phase of the crop are often the most troublesome as they inflict severe damage to the economically viable part. These pod bugs suck sap from the developing pods and seeds and cause shrivelling of pods and seeds and affect their germination (Nair, 1978; Singh and Emden, 1979). At present, the practical method of controlling these bugs, inevitably involves a heavy insecticide blanket which often culminates in the presence of toxic residues in the pods harvested periodically for vegetable purpose. So, ways and means to contain these bugs in a safe and sustainable manner is to be thought of.

Pod bugs are oligophagous or polyphagous. Several wild hosts as well as cultivated plants support the survival of pod bugs during off season. Besides this, food switch during the transition from nymph to adult is evident in the nutritional ecology of heteropterans (Panizzi, 1997).

A maze of complex interactions exerted by abiotic factors often govern insect population either positively or negatively. The abundance of a species in time and space is determined in nature by biotic factors also. As pest management deals largely with population, it is imperative that we know the impact of abiotic and biotic factors. Knowledge on the different life stages of the pest concerned is also important in identifying the vulnerable links in the life cycle for successful management.

It is a known fact since ancient times that plant products are capable of suppressing pest population. Now globally there is a revival of interest in plant products, particularly in pest management. Though subtle, the effects of neem such as repellence and feeding and oviposition deterrence are valuable in pest suppression. Among the farmers also there is a growing acceptance of standardised neem products.

The importance of entomopathogens also have greatly enhanced today with the realization that they are successful tools capable of suppressing pest population without any environmental risks. Entomopathogenic fungi exhibit contact action and are effective against both chewing and sucking insects. The effect of the fungus, *Beauveria bassiana* (Bals.) was proved against sucking pests *viz., Aphis craccivora*, Koch (Zaki, 1998), *Nilaparvata lugens* (Stal.) and *Pentalonia nigronervosa* (Coq.) (Singh, 2001).

Quite often, one of the constraints faced by farmers in the adoption of biopesticides is their non availability. In such situations, insecticides have to be depended upon. Then the right selection of the chemical and its application at the correct dose are absolutely essential.

Considering the above facts, a project entitled "Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt" was chalked out with the following objectives to :

1. Document the pod bugs and their natural enemies associated with vegetable cowpea

2. Identify the host plants of pod bugs

3. Assess the seasonal occurrence of pod bugs and their natural enemies

4. Derive information on the biology of pod bugs

5. Select botanical insecticides / entomopathogens / chemical insecticides effective against pod bugs and to evaluate their efficacy in the field.

Review Of Literature

2. REVIEW OF LITERATURE

Many species of pod bugs have emerged as important sucking pests in the post flowering phase of vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt and related leguminous crops. The literature pertaining to the different aspects of pod bugs, their host plants, natural enemies, seasonal abundance and management methods are presented.

2.1 POD BUGS - OCCURRENCE AND DAMAGE

2.1.1 Pod bugs infesting leguminous crops

2.1.1.1 *Acrosternum* spp.

***Acrosternum acutum* (Dallas)**

Adamu *et al.* (2000) identified *A. acutum* as an important pest of green gram, *Vigna radiata* L. (Wilczek) causing necrosis, pod malformation, premature pod drying and formation of empty pods.

***Acrosternum hilare* (Say)**

McPherson *et al.* (1979) observed *A. hilare* causing significant damage and yield reduction in soybean with the adults and fifth instar nymphs causing more damage than the other stages. In Georgia, USA, McPherson (1996) reported *A. hilare* as a commonly occurring stink bug pest of soybean but at low population levels. Bundy and McPherson (2000) opined that *A. hilare* was one among the most abundant pentatomid species occurring in soybean ecosystem.

2.1.1.2 *Clavigralla* spp.

Species of *Clavigralla* was reported to cause wrinkling of seed coat due to the toxic effect of saliva injected while feeding in the cotyledons of *Phaseolus vulgaris* (L.). Further, the bugs reduced seed viability by 65-80 per cent (Materu, 1970). In India, *Clavigralla* spp. were reported as notable pests of pigeonpea (Kashyap and Mehta, 1992; Arora and Monga, 1993; Veda, 1993).

Amatobi (1995) stated that *Clavigralla* sp. was a major pod sucking bug of cowpea. Abate and Ampofo (1996) observed that feeding by adults and nymphs of *Clavigralla* spp. produced symptoms like dimpling and wrinkling of seed coat followed by browning and shrivelling of seeds in the common bean, *P. vulgaris*.

***Clavigralla gibbosa* Spinola**

Lefroy (1909) observed *C. gibbosa* as a pest in the post flowering phase of cowpea. Nair (1978) opined that *C. gibbosa* damaged green pods of pulses by desapping unripe seeds. Pigeonpea was the most preferred host of the bug followed by lablab, cowpea and cluster bean (Singh *et al.*, 1988). Thakur *et al.* (1990) reported significantly lesser grain damage in shrivelled pods of red gram than in smooth pods. Chand (1995) stated that infested pods developed yellowish patches followed by withering and drying.

In India, *C. gibbosa* has been recorded from Delhi, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamilnadu and Uttar Pradesh. Affected pods presented shrivelled appearance with smaller grains inside (Srivastava, 1996).

Thippeswamy and Rajagopal (1998) reported *C. gibbosa* infestation in field bean, *Lablab purpureas* var. *lignosus* Medikus in Karnataka.

Clavigralla horrens **Dohrn**

C. horrens was known to frequent cowpea crop (Lefroy, 1909). Nair (1978) stated that those pods damaged by the bug developed light yellow patches on their surface followed by shrinking and shrivelling.

Clavigralla scutellaris **Westwood**

The percentage of flowers damaged by *C. scutellaris* in winter crop of pigeonpea in Rajasthan varied from 5.2 per cent to 35 per cent (Verma and Henry, 2003).

Clavigralla tomentosicollis **Stal.**

Jackai (1984) reported that puncturing of pod wall by *C. tomentosicollis* caused seed damage in cowpea. Further, he observed female bugs doing more damage than the males with respect to daily average seed damage and number of punctures. *C. tomentosicollis* was recorded as one of the most widespread and damaging species of coreids infesting cowpea pods (Chiang and Jackai, 1988; Alghali, 1992; Jackai *et al.*, 1992; Decri *et al.*, 2000; Pitan *et al.*, 2001). Dreyer and Baumgartner (1995) observed that heavy seed attack by *C. tomentosicollis* in cowpea fields reduced the available food for other species and masked their real damage potential. In Nigeria, Ameh *et al.* (2000) found that pod sucking hemipteran complex of cowpea was dominated by *C. tomentosicollis* with infestation levels ranging from 90.5 per cent to 93 per cent.

Minja *et al.* (2000) observed pigeonpea fields heavily infested by *C. tomentosicollis*.

2.1.1.3 *Cletus* sp.

In India, Faleiro *et al.* (1986) observed the coreid bug *Cletus* sp. as a regular insect pest of cowpea during the active vegetative, flowering and pod formation stages.

2.1.1.4 *Coptosoma cribraria* Fab.

Nair (1978) reported the infestation of *C. cribraria* in pulse crops. Thippeswamy and Rajagopal (1998) recorded *C. cribraria* as a pest of field bean.

2.1.1.5 *Homoeocerus* sp.

Homoeocerus dilatatus Horvath was reported as one among the dominant insect pests of soybean in Korea (KeonSoo *et al.*, 1998).

2.1.1.6 *Nezara* spp.

***Nezara antennata* Scott**

N. antennata did considerable damage to seeds of soybean in the warmer areas of Japan (Kobayashi, 1972) and Korea (KeonSoo *et al.*, 1998; ChangKi *et al.*, 2000).

***Nezara viridula* (L.)**

Wallace (1939) observed that the stink bug, *N. viridula* injected a fungus *Nematospora coryli* Peglion into developing seeds of french bean while feeding. It occurred as a major pest of soybean in the tropics and subtropics of Africa, Asia, Australia, South America and the United States. The bug also attacked common beans, pigeonpeas and other grain legumes (Corpuz, 1969; Swaine, 1969). Turnipseed and Kogan (1976) reported detoriation of seed quality in soybean by feeding of *N. viridula*. Nair (1978) reported *N. viridula* as a minor pest of pulse crops in Kerala.

McPherson *et al.* (1979) stated that the pod filling stage of soybean was highly susceptible to *N. viridula* attack. Further, they concluded that late season population build up was least detrimental to yield. Bhalani and Bharodia (1988) observed *N. viridula* infestation in pigeonpea fields of Gujarat. Brier and Rogers (1991) recorded severe yield reduction in soybean especially during pod fill stage. According to Suzuki *et al.* (1991) the density of adult bugs considerably affected feeding frequency and total feeding time in larger pods of soybean. Chand (1995) reported that feeding by nymphs and adults on pods of pulses resulted in the formation of necrotic spots and seeds failed to develop.

Das *et al.* (1996) recorded *N. viridula* as a pest of green gram in Assam. In Karnataka, Thippeswamy and Rajagopal (1998) observed its incidence in field bean *L. purpureas* var. *lignosus*.

Bundy and McPherson (2000) opined that *N. viridula* was one among the abundant pentatomid species present in soybean ecosystems of Georgia, USA. Abudulai and Shepard (2001) observed that the early pod fill stage of cowpea was the most susceptible stage for *N. viridula* infestation. Artabe and Martinez (2003) reported that Cuban soybean agroecosystems were dominated by this bug.

2.1.1.7 *Piezodorus* spp.

***Piezodorus guildinii* Westwood**

Costa and Link (1977) noted the incidence of *P. guildinii* in soybean crop. Ramiro *et al.* (1989) observed that the bug frequented the fields during pod formation and pod maturation phases. In Brazil, pigeonpea was found hosting *P. guildinii*. However, the bug showed greater preference and feeding activity on soybean rather than pigeonpea. (Panizzi *et al.*, 2000). Artabe and Martinez (2003) opined that the pod and seed development stages of soybean hosted more number of bugs. Aragon (2004) reported severe damage and yield loss due to the bug.

In Japan, Kobayashi (1972) observed *P. guildinii* attacking growing pods of soybean. Kono (1989a) found that severe seed injuries by the bug coincided with the middle pod elongation stage of soybean. ChangKi *et al.* (2000) recorded damage levels ranging up to 50 per cent.

***Piezodorus rubrofasciatus* Fabricius**

In India, Joseph (1953) reported the incidence of *P. rubrofasciatus* in lucerne crop. Singh *et al.* (1989) described *P. rubrofasciatus* as an emerging pest of soybean in Madhya Pradesh.

2.1.1.8 *Riptortus* spp.

Several species in the genus *Riptortus* occur as serious pests of grain legumes in Asia and Africa (Singh and Emden, 1979). About 30 per cent yield reduction in cowpea has been reported by Ofuya (1989). Rajapakse and Jayasena (1989) observed *Riptortus* sp. as a minor pest of green gram in Srilanka.

***Riptortus clavatus* Thnb.**

According to Sawada (1988) *R. clavatus* was the most serious pest of late cultivated soybean in Japan. Kono (1989a) found that the third and fifth instar nymphs of *R. clavatus* caused more damage than the first and second instars. Further, they observed that the female adults attacking the mid pod elongation stage caused the highest number of seed injuries. KeonSoo *et al.* (1998) identified *R. clavatus* as one of the dominating pod sucking bugs of soybean in Korea.

***Riptortus dentipes* (Fab.)**

R. dentipes was a serious pest of cowpea causing injury to mature pods (Nyiira, 1971; Aina, 1975; Halteran, 1971). Khaemba (1985) found that more than 99 per cent of the 4022 cultivars tested were susceptible to the damage caused by the bug. Alghali (1992) reported an yield loss of 75 per cent when the bug infested during flowering phase and 23 per cent during pod development stage. Ewete and Joda (1996) confirmed soybean as a suitable host for *R. clavatus*. In Northern Ghana, Tanzubil (2000) observed its incidence and damage in pulse crops.

Koona *et al.* (2001) found that *R. dentipes* caused significant damage to young pods of cowpea with distinct preference for eight day old pods located within crop canopy.

***Riptortus fuscus* (Fab.)**

In India, Davies and Lateef (1975) recorded *R. fuscus* as one of the major pod sucking bugs of pigeonpea.

***Riptortus linearis* (Fab.)**

Sarma and Dutta (1999) observed *R. linearis* causing damage to green gram seeds.

***Riptortus pedestris* (Fab.)**

According to Davies and Lateef (1975), *R. pedestris* was a commonly occurring pod bug of pigeonpea in India. Nair (1978) reported shrivelling and discolouration of pulse seeds in response to feeding by *R. pedestris*. Visalakshi *et al.* (1976) observed severe incidence of the bug in cowpea fields of Kerala.

Further, they found that the skin surface of infested pods became rough and uneven with feeding punctures localized in the seed regions. Tender pods failed to develop fully and older pods were rendered unfit for culinary or seed purposes. Garg (1992) recorded damaging levels of *R. pedestris* population in black gram fields at Uttar Pradesh. Chand (1995) stated that adults and nymphs of the bug desapped tender shoots and pods of red gram, green gram, black gram, cowpea and beans causing premature withering.

***Riptortus serripes* (Fab.)**

R. serripes, a pest of soybean desapped from the pods and thereby reduced seed yield and oil content considerably. The pod fill stage suffered more such losses than pod elongation or pod ripening stages (Brier and Rogers, 1991).

2.1.2 Other host plants of pod bugs

***Cletus bipunctatus* Westwood**

Jena *et al.* (2002) observed infestation of *C. bipunctatus* in amaranthus. Adults and nymphs desapped from developing grains and caused economic losses.

***N. viridula* (L.)**

Lefroy (1906) reported that *N. viridula* frequented potato crop and sucked the juice of young plants. Song (1987) recorded amaranthus, black night shade, chinese cabbage, chinese milkvetch, cucumber, jimson weed, tomato and wax gourd as food plants of *N. viridula*. In South Africa, Dennill and Erasmus (1992) observed feeding injury caused by the bug in 1.8 per cent of avacado fruits. The milky and dough stages of rice plants were prone to *N. viridula* attack in Orissa (Gupta *et al.*, 1993).

In South Africa, Dupont (1993) found that feeding by *N. viridula* in the early fruit development stage of avacado, induced formation of protrusions on fruit surface. In Germany and South Africa, *N. viridula* was recorded as a pest of sugarbeet and pecan kernels respectively (Hesse, 1994; Joubert and Neethling, 1994).

Yadav and Rizvi (1995) observed lime trees, *Citrus aurantifolia* Swinh. hosting *N. viridula* in eastern Uttar Pradesh. In Australia, Coombs and Khan (1998a) reported raspberry, *Rubus idaeus* L. as a suitable host for *N. viridula*. Shaw *et al.* (1998) observed spine gourd crop infested with *N. viridula* in Madhya Pradesh.

According to Sileshi *et al.* (2000) the bug has the potential to become pest of agroforestry systems as they damaged trees like sesbania.

Odermatt *et al.* (2000) denoted *N. viridula* as a secondary pest of egg plant. Biswas *et al.* (2001) reported *N. viridula* infestation in sesame. Panizzi and Grazia (2001) identified privet trees as a host of *N. viridula*.

In a study conducted in West Bengal, *N. viridula* was observed as a pest on aswagandha (Mitra and Biswas, 2002). Bhagat (2003) reported *N. viridula* infestation in the medicinal plant *Abelmoschus moschatus* Medik in Jammu.

Kumar and Ahmad (2003) found that feeding injury caused by *N. viridula* in *Paulownia fortunei* (Seem.) Hemsl. resulted in drying of young growing tips. Singh and Joshi (2004) identified *N. viridula* as a minor pest of okra, *Abelmoschus esculentus* Moench in Himachal Pradesh. Willrich *et al.* (2004) found that cotton seedlings and reproductive structures including flower buds and bolls were infested by adults and nymphs of *N. viridula*.

R. serripes

Ingram (1998) reported that the main possible alternate hosts of *R. serripes* in Australia were senna trees and sesbania.

2.2 NATURAL ENEMIES OF POD BUGS

2.2.1 Parasitoids of pod bugs

2.2.1.1 *Clavigralla* spp.

In India, Shanower *et al.* (1996) identified *Gryon clavigrallae* Mineo as an effective egg parasitoid of *Clavigralla* spp., parasitizing 69 per cent of the eggs. Srivastava (1996) reported parasitization of *C. gibbosa* eggs by *Gryon antestiae* Dodd.

Kalariya *et al.* (1999) observed that *Gryon fulviventris* (Crawford) could effectively suppress populations of *C. gibbosa* in red gram fields of Gujarat.

In Northern Nigeria, two species of parasitoids *viz., Anastatus* sp, and *G. fulviventris* were collected from parasitized egg masses of *C. tomentosicollis* (Asante *et al.,* 2000). Further, they observed that *G. fulviventris* was the most abundant species and the proportion of egg mass parasitized was inversely related to the size of the egg mass.

2.2.1.2 *Cletus* spp.

Noda (1993) confirmed the parasitization of eggs of *Cletus punctiger* (Dallas) and *Cletus rusticus* (Stal.) by the solitary egg parasitoid, *Gryon japonicum* (Ashmead) under laboratory conditions.

2.2.1.3 *Nezara* spp.

Mizutani (2001) opined that, the parasitoid, *Ooencyrtus nezarae* Ishii could develop in the eggs of the stink bug, *N. antennata*.

In the tropics, several egg parasitoids kept the population of *N. viridula* in check (Singh and Emden, 1979). Menezes *et al.* (1985) observed that percentage parasitism and mean number of eggs laid by the tachinid, *Trichopoda pennipes* (F.) on the body surface of males of *N. viridula* was higher than that of females. Orr *et al.* (1985) reported successful emergence of the parasitoid, *Telenomus chloropus* (Thompson) from eggs of *N. viridula*. Ferreira *et al.* (1991) reported that parasitism by *Eutrichopodopsis nitens* Blanchard reduced adult longevity and reproduction of *N. viridula*. Coombs and Khan (1998b) found that parasitism of immature, newly moulted females of *N. viridula* by *Trichopoda giacomellii* (Blanchard) resulted in 84 per cent of them failing to reproduce.

Trissolcus basalis (Wollaston) exhibited parasitism rates ranging from 50 per cent to 70 per cent in egg masses of *N. viridula* (Loch and Walter, 1999). Pachecho *et al.* (1999) recorded 7.7 per cent parasitization of *N. viridula* egg masses by *Telenomus podisi* Ashmead. Venzon *et al.* (1999) observed that *T. basalis* parasitized egg masses of *N. viridula* when released in soybean fields, kept the population of stink bugs below economic injury level until harvest, yielding comparable to insecticide treatments. Loch (2000) stated that *N. viridula* was the major host of *T. basalis*. Mizutani (2001) recorded parasitization of *N. viridula* egg masses by *O. nezarae.*

In Italy, Shaw *et al.* (2001) collected a braconid, nymphal parasitoid *Aridelus rufotestaceous* Tobias from nymphs of *N. viridula.*

Ehler (2002) observed egg masses of *N. viridula* hosting the scelionids, *T. basalis, T. podisi* and the encyrtids *Ooencystus californicus* Girault and

Ooencyrtus johnsonii (Howard). Further, he found that *T. basalis* could parasitize cent per cent of the eggs in an unexploited egg mass.

2.2.1.4 *Piezodorus* spp.

Pachecho *et al.* (1999) reported 27.9 per cent parasitization of eggs of *P. guildinii* by *T. podisi* in soybeans. Further, they observed that the parasitoid could make use of 97.4 per cent of stink bug egg masses in soybean. The egg parasitoid *Trissolcus brochymenae* (Ashmead) could also suppress the population of *P. guildinii* (Maruyama *et al.,* 2002). In Japan, Higuchi (1993) identified *Telenomus triptus* Nixon and *O. nezarae* as successful egg parasitoids of *Piezodorus hybneri* (Gmelin). According to Hirose *et al.* (1996) the latter was a good colonizer in soybean fields.

2.2.1.5 *Riptortus* spp.

Noda (1993) observed eggs of *R. clavatus* as a suitable host for the parasitoids *Anastatus japonicus* Ashmead, *Gryon* spp., *G. japonicum, Ooencyrtus* spp. and *O. nezarae.* Hirose *et al.* (1996) recorded successful emergence of *O. nezarae* from eggs of *R. clavatus* in soybean fields of Japan. Higuchi *et al.* (1999) reported that wasps of *Gryon nigricorne* (Dodd) emerged from parasitized eggs of *R. linearis* artificially placed in soybean fields. Mizutani (2001) found that *R. clavatus* was one among the hosts of *O. nezarae.*

2.2.2 Predators of pod bugs

2.2.2.1 *Clavigralla* spp.

Arora and Monga (1993) observed that in pigeonpea fields of Haryana, the most abundantly occurring spiders, *viz., Hippasa haryanensis* Arora and Monga, *Pardosa tikader* Buchar, *Lycosa bistriata* Gravely, *Cheiracanthion punjabensis* Sadana and Bajaj showed moderate preference to *Clavigralla* spp. Ambrose *et al.*

(2003) opined that *C. gibbosa* was a preferred prey of the assasin bug *Rhynocoris longifrons* (Stal.). Further, they observed that the predator exhibited greater preoviposition and developmental periods on this host. Okoronkwo and Abba (2000) reported a reduviid predator, *Rhynocoris segmentarius* Germar feeding upon *C. tomentosicollis*.

2.2.2.2 *N. viridula*

Eisner *et al.* (1991) observed the orb weaving spider *Nephila clavipes* (Linn.) preying upon *N. viridula*. James (1994) found that the generalist reduviid predator, *Pristhesancus plagipennis* Walker could feed on nymphs of *N. viridula*. Sarma and Dutta (1996b) recorded *N. viridula* as one of the preferred prey of the araneae, *Thomisus* sp. Clercq *et al.* (2002) described *N. viridula* as a suboptimal prey for the spined soldier bug *Podisus maculiventris* (Say). Further, they observed that adults of *N. viridula* often escaped due to their greater agility whereas eggs and nymphs formed an easy prey.

2.2.2.3 *P. guildinii*

The orb weaving spider *N. clavipes* preyed upon *P. guildinii* (Eisner *et al.*, 1991).

2.2.2.4 *Riptortus* spp.

Ambrose and Claver (2001) recorded 17.86 per cent control of *R. clavatus* by predation of the reduviid bug *Rhynocoris kumari* Ambrose and Livingstone in cotton fields. Claver and Ambrose (2003) observed that *Rhynocoris fuscipes* Fabricus effectively suppressed *R. clavatus* populations in pigeonpea thereby reducing flower and pod damage. Sarma and Dutta (1996b) opined that the feeding rate of the spiders *Thomisus* sp. increased with increase in the availability of its prey *viz., R. linearis*. Manu (2005) reported 17 species of spiders from vegetable cowpea fields. The araneae showed lesser preference for adults and nymphs of *R. pedestris* compared to nymphs of cowbugs.

2.3 SEASONAL OCCURRENCE OF POD BUGS AND THEIR NATURAL ENEMIES

2.3.1 Pod bugs

Kobayashi (1976) observed that in Japan, the percentage of pod bug damaged soybean seeds was highly correlated with mean temperatures during January, July and August. Further reports from Japan, showed that the population of hemipterans in late cultivated soybean increased one month after flowering and peaked in September (Sawada, 1988).

Dreyer and Baumgartner (1995) reported heavy seed attack by coreid pod sucking bugs during the early pod formation stage of cowpea in southern Benin.

2.3.1.1 *Clavigralla* spp.

Veda (1993) reported that the activity of *C. gibbosa* in pigeonpea started in the first fortnight of September and continued until the harvest of the crop. Further, he opined that temperature and rainfall played a key role in the multiplication of the pest. Maximum mean fortnightly temperature of 32.33°C and minimum of 27.26°C coupled with 98.5 mm rainfall during October proved congenial for the pest.

Singh *et al.* (2002) observed that population build up of *C. gibbosa* in cowpea was positively correlated with maximum and minimum temperature whereas relative humidity was inversely correlated.

Kumar and Nath (2004) found that rainfall, relative humidity and shorter duration of sunshine favoured the development of *C. gibbosa* in pigeonpea. Also they observed that though most of the weather parameters had only a weak influence on pod bug populations, maximum and minimum relative humidity exhibited significant positive correlation.

In black gram fields of Uttar Pradesh, population of *Clavigralla* spp. was negatively correlated with minimum temperature and relative humidity (Nayak *et al.*, 2004).

2.3.1.2 *Cletus* spp.

Faleiro *et al.* (1986) observed regular incidence of the coreid bug *Cletus* sp. in cowpea during the kharif season of 1983 and 1984 and summer season of 1984.

Singh *et al.* (1990) found that increase in population of *Cletus signatus* Walker in groundnut was favoured by high relative humidity whereas heavy rainfall decreased its abundance.

2.3.1.3 *N. viridula*

Nath and Dutta (1995) recorded the occurrence of *N. viridula* in summer green gram crop during the first week of April, coinciding with the blooming stage of the crop. Further, they observed adult and nymphal population peaking by the middle of May and declining towards crop maturity. Again the population peaked by October end showing significant positive correlation with morning relative humidity of summer season. Similarly Sarma and Dutta (1996a) observed peak population of the bug in summer green gram crop coinciding with pod maturity and declining towards full maturity. They deduced a positive correlation between minimum temperature and population build up of *N. viridula.*

Singh *et al.* (2002) reported that in cowpea fields of Uttar Pradesh, the population build up of *N. viridula* showed positive correlation with maximum, minimum temperatures and relative humidity. Contrastingly, in black gram crop, Nayak *et al.* (2004) observed a negative correlation between peak numbers of *N. viridula* with minimum temperature and relative humidity.

2.3.1.4 *P. rubrofasciatus*

Singh *et al.* (1989) observed a scarce population of *P. rubrofasciatus* during rainy season of 1985 in Madhya Pradesh. However, in 1986 as many as 16.4 nymphs and 11.3 adults per plant were observed in soybean pods.

2.3.1.5 *Riptortus* spp.

Nayak *et al.* (2004) found that minimum temperature and relative humidity had a negative influence on activity of *Riptortus* spp. in black gram crop.

2.3.2 Natural Enemies

2.3.2.1 Parasitoids

In Japan, Higuchi (1993) observed higher parasitism rates of *T. triptus* on eggs of *P. hybneri* from early July to early August in 1989-1990 coinciding with the ovipositional period of the host.

2.3.2.2 Predators

Bechinsk and Pedigo (1981) stated that predators were more abundant during the pod fill stages in soybean cropping systems of United States of America.

Buschmann *et al.* (1984) observed that the population of predatory spiders in soybean in Mississippi gradually increased during summer and was high in late than early planted crops.

In Egypt, Hussein (1999) recorded peak activity and higher density of spiders in summer. They opined that the abundance of spiders in summer was a result of three factors *viz.*, dense vegetation cover, high temperature and significant high relative humidity.

In India, appreciable populations of spiders, *Oxyopes shweta* Tikader *Neoscona* sp. and *Plexippus paykulli* Audauin were observed from flowering phase of pigeonpea until crop maturity (Borah and Dutta, 2003). Manu (2005) opined that in vegetable ecosystems the growth stage of the plant influenced the abundance of spiders rather than seasonal variations.

2.4 BIOLOGY OF POD BUGS

2.4.1 *N. viridula*

Kariya (1961) reported that the development of *N. viridula* from egg to adult took 23.2 days at 30°C which was the optimal temperature for its development. Kiritani (1964) observed that *N. viridula* developed through five nymphal instars. Kiritani and Sasaba (1969) found that females of *N. viridula* dispersed up to 1000 m per day flying in search of feeding or oviposition sites.

Nair (1978) described the adult of *N. viridula* as a uniformly green flat shield bug measuring 1.3 cm long and 0.7 cm wide. Panizzi and Rossini (1987) observed that the survivorship and developmental time of nymphs differed on pods, seeds or pod walls of legumes. Further, they recorded lower mortality, around 30 per cent for nymphs feeding on green pods or mature seeds of soybean. Mukhopadhyay and Roychoudhury (1987) reported that *N. viridula* took an average of 44.4 days to complete its life cycle on *Vigna umbellata* (Thunb.) with a mean duration ranging from 37 to 52 days.

Bhalani and Bharodia (1988) observed a mean fecundity of 260 eggs for *N. viridula* reared on pigeonpea. The total nymphal period and total life cycle averaged 45.1 and 53 days respectively. Mean adult life span of 8.5 days for males and 25.1 days for females were reported. Calhoun *et al.* (1988) opined that males and females had similar developmental periods on soybean.

The eggs of *N. viridula* were pale yellow or cream coloured deposited in polygonal clusters with individual eggs firmly glued to each other and the substrate (Todd, 1989).

McLain and Marsh (1990) found that females of *N. viridula* which copulated with successful males were more fecund than those which copulated with less successful males. Further, they deduced a positive relationship between offspring quality and mate effects on fecundity.

Panizzi and Slansky (1991) stated that green pods of *P. vulgaris*, *Desmodium tortuosum* (Sw.) DC. and soybean resulted in intermediate nymphal performance.

McLain (1991) observed that the size of *N. viridula* bug measured as the width across the pronotum was positively correlated with longevity, fecundity, rate of development and mating success. Chand (1995) stated that the first instars of *N. viridula* remained gregarious without feeding and only after the first moult they dispersed to feed. A single female could lay 300 eggs and the development period extended for about two months.

DerChien *et al.* (1997) reported that *N. viridula* reared on young asparagus beans, *V. unguiculata* ssp. *sesquipedalis* had an egg, nymphal and adult period of 5.4, 34.9 and 22.6 days respectively. Four moults were observed and each female on an average of 3.4 occassions laid 215 eggs. Kumar and Ahmad (2003) observed that nymphs hatched almost simultaneously from an egg mass.

2.4.2 *P. guildinii*

Panizzi (1987) observed that nymphs of *P. guildinii* recorded lowest mortality levels of 25 per cent on immature pods of sesbania whereas the mature pods of the same caused 97.5 per cent mortality. Further, they found that development time from second to fifth instar was longer for nymphs reared on mature pods of *Sesbania aculeata* (Willd.) Poir. and soybean pods. Serra *et al.* (2001) reported highest mortality levels during the second instar, when reared on *P. vulgaris*. The mean fecundity was 86.33. Adult males and females lived for 60 and 78.5 days respectively.

Panizzi *et al.* (2000) studied the biology of *P. guildinii* on pigeonpea. The duration of second, third, fourth and fifth instars were 6.0 ± 0.26, 5.8 ± 0.96, 5.4 ± 0.68 and 7.8 ± 0.49 days respectively. The male and female longevity was 25.3 ± 1.85 and 22.5 ± 0.5 days respectively.

The total developmental time in lance leaf crotolaria was 18.2 ± 0.49 days for females and 18.7 ± 1.44 days for males. In soybean, female bugs and male bugs took 20 days and 23 days for development. The mean fecundity was 29.7 ± 3.49 and 27.7 ± 3.8 in crotolaria and soybean respectively (Panizzi *et al.* 2002).

2.4.3 *P. rubrofasciatus*

In India, Joseph (1953) observed that *P. rubrofasciatus* preferred to oviposit on upper surfaces of lucerne leaves. During the winter season the incubation period extended for six days.

Singh *et al.* (1989) observed the biology of *P. rubrofasciatus* in soybean. They found that an adult pair in confinement mated two to three times and females laid eggs 24 hours after mating. 48-80 eggs were laid in two elongated rows with 14-40 eggs per row. Eggs were cylindrical, 0.96 mm long and 0.62 mm wide, with the periphery at the top bearing fine whitish structures. Eggs hatched in two days in summer and the nymphs passed through five instars in 15.7 days.

2.4.4 *R. clavatus*

Riptortus adults were cylindrical, generally light brown with characteristic whitish or yellowish lines on the ventral surface and were strong fliers (Singh and Emden, 1979).

Kono (1989b) found that *R. clavatus* completed three generations per year on dried soyabeans. Sakurai (1996) observed that during the first 21 days after emergence, females of *R. clavatus* in single mated group laid more eggs than those in life time mated group. However, life time fecundity and hatchability were higher for the latter than the former. Sakurai (1998) artificially manipulated copulation periods of *R. clavatus* and deduced that shorter copulation periods resulted in higher remating rates.

2.4.5 *R. dentipes*

Singh and Emden (1979) stated that *R. dentipes* had five nymphal instars and the eggs were usually laid in leguminous trees.

Ewete and Joda (1996) observed the post embryonic development of *R. dentipes* on different soybean varieties. The average incubation period and developmental period ranged between 6.4 – 7.0 and 22.19 – 25.21 days respectively in different soybean varieties. Further they recorded an ovipositional period of 28.4 – 43 days and fecundity of 142.1 – 381.9 eggs. Abate and Ampofo (1996) reported that adults of *R. dentipes* were slender, 17 mm long, light brown with white or yellow lateral lines.

2.4.6 *R. linearis*

Baruah and Dutta (1994) reported that *R. linearis* took a total nymphal period of 14.86 – 17.57 days and 15.14 – 17.14 days in the first and second generations respectively when reared on green gram. Females laid an average of 1.77 – 4.37 eggs per day during an ovipositional period of 8.67-40 days.

2.4.7 *R. pedestris*

Visalakshi *et al.* (1976) studied the biology of *R. pedestris* in cowpea. They observed that mating commenced 14-16 days after adult emergence and was repeated throughout the adult period. A mean fecundity of 115 eggs during an ovipositional period of 30 days was recorded. Nair (1978) described the adult as a dark brown, elongated bug with two black bands ventrally on the abdomen.

2.5 EFFECT OF BOTANICALS, CHEMICAL INSECTICIDES AND ENTOMOPATHOGENS ON POD BUGS AND THEIR NATURAL ENEMIES

2.5.1 Effect on pod bugs

2.5.1.1 Botanical insecticide (Neem)

Neem products have shown antifeedant, anti ovipositional, growth disrupter and fecundity reducing properties on insect pests. (Schumutterer, 1990). Ivibijaro and Bolaji (1990) found that pest population densities on cowpea were reduced by sprays with aqueous extracts of unripe seeds of neem. Further they recorded a marginal increase in seed yield compared to untreated plots.

Jackai *et al.* (1992) opined that neem at a concentration as low as about nine per cent solution affected the rate of development of *C. tomentosicollis*. Imaginal survival was found to decrease with increasing neem concentrations but at a certain point, further increase in concentration produced no significant changes in survival rate. It was observed that most nymphs died nine days after treatment with five per cent solution. Ameh *et al.* (2000) reported that aqueous extracts of *Azhadirachta indica*. A. Juss. seeds applied thrice at ten day intervals significantly reduced the population densities of pod sucking hemipteran complex dominated by *C. tomentosicollis*. About 77.2 – 86.1 per cent and 90.5 – 93 per cent reduction of pod sucking hemiptera was observed in 1997 and 1998 respectively. Ekesi (2000) observed that aqueous extracts of neem, *A. indica* at five per cent, ten per cent and 15 per cent concentrations caused a severe reduction in egg hatch of *C. tomentosicollis.*

Tanzubil (2000) found that five per cent and ten per cent aqueous neem seed extracts were effective against the cowpea pod bugs, *C. gibbosa* and *R. dentipes.* Early planting coupled with two applications of ten per cent aqueous neem seed extracts were as effective as 0.002 per cent lambda cyhalothrin. Jayappa *et al.* (2002) reported minimum pod damage of 8.27 per cent on soybean plots treated with five per cent neem seed extract compared to untreated control with 26.22 per cent damage. 1.25, 2.5 and 5 per cent extracts of neem seed kernel significantly reduced the feeding activity of *C. scutellaris* and not interfered with predators.

Abudulai *et al.* (2003) showed that Neemix 4.5EC at five per cent concentration had antifeedant effects on nymphs of *N. viridula.* They also observed that though neem was slow acting, sublethal treatment of nymphs caused disrupted moulting, induced adulthood morphological defects, prolonged developmental period and reduced female longevity. Durmusoglu *et al.* (2003) opined that neem oil was more effective than Neem Azal T/s on nymphs and four day old eggs of *N. viridula* at seven and 14 days after treatment. However both treatments showed an insecticidal efficacy of approximately 60 per cent against nymphs at recommended concentrations.

2.5.1.2 Chemical insecticides

2.5.1.2.1 *Chlorpyrifos*

Kobayashi (1976) reported that two to three applications of chlorpyrifos 0.05 per cent at one to two week intervals from early pod setting to seed filling stages of soybean considerably reduced the population of pod bugs. According to

Varghese (2003) chlorpyrifos 0.05 per cent gave more than 75 per cent mortality of *R. pedestris* after 24 hours of treatment. Further lowest pod bug damage in treated plots and good persistent toxicity upto 12 days was noticed.

2.5.1.2.2 ***Dimethoate***

Ivibijaro and Bolaji (1990) showed that dimethoate 0.05 per cent was consistently superior in substantially reducing the population densities of *R. dentipes* and *N. viridula* in cowpea.

In Nigeria, Amatobi (1995) found that two sprays of dimethoate 0.05 per cent applied at 10 days interval beginning from flower bud stage gave protection against pod bugs and resulted in high economic grain yield from cowpea.

Decri *et al.* (2000) observed that grain yields of cowpea plots treated with dimethoate 0.05 per cent was significantly higher when compared to plots treated with malathion 0.05 per cent.

Minja *et al.* (2000) reported that dimethoate 0.05 per cent effectively checked the population of *C. tomentosicollis* in pigeon pea and improved seed yields of about 57-152 per cent could be obtained.

2.5.1.2.3 ***Fenvalerate***

According to Sawada (1988), in late cultivated soybean, three sprays of fenvalerate 0.03 per cent applied at 15 days interval starting 10 days after beginning of flowering reduced pest damage to below 8-15 per cent level. Kumar and Nath (2002) showed that fenvalerate 0.03 per cent applied two times, first at flowering and podding stage and second at 25 days after first spray, effectively checked populations of *C. gibbosa* in red gram and was consistently superior to single application.

2.5.1.2.4 *Imidacloprid*

Varghese (2003) observed that imidacloprid 0.025 per cent was effective against *R. pedestris* and was on par with profenfos 0.05 per cent. Further, it was observed that imidacloprid treated cowpea plots recorded only 9.33 per cent pod damage with appreciable persistent toxicity.

2.5.1.2.5 *Lambda cyhalothrin*

Baptista *et al.* (1995) confirmed that lambda cyhalothrin 0.002 per cent was 20-40 times more active against nymphs of *N. viridula* than monocrotophos 0.05 per cent. McPherson *et al.* (1995) observed that lambda cyhalothrin 0.002 per cent gave protection against *N. viridula* attack on soybean. Ballanger and Jouffret (1997) opined that lambda cyhalothrin 0.002 per cent should be sprayed before the immatures of *N. viridula* had reached the ripening pods in soybean.

Ameh *et al.* (2000) reported that in cowpea, lambda cyhalothrin 0.002 per cent spray could reduce damage by pod sucking bugs upto 87.5 per cent. According to Vandekerkhove and Clercq (2004) an encapsulated formulation of lambda cyhalothrin 0.002 per cent was effective against nymphs and adults of *N. viridula*. Further, they observed that the insecticidal activity was six to ten times greater against nymphs than adults with little adverse effects on the predator *P. maculiventris*.

2.5.1.2.6 *Malathion*

Saxena *et al.* (1984) observed that cowpea plots treated with malathion 0.05 per cent yielded 30-50 per cent higher than untreated plots. Jackai and Singh (1986) found that pest populations in cowpea could be effectively suppressed by spraying malathion 0.05 per cent. Stofella *et al.* (1990) found that cowpea plants receiving a preventive spray schedule of malathion 0.05 per cent had higher seed yields than plants receiving sprays on demand or control plants receiving no spray. Further they observed that weekly sprays improved seed and biological yields. Varghese (2003) observed that malathion 0.10 per cent showed moderate toxicity towards pod bugs of cowpea and its persistence was low.

2.5.1.3 Entomopathogens

2.5.1.3.1 *Beauveria bassiana* (Balsamo) Vuillemin

B. bassiana has been recorded from approximately 750 host insects (Dhaliwal and Arora, 1998).

Leite *et al.* (1988) recorded 66.7 per cent mortality of fifth instar nymph of *N. viridula* on spraying *B. bassiana* spore suspension @ 10^7 conidia ml^{-1}, 14 days after treatment.

According to WenJin *et al.* (1996), *B. bassiana* was pathogenic to nymphs and adults of *R. linearis* @ 4.5 x 10^3 – 4.5 x 10^5 conidia ml^{-1}.

B. bassiana @ 10^8 conidia ml^{-1} was highly pathogenic to eggs and nymphs of *C. tomentosicollis* resulting in 91-94 per cent hatching failure and 91-100 per cent nymphal mortality (Ekesi *et al.*, 2002).

2.5.2 Effect on natural enemies

Mitchell *et al.* (2004) observed that eggs of *C. scutellaris* dipped in neem extracts were accepted for oviposition by the egg parasitoid *Gryon fulviventre* (Crawford) and the progeny emerged successfully from the treated eggs.

Manu (2005) reported that dimethoate 0.05 per ecnt, malathion 0.1 per cent and imidacloprid 0.02 per cent were more toxic to spiders of vegetable ecosystems than botanical insecticides. Neem Azal 1 per cent, neem seed kernel extract 5 per cent, neem leaf extract 5 per cent and neem oil 2 per ent registered only 50 per cent mortality.

Materials And Methods

3. MATERIALS AND METHODS

Studies were carried out at College of Agriculture, Vellayani during 2005-06 to identify the different species of pod bugs infesting vegetable cowpea, their natural enemies, to assess their seasonal incidence, host range, biology and to evolve management strategies against the pod bugs.

3.1 IDENTIFICATION OF POD BUGS AND THEIR NATURAL ENEMIES

3.1.1 Pod bugs

Vegetable cowpea, raised both in garden lands and reclaimed wet lands in the Instructional Farm, College of Agriculture, Vellayani were monitored constantly during 2005-2006 and the pod bugs present were collected using sweep nets. Critical observations were made regarding their preference for specific ecosystems, preferred feeding and resting positions on pods, time of adult activity and crop stage. The adult bugs were preserved either in 70 per cent ethyl alcohol or as dry specimens for identification. The alydids and coreids were identified by Dr. K.D. Prathapan, Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani. The pentatomids were identified by Dr. C.A. Viraktamath, Professor, Department of Entomology, University of Agricultural Sciences, Bangalore.

3.1.2 Natural enemies of pod bugs

Predators present in vegetable cowpea were collected using sweep nets or hand picked. Pod bugs as their prey was confirmed by confinement of the predators along with the pod bugs in glass jars in the laboratory. The predators were preserved in 70 per cent ethyl alcohol for identification. The preying mantids were identified by Dr. H.V. Ghate, Head of the Department, Department of Zoology, Modern College, Pune. The spiders were identified by Dr. P.A. Sebastian, Reader, Division of Arachnology, Department of Zoology, Sacred Heart College, Kochi. Predatory ant was identified by Dr. Priyadarsanan Dharma Rajan, Ashoka Trust for Research in Ecology and Environment, Bangalore.

The pod bugs *N. viridula* and *R? linearis,* observed to harbour ectoparasitic mites in the field were collected and confined in the laboratory. Constant supply of nymphs and adult pod bugs were ensured for multiplication of the mites. Confirmation on the parasitization was done by releasing nymphs of the pod bugs along with parasitized individuals and observing the time taken for death.

3.2 NATURE OF DAMAGE AND SYMPTOMS

The nature of damage and symptoms produced by the different species of pod bugs were closely observed in vegetable cowpea pods at all stages of its development in the field. In addition, mature pods of vegetable cowpea were collected from the field along with stalk and the adult bugs of *N. viridula*, *R? linearis* and *R. pedestris* were released separately @ 3 nos. per pod and kept in confinement for observing the symptom development. Five such replications were maintained. The weight reduction of seeds due to feeding was worked out for each of the bug species, after seven days of feeding in comparison with the weight of seeds from uninfested pods.

3.3 HOST RANGE

The host range of the dominant species of the pod bug, *viz*., *R. pedestris* was studied by closely monitoring crops plants, ornamentals and weed plants in the Instructional Farm, College of Agriculture, Vellayani during 2005-2006. Fifty plant species present in the vicinity of vegetable cowpea field were selected. Plants observed to host the bugs in the field were recorded. Further, plants capable of supporting the survival of adult bugs were identified by laboratory confinement. The plants were excised in such a way, so as to obtain the stem portion along with leaves, flowers and fruiting structures when present. Turgidity of the plant parts was maintained by dipping the cut end in a glass vial filled with water. This set up was kept inside a glass jar measuring 16 x 7 cm. Three freshly moulted adults were released into each jar and the mouth of the jar was secured with muslin cloth. Three such replications were maintained for each plant species.

Observations were made on adult probing, plant part desapped and symptom development if any. Plants were categorized into three groups based on the duration for which they supported adult survival and their suitability for successful completion of life cycle of the bug.

1. Plants which do not support the survival of the bugs - Non hosts (-)
2. Plants supporting the survival of bugs for 5-20 days – Potential adult survival supporters (+)
3. Plants supporting the survival of bugs and successful completion of life cycle – Hosts (++)

The crop plants, weeds and ornamentals were got identified by the Faculties of Department of Agronomy and Department of Horticulture, College of Agriculture, Vellayani.

3.4 SEASONAL OCCURRENCE OF POD BUGS AND THEIR NATURAL ENEMIES

The seasonal occurrence of different species of pod bugs and their natural enemies in vegetable cowpea was studied by recording their population in the crop raised in the Instructional Farm, College of Agriculture, Vellayani during August, 2005 to September, 2006. Seeds of vegetable cowpea var. Sharika were sown at a spacing of 45 x 15 cm in 40 sqm area every month so as to ensure continuous supply of pods throughout the period of observation. The crop was maintained in the field as per package of practices (KAU, 2002) with the exception of pesticide application.

3.4.1 Pod bugs

Fortnightly observations were taken from five observational plants in the pod bearing stage. The pods, flowers, leaves and stem were closely examined for pod bug nymphs and adults and the total number present in each plant was recorded.

3.4.2 Natural enemies

Five observational plants were examined every fortnight and the number of natural enemies present were recorded by visual counting.

3.4.3 Correlation between weather parameters and incidence of pod bugs and their natural enemies

The meteorological parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity, rainfall and number of rainy days were recorded from the Department of Meteorology, College of Agriculture, Vellayani. The relationship between the population of different species of pod bugs and their natural enemies with weather parameters was worked out by correlation matrix.

3.5 BIOLOGY OF POD BUGS

Laboratory culture of the pod bugs *viz., N. viridula, P. rubrofasciatus, R? linearis* and *R. pedestris* was initiated from the field collected adult bugs. The bugs were kept in glass chimneys (15 x 10 cm) with the tops secured with muslin cloth. The bottom of the glass chimneys were provided with filter paper to facilitate absorption of excretory materials produced by the bugs. Fresh cowpea pods were kept as food for the bugs inside glass chimneys. In the case of *R. pedestris,* development of the bug was studied on two more plants *viz.*, grain cowpea var. Pusa komal and coffee senna weed (*Cassia* occidentalis L.). A cotton swab soaked in dilute honey solution was provided as supplementary food source. Desapped pods were replaced by fresh pods periodically. Eggs laid were used for studying biology.

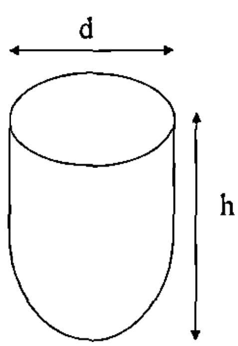
3.5.1 Assessment of biological parameters

3.5.1.1 Egg

The eggs laid were removed using camel hair brush and transferred to petriplates lined with filter paper. The eggs so obtained were taken individually and measurements were recorded on five eggs using a caliberated ocular micrometer mounted on stereo binocular microscope.

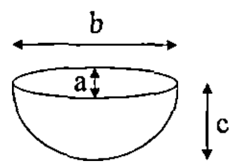
For eggs of pentatomid bugs, the diameter and height were measured. For eggs of alydid bugs, the short length diameter, long length diameter and height were measured. A diagrammatic representation of the measurements taken are presented below.

Egg of pentatomid bug



d - diameter
h - height

Egg of Alydid bug



a - short length diameter
b - long length diameter
c - height

Eggs kept in petriplates were observed daily for colour change and hatching. Incubation period of egg was worked out for 10 eggs of each bug species.

3.5.1.2 Nymph

The newly hatched first instar nymph was immediately transferred one each into glass chimney and provided with fresh pods excepting pentatomids where segregation was done only from second instar onwards.

Duration of each nymphal instar, colour change and morphological characters were noted for 10 nymphs of each bug species. Length and width of each of the nymphal instar were measured from five fully grown nymphs using a caliberated ocular micrometer mounted on stereo binocular microscope.

3.5.1.3 Developmental period

The total life cycle was computed from the day of egg laying till the emergence of the adult.

3.5.1.4 Mating and oviposition

A pair of freshly moulted adult male and female of the respective bug species were confined and provided with fresh cowpea pods. A cotton swab soaked in dilute honey solution was also provided. Twelve hours of darkness was ensured for the bugs in confinement. The observations on mating behaviour and ovipositional period were recorded from 10 such pairs.

3.5.1.5 Fecundity

Fecundity of the insects was studied by counting the number of eggs laid by an individual female bug during the entire ovipositional period. Ten replications were maintained for each species. The eggs laid on the pods, twigs, muslin cloth, glass walls of chimney, cotton swab were counted daily and dislodged separately in a petri dish till the death of the female.

3.5.1.6 Adult longevity

Longevity was worked out from the date of adult emergence till the death of the insect.

3.6 MANAGEMENT OF POD BUGS

3.6.1 Bioassay to determine the efficacy of insecticides / pathogenicity of entomopathogens to *R. pedestris*

3.6.1.1 Botanical insecticides

Treatments

1. Amrutneem - 5 ml l^{-1}
2. Neem Azal - 2 ml l^{-1}
3. Nimbecidine - 2 ml l^{-1}
4. Control - Water spray

3.6.1.1.1 Preparation of test solutions

The botanical insecticides were measured using a micropipette. The test solutions were prepared as follows

Amrutneem 5 ml l^{-1}

100 ml acetone + 0.50 ml Amrutneem of Ocean agro (India) Ltd., Baroda

Neem Azal

100 ml acetone + 0.20 ml of Neem Azal T.S of E.I.D. Parry (India) Ltd., Chennai

Nimbecidine 2 ml l^{-1}

100 ml acetone + 0.20 ml of Nimbecidine of T. Stanes & Company Pvt., Ltd., Coimbatore.

3.6.1.1.2 Preparation of dry film and release of test insects

A uniform dry film was prepared by swirling 2 ml of each of the test solutions in a clean dry glass tube (15 x 2 cm). The tubes were shade dried for eight hours. Six numbers of uniformly, freshly moulted third instar nymphs of *R. pedestris* from the second generation laboratory culture were released into each tube. The experiment was conducted in a completely randomized design with five replications. Fresh cowpea pods were provided as food six hours after release of insects. An untreated control was maintained by preparing dry film with acetone.

3.6.1.1.3 Mortality

Observations on nymphal mortality were recorded every 12 hours by counting the number of dead insects in each tube and percentage mortality in each treatment was worked out.

3.6.1.2 Chemical insecticides

Treatments

1. Imidacloprid - 0.005 %
2. Fenvalerate - 0.03 %
3. Lambda cyhalothrin - 0.002 %
4. Chlorpyrifos - 0.03 %
5. Dimethoate - 0.05 %
6. Malathion - 0.05 %

7. Control - Water spray

3.6.1.2.1 Preparation of test solutions

The chemical insecticides were measured using a micropipette. The test solutions were prepared as follows

Imidacloprid 0.005 %

100 ml acetone + 0.028 ml of the commercial formulation Confidor 200 SL of Bayer Crop Science Ltd., Chennai.

Fenvalerate 0.03 %

100 ml acetone + 0.15 ml of the commercial formulation Tagfen 20 EC of Tropical Agrosystem (India) Ltd., Chennai.

Lambda cyhalothrin 0.002 %

100 ml acetone + 0.04 ml of the commercial formulation Command 5 EC of Tropical Agrosystem (India) Ltd., Chennai.

Chlorpyrifos 0.03 %

100 ml acetone + 0.15 ml of the commercial formulation Tribon 20 EC of Keminol Enterprises, Chennai.

Dimethoate 0.05 %

100 ml acetone + 0.16 ml of the commercial formulation Tagor 30 EC of Tropical Agrosystem (India) Ltd., Chennai.

Malathion 0.05 %

100 ml acetone + 0.10 ml the commercial formulation Malathion 50 EC of Thudiyalur Co-operative Agricutural Services Ltd., Thudiyalur.

3.6.1.2.2 Preparation of dry film and release of test insects

A uniform dry film was prepared as described in 3.5.1.1.2. Ten numbers of uniformly, freshly moulted third instar nymphs from the second generation laboratory culture were released into each tube. The experiment was conducted in a completely randomized design with three replications. An untreated control was maintained by preparing dry film with acetone.

3.6.1.2.3 Mortality

Observations on nymphal mortality were recorded every 30 minutes by counting the number of dead insects in each tube and the percentage mortality in each treatment was worked out.

3.6.1.3 Entomopathogens

Two entomopathogenic fungi and one entomopathogenic bacteria were tested for their pathogenecity to *R. pedestris*.

1. *Beauveria bassiana* - 2.5×10^7 spores ml^{-1}
2. *Rhizopus oryzae* - 7×10^6 spores ml^{-1}
3. *Pseudomonas fluorescens* (P.F.I.) - 20 g l^{-1}
4. Control - Water spray

3.6.1.3.1 Preparation and application of spore suspension of entomopathogenic fungi and bacteria

The fungi *viz., B. bassiana* and *R. oryzae* were grown in Potato Dextrose Agar (PDA). From seven day old cultures, stock suspension of spores was prepared. For this 5mm diameter discs were placed in 10 ml of water and the suspension was shaken well for two minutes and filtered through muslin cloth. From the filtered spore suspension 1 ml was taken out and the spore count was estimated using a haemocytometer. Required concentrations were prepared either by adding fungal discs or by adding sterile water. The spore suspension was sprayed on uniformly freshly moulted third instar nymphs from the second generation laboratory culture using atomizer. After 20 minutes, treated insects were transferred into fresh cowpea pods placed in glass chimneys secured with muslin cloth at the top.

For preparing the spray suspension of *P. fluorescens,* 2 g of the commercial formulation of *P. fluorescens* (P.F.I.) obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was added to 100 ml of sterile water and shaken well. The resulting suspension was sprayed over the nymphs.

The bioassay was conducted in a completely randomized design with five replications each with six insects. An untreated control was maintained by spraying the nymphs with sterile water.

3.6.1.3.2 Observations

The treated insects were examined daily for their feeding behaviour, morphological changes and mortality. Dead insects were transferred to petri plates containing moist filter paper and observed for the presence of mycelial growth on the cadavers or symptoms of bacterial infection. In case of fungi, pathogenecity was further confirmed by Koch's postulate (Aneja, 1996).

3.6.2 Field experiment

A field experiment was conducted during September 2006 to December 2006 at the Instructional Farm, College of Agriculture, Vellayani. The treatments found promising in the laboratory bioassay were selected for the field experiment.

Details of the trial

Design	-	RBD
Replications	-	3
Plot size	-	2 x 2 m
Spacing	-	45 x 15 cm
Variety	-	Sharika
Treatments	-	10

1.	Amrutneem	-	5 ml l^{-1}
2.	Neem Azal	-	2 ml l^{-1}
3.	Nimbecidine	-	2 ml l^{-1}
4.	Imidacloprid	-	0.005 %
5.	Fenvalerate	-	0.03 %
6.	Lambda cyhalothrin	-	0.002 %
7.	Chlorpyrifos	-	0.03 %
8.	Dimethoate	-	0.05 %
9.	Malathion	-	0.05 %
10.	Untreated control		

The crop was maintained as per package of practices (KAU, 2002) except for plant protection measures which were given according to the treatments fixed.

3.6.2.1 *Preparation and application of spray solution*

The required quantity of spray solutions for the respective treatments were prepared as per the methods described in 3.6.1.1.1 and 3.6.1.2.1 using water as solvent.

The first spray was given 60 days after sowing when pod bugs were noticed. The second spray was given 15 days after the first spray. Observations on population of pod bugs and their natural enemies were recorded one day prior to the application of treatments and on the first, third, fifth, seventh and fifteenth days after each spraying as in 3.4.1 and 3.4.2.

3.6.2.2 Yield

Yield was recorded in terms of weight and number of fresh marketable pods obtained treatment wise in all replications and the benefit cost ratio was worked out.

3.7 STATISTICAL ANALYSIS

Mean and standard error was worked out for biological parameters. Data was subjected to ANOVA or ANCOVA as per requirement (Panse and Suhatme, 1985).

Results

4. RESULTS

4.1 POD BUGS AND THEIR NATURAL ENEMIES ASSOCIATED WITH VEGETABLE COWPEA IN THE INSTRUCTIONAL FARM, VELLAYANI

4.1.1 Pod bugs

Nine species of pod bugs belonging to eight genera and four families were found associated with vegetable cowpea (Table 1). They were *Acrosternum graminea* (Fab.), *Clavigralla gibbosa* Spinola, *Cletus bipunctatus* Westw., *Coptosoma cribraria* Fab., *Homoeocerus* sp., *Nezara viridula* (L.), *Piezodorus rubrofasciatus* (Fab.), *Riptortus*? *linearis* (Fab.) and *Riptortus pedestris* Fab.

Of these, the occurrence of *A. graminea*, *C. bipunctatus*, *Homoeocerus* sp., *P. rubrofasciatus* and *R*? *linearis* are new reports from vegetable cowpea in India.

A. graminea

The adult was a small green pentatomid stink bug (Plate 1) observed in reclaimed wet land. It preferred to feed on cowpea pods present in the middle region of the plants within dense canopy of leaves. The bug was observed in the field during the vegetable pod stage of the crop. Adults were seen during early morning and twilight hours. It's presence was rare in vegetable cowpea fields.

C. gibbosa

The adult was a brown, ochraceous, moderately pilose coreid bug (Plate 1) infesting vegetable cowpea grown in reclaimed wetland. Pronotal spines were black, acutely produced and directed a little forward and upward. The bug was

A. graminea

C. gibbosa

C. bipunctatus

C. cribraria

Homoeocerus sp.

N. viridula

P. rubrofasciatus

R? linearis

R. pedestris

Plate 1. Pod bugs infesting vegetable cowpea

Table 1. Pod bugs infesting vegetable cowpea in the Instructional Farm, Vellayani

Pod bug	Family	Ecosystem		Crop stage	Preferred resting and feeding positions of bugs	Adult occurrence
		Reclaimed wet land	Garden land			
Acrosternum graminea (Fab.)	Pentatomidae	+	-	B	Pods occurring within dense canopy of leaves in the middle region	Early morning and twilight hours
Clavigralla gibbosa Spinola	Coreidae	++	-	B	Pods in occurring within dense canopy of leaves in the middle and lower most region	Mostly in mid day and twilight hours
Cletus bipunctatus Westw.	Coreidae	++	+	A, B	Pods occurring within dense canopy of leaves irrespective of their position on the plant	Mostly in twilight hours
Coptosoma cribraria Fab.	Plataspididae	+	-	B	Pods exposed to sunlight irrespective of their position on the plant.	Throughout the day
Homoeocerus sp.	Coreidae	+	-	B	Lower most pods occurring within dense canopy of leaves	Mostly in twilight hours
Nezara viridula (L.)	Pentatomidae	++++	+++	B	Upper most pods and pods in the middle region exposed to sunlight.	Throughout the day
Piezodorus rubrofasciatus (Fab.)	Pentatomidae	++	+	B	Pods occurring in the middle region	Throughout the day
Riptortus ? linearis (Fab.)	Alydidae	+++	+++	B	Lower most pods	Throughout the day
Riptortus pedestris (Fab.)	Alydidae	+++	++++	A, B, C	All pods irrespective of their position on plants	Throughout the day

-   - Absent
+   - Rare
++   - Less frequent (1-2 bugs / 100 plants)
+++   - Common (1-2 bugs / 5 plant)
++++   - Abundant (1-2 bugs / plant)

A - Tender pods
B - Vegetable pods
C - Dry pods

noted in the field in the vegetable pods stage of the crop. It showed much preference for pods in the middle and lower most region of the plant amidst dense canopy of leaves. Adults were seen in the field mostly during mid day and twilight hours. The population of the pest was very low.

C. bipunctatus

The adult was a reddish brown, ochraceous coloured coreid bug (Plate 1) with two distinct white spots beneath the scutellum. Pronotal spines were black, short and acutely produced. It was usually observed in reclaimed wet land, though it occurred rarely in garden land cowpea. The bug was seen infesting immature tender pods as well as mature pods. It preferred to feed on pods occurring within dense canopy of leaves. Adults were sighted mostly during twilight hours. It exhibited meagre population levels.

C. cribraria

The adult was a broadly ovate, shiny greenish plataspidid bug (Plate 1) occurring in reclaimed wet land. It preferred to feed on cowpea pods exposed to sunlight irrespective of their position on the plant. The adults were seen feeding on green mature pods of the plant. Adults were present in the field throughout the day in very few numbers during December 2005 only.

***Homoeocerus* sp.**

The adult of this coreid bug was dull brown and ochraceous coloured (Plate 1). Pronotal spines were brown coloured, short with blunt end. It was a very rare bug observed in vegetable cowpea grown in reclaimed wet land. The bug was found infesting green mature pods. It showed distinct preference for lower most pods occurring within dense canopy of leaves and was never observed in pods positioned elsewhere. Adults were mostly seen during twilight hours.

N. viridula

The green pentatomid stink bug (Plate 1) occurred both in garden land and reclaimed wetland cowpea with a preference for the latter. It was noticed desapping green mature pods occurring in uppermost and middle region of the plant exposed to sunlight. Adults were noticed in the field throughout the day.

P. rubrofasciatus

The adult was a small pale green pentatomid stink bug (Plate 1). It was occasionally observed in reclaimed wet land and very rarely in garden land. The bugs were mostly seen feeding on the mature vegetable pods occurring in the middle region of the plant. Adults were seen in the field throughout the day.

R? linearis

The brown alydid bug (Plate 1) was present in both reclaimed wet land as well as garden land cowpea. It was seen infesting green mature vegetable pods. It preferred to feed on lower most pods and were seldom observed in pods positioned elsewhere. Adults were noted throughout the day.

R. pedestris

The adult was a dark brown, alydid bug (Plate 1) that occurred both in reclaimed wetland and garden land cowpea but dominated in the latter. The bugs appeared during pod initiation stage and dominated throughout the reproductive phase of the crop. It fed on the pods irrespective of their position in the plant. Adults were observed in the field throughout the day.

During hot periods of the day, nymphs of *Riptortus* spp. were found hiding under dry leaves. By simply tapping a dry leaf, it was possible to collect a handful of nymphs especially during dry pod stage. On being disturbed, the immediate response of the nymph was to drop down and take refuge under weed

Plate 2. Camouflaging of nymphs of *Riptortus* spp. within dry leaves of cowpea

cover. When adults or nymphs were caught between the fingers, they usually let out drops of offensive smelling, dull white coloured fluid. An interesting observation made was the camouflaging of the fourth and fifth instar nymphs on dry leaves (Plate 2). The colour of the nymphs matched well with the brown background of dry leaves under which they hide.

4.1.2 Natural enemies of pod bugs

Nine species of predators and one ectoparasitic mite were found associated with pod bugs (Table 2). Four species of preying mantids *viz.*, *Elmantis tricomaliae* (Mukharji–Hazra), *Euantissa pulchra* (Fabricius), *Humbertiella ceylonica* (Saussure), *Hierodula* ? *ventralis* Giglio-Tos, one ant, *Camponotus compressus* Fabricius and an unidentified reduviid bug were found preying on pod bugs. Three species of araneae *viz.*, *Argiope pulchella* (Thorell), *Peucetia virdana* (Stoliczka) and *Telamonia dimidiata* (Simon) were also identified as predators. *C. compressus*, ectoparasitic mite and all the preying mantids are new reports of natural enemies of pod bugs in India.

4.1.2.1 Predators

Black ant

The black ant, *C. compressus* preyed upon freshly laid eggs of *N. viridula.* The top most portion of the egg was split open and the contents were lapped up. The egg mass was only partially utilized with only 30-40 per cent of the eggs being broken. Hatching and nymphal development occurred normally in the eggs left untouched.

Reduviid bug (unidentified)

The brown coloured reduviid bug (Plate 3) was a predator of nymphs of the pod bugs *N. viridula*, *R*? *linearis* and *R. pedestris*. After catching hold of the prey with its forelegs it sucked out the contents.

Table 2. Natural enemies of pod bugs observed in the Instructional Farm, Vellayani

Natural enemy	Family	Order	Prey / Host
PREDATOR			
Black ant *Camponotus compressus* Fabricius	Formicidae	Hymenoptera	Eggs of *N. viridula*
Preying mantids *Elmantis tricomaliae* (Mukharji-Hazra)	Mantidae	Dictyoptera	Nymphs of *R? linearis*, *R. pedestris* and 1st – 4th instar nymphs of *N. viridula*
Euantissa pulchra (Fabricius)	Hymenopodidae	Dictyoptera	Nymphs of *R? linearis*, *R. pedestris* and 1st – 4th instar nymphs of *N. viridula*
Hierodula ? ventralis Giglio-Tos	Mantidae	Dictyoptera	Nymphs and adults of *R? linearis*, *R. pedestris* and nymphs of *N. viridula*
Humbertiella ceylonica (Saussure)	Mantidae	Dictyoptera	Nymphs and adults of *R? linearis*, *R. pedestris* and nymphs of *N. viridula*
Reduviid bug (unidentified)	Reduviidae	Hemiptera	Nymphs of *N. viridula, R? linearis* and *R. pedestris*
Spiders *Argiope pulchella* (Thorell)	Araeneidae	Araneae	Nymphs of *R? linearis, R. pedestris* and *N. virdula*
Peucetia virdana (Stoliczka)	Oxyopidae	Araneae	Nymphs of *R? linearis, R. pedestris* and *N. viridula*
Telamonia dimidiata (Simon)	Salticidae	Araneae	Nymphs of *R? linearis, R. pedestris* and *N. viridula*
PARASITE Mite (unidentified)	-	-	Nymphs and adults of *N. viridula, P. rubrofasciatus, R? linearis*

E. tricomaliae

E. pulchra

H. ceylonica

H? ventralis

Reduviid bug (unidentified)

Plate 3. Mantid and reduviid predators of pod bugs

A. pulchella

P. virdana

T. dimidiata (juvenile)

Plate 4. Spider predators of pod bugs

Preying mantids

The prey was captured using the front pair of raptorial legs. Nymphs of pod bugs were usually eaten up fully. In the case of adults, wings and portions of legs were left as remnants.

E. tricomaliae

The brown coloured medium sized preying mantid (Plate 3) preferred to feed on nymphs of *R? linearis*, *R. pedestris*, first, second, third and fourth instar nymphs of *N. viridula.*

E. pulchra

The dark brown black coloured, medium sized preying mantid (Plate 3) had a prey range similar to that of *E. tricomaliae.*

H. ceylonica

It was a brown coloured, medium sized preying mantid (Plate 3). It could feed on adults as well as nymphs of *R? linearis*, *R. pedestris* and nymphs of *N. viridula.*

H? ventralis

It was a pale green coloured, long preying mantid (Plate 3). The prey range was similar to that of *H. ceylonica.*

Spiders

The spiders *A. pulchella*, *P. virdana* and *T. dimidiata* (Plate 4) preyed upon pod bug nymphs but showed only slight preference.

Plate 5. Ectoparasitic mite on *N. viridula*

4.1.2.2 Ectoparasitic mite

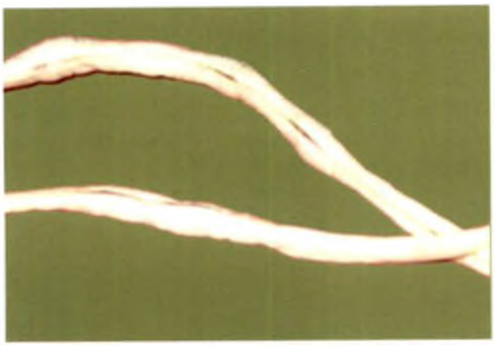
The pod bugs *R*? *linearis*, *N. viridula* were found to host an ectoparasitic mite (Plate 5). The mites were found on all body parts of the insect. General weakness and poor feeding were noticed on parasitized insects. The mites formed a dirty white crust over the insect and caused the death of the insect. Fourth instar nymphs of *N. viridula*, *P. rubrofasciatus* and *R*? *linearis* died within 5-7 days when confined with a parasitized insect hosting 400-500 mites. All the nymphal instars were killed except fifth instar of *N. viridula* which occasionally moulted to become adult. Parasitized adult bugs rarely mated but never laid fertile eggs.

4.2 NATURE OF DAMAGE AND SYMPTOM DEVELOPMENT

Pod bugs inserted their stylets through the pod wall and sucked the sap preferably from the seeds. The symptom development in the pod due to feeding by *N. viridula*, *R*? *linearis* and *R. pedestris* was almost similar and exhibited no visible difference. However, desapped seeds presented varied symptoms and weight losses.

The desapped pods showed light brown feeding punctures initially. The feeding punctures were concentrated on the pod wall over the seed regions. The rind portion adjacent to the seeds showed deep brown lines. Ultimately the pods shrivelled (Plate 6). In case of tender pods, the seeds were completely desapped leaving behind only the seed coat. Sometimes when only one or two seeds were utilised, that particular portion of the pod alone was shrivelled whereas the rest of the seeds developed normally. Excretory materials of the bugs dripping over the pods resulted in discolouration and secondary fungal infections.

Seeds of mature pods were only partially desapped with each of the bug species causing varying levels of discolouration, shrinking, shrivelling and weight loss (Plate 6).



Rind browning symptom

Desapped pods

Uninfested seed

Seeds damaged by *N. viridula*

Seeds damaged by *R? linearis*

Seeds damaged by *R. pedestris*

Plate 6. Vegetable cowpea pods and seeds damaged by pod bugs

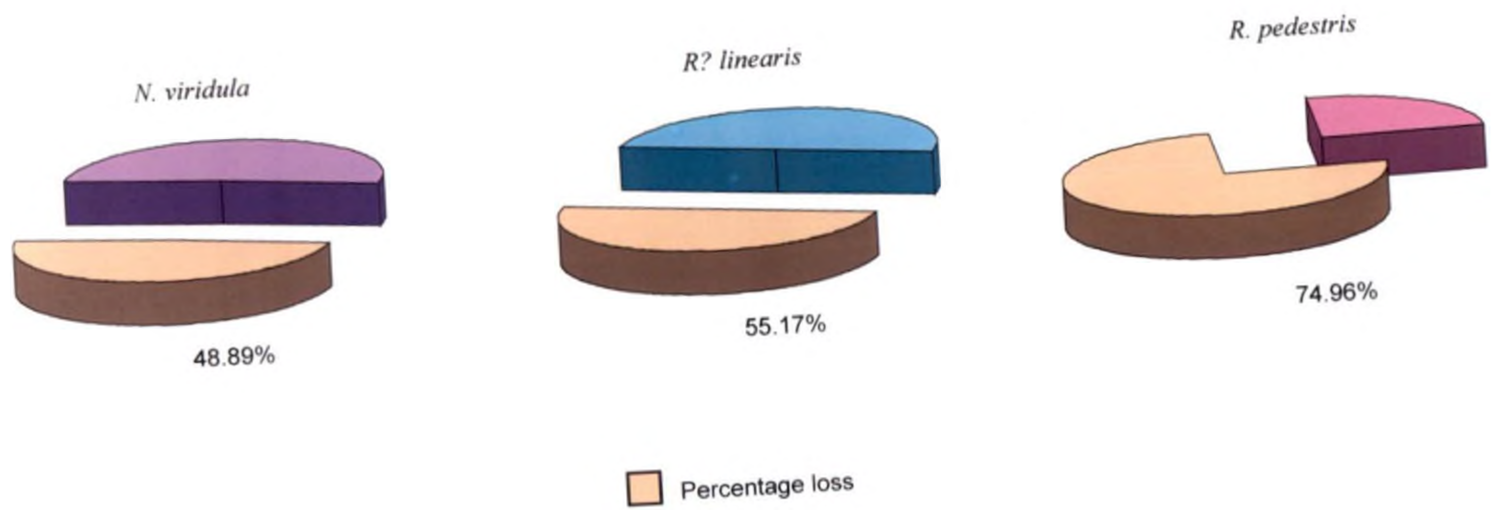


Fig. 1. Percentage loss in seed weight due to different pod bugs

N. viridula

Slight shrivelling of seeds was observed. Seeds were completely discoloured presenting a pale brown colouration, much different from the original black colour of the seeds. Mild traces of dark brown colour was observed near the embryo region.

R? linearis

Slight shrivelling of seeds was observed. Seeds turned deep brown in colour with patches of pale brown regions.

R. pedestris

Seeds presented a typical shrivelled appearance with distortion of seed shape. Densely distributed patches of pale brown discolouration was seen over the seed surface.

A comparison of the loss in weight of seeds due to feeding of the bugs revealed that maximum damage was caused by *R. pedestris*. A weight loss of 74.96 per cent was caused by this bug. It was followed by *R? linearis* and *N. viridula* with 55.17 per cent and 48.89 per cent weight losses respectively (Fig. 1).

4.3 HOST RANGE OF *R. pedestris* ASSESSED IN THE LABORATORY AND FIELD CONDITIONS

As *R. pedestris* was the dominant species of pod bug in cowpea ecosystem, its host range was studied in detail and the results are presented in Table 3.

Vegetable crops

Among the vegetable crops observed in field, occurrence of *R. pedestris* was noted on *Abelmoschus esculentus* (L.) Moench and *Capsicum annum* L. The bug was found to feed on mature fruits and seeds of *A. esculentus.* Bhendi fields

Table 3. Host range of *Riptortus pedestris* Fab. assessed in the laboratory and field conditions

Sl. No.	Scientific Name	Common name	Family	Status	Plant part desapped	Feeding symptoms
I	**Vegetables**					
1	*Abelmoschus esculentus* (L.) Moench	Bhendi	Malvaceae	+	Mature fruits and seeds	Seeds were emptied of their contents and turned dry with black discolouration.
2	*Amaranthus tricolor* L.	Amaranthus	Amaranthaceae	-	-	-
3	*Capsicum annum* L.	Chilli	Solanaceae	+	Leaf	General chlorosis. Prolonged feeding resulted in formation of brown necrotic spots.
4	*Cyamopsis tetragonoloba* (L.) Traub	Cluster bean	Leguminosae	+	Pod	Shrinking and shrivelling of pods, with few feeding punctures
5	*Coccinia grandis* (L.) Voigt.	Coccinia	Cucurbitaceae	-	-	-
6	*Lycopersicon esculentum* Mill.	Tomato	Solanaceae	-	-	-
7	*Manihot esculenta* Crantz.	Tapioca	Euphorbiaceae	-	-	-
8	*Momordica charantia* L.	Bittergourd	Cucurbitaceae	-	-	-
9	*Moringa oleifera* Lam.	Drumstick	Moringaceae	-	-	-
10	*Psophocarpus tetragonolobus* (L.) D.C	Winged bean	Leguminosae	+	Pod	Shrinking and shrivelling of pods, with browning of ridges
11	*Solanum melongena* L.	Brinjal	Solanaceae	-	-	-

- Continued

II.	**Pulses**					
1	*Cajanus cajan* (L.) Millsp.	Pigeon pea	Leguminosae	++	Pod	Brown coloured feeding punctures on pods followed by shrinking and shrivelling. Seeds were emptied of their contents. Pods dried up.
2	*Vigna radiata* (L.) R. Wilcz. (= *Phaseolus aureus* Roxb.)	Green gram	Leguminosae	++	Pod	"
3	*Vigna mungo* (L.) Hepper	Black gram	Leguminosae	++	Pod	"
4	*Vigna unguiculata* (L.) Walp.	Grain cowpea	Leguminosae	++	Pod	"
III	**Oil seeds**					
	Sesamum indicum L.	Gingelly	Pedaliaceae	-	-	-
IV	**Fruit crops**					
1	*Achras zapota* L. Auct non (= *Manilkara zapota* J.)	Sapota	Sapotaceae	-	-	-
2	*Anacardium occidentale* L.	Cashew	Anacardiaceae	-	-	-
3	*Mangifera indica* L.	Mango	Anacardiaceae	-	-	-
4	*Psidium gujava* L.	Guava	Myrtaceae	+	Leaf	Dark brown necrotic patches on lamina and browning of veins
V	**Spices**					
	Piper nigrum L.	Black pepper	Piperaceae	-	-	-
VI	**Medicinal plants**					
	Ocimum sanctum L.	Tulasi	Labiatae	+	Leaf	No typical feeding symptoms

- Continued

VII	**Fodder crop**					
	Tephrosia purpurea (L.) Pers.	Wild indigo	Leguminosae	+	Pod	Shrinking and shrivelling of pods, emptying of seed contents and drying of pods
VIII	**Ornamentals**					
1	*Antigonon leptopus* Hook. & Arn.	Coral vine	Polygonaceae	+	Leaf	Small brown spots on leaf lamina
2	*Caesalpinia pulcherrima* (L.) Sw.	Red Bird of Paradise	Leguminosae	++	Pod	Dark brown black patches on pods followed by emptying of seeds and drying of pods
3	*Celosia plumosa* L.	Cockscomb	Amaranthaceae	-	-	-
4	*Chrysanthemum cinerariifolium* (Trevir.) Vis.	Daisy	Compositae	-	-	-
5	*Clerodendrum thomsoniae* Balf. f.	Bleeding heart	Verbenaceae	+	Leaf	Dark brown necrotic patches on lamina
6	*Cosmos bipinnatus* Cav.	Garden cosmos	Compositae	+	Leaf, flower buds	Dark brown necrotic patches on leaf lamina. No typical feeding symptoms on flower buds
7	*Duranta plumieri* Jacq.	Bachelor's buttons	Verbenaceae	-	-	-
8	*Gomphrena globosa* L.	Common globe amaranthus	Amaranthaceae	+	Leaf	No typical feeding symptoms
9	*Hibiscus rosa sinensis* L.	Hibiscus/Rose of China	Malvaceae	-	-	-
10	*Ixora chinensis* Lam.	Flame of the woods	Rubiaceae	+	Leaf	Dark brown necrotic patches on leaf lamina

-- *Continued*

11	*Kopsia fruticosa* (Ker.) A.DC.	Pink kopsia	Apocynaceae	+	Leaf	Dark brown necrotic patches on leaf lamina
12	*Plectranthus scutellarioides* R.Br.	Flame nettle	Labiatae	-	-	-
13	*Tagetus erecta* L.	Marigold	Compositae	-	-	-
IX	**Weeds**					
1	*Ageratum conyzoides* L.	Billy goat weed	Compositae	+	Leaf	Dark brown necrotic patches on leaf lamina
2	*Boerhaavia diffusa* L.	Tar vine	Nyctaginaceae	+	Leaf	No typical feeding symptoms
3	*Cassia occidentalis* L.	Coffee senna	Leguminosae	++	Pod	Dark brown discolouration of pods followed by discolouration of seeds and drying of pods
4	*Centrosema pubescens* Benth.	Blue bell	Leguminosae	+	Pod	Brown feeding punctures followed by shrinking of pods
5	*Cleome monophylla* L.	Spider plant	Capparidaceae	-	-	-
6	*Clitoria ternatea* L.	Asian pigeon wings	Leguminosae	-	-	-
7	*Commelina benghalensis* L.	Day flower / Dew flower	Commelinaceae	+	Leaf	No typical feeding symptoms
8	*Desmodium gyrans* (L.f) DC.	Telegraph plant	Leguminosae	-	-	-
9	*Justicia prostrata* Gamble	.....	Acanthaceae	-	-	-
10	*Lantana camara* L.	Wild sage	Verbenaceae	+	Leaf	Dark brown necrotic spots on leaf lamina

- Continued

11	*Panicum maximum* L.	Guinea grass	Poaceae	+	Leaf	General chlorosis
12	*Synedrella nodiflora* (L.) Gaertn.	Cinderella weed	Compositae	+	Leaf	Dark brown black necrotic patches on leaves
13	*Tridax procumbens* L.	Coat buttons	Asteraceae	-	-	-
14	*Vernonia cinerea* (L.) Less	Iron weed	Asteraceae	-	-	-

- \- Plants which do not support the survival of bugs (Non-hosts)
- \+ - Plants supporting the survival of bugs for 5-20 days (Potential adult survival supporters)
- ++ - Plants supporting the survival of bugs and successful completion of their life cycle (Hosts)

forsaken after harvest, in weedy areas harbouring *Synedrella nodiflora* (L.) Gaertn. hosted adults and nymphs of *R. pedestris* @ 5-20 per plant. The bug inserted its stylets through the fruit rind and desapped from seeds making them empty (Plate 7).

Chilli fields adjacent to cowpea were infested with adults and nymphs of *R. pedestris* soon after the harvest of cowpea crop. Leaves of *C. annum* were desapped by the bug. Under laboratory confinement, in the excised plant part, the bugs produced premature yellowing of leaf and formation of small necrotic spots in them.

In *Cyamopsis tetragonoloba* (L.) Traub and *Psophocarpus tetragonolobus* (L.) D.C., pods were desapped producing shrinking and shrivelling symptoms with few feeding punctures.

Amaranthus tricolor L., *Coccinia grandis* (L.) Voigt, *Lycopersicon esculentum* Mill., *Manihot esculenta* Crantz, *Momordica charantia* L., *Moringa oleifera* Lam., and *Solanum melongena* L. did not support the survival of *R. pedestris*.

Pulses

All the four pulse crops observed *viz.*, *Cajanus cajan* (L.) Millsp., *Vigna radiata* (L.) R. Wilcz., *Vigna mungo* (L.) Hepper and *Vigna unguiculata* (L.) Walp. hosted *R. pedestris* in the field. The bugs preferred to feed on pods and could survive for more than 20 days and complete its lifecycle in them. Infested pods showed shrinking and shrivelling symptoms with empty seeds. Symptoms of desapping by adults in grain cowpea is presented in (Plate 7).

Oil seeds

R. pedestris did not rest/feed on *Sesamum indicum* L., the only oil seed crop tested.

Grain cowpea

Bhendi

Coffee senna weed

Plate 7. Symptoms of pod bug infestation in grain cowpea and other host plants

Fruit crops

Among the four fruit trees observed during the study, field incidence of *R. pedestris* was noticed only on *Psidium gujava* L. Under laboratory confinement, adult bugs were found to desap from leaves. It resulted in the formation of dark brown necrotic patches and browning of veins. Mature leaves were most preferred. Flowers and fruits were left untouched. Leaves of *Achras zapota* L. Auct non, *Anacardium occidentale* L. and *Mangifera indica* L. did not support the survival of *R. pedestris*.

Spices

The bugs did not feed upon *Piper nigrum* L., the only spice crop tested.

Medicinal plants

Ocimum sanctum L. was the only medicinal plant tested. The bug desapped from leaves but no typical feeding injury was noticed.

Fodder crop

Tephrosia purpurea (L.) Pers., the only fodder crop tested was found suitable for the survival of *R. pedestris*. Pods were desapped resulting in dark brown discolouration initially with slight shrinking and shrivelling. Later the pods dried up with empty seeds.

Ornamentals

Among the 13 ornamental plants observed, only *Caesalpinia pulcherrima* (L.) Sw. was observed to host *R. pedestris* in the field. Under laboratory confinement, the bugs could survive for more than 20 days and complete its life cycle on this host. Desapping from pods resulted in development of broad, brown black necrotic patches followed by emptying of seeds and drying of pods. *Antigonon leptopus* Hook. & Arn. *Clerodendrum thomsoniae* Balf. f., *Cosmos bipinnatus* Cav., *Gomphrena globosa* L., *Ixora chinensis* Lam. and *Kopsia fruticosa* (Ker.) A.DC. could support the survival of *R. pedestris*. Feeding by bugs resulted in the formation of necrotic spots on the leaf lamina of these plants except *G. globosa,* where no typical feeding symptoms were noticed.

Celosia plumosa L., *Chrysanthemum cinerariifolium* (Trevir.) Vis., *Plectranthus scutellarioides* R. Br., *Duranta plumieri* Jacq., *Hibiscus rosa sinensis* L. and *Tagetus erecta* L. were not suitable for the survival of *R. pedestris*.

Weeds

Out of the 14 weed plants observed during the study, nymphs and adults of *R. pedestris* were noticed on *Cassia occidentalis* L., *Panicum maximum* L. and *S. nodiflora.*

Laboratory confinement studies confirmed that the pods of *C. occidentalis* could support the survival and development of *R. pedestris*. Desapping of pods by the bug resulted in brown black discolouration of the pods with no shrinking or shrivelling symptoms (Plate 7). Seeds too, showed brown black discolouration but remained intact with no change in the smooth, shining surface texture.

S. nodiflora and *P. maximum* were found to be suitable for the survival of *R. pedestris*. Symptoms appeared as brown black necrotic patches on leaves in the former and general chlorosis of leaves in the latter. Soon after the harvest of cowpea crop these three weeds in and around cowpea fields hosted nymphs and adults of *R. pedestris.*

Centrosema pubescens Benth. could also support the survival of *R. pedestris* with the infested pods showing brown feeding punctures and very slight shrinking symptoms. *R. pedestris* desapped from leaves of *Ageratum conyzoides* L., *Boerhaavia diffusa* L., *Commelina benghalensis* L. and *Lantana camara* L.

Leaves of *A. conyzoides* and *L. camara* developed dark brown necrotic patches. No typical symptom was seen in *B. diffusa* and *C. benghalensis*.

Cleome monophylla L., *Clitoria ternatea* L., *Desmodium gyrans* (L.f) DC., *Justicia prostrata* Gamble, *Tridax procumbens* L. and *Vernonia cinerea* (L.) Less. were rejected by *R. pedestris*.

4.4 SEASONAL OCCURRENCE OF POD BUGS AND THEIR NATURAL ENEMIES

4.4.1 Pod bugs

The details on the population of *N. viridula, R? linearis* and *R. pedestris* in vegetable cowpea from October 2005 to September 2006 are presented in Table 4.

***N. viridula* nymph**

The nymphal stages of *N. viridula* were completely absent in the field during October 2005 and the population gradually started building up from the second fortnight of December 2005 onwards (0.31). The population reached its peak in the second fortnight of January 2006 (4.20). There was a slight fall during February 2006 followed by a sudden hike in the first fortnight of March 2006 (10.35). There was a diminishing pattern in the population until the second fortnight of April 2006 (2.05). The population further showed a second peak in the first fortnight of May 2006 (11.29), followed by a gradual decreasing phase, reaching a low value in the first fortnight of August 2006 (0.17). Again the population peaked in the second fortnight of August 2006 (7.88) followed by a diminishing phase until the second fortnight of September 2006. The population observed during October 2005 to December 2005 was significantly lower than the population observed in first fortnight of March 2006, May 2006, second fortnight of August 2006 and first fortnight of September 2006.

Table 4. Population of different species of pod bugs on vegetable cowpea from October 2005 to September 2006

Period	Pod bug (Mean number per plant)				
	N. viridula (Nymph)	*N. viridula* (Adult)	*Riptortus* spp. (Nymph)	*R. pedestris* (Adult)	*R? linearis* (Adult)
I FN October 2005	0.00 (1.00)	0.00 (1.00)	10.48 (3.39)	4.14 (2.27)	0.00 (1.00)
II FN October 2005	0.00 (1.00)	0.00 (1.00)	10.94 (3.46)	4.99 (2.45)	0.00 (1.00)
I FN November 2005	0.31 (1.15)	0.51 (1.23)	14.52 (3.94)	3.42 (2.10)	0.00 (1.00)
II FN November 2005	0.00 (1.00)	0.17 (1.08)	13.01 (3.74)	2.70 (1.92)	0.0 (1.00)
I FN December 2005	0.00 (1.00)	0.17 (1.08)	5.24 (2.50)	3.39 (2.10)	0.51 (1.23)
II FN December 2005	0.31 (1.15)	0.31 (1.15)	10.11 (3.33)	2.06 (1.75)	0.36 (1.17)
I FN January 2006	0.67 (1.29)	0.51 (1.23)	8.79 (3.13)	1.63 (1.62)	0.51 (1.23)
II FN January 2006	4.20 (2.28)	0.67 (1.29)	9.16 (3.19)	2.80 (1.95)	0.36 (1.17)
I FN February 2006	4.78 (2.40)	0.17 (1.08)	8.74 (3.12)	1.75 (1.66)	0.72 (1.31)
II FN February 2006	0.66 (1.29)	0.17 (1.08)	10.32 (3.37)	2.10 (1.76)	0.17 (1.08)
I FN March 2006	10.35 (3.37)	0.51 (1.23)	13.17 (3.76)	3.87 (2.21)	0.72 (1.31)
II FN March 2006	5.11 (2.47)	0.31 (1.15)	11.10 (3.48)	2.39 (1.84)	0.00 (1.00)
I FN April 2006	2.28 (1.81)	1.32 (1.52)	13.85 (3.85)	3.25 (2.06)	0.31 (1.15)
II FN April 2006	2.05 (1.75)	1.18 (1.48)	17.42 (4.29)	6.10 (2.66)	0.67 (1.29)
I FN May 2006	11.29 (3.51)	0.51 (1.23)	36.07 (6.09)	8.07 (3.01)	0.95 (1.39)
II FN May 2006	10.87 (3.45)	0.89 (1.38)	24.78 (5.08)	7.41 (2.90)	0.99 (1.41)
I FN June 2006	5.32 (2.51)	1.13 (1.46)	22.58 (4.86)	9.02 (3.17)	1.60 (1.61)
II FN June 2006	5.17 (2.48)	1.31 (1.52)	21.79 (4.77)	7.37 (2.89)	3.30 (2.07)
I FN July 2006	2.50 (1.87)	0.31 (1.15)	10.24 (3.35)	5.42 (2.53)	0.36 (1.17)
II FN July 2006	1.59 (1.61)	0.17 (1.08)	11.58 (3.55)	7.87 (2.98)	1.04 (1.43)
I FN August 2006	0.17 (1.08)	0.00 (1.00)	7.73 (2.95)	4.02 (2.24)	0.81 (1.35)
II FN August 2006	7.88 (2.98)	0.17 (1.08)	21.85 (4.78)	7.70 (2.95)	0.31 (1.15)
I FN September 2006	9.69 (3.27)	0.17 (1.08)	19.20 (4.49)	4.18 (2.28)	1.13 (1.46)
II FN September 2006	0.17 (1.08)	0.17 (1.08)	12.13 (3.62)	7.60 (2.93)	1.71 (1.65)
CD (0.05)	1.863	0.336	1.370	0.783	0.404

Figures in parentheses are $\sqrt{x+1}$ values

***N. viridula* adult**

The adults of *N. viridula* were absent in the field during October 2005. The bugs appeared in the field from the first fortnight of November 2005 onwards (0.51). The population diminished in the next fortnight (0.17). This was followed by gradual increase in the population reaching comparatively higher values during the first fortnights of April 2006 (1.32). There was a sharp fall in the first fortnight of May 2006 (0.51). Later on the population started building up steadily until the second fortnight of June 2006 (1.31). A diminishing phase followed afterwards and adult bugs were absent from the field by the first fortnight of August 2006. The population followed a constant value (0.17) during the next three fortnights until the second fortnight of September 2006. The population during October 2005, December 2005 and February 2006 was significantly lower than that observed in the first fortnight of April 2006 and second fortnight of June 2006.

***Riptortus* spp. nymph**

During the two fortnights of October 2005, the population of *Riptortus* spp. nymphs was almost constant (10.48 and 10.94 respectively). Later on, the population showed an increase in the first fortnight of November 2005 (14.52), followed by a slight fall in the second fortnight of November 2005 (13.01). From then onwards, the population followed a more or less constant pattern of rise and fall in the alternate fortnights attaining a maximum value by the first fortnight of May 2006 (36.07). Later the population decreased gradually until the first fortnight of July 2006 (10.24). Again there was population rise and fall in the alternate fortnights. The population reached a peak value in the second fortnight of August 2006 (21.85) followed by a gradual diminishing phase until the second fortnight of September 2006 (12.13). The population observed during the first fortnight of May 2006 was significantly higher than that observed in any other fortnight except the succeeding three fortnights which were on par.

***R. pedestris* adult**

The population of adult *R. pedestris* showed a gradual diminishing pattern from the first fortnight of October 2005 (4.14) to the second fortnight of November 2005 (2.70). Later on the population was more or less constant until the first fortnight of March 2006 (3.87) except for slight rise and fall in the alternate fortnights. The population started building up gradually from then onwards reaching a peak value by the first fortnight of June 2006 (9.02). The population then followed a diminishing pattern until the first fortnight of July 2006 (5.42). A hike in the population was observed in the next fortnight (7.87). This was followed by sharp rise and fall in the alternate fortnights until the second fortnight of September 2006. The population observed during the first fortnight of June 2006 was significantly higher than that observed in the first fortnight of October 2005, November 2005 to March 2006, first fortnight of August 2006 and first fortnight of September 2006.

***R? linearis* adult**

The adult population of *R? linearis* was completely absent from the fields during October 2005 and November 2005. The adult bugs appeared from the first fortnight of December 2005 onwards (0.51) with slight rise and fall in number in alternate fortnights until the second fortnight of March 2006 during which it was absent in the field. The bugs reappeared on the first fortnight of April 2006 followed by a steady increase in the population and reached the maximum value (3.30) on the second fortnight of June 2006. This was again followed by yet another phase of slight rise and fall in the population until the first fortnight of September 2006 (1.13). By the second fortnight of September 2006 the population increased slightly (1.71). The population observed during the second fortnight of June 2006 was significantly higher than in any other fortnight of observation.

4.4.2 Natural enemies

Details on the seasonal occurrence of natural enemies of pod bugs in vegetable cowpea from October 2005 to September 2006 are presented in Table 5.

Preying mantids

The highest population of preying mantids (1.93) was noted during the second fortnight of December 2005. During other periods of the year, population levels ranging from 0.17 to 1.86 was observed. There was no significant difference in the population of mantids observed during the different fortnights

Spiders

In the initial observations made during October 2005, the population was only 0.56 and 0.36 in the first and second fortnights respectively. Population levels ranging from 0.31 to 1.54 was observed during the rest of the year. The population of spiders observed during the different fortnights did not differ significantly.

4.4.3 Correlation between pod bugs and their natural enemies population and weather parameters

Correlation coefficients between weather parameters and occurrence of pod bugs and their natural enemies during the current and succeeding fortnight of observation are presented in Table 6 and Table 7 respectively.

***N. viridula* nymph**

All the weather parameters had insignificant effect on the population of *N. viridula* nymphs during the fortnight as well as the succeeding fortnight of observation.

Table 5. Population of natural enemies of pod bugs on vegetable cowpea from October 2005 to September 2006

Period	Predators (mean number per plant)	
	Preying mantids	Spiders
I FN October 2005	1.86 (1.69)	0.56 (1.25)
II FN October 2005	1.60 (1.61)	0.36 (1.17)
I FN November 2005	0.36 (1.17)	0.51 (1.23)
II FN November 2005	0.31 (1.15)	0.36 (1.17)
I FN December 2005	0.51 (1.23)	0.72 (1.31)
II FN December 2005	1.93 (1.71)	0.89 (1.38)
I FN January 2006	0.17 (1.08)	0.72 (1.31)
II FN January 2006	0.17 (1.08)	0.51 (1.23)
I FN February 2006	0.51 (1.23)	0.36 (1.17)
II FN February 2006	0.36 (1.17)	0.72 (1.31)
I FN March 2006	0.51 (1.23)	0.89 (1.38)
II FN March 2006	0.17 (1.08)	0.72 (1.31)
I FN April 2006	1.13 (1.46)	1.23 (1.49)
II FN April 2006	0.51 (1.23)	1.48 (1.58)
I FN May 2006	0.95 (1.39)	1.13 (1.46)
II FN May 2006	0.89 (1.38)	1.54 (1.59)
I FN June 2006	0.56 (1.25)	0.72 (1.31)
II FN June 2006	0.56 (1.25)	1.23 (1.49)
I FN July 2006	0.51 (1.23)	0.51 (1.23)
II FN July 2006	0.36 (1.17)	0.56 (1.25)
I FN August 2006	0.17 (1.08)	0.36 (1.17)
II FN August 2006	0.56 (1.25)	0.67 (1.29)
I FN September 2006	0.17 (1.08)	0.31 (1.15)
II FN September 2006	1.22 (1.49)	0.56 (1.25)
CD (0.05)	--	--

Figures in parentheses are $\sqrt{x+1}$ values

Table 6. Correlation coefficient of weather parameters with the population of pod bugs and their natural enemies of the current fortnight of observation

Pod bug/Natural enemy	Maximum Temperature	Minimum temperature	Morning relative humidity	Evening relative humidity	Rainfall	Rainy days
N. viridula (nymph)	0.0423	0.1589	-0.1184	0.0937	-0.2660	-0.085
N. viridula (adult)	0.1970	0.5802**	-0.0586	-0.1028	-0.1367	-0.0865
Riptortus spp. (nymph)	0.1598	0.6653**	-0.4814*	0.1768	-0.0321	-0.0016
R. pedestris (adult)	-0.2090	0.5278**	-0.3817	0.4404*	0.1907	0.2474
R? linearis (adult)	-0.3573	0.3161	-0.2563	0.2578	0.2828	0.2686
Preying mantids	0.1480	-0.0226	-0.2592	-0.1172	0.1336	0.0300
Spiders	0.3923	0.6635**	-0.0826	-0.2315	-0.1407	-0.0799

* - Significant at 5 per cent level ** - Significant at 1 per cent level

Table 7. Correlation coefficient of weather parameters with the population of pod bugs and their natural enemies of the succeeding fortnight of observation

Pod bug/Natural enemy	Maximum temperature	Minimum temperature	Morning relative humidity	Evening relative humidity	Rainfall	Rainy days
N. viridula (nymph)	0.1579	0.1250	0.1162	-0.1453	-0.2920	-0.1442
N. viridula (adult)	0.5205**	0.5035*	0.2540	-0.1778	-0.2247	-0.1684
Riptortus spp. (nymph)	0.3383	0.6338**	-0.0510	0.1474	-0.1224	0.0569
R. pedestris (adult)	-0.0433	0.6058**	-0.2385	0.4421*	0.2357	0.3197
R? linearis (adult)	-0.0661	0.2338	0.0241	0.3474	-0.0808	0.0349
Preying mantids	0.1883	0.0922	-0.4620*	-0.1527	0.1114	-0.0261
Spiders	0.6873**	0.6003**	0.0946	-0.2650	-0.2632	-0.3269

* - Significant at 5 per cent level ** - Significant at 1 per cent level

***N. viridula* adult**

The adult population of *N. viridula* during the fortnight of observation showed highly significant positive correlation (r = 0.5802) with the minimum temperature. Maximum temperature too had a positive association but the relationship was insignificant. All other weather parameters had negative influence on the population but with insignificant values.

Maximum and minimum temperatures exhibited significant positive correlations with the adult population of *N. viridula* of the succeeding fortnight (r = 0.5205 and 0.5035 respectively. All other weather parameters did not show any significant influence on the adult population of *N. viridula* during the succeeding fortnight of observation.

***Riptortus* spp. nymph**

The nymphal population of *Riptortus* spp. showed a highly significant positive correlation with minimum temperature during the fortnight of observation (r = 0.6653). Though a positive correlation was observed between the population of nymphs with maximum temperature and evening relative humidity, the relationship was insignificant. Morning relative humidity was negatively correlated with the nymphal population (r = -0.4814). Rainfall and number of rainy days also had a negative association with the population but the values were insignificant.

A highly positive correlation was observed between minimum temperature and population of nymphs of *Riptortus* spp. of the succeeding fortnight (r = 0.6338). All other weather parameters were insignificantly correlated with the nymphal population of *Riptortus* spp. of the succeeding fortnight.

***R. pedestris* adult**

The adult population of *R. pedestris* during the fortnight of observation showed a highly significant positive correlation with minimum temperature (r = 0.5278) and a significant positive correlation with evening relative humidity (r = 0.4404). Maximum temperature and morning relative humidity exerted a negative influence on the population whereas rainfall and number of rainy days had a positive influence with the values being insignificant.

Minimum temperature showed a highly significant positive correlation with the adult population of *R. pedestris* of the succeeding fortnight also (r = 0.6058). Evening relative humidity was significantly correlated with the population of the succeeding fortnight (r = 0.4421). None of the other weather parameters showed significant association with the adult population of *R. pedestris* of the succeeding fortnight of observation.

***R? linearis* adult**

The population of *R? linearis* adults during the fortnight of observation was negatively correlated with maximum temperature and morning relative humidity but the relationship was insignificant. The other weather parameters were positively associated with the adult population of *R? linearis* though the values were not significant.

None of the other parameters exhibited significant influence on the adult population of *R? linearis* of the succeeding fortnight observation.

Preying mantids

The population of preying mantids did not show any significant correlation with any of the weather parameters during the fortnight of observation. However, the morning relative humidity showed significant negative correlation with population of the succeeding fortnight (r value = -0.4620). None of the other weather parameters showed significant correlation with the mantid population of the succeeding fortnight.

Spiders

The population of spiders showed a highly significant positive correlation only with minimum temperature (r = 0.6655).

Maximum and minimum temperature showed highly significant correlation (r = 0.6873 and 0.6003 respectively) with the spider population of the succeeding fortnight. All other weather parameters were insignificantly associated with the spider population during the fortnight of observation as well as the succeeding fortnight.

4.4.4 Correlation between population of pod bugs and their natural enemies

Details on the correlation between population of pod bugs and their natural enemies are presented in Table 8.

The population of preying mantids showed negative correlation with the adult and nymphal population of *N. viridula*, nymphal population of *Riptortus* spp. and adult population of *R? linearis* during the fortnight of observation as well as the succeeding fortnight but the relationship was insignificant.

The population of spiders showed highly significant positive correlation (r = 0.7937) with adults of *N. viridula* and with nymphs of *Riptortus* spp. (r = 0.5164) in the current fortnight of observation. The spiders did not show any negative impact on the pod bug population during the fortnight of observation as well as the succeeding fortnight.

Table 8. Correlation coefficient between population of pod bugs and natural enemies

Podbug	Preying mantids		Spiders	
	A	B	A	B
N. viridula (nymph)	-0.2548	-0.3149	0.2496	0.2106
N. viridula (adult)	-0.1354	-0.0333	0.7937**	0.5313*
Riptortus spp (nymph)	-0.0358	-0.0561	0.5164*	0.5560**
R. pedestris (adult)	0.0417	-0.0786	0.3134	0.3805
R? linearis (adult)	-0.1294	-0.1909	0.3243	0.1807

A - During the fortnight of observation

B - Succeeding fortnight of observation

* - Significant at 5 per cent level

** - Significant at 1 per cent level

4.5 BIOLOGY OF POD BUGS

4.5.1 Biology of *N. viridula*

Details on the biology and morphometrics of *N. viridula* are presented in Table 9.

Egg

Eggs were pale yellow in colour and barrel shaped. The diameter and height of the egg were 0.73 mm and 1.05 mm respectively. The egg mass was hexagon shaped (Plate 8). The eggs turned orange yellow in colour, 1.40 days after oviposition. Incubation period was 4.50 days. The day before hatching the eggs developed a characteristic deep orange colouration. The eggs (from a single egg mass) hatched almost simultaneously.

Nymph

The nymphs were slightly convex shaped and underwent five instars before adulthood (Plate 8). Antennae and rostrum were uniformly four segmented in all the five instars.

First instar nymph

The first instar nymphs were bright orange in colour with wavy red markings. It measured 1.66 $\pm$ 0.02 mm and 1.08 $\pm$ 0.02 mm in length and width respectively. Eyes were brown in colour. Antennae were glossy, pale brown coloured. Thoracic segments were bordered brown. Legs were glossy yellow in colour. Abdomen was orange brown in colour with a series of horizontal orange markings each bordered with a pair of white spots one on either sides laterally. First instar duration was 2.42 days.

Table 9 Biology and morphometrics of *Nezara viridula* (L.) on vegetable cowpea var. Sharika

Stage	*Duration (Days) (Mean ± SD)	**Morphometrics (mm) (Mean ± SD)	
		Diameter	Height
Egg	4.50 ± 0.00	0.73 ± 0.00	1.05 ± 0.00
		Length	Width
First instar nymph	2.42	1.66 ± 0.02	1.08 ± 0.02
Second instar nymph	3.41 ± 0.38	2.32 ± 0.02	1.84 ± 0.02
Third instar nymph	2.92 ± 0.23	5.30 ± 0.06	3.74 ± 0.04
Fourth instar nymph	3.75 ± 0.37	6.91 ± 0.11	5.48 ± 0.06
Fifth instar nymph	5.59 ± 0.33	11.60 ± 0.06	8.60 ± 0.49
Total nymphal period	18.09 ± 0.41		
Total life cycle	22.59 ± 0.41		
Adult male	32.00 ± 1.13	13.20 ± 0.40	7.00 ± 0.00
Adult female	50.70 ± 1.60	13.60 ± 0.49	7.00 ± 0.00
Oviposition period	0.34 ± 0.06		
Fecundity (Egg No.)	81.80 ± 17.76		

* - Mean of ten observations ** - Mean of five observations

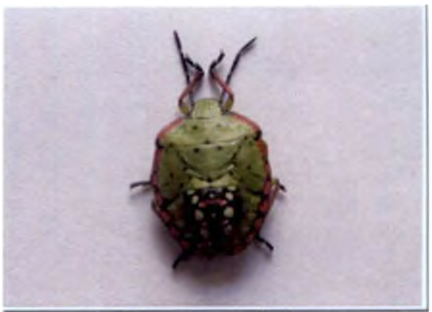
Eggs

First instar nymphs

Second instar nymph

Third instar nymph

Fourth instar nymph



Fifth instar nymph

Adult

Plate 8. Life stages of *N. viridula*

The nymphs clustered over the egg shells for 24 hours before they moved to feed on pods. Siblings from an egg mass moulted uniformly from the first to the second instar. These nymphs were gregarious. Most often, the first instar nymphs moulted before moving to feed on pods. First instar nymphs could not right themselves on falling upside down and never survived when confined on pods individually. Efforts made to segregate the first instar nymphs resulted in cent per cent mortality.

Second instar nymph

The second instar nymphs were blackish brown coloured measuring 2.32 $\pm$ 0.02 mm and 1.84 $\pm$ 0.02 mm in length and width respectively. Eyes and antennae were black in colour. Each of the thoracic segments had a pair of golden brown rectangular spots with black border on either sides laterally. Legs were black. Notum of abdomen presented a complex pattern of yellow and white spots of varying shapes. The second instar duration was 3.41 $\pm$ 0.38 days. The nymphs were gregarious feeders. The nymphs could right themselves on falling down from second instar onwards.

Third instar nymph

Third instar nymphs were blackish brown in colour, measuring 5.30 $\pm$ 0.06 mm and 3.74 $\pm$ 0.04 mm in length and width respectively. Eyes and antennae were black. The paired rectangular spots in the pro and meso thorax turned orange yellow during third instar. These spots appeared more like lateral extensions from thorax and were absent on the meta thorax. Notum of abdomen presented a complex pattern of yellow, white and black spots of varying shapes bordered by a definite pattern of white spots near edges of the abdomen. The third instar duration was 2.92 $\pm$ 0.23 days.

Fourth instar nymph

Fourth instar nymphs were blackish brown/green coloured, measuring 6.91 $\pm$ 0.11 mm and 5.48 $\pm$ 0.06 mm in length and width respectively. Eyes were black in colour. Antennal segments were coloured with varying shades of brown. The paired rectangular spots of pro and meso thorax turned deep yellow in colour with black border. These spots appeared more prominently like lateral extensions from the thorax. Legs-coxa, trochanter and femur were green in colour. Tibia was pink and the tarsal segments were black coloured. Notum of abdomen presented a complex pattern of white, rufous and yellow spots of varying shapes bordered by a definite pattern of white spots adjacent to the edges of the abdomen. The fourth instar duration was 3.75 $\pm$ 0.37 days.

Fifth instar nymph

Fifth instar nymphs were green in colour, measuring 11.60 $\pm$ 0.06 mm and 8.60 $\pm$ 0.49 mm in length and width respectively. Eyes were black coloured. Basal two segments of the antennae showed varying shades of brown and the terminal two segments were black coloured. The paired rectangular spots of pro and meso thorax turned rufous coloured with black border. Though these spots appeared like lateral extensions from the thorax they were comparatively smaller than those observed in fourth instar. Circular, triangular, linear, dotted black markings were seen in the notum of thorax. Legs were as described in the fourth instar except for the tarsal segments which were brown coloured. The notum of abdomen presented a complex pattern of white and rufous spots. The bordering spots near the edges of the abdomen were rufous coloured. Wing buds were prominently visible. The fifth instar duration was 5.59 $\pm$ 0.33 days. Occasionally, fifth instar nymphs were seen assisting the fourth instars while moulting. The fifth instar nymph was seen holding the fourth instar nymph from behind, with its front pair of legs, while the latter slowly relieved itself of the exuvium. This was a rare phenomena observed when siblings from an eggs mass were reared collectively.

Developmental period

The total nymphal period and the total life cycle was completed in 18.09 $\pm$ 0.41 days and 22.59 $\pm$ 0.41 days respectively.

Adult

The adult was a green coloured stink bug (Plate 8) with three white spots lying horizontally on the pronotum. Notum was bright green coloured while the sternum showed paler shade of green. Adult female measured 13.60 $\pm$ 0.49 mm, 7.00 mm and adult male measured 13.20 $\pm$ 0.40 mm, 7.00 mm in length and width respectively. Eyes were brown coloured. Antennae were five segemented with each of the segments, coloured in varying shades of brown and green. Rostrum was four segmented. . Legs were green in colour with brown tarsal segments. Adult male and female longevity was 32.00 $\pm$ 1.13 and 50.70 $\pm$ 1.60 days respectively.

Mating, oviposition and fecundity

Multiple matings were noticed. The bugs mated in an end to end position. The oviposition period observed was 0.34 $\pm$ 0.06 days. When the adult bugs in confinement were subjected to more than 12 hours of light exposure, the females never laid eggs even after several matings.

The adults died after four to five matings in such conditions. Egg laying occurred almost instantly on the same night when female bugs were confined in darkness for 12 hours which previously did not oviposit after multiple matings under light exposure. An adult female on an average laid 81.8 $\pm$ 17.76 eggs.

4.5.2 Biology of *P. rubrofasciatus*

Details on morphometrics and biology of *P. rubrofasciatus* on vegetable cowpea are presented in Table 10.

Egg

Eggs were pale greyish green coloured, barrel shaped with two dark green, horizontal bands, encircling the sides. The top most circular portion was glistening grey green in colour bordered by minute, fragile, white, pedicellate structures. The egg measured 0.72 mm and 0.86 mm in diameter and height respectively. The eggs were laid in paired row each with 6-23 eggs. The eggs were glued to each other compactly. The incubation period was 4.58 days. The day before hatching, the eggs turned orange brown in colour. The eggs from a single egg mass hatched almost simultaneously.

Nymph

Nymphs were slightly convex shaped and underwent five instars before adulthood (Plate 9). Head, thorax, legs were black coloured and eyes were brown. Antennae and rostrum were uniformly four segmented in all the five instars.

First instar nymph

The first instar nymphs measured 0.86 $\pm$ 0.01 mm and 0.83 $\pm$ 0.01 mm in length and width respectively. Antennae were black coloured. Abdomen was deep orange in colour. Notum of abdomen presented a series of irregularly rectangular shaped black spots lying horizontally parallel to each other bordered by a definite pattern of smaller rectangular spots near the edges of abdomen. The first instar duration lasted for 2.88 days. Siblings from an egg mass moulted uniformly from the first to the second instar.

Table 10. Biology and morphometrics of *Piezodorus rubrofasciatus* (Fab.) on vegetable cowpea var. Sharika

Stage	*Duration (Days) Mean ± SD	**Morphometrics (mm) Mean ± SD	
		Diameter	Height
Egg	4.58 ± 0.00	0.72 ± 0.00	0.86 ± 0.00
		Length	Width
First instar nymph	2.88 ± 0.00	0.86 ± 0.01	0.83 ± 0.01
Second instar nymph	3.20 ± 0.11	1.74 ± 0.02	1.59 ± 0.02
Third instar nymph	2.70 ± 0.09	3.27 ± 0.02	2.38 ± 0.02
Fourth instar nymph	2.63 ± 0.08	4.01 ± 0.10	2.94 ± 0.05
Fifth instar nymph	4.20 ± 0.13	7.62 ± 0.05	4.30 ± 0.03
Total nymphal period	15.60 ± 0.20		
Total life cycle	20.19 ± 0.20		
Adult male	21.50 ± 2.74	7.93 ± 0.05	4.62 ± 0.05
Adult female	29.80 ± 1.80	8.59 ± 0.04	5.07 ± 0.03
Oviposition period	9.90 ± 1.56		
Fecundity (Egg No.)	52.00 ± 8.77		

* - Mean of ten observations   ** - Mean of five observations

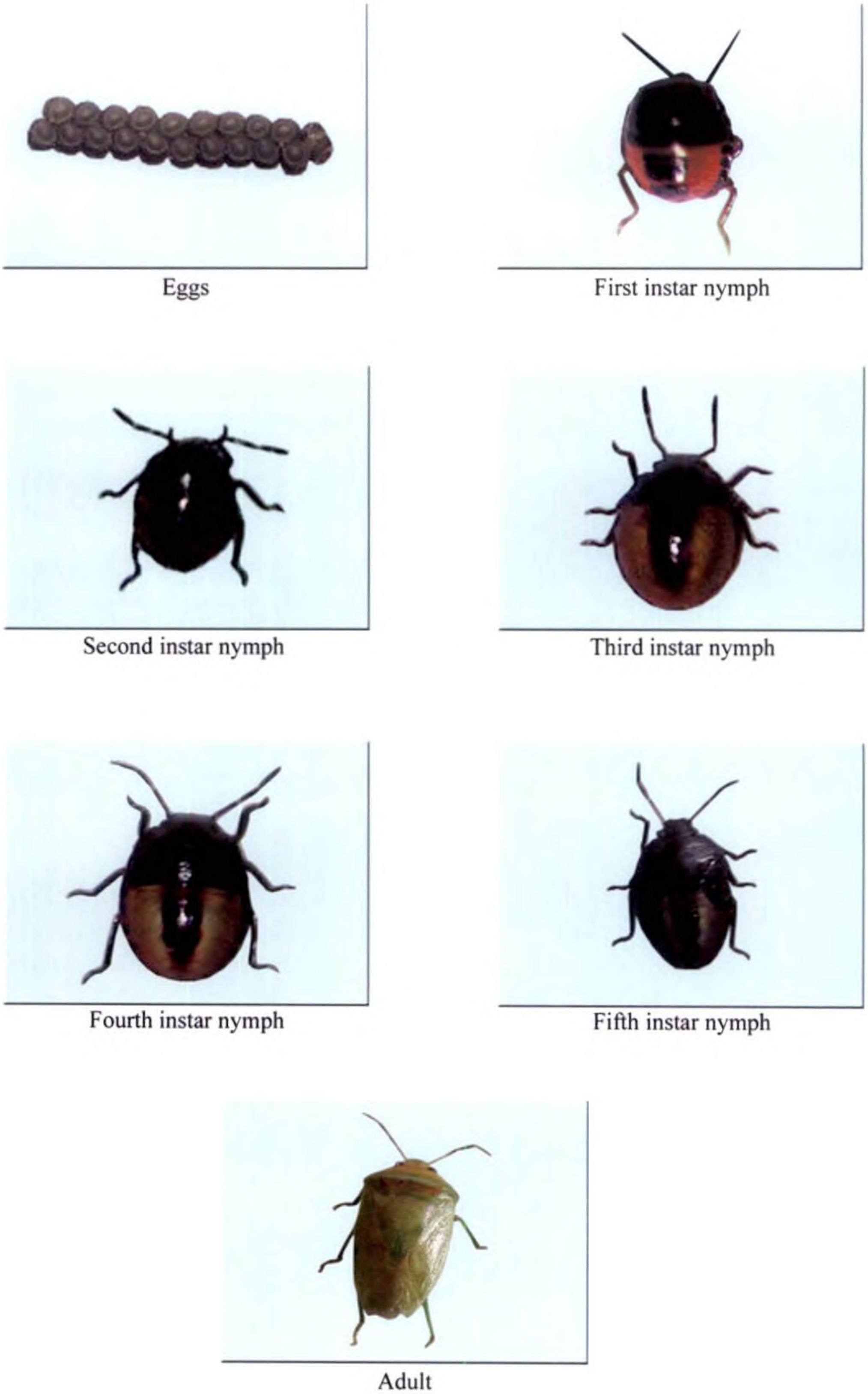


Plate 9. Life stages of *P. rubrofasciatus*

Second instar nymph

The second instar nymphs measured 1.74 ± 0.02 mm and 1.59 ± 0.02 mm in length and width respectively. Antennae were black coloured. Colour and markings of the abdomen was similar to that of first instar nymph. The second instar duration lasted for 3.20 ± 0.11 days.

Third instar nymph

The third instar nymphs measured 3.27 ± 0.02 mm and 2.38 ± 0.02 mm in length and width respectively. Antennae were black coloured. Abdomen was metallic yellow in colour. Notum of abdomen presented similar markings as observed in the previous instar except for blood red streaks between each one of the parallely placed, irregularly rectangular spots. A red background was seen around the bordering black spots near the edges of the abdomen. The third instar duration lasted for 2.70 ± 0.09 days.

Fourth instar nymph

The fourth instar nymph measured 4.01 ± 0.10 mm and 2.94 ± 0.05 mm in length and width respectively. It resembled the third instar in all morphological aspects except for general size increase and lateral broadening of thorax. The fourth instar duration was 2.63 ± 0.08 days.

Fifth instar nymph

The fifth instar nymph measured 7.62 ± 0.05 mm and 4.30 ± 0.03 mm respectively. Each of the antennal segments were coloured with varying shades of brown. Notum of thorax showed dirty white streaks. Wing buds were prominently visible. Abdomen was metallic yellow in colour with patches of rufous colouration. Markings on the notum of abdomen was identical to that of third and fourth instars. The fifth instar duration was 4.20 ± 0.13 days.

Developmental period

The total nymphal period and total life cycle was completed in 15.60 $\pm$ 0.20 and 20.19 $\pm$ 0.20 days respectively.

Adult

The adult was a pale green stink bug (Plate 9). There was a red or green band on the pronotum of adult females. Green band on the pronotum was characteristic of adult male. Eyes were brown coloured. Antennae were five segmented with each of the segments showing varying shades of green. Rostrum was four segmented. Legs were green coloured.

Adult female measured 8.59 $\pm$ 0.04 mm, 5.07 $\pm$ 0.03 mm, adult male measured 7.93 $\pm$ 0.05 mm, 4.62 $\pm$ 0.05 mm in length and width respectively. Adult male and female lived for 21.50 $\pm$ 2.74 and 29.80 $\pm$ 1.80 days respectively.

Mating, oviposition and fecundity

Multiple matings were observed. The bugs mated in an end to end position. The adult female laid 52.00 $\pm$ 8.77 eggs in an oviposition period of 9.90 $\pm$ 1.56 days. Mating and ovipostion occurred on alternate days.

4.5.3 Biology and morphometrics of *R*? *linearis*

Details on the biology and morphometrics of *R*? *linearis* on vegetable cowpea var. Sharika are presented in Table 11.

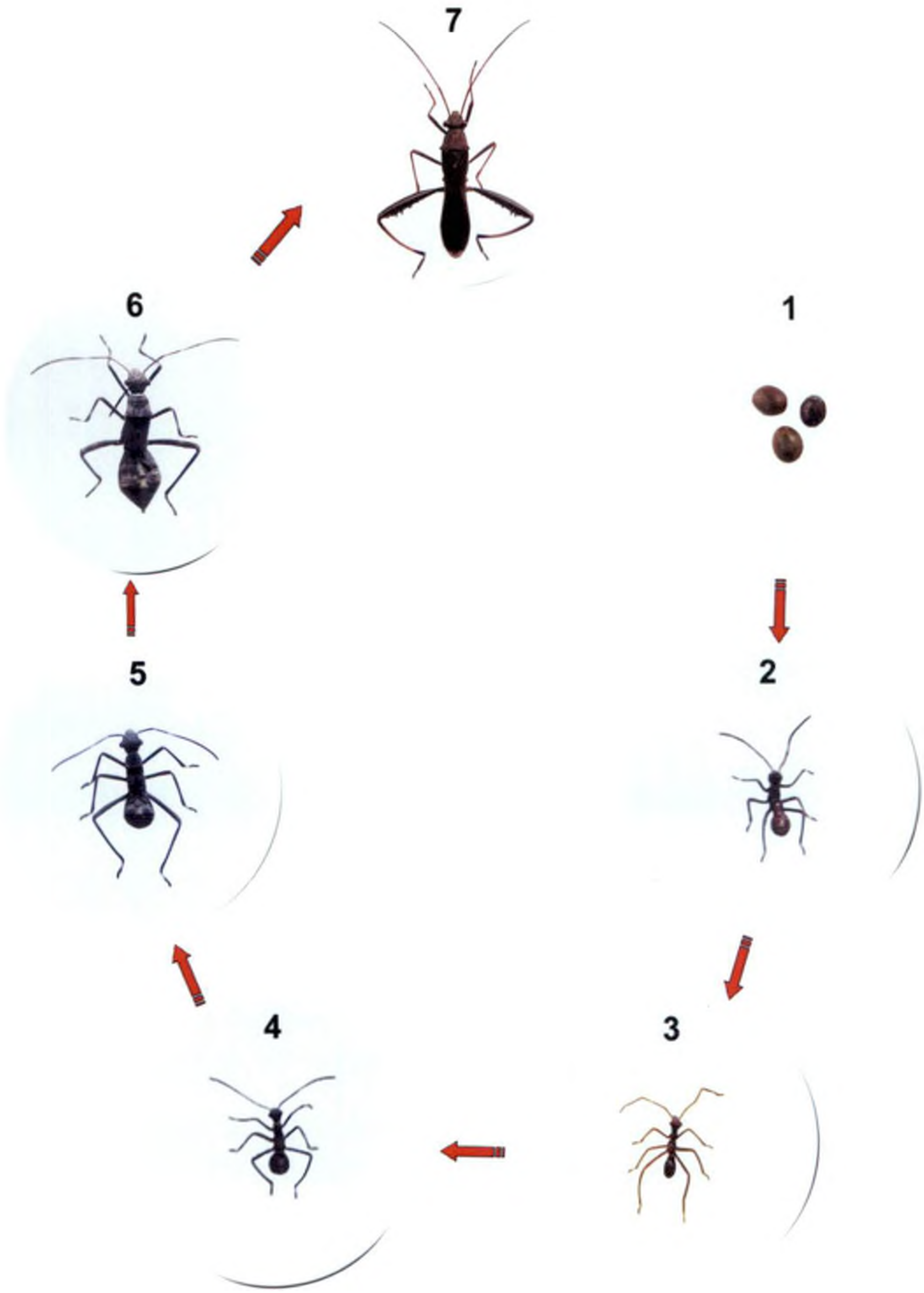
Egg

Eggs were subglobular in shape measuring 1.13 $\pm$ 0.03 mm, 1.08 $\pm$ 0.03 mm, 0.76 mm in long length diameter, short length diameter and height respectively. Eggs were dull green coloured when freshly laid and turned to

Table 11. Biology and morphometrics of *Riptortus? linearis* (Fab.) on vegetable cowpea var. Sharika

Stage	*Duration (Days) Mean ± SD	**Morphometrics (mm) Mean ± SD		
		Long length diameter	Short length diameter	Height
Egg	7.44 ± 0.01	1.13 ± 0.03	1.08 ± 0.03	0.76 ± 0.00
		Length	Width	
First instar nymph	1.69 ± 0.02	3.08 ± 0.12	0.9 ± 0.03	
Second instar nymph	3.03 ± 0.04	4.87 ± 0.00	1.48 ± 0.00	
Third instar nymph	2.62 ± 0.06	5.36 ± 0.04	1.48 ± 0.03	
Fourth instar nymph	3.42 ± 0.06	6.51 ± 0.03	2.20 ± 0.04	
Fifth instar nymph	3.84 ± 0.17	13.2 ± 0.04	4.07 ± 0.03	
Total nymphal period	14.61 ± 0.26			
Total life cycle	22.05 ± 0.25			
Adult male	21.10 ± 1.83	11.00 ± 0.04	2.29 ± 0.00	
Adult female	30.20 ± 0.57	10.20 ± 0.00	2.67 ± 0.03	
Oviposition period	11.10 ± 2.35			
Fecundity (Egg No.)	37.70 ± 8.86			

* - Mean of ten observations ** - Mean of five observations



1. Eggs 2. First instar nymph 3. Second instar nymph 4. Third instar nymph
5. Fourth instar nymph 6. Fifth instar nymph 7. Adult

Plate 10. Life stages of *R? linearis*

chocolate brown colour, two to four days after oviposition (Plate 10). Eggs were laid singly and were firmly glued to the substratum. The incubation period was 7.44 $\pm$ 0.01 days.

Nymph

R? linearis underwent five nymphal instars before adulthood (Plate 10). The nymphs closely resembled ants and started feeding on the pods on the day of hatch itself. Eyes were brown coloured. Antennae and rostrum were uniformly four segmented in all the nymphal instars. Legs were deep brown coloured. Tarsi was two segmented with the basal and distal segment, dull white and brown coloured respectively. Nymphs could survive even when confined individually in the first instar. However, gregarious feeding was observed when nymphs were reared collectively.

First instar nymph

The newly hatched first instar nymphs were bright red in colour with deep brown abdomen. The nymphs turned uniformly brown coloured 30-45 minutes after hatching. The colour change started 10 minutes after hatching. After five to six hours of feeding the abdomen turned shiny, golden brown coloured, conspicuously bulged and slightly curled away from head and thorax. The basal three segments of the antennae were glossy brown, whereas the terminal segment was deep brown, highly flattened and slightly ribbon shaped. A distinct, white, acute triangular projection was seen on the metanotum. The first instar nymph measured 3.08 $\pm$ 0.12 mm and 0.90 $\pm$ 0.03 mm in length and width respectively. The first instar duration extended for 1.69 $\pm$ 0.02 days.

Second instar nymph

Second instar nymphs were black coloured with greyish green coloured abdomen which was slightly curled upwards and away from the head and thorax.

Antennal segments showed varying shades of brown. Terminal segment was highly flattened, slightly ribbon shaped, tapering abruptly. The acute triangular projection on the metanotum turned black in colour and was more prominent than in the previous instar. The second instar nymph measured 4.87 mm and 1.48 mm in length and width respectively. The second instar duration extended for 3.03 $\pm$ 0.04 days.

Third instar nymph

Third instar nymphs were uniformly black coloured. Abdomen was slightly spindle shaped and less distinctly curled away from head and thorax. Antennae were deep brown coloured and the terminal segment was as described in the second instar nymph. Lateral pronotal spines started to develop in this instar. The acute triangular projection on the metanotum was black coloured and more prominent than that of the second instar. The third instar nymph measured 5.36 $\pm$ 0.04 mm and 1.48 $\pm$ 0.03 mm in length and width respectively. The third instar duration extended for 2.62 $\pm$ 0.06 days.

Fourth instar nymph

The fourth instar nymphs were uniformly black coloured. Abdomen was typically spindle shaped and was very slightly curled away from head and thorax. Antennae were as described in the third instar nymph. Lateral pronotal spines became more prominent and evidently visible.

The acute triangular projection on the metanotum was brown coloured and shorter than that of the previous instar. The fourth instar nymph measured 6.51 $\pm$ 0.03 mm and 2.20 $\pm$ 0.04 mm in length and width respectively. The fourth instar duration extended for 3.42 $\pm$ 0.06 days.

Fifth instar nymph

The fifth instar nymphs were shiny brown coloured with a definite pattern of brown black spots on the abdomen. Abdomen was typically spindle shaped. Antennae were brown coloured with the terminal segment flattened, tapering abruptly but not ribbon shaped. Lateral pronotal spines were more evident than in the fourth instar. Wing buds were prominently visible. The acute triangular projection on the metanotum was absent. The fifth instar nymph measured 13.2 $\pm$ 0.04 mm and 4.07 $\pm$ 0.03 mm in length and width respectively. The fifth instar duration extended for 3.84 $\pm$ 0.17 days.

Developmental period

The total nymphal period and the total life cycle was completed in 14.61 $\pm$ 0.26 and 22.05 $\pm$ 0.25 days respectively.

Adult

The adult was a slender, cinnamon brown alydid bug (Plate 10). Eyes were brown coloured. Antennae and rostrum were four segmented and brown coloured. Pronotum showed well developed lateral spines. Hind femora were laterally edged with a row of spines. Abdomen was broader in females than in males. In females, abdomen was bluntly ending whereas in males it was gradually tapering. The sternum of abdomen showed a spindle shaped black center with a shining yellow border. This yellow border was narrower and less conspicuous in females than in males. Adult female measured 10.2 mm, 2.67 $\pm$ 0.03 mm and adult male measured 11.00 $\pm$ 0.04 mm, 2.29 mm in length and width respectively. Male and female longevity was 21.10 $\pm$ 1.83 and 30.20 $\pm$ 0.57 days respectively.

Mating, oviposition period and fecundity

Multiple matings were noticed with a mating duration of 1-1.5 hours. The male bug mounted over the female bug and mated in an end to end position. As mating progressed, the abdomen of female became conspicuously swollen. Towards egg laying the lateral edges of the abdomen developed a characteristic pink colouration. An adult female on an average laid 37.70 ± 8.86 eggs in an oviposition period of 11.10 ± 2.35 days.

4.5.4 Biology and morphometrics of *R. pedestris*

Details on the biology of *R. pedestris* on vegetable cowpea var. Sharika, grain cowpea var. Pusa komal and coffee senna weed, *C. occidentalis* and the morphometrics are presented in Table 12 and 13 respectively. The biology of the bug in a weed host is reported for the first time in India.

Egg

Eggs were sub globular in shape (Plate 11) measuring 1.37 ± 0.01 mm, 1.13 ± 0.01 mm and 0.63 mm in long length diameter, short length diameter and height respectively. The colour change and characteristic features of the egg were as described in *R? linearis.* The incubation period was 7.88, 7.55, 8.15 days in vegetable cowpea, grain cowpea and coffee senna weed respectively.

Nymph

R. pedestris underwent five nymphal instars before adulthood. Description of the nymph is as given in *R? linearis.*

First instar nymph

The first instar nymph measured 3.52 ± 0.21 mm and 1.06 ± 0.06 mm in length and width respectively. The colour change and morphological features were as described for *R? linearis*, except for the terminal segment of the antenna

Table 12. Biology of *Riptortus pedestris* Fab.

Stage	Duration (days)			
	Vegetable cowpea var. Sharika	Grain cowpea var. Pusa komal	Coffee senna weed	CD (0.05)
Egg	7.88	7.55	8.15	0.244
First instar nymph	1.58	2.42	1.69	0.072
Second instar nymph	2.77	3.38	3.03	0.072
Third instar nymph	2.41	2.92	3.13	0.1777
Fourth instar nymph	2.68	3.14	2.28	0.052
Fifth instar nymph	4.08	4.83	5.72	0.094
Total nymphal period	13.52	16.69	15.84	0.245
Total life cycle	21.40	24.24	24.00	0.37
Adult male	53.60	54.30	36.40	3.615
Adult female	61.40	59.70	44.00	4.681
Oviposition period	9.20	8.70	6.10	1.231
Fecundity (Egg No.)	94.40	76.90	27.30	7.849

Mean of ten observations

Table 13. Morphometrics of *Riptortus pedestris* Fab.

<table>
<tr><th rowspan="2">Stage</th><th colspan="3">Morphometrics (mm)
Mean ± SD</th></tr>
<tr><th>Long length diameter</th><th>Short length diameter</th><th>Height</th></tr>
<tr><td>Egg</td><td>1.37 ± 0.01</td><td>1.13 ± 0.01</td><td>0.63 ± 0.00</td></tr>
<tr><td>Nymph</td><td>Length</td><td colspan="2">Width</td></tr>
<tr><td>First instar nymph</td><td>3.52 ± 0.21</td><td colspan="2">1.06 ± 0.06</td></tr>
<tr><td>Second instar nymph</td><td>4.88 ± 0.09</td><td colspan="2">1.37 ± 0.06</td></tr>
<tr><td>Third instar nymph</td><td>6.41 ± 0.03</td><td colspan="2">2.39 ± 0.07</td></tr>
<tr><td>Fourth instar nymph</td><td>8.70 ± 0.40</td><td colspan="2">2.50 ± 0.04</td></tr>
<tr><td>Fifth instar nymph</td><td>13.80 ± 0.40</td><td colspan="2">3.59 ± 0.05</td></tr>
<tr><td>Adult Male</td><td>16.60 ± 0.49</td><td colspan="2">3.57 ± 0.06</td></tr>
<tr><td>Adult Female</td><td>15.80 ± 0.40</td><td colspan="2">3.97 ± 0.12</td></tr>
</table>

Mean of five observations

which was not ribbon shaped but slightly sickle shaped and tapering bluntly. The first instar duration was 1.58, 2.42, 1.69 days in vegetable cowpea, grain cowpea and coffee senna weed respectively.

Second instar nymph

The second instar nymphs were brick red in colour with olive green coloured abdomen measuring 4.88 $\pm$ 0.09 mm and 1.37 $\pm$ 0.06 mm in length and width respectively. Terminal segment of the antenna was as described in the first instar. The acute triangular projection on the metanotum turned brown in colour and was more prominent than in the previous instar. Other morphological features were as in *R? linearis.*

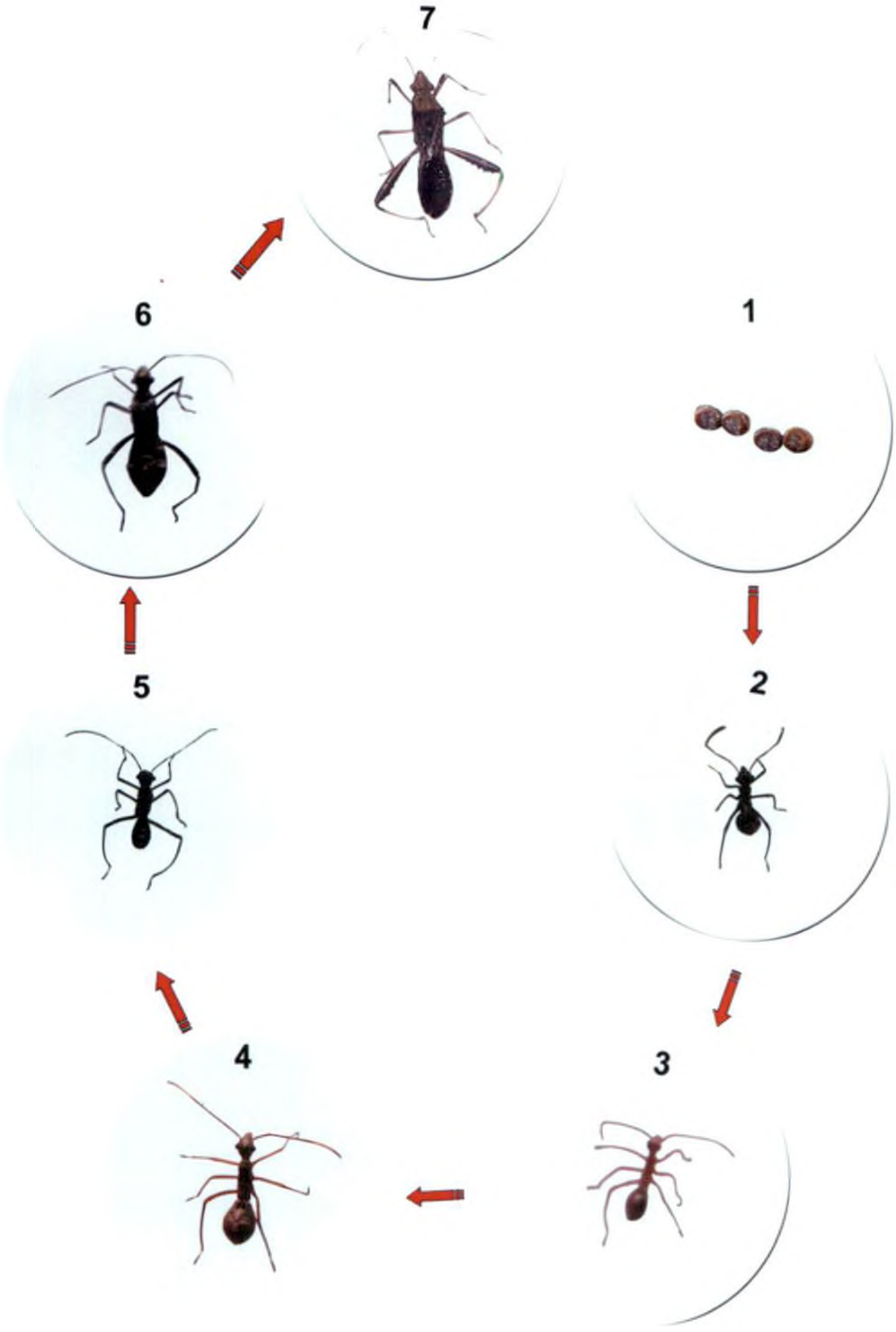
The second instar duration was 2.77, 3.38, 3.03 days in vegetable cowpea, grain cowpea and coffee senna weed respectively.

Third instar nymph

The third instar nymphs were brick red in colour with only the sternum of abdomen showing an olive green shade. Third instars measured 6.41 $\pm$ 0.03 mm and 2.39 $\pm$ 0.07 mm in length and width respectively. The acute triangular projection on the metanotum turned orange in colour and was tipped black. Other morphological features were as described in *R? linearis* except for the terminal segment of the antenna which was slightly sickle shaped and tapering abruptly. The third instar duration was 2.41, 2.92, 3.13 days on vegetable cowpea, grain cowpea and coffee senna weed respectively.

Fourth instar nymph

The fourth instar nymphs were blackish brown coloured measuring 8.70 $\pm$ 0.40 mm and 2.50 $\pm$ 0.04 mm in length and width respectively. The acute triangular projection on the metanotum turned black and was shorter than in the



1. Eggs 2. First instar nymph 3. Second instar nymph 4. Third instar nymph
5. Fourth instar nymph 6. Fifth instar nymph 7. Adult

Plate 11. Life stages of *R. pedestris*

previous instar. The other morphological features were as described in *R? linearis* except for the terminal segment of the antenna which was slightly sickle shaped and tapering abruptly. The fourth instar duration was 2.68, 3.14, 2.28 days in vegetable cowpea, grain cowpea and coffee senna weed respectively.

Fifth instar nymph

The colour and morphological features of the fifth instar nymph were as described in *R? linearis*, except for the terminal segment of the antenna which was only slightly flattened, sickle shaped and tapering abruptly. The fifth instar nymph measured 13.80 $\pm$ 0.40 mm and 3.59 $\pm$ 0.05 mm in length and width respectively. The fifth instar duration was 4.08, 4.83, 5.72 days on vegetable cowpea, grain cowpea and coffee senna weed respectively.

Developmental period

The total nymphal period and the total developmental period were completed in 13.52, 16.69, 15.84 days and 21.40, 24.24, 24.00 days in vegetable cowpea, grain cowpea and coffee senna weed respectively.

Adult

The adult was a dark brown alydid bug (Plate 11). Eyes, antennae, rostrum were as described in *R? linearis.* Lateral spines of pronotum as well as the spines on the lateral edges of the hind femora were sharper, tougher and well developed than in *R? linearis* adult. Abdomen of female was broader than that of the male, bluntly ending, dull white or yellow coloured with a prominent black horizontal band on the sternum. Adult female measured 15.80 $\pm$ 0.40 mm and 3.97 $\pm$ 0.12 mm in length and width respectively. Abdomen of male was gradually tapering, often yellow coloured, rarely dull white with a series of 'U' shaped black markings on the sternum.

Adult male measured 16.60 $\pm$ 0.49 mm and 3.57 $\pm$ 0.06 mm in length and width respectively. The male and female longevity were 53.60, 54.30, 36.40 days and 61.40, 59.70, 44.00 days on vegetable cowpea, grain cowpea and coffee senna weed respectively.

Mating, oviposition period and fecundity

Mating and associated morphological changes in female were as described in *R? linearis* except that the pink colouration on the lateral edges of the abdomen towards oviposition was of a lighter shade and developed occasionally. The oviposition period and fecundity were 9.20, 8.70, 6.10 days and 94.40, 76.90, 27.30 on vegetable cowpea, grain cowpea, coffee senna weed respectively.

4.6 MANAGEMENT OF POD BUGS

4.6.1 Bioassay for assessing the effect of botanical / chemical insecticides / entomopathogens on *R. pedestris*

4.6.1.1 Botanical insecticides

The percentage mortality of the third instar nymphs of *R. pedestris* exposed to dry film of botanical insecticides during different periods of observation is presented in Table 14.

Twelve hours after the release of the nymphs, Amrutneem 5ml l^{-1} proved significantly superior to Neem Azal 2ml l^{-1} and Nimbecidine 2 ml l^{-1} with 29.71 per cent mortality. Neem Azal 2ml l^{-1} and Nimbecidine 2ml l^{-1} recorded no mortality.

After twenty four hours of exposure to the dry film, both Neem Azal 2 ml l^{-1} and Nimbecidine 2ml l^{-1} recorded similar mortality percentages (0.71). Amrutneem 5ml l^{-1} recorded the highest mortality level of 36.57 per cent.

Table 14. Effect of botanical insecticides on third instar nymphs of *Riptortus pedestris* Fab. upon exposure to dry film

Treatment	Mean percentage mortality at different intervals after treatment						
	12 Hrs	24 Hrs	36 Hrs	48 Hrs	3 days	5 days	7 days
Amrutreem 5ml l^{-1}	29.71 (33.02)	36.57 (37.19)	43.22 (41.09)	60.13 (50.82)	60.13 (50.82)	60.13 (50.82)	60.13 (50.82)
Neem Azal 2ml l^{-1}	0.00 (0.00)	0.71 (4.82)	16.67 (24.09)	19.67 (26.32)	19.67 (26.32)	19.67 (26.32)	19.67 (26.32)
Nimbecidine 2ml l^{-1}	0.00 (0.00)	0.71 (4.82)	22.86 (28.55)	39.87 (39.14)	39.87 (39.14)	39.87 (39.14)	39.87 (39.14)
CD (0.05)	3.346	10.622	5.438	6.062	6.062	6.062	6.062

Figures in parentheses are angular values

Amrutneem 5 ml l^{-1} (43.22) proved superior in the observation made after 36 hours of exposure. Neem Azal 2 ml l^{-1} (16.67) and Nimbecidine 2 ml l^{-1} (22.86) were on par with each other.

The toxic effect of Amrutneem 5ml l^{-1} (60.13) continued upto 48 hours after the release of nymphs. Nimbecidine 2ml l^{-1} was the next best treatment causing 39.87 per cent mortality. Neem Azal 2 ml l^{-1} (19.67) recorded the lowest morality. No further mortality was observed in all the three treatments during observations made in the third, fifth and seventh day after exposure to dry film.

4.6.1.2 Chemical insecticides

The percentage mortality of the third instar nymphs of *R. pedestris* during different periods of observation after exposure to dry film of chemical insecticides is presented in Table 15.

No significant difference in the mortality of nymphs was noted between any of the treatments after 30 minutes of exposure to the dry film. Sixty minutes after the release of nymphs, fenvalerate 0.03 per cent recorded the maximum mortality level (53.50) followed by malathion 0.05 per cent (43.16). Imidacloprid 0.005 per cent, lambda cyhalothrin 0.002 per cent, chlorpyrifos 0.03 per cent, dimethoate 0.05 per cent were all on par with each other.

After 90 minutes of exposure to the dry film, malathion 0.05 per cent proved significantly superior to all other treatments recording cent per cent mortality. The next highest mortality percentage (88.40) was observed in dimethoate 0.05 per cent which was on par with fenvalerate 0.03 per cent (84.28). The efficacy of all other treatments was statistically on par with each other.

Fenvalerate 0.03 per cent and malathion 0.05 per cent recorded the highest mortality (100.00) 120 minutes after the release of nymphs. However the toxic

Table 15. Effect of chemical insecticides on third instar nymphs of *Riptortus pedestris* Fab. upon exposure to dry film

Treatment	Mean percentage mortality at different intervals after treatment				
	30 min	60 min	90 min	120 min	150 min
Imidacloprid 0.005%	4.53 (12.29)	19.31 (26.06)	43.16 (41.05)	86.99 (68.83)	100.00 (90.00)
Fenvalerate 0.03%	0.00 (0.00)	53.50 (46.99)	84.28 (66.61)	100.00 (90.00)	100.00 (90.00
Lambda cyhalothrin 0.002%	0.00 (0.00)	26.52 (30.98)	63.90 (53.05)	76.82 (61.20)	100.00 (90.00)
Chlorpyrifos 0.03%	1.15 (6.14)	26.20 (30.77)	43.16 (41.05)	86.06 (68.05)	100.00 (90.00)
Dimethoate 0.05%	1.15 (6.14)	33.26 (35.20)	88.40 (70.06)	96.33 (78.92)	100.00 (90.00)
Malathion 0.05%	0.00 (0.00)	43.16 (41.05)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
CD (0.05)	-	10.70	16.61	18.80	-

Figures in parentheses are angular values effect of dimethoate 0.05 per cent (96.33), was statistically on par with both the treatments. Imidacloprid 0.005 per cent (86.99), lambda cyhalothrin 0.002 per cent (76.82) and chlorpyrifos 0.03 per cent (86.06) showed toxic effects which was statistically on par with each other. All the treatments recorded cent per cent mortality and none was significantly superior, 150 minutes after the release of nymphs.

4.6.1.3 Entomopathogens

The spore suspensions of *Beauveria bassiana* @ 2.5 x 10^7 spores ml^{-1} and *Rhizopus oryzae* @ 7 x 10^6 spores $ml^{-1}$and caused mortality levels of 0.00 to 16.67 per cent only, when sprayed on *R. pedestris* nymphs. In the infected insects white mycelial growth was produced. In *R. oryzae* infection, mycelial growth later turned fluffy. The talc based suspension of *Pseudomonas fluorescens* P.F.I did not cause any mortality. Further no pathological changes were noticed.

4.6.2 Field experiment

4.6.2.1 Effect of botanical and chemical insecticides on the adult population of *R. pedestris*

The population of adult *R. pedestris* at different intervals after application of the treatments is presented in Table 16.

After first spraying

One day after spraying, all the treatments suppressed the population of adult *R. pedestris* significantly when compared to control (5.48). Except Neem Azal 2 ml l^{-1} and chlorpyrifos 0.03 per cent all the other treatments were on par.

Of all the treatments evaluated, lambda cyhalothrin 0.002 per cent recorded the least count (0.00) of the pest followed by fenvalerate 0.03 per cent (0.01),

Table 16. Effect of insecticides on the adult population of *Riptortus pedestris* Fab. in the field experiment

Treatments	Mean number per plant									
	Days after first spray					Days after second spray				
	1	3	5	7	15	1	3	5	7	15
Amrutneem 5ml l^{-1}	0.04 (1.02)	1.41 (1.55)	0.69 (1.30)	0.29 (1.14)	3.34 (2.08)	0.44 (1.20)	1.50 (1.58)	1.29 (1.51)	1.34 (1.53)	4.89 (2.43)
Neem Azal 2ml l^{-1}	0.92 (1.39)	1.15 (1.47)	2.04 (1.74)	0.29 (1.14)	3.66 (2.16)	0.77 (1.33)	1.80 (1.67)	2.29 (1.81)	2.69 (1.92)	7.20 (2.86)
Nimbecidine 2ml l^{-1}	0.31 (1.15)	0.66 (1.29)	0.98 (1.41)	0.29 (1.14)	2.75 (1.94)	0.00 (1.00)	1.94 (1.72)	2.00 (1.73)	1.94 (1.72)	6.22 (2.69)
Imidacloprid 0.005%	0.60 (1.27)	0.12 (1.06)	1.49 (1.58)	1.65 (1.63)	3.10 (2.02)	0.27 (1.13)	0.31 (1.15)	1.32 (1.52)	1.64 (1.62)	2.65 (1.91)
Fenvalerate 0.03%	0.01 (1.01)	0.00 (1.00)	0.04 (1.02)	0.00 (1.00)	1.79 (1.67)	0.00 (1.00)	0.43 (1.20)	0.02 (1.01)	0.00 (1.00)	2.93 (1.98)
Lambda cyhalothrin 0.002%	0.00 (1.00)	0.05 (1.02)	0.00 (1.00)	0.63 (1.28)	1.74 (1.66)	0.00 (1.00)	0.16 (1.08)	0.03 (1.01)	0.00 (1.00)	2.33 (1.82)
Chlorpyrifos 0.03%	1.01 (1.42)	0.85 (1.36)	0.02 (1.01)	0.91 (1.38)	2.22 (1.79)	0.51 (1.23)	1.42 (1.56)	0.31 (1.14)	1.19 (1.48)	3.46 (2.11)
Dimethoate 0.05%	0.01 (1.00)	0.00 (1.00)	0.02 (1.01)	0.00 (1.00)	1.69 (1.64)	0.66 (1.29)	0.46 (1.21)	0.95 (1.40)	0.26 (1.12)	2.59 (1.89)
Malathion 0.05%	0.01 (1.01)	0.00 (1.00)	0.33 (1.15)	0.91 (1.38)	3.11 (2.03)	0.04 (1.02)	0.26 (1.12)	0.99 (1.41)	1.17 (1.47)	2.81 (1.95)
Control	5.48 (2.55)	7.00 (2.83)	5.09 (2.47)	6.68 (2.77)	7.57 (2.93)	8.13 (3.02)	5.84 (2.61)	5.83 (2.61)	7.52 (2.92)	7.06 (2.84)
CD (0.05)	0.30	0.582	0.429	0.424	-	0.331	0.411	0.334	0.465	-

Figures in parentheses are $\sqrt{x+1}$ values

dimethoate 0.05 per cent (0.01) and malathion 0.05 per cent (0.01). Chlorpyrifos 0.03 per cent treated plants recorded the maximum count of *R. pedestris* (1.01). Among the botanicals, Amrutneem 5 ml l^{-1} (0.04) was superior to Neem Azal 2 ml l^{-1} (0.92).

On the third day after spraying, there was no incidence of *R. pedestris* adults in the plants treated with fenvalerate 0.03 per cent, dimethoate 0.05 per cent and malathion 0.05 per cent. Imidacloprid 0.005 per cent (0.12) was on par with lambda cyhalothrin 0.002 per cent (0.05). Among the chemical treatments, chlorpyrifos 0.03 per cent treated plants recorded the highest count of *R. pedestris* adults (0.85). However all the treatments were on par and significantly superior to control (7.00) in reducing the pest population. Amrutneem 5ml l^{-1} (1.41) recorded the maximum population of *R. pedestris* adults among the treatments and it was followed by Neem Azal 2ml l^{-1} (1.15). Nimbecidine 2ml l^{-1} recorded the lowest population of *R. pedestris* adults (0.66) among the botanicals.

On the fifth day after spraying, Neem Azal 2ml l^{-1} treated plants recorded the maximum number of *R. pedestris* adults (2.04) followed by imidacloprid 0.005 per cent treated plants (1.49). Amrutneem 5ml l^{-1} (0.69), Nimbecidine 2ml l^{-1} (0.98) and all the other chemicals tested except imidacloprid 0.005 per cent (1.49) were statistically similar to each other in reducing the pest count. Population reduction of *R. pedestris* adults in fenvalerate 0.03 per cent, lambda cyhalothrin 0.002 per cent and dimethoate 0.05 per cent treated plants followed the similar trend as observed on the third day after spraying with population counts of 0.04, 0.00, 0.02 respectively. Chlorpyrifos 0.03 per cent (0.02) efficiently suppressed the population whereas malathion 0.05 per cent treated plants showed increase in population (0.33) than on the third day after spraying.

On the seventh day after spraying, in all the botanical insecticide treated plants, similar counts of *R. pedestris* adults (0.29) was observed which was significantly superior over control in reducing the pest population and was on par with other chemicals except imidacloprid 0.005 per cent (1.65). Among the chemical insecticides, fenvalerate 0.03 per cent and dimethoate 0.05 per cent recorded no population of the pest but were stastistically on par with lambda cyhalothrin 0.002 per cent (0.63), chlorpyrifos 0.03 per cent (0.91) and malathion 0.05 per cent (0.91). Imidacloprid 0.005 per cent recorded the maximum population of *R. pedestris* (1.65) and was significantly inferior fo fenvalerate 0.03 per cent and dimethoate 0.05 per cent.

On the fifteenth day after spraying none of the treatments were superior to each other in reducing the pest population.

After second spraying

On the first day after spraying, all the treatments were significantly superior to control (8.13) in reducing the population of *R. pedestris* adults. Among the treatments, Neem Azal 2ml l^{-1} treated plants harboured the maximum number of *R. pedestris* (0.77) followed by dimethoate 0.05 per cent (0.06) and chlorpyrifos 0.03 per cent (0.51). Neem Azal 2 ml l^{-1} was on par with Amrutneem 5 ml l^{-1} (0.44).

Nimbecidine 2ml l^{-1}, fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent recorded no population of the pest. The toxic effect of malathion 0.05 per cent (0.04) followed a similar trend as that of first spray. Nimbecidine 2 ml l^{-1} was on par with all chemical treatments.

On the third day after spraying also, all the treatments were efficient in suppressing the population of *R. pedestris* adults when compared to the control (5.84). Neem Azal 2ml l^{-1} (1.80) and Nimbecidine 2ml l^{-1} (1.94) almost had a similar effect in controlling the pest as in the first spraying. However all the three botanical insecticides were on par with each other. Among the chemical treatments, chlorpyrifos 0.03 per cent (1.42) recorded the maximum population of *R. pedestris* adults followed by dimethoate 0.05 per cent (0.46), fenvalerate 0.03

per cent (0.43), imidacloprid 0.005 per cent (0.31) and malathion 0.05 per cent (0.26). Lambda cyhalothrin 0.002 per cent (0.16) recorded the lowest count of the pest. Chlorpyrifos 0.03 per cent was significantly inferior to lambda cyhalothrin 0.002 per cent.

The efficacy of all the treatments were indicated in the fifth day after spraying also. The population of *R. pedestris* adults was maximum in Neem Azal 2ml l^{-1} treated plants (2.29). However, a similar trend was observed regarding the statistical effect of the botanical insecticides as observed in the first and third day after spraying but were significantly inferior to fenvalerate 0.03 per cent (0.02), lambda cyhalothrin 0.002 per cent (0.03) and chlorpyrifos 0.03 per cent (0.31). Dimethoate 0.05 per cent (0.95) and malathion 0.05 per cent (0.99) showed almost similar effects in reducing the pest population.

On the seventh day after spraying, again a similar trend was followed in the botanical insecticide treatments as in the fifth day after spraying. Amrutneem 5ml l^{-1}, (1.34) harboured the least count of *R. pedestris* adults among the botanicals followed by Nimbecidine 2ml l^{-1} (1.94) and Neem Azal 2ml l^{-1} (2.69). All the treatments were significantly effective in suppressing the pest population when compared to the control (7.52). The toxicity of fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent was evident and highly superior to all other treatments applied except dimethoate 0.05 per cent (0.26) which was on par. Imidacloprid 0.005 per cent (1.64) recorded the maximum number of *R. pedestris* adults among the chemical insecticides followed by chlorpyrifos 0.05 per cent (1.19). Malathion 0.05 per cent (1.17) was on par with all the botanical insecticides.

On the fifteenth day after spraying, none of the treatments differed significantly in controlling the pest.

4.6.2.2 Effect of botanical and chemical insecticides on the nymphal population of *Riptortus* spp.

The population of *Riptortus* spp nymphs at different intervals after application of treatments is given in Table 17.

After first spraying

On the first day after spraying there was no incidence of *Riptortus* spp. nymphs except for Nimbecidine 2ml l^{-1} (0.02), fenvalerate 0.03 per cent (0.01) and dimethoate 0.05 per cent (0.01). However, all the treatments were superior to control (5.65) and on par with each other in reducing the nymphal population of the pest.

On the third day after spraying, similar trend was followed in the toxic effect of fenvalerate 0.03 per cent, lambda cyhalothrin 0.002 per cent and malathion 0.05 per cent. The population of the nymphs shot up in botanical insecticide treatments with Neem Azal 2ml l^{-1} hosting the maximum number of nymphs (3.72) followed by Amrutneem 5ml l^{-1} (2.64) and Nimbecidine 2ml l^{-1} (0.80). Amrutneem 5ml l^{-1} was on par with Neem Azal 2ml l^{-1} and Nimbecidine 2ml l^{-1}. Among the chemical insecticide treatments, chlorpyrifos 0.03 per cent (0.75) harboured the maximum count of nymphs but the toxic effect was on par with all other chemicals.

On the fifth day after spraying, all the treatments were significantly superior when compared to control (8.35). The toxic effect of fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent was strongly pronounced in the fifth day after spraying also. Imidacloprid 0.005 per cent (2.02) was observed to harbour the highest count of nymphs followed by chlorpyrifos 0.03 per cent (1.91). The toxic effect of dimethoate 0.05 per cent (0.00) was on par with malathion 0.05 per

Table 17. Effect of insecticides on the population of nymphs of *Riptortus* spp. in the field experiment

Treatments	Mean number per plant									
	Days after first spray					Days after second spray				
	1	3	5	7	15	1	3	5	7	15
Amrutneem 5ml l^{-1}	0.00 (1.00)	2.64 (1.91)	0.31 (1.15)	0.00 (1.00)	9.60 (3.26)	1.33 (1.53)	0.85 (1.36)	1.79 (1.67)	2.80 (1.95)	12.91 (3.73)
Neem Azal 2ml l^{-1}	0.00 (1.00)	3.72 (2.17)	1.81 (1.68)	0.73 (1.31)	14.86 (3.98)	3.41 (2.10)	3.46 (2.11)	5.23 (2.50	6.93 (2.82)	14.44 (3.93)
Nimbecidine 2ml l^{-1}	0.02 (1.01)	0.80 (1.34)	0.20 (1.09)	0.82 (1.04)	13.84 (3.85)	0.68 (1.29)	3.26 (2.06)	1.16 (1.47)	1.82 (1.68)	12.22 (3.64)
Imidacloprid 0.005%	0.00 (1.00)	0.03 (1.02)	2.02 (1.74)	0.00 (1.00)	3.49 (2.12)	0.00 (1.00)	0.19 (1.09)	0.75 (1.32)	0.99 (1.41)	3.07 (2.02)
Fenvalerate 0.03%	0.01 (1.00)	0.00 (1.00)	0.00 (1.00)	0.60 (1.26)	3.63 (2.15)	0.00 (1.00)	0.18 (1.09)	0.40 (1.18)	0.35 (1.16)	5.75 (2.60)
Lambda cyhalothrin 0.002%	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.89 (2.43)	0.00 (1.00)	0.12 (1.06)	0.26 (1.12)	0.24 (1.11)	5.04 (2.46)
Chlorpyrifos 0.03%	0.00 (1.00)	0.75 (1.32)	1.91 (1.71)	5.69 (2.59)	6.06 (2.66)	0.00 (1.00)	3.10 (2.02)	1.11 (1.45)	1.18 (1.48)	5.61 (2.57)
Dimethoate 0.05%	0.01 (1.00)	0.23 (1.11)	0.00 (1.00)	4.37 (2.32)	4.02 (2.24)	0.00 (1.00)	0.75 (1.32)	1.07 (1.44)	0.65 (1.29)	3.79 (2.19)
Malathion 0.05%	0.00 (1.00)	0.00 (1.00)	0.27 (1.13)	0.94 (1.39)	10.02 (3.32)	0.12 (1.01)	0.00 (1.00)	1.15 (1.47)	1.02 (1.42)	8.57 (3.09)
Control	5.65 (2.58)	7.07 (2.84)	8.35 (3.06)	9.27 (3.20)	18.61 (4.43)	17.57 (4.31)	14.57 (3.94)	13.43 (3.80)	16.81 (4.22)	15.76 (4.09)
CD (0.05)	0.06	0.718	0.659	0.524	0.575	0.335	0.704	0.617	0.922	-

Figures in parentheses are $\sqrt{x+1}$ values

cent (0.27), Nimbecidine 2ml l^{-1} (0.20), Amrutneem 5ml l^{-1} (0.31), fenvalerate 0.03 per cent (0.00) and lambda cyhalothrin 0.002 per cent (0.00).

On the seventh day after spraying, Amrutneem 5ml l^{-1}, imidacloprid 0.005 per cent and lambda cyhalothrin 0.002 per cent recorded no *Riptortus* spp. nymphs. Neem Azal 2ml l^{-1} (0.73) and Nimbecidine 2ml l^{-1} (0.82) showed statistically similar effects on the population reduction of nymphs. Chlorpyrifos 0.03 per cent (5.69) harboured the maximum number of nymphs followed by dimethoate 0.05 per cent (4.37). Fenvalerate 0.03 per cent (0.60) and malathion 0.05 per cent (0.94) were on par with each other. However, all the treatments were significantly superior to the control (9.27) and showed statistically similar effects except chlorpyrifos 0.03 per cent and dimethoate 0.05 per cent.

On the fifteenth day after spraying though all the treatments were superior to control (18.61) in causing population reduction of the nymphs, high levels of population was observed in botanical insecticide treatments with a mean population of 9.60, 14.86, 13.84 in Amrutneem 5 ml l^{-1}, Neem Azal 2 ml l^{-1} and Nimbecidine 2 ml l^{-1} treatments respectively and also in malathion 0.05 per cent (10.02) treated plants. Imidacloprid 0.005 per cent (3.49) fenvalerate 0.03 per cent (3.63) and lambda cyhalothrin 0.002 per cent (4.89), chlorpyrifos 0.03 per cent (6.06) and dimethoate 0.05 per cent (4.02) showed statistically similar effects in suppressing the nymphal population of *Riptortus* spp.

After second spraying

All the treatments applied gave significantly superior effects on the population reduction of *Riptortus* spp. nymphs when compared to the control (17.57). Amrutneem 5ml l^{-1} (1.33) and Nimbecidine 2ml l^{-1} (0.68) were significantly superior to Neem Azal 2ml l^{-1} (3.41). Imidacloprid 0.005 per cent, fenvalerate 0.03 per cent, lambda cyhalothrin 0.002 per cent, chlorpyrifos 0.03 per cent and dimethoate 0.05 per cent recorded no population of *Riptortus* spp. nymphs. However the toxic effects of these treatments was on par with malathion

0.05 per cent (0.12). All the chemical treatments were significantly superior to Neem Azal 2 ml l^{-1} and on par with each other.

On the third day after spraying also, all the treatments were significantly superior to control (14.57). Amrutneem 5ml l^{-1} (0.85) was significantly effective in suppressing the population of *Riptortus* spp. nymphs when compared to Neem Azal 2ml l^{-1} (3.46). Among the chemical treatments, chlorpyrifos 0.03 per cent (3.10) recorded the maximum population of nymphs. Imidacloprid 0.005 per cent (0.19), fenvalerate 0.03 per cent (0.18), lambda cyhalothrin 0.002 per cent (0.12) and dimethoate 0.05 per cent (0.75) showed statistically similar effects on the population reduction of the nymphs. Malathion 0.05 per cent recorded no incidence of the pest but was on par with other chemical insecticides except chlorpyrifos 0.03 per cent (3.10). All the botanical insecticides were on par with chlorpyrifos 0.03 per cent.

On the fifth day after spray, again all the treatments were superior in controlling the nymphs of *Riptortus* spp. when compared to the control (13.43). Similar trend was exhibited in the superior effects of Amrutneem 5ml l^{-1} (1.79) and Nimbecidine 2ml l^{-1} (1.16) in population suppression of the nymphs when compared to Neem Azal 2ml l^{-1}. Though malathion 0.05 per cent harboured the maximum number of nymphs (1.15) the effect was on par with all chemical insecticides.

On the seventh day after spraying, all the treatments applied could effectively suppress the population of *Riptortus* spp. nymphs when compared to control (16.81). Neem Azal 2ml l^{-1} (6.93) hosted the maximum number of nymphs whereas all the other treatments showed statistically similar effects on population reduction. The efficacy of fenvalerate 0.03 per cent (0.35) and lambda cyhalothrin 0.002 per cent (0.24) continued even on the seventh day after spraying.

On the fifteenth day after spraying none of the treatments significantly differed from each other in controlling the population of *Riptortus* spp. nymphs.

4.6.2.3 Effect of botanical and chemical insecticides on other pod bugs

N. viridula and *R? linearis* were observed in the tune of 0.1 and 0.3 per plant respectively one day prior to the first spraying. But the population was completely eliminated after the application of treatments. The control plants however harboured 0.3 and 0.6 *N. viridula* and *R? linearis* per plant respectively. Since the number present was to meagre the results could not be analysed further.

4.6.2.4 Effect of botanical and chemical insecticides on the population of spiders

The population of spiders at different intervals after the application of treatments is presented in Table 18.

After first spraying

Except on the first day after spraying, none of the treatments recorded significant reduction in the population of spiders. On the first day after spraying, plants treated with Neem Azal 2ml l^{-1} and lambda cyhalothrin 0.002 per cent did not support spiders. In all the other treatments also, significantly lesser values were recorded when compared with control (1.07). Nimbecidine 2ml l^{-1} (0.70) recorded the maximum population of spiders among the treatments followed by imidacloprid 0.005 per cent (0.57).

After second spraying

None of the treatments showed any significant effect on hampering the activity of spiders on the first, third, fifth, seventh and fifteenth day of observation after spraying.

Table 18. Effect of insecticides on spiders in vegetable cowpea observed in the field experiment

Treatments	Mean number per plant									
	Days after first spray					Days after second spray				
	1	3	5	7	15	1	3	5	7	15
Amrutneem 5ml l^{-1}	0.01 (1.00)	0.30 (1.14)	0.63 (1.27)	1.31 (1.52)	1.29 (1.51)	0.04 (1.02)	0.34 (1.16)	1.31 (1.52)	1.30 (1.52)	1.68 (1.64)
Neem Azal 2ml l^{-1}	0.00 (1.00)	0.30 (1.14)	0.32 (1.15)	0.64 (1.28)	1.47 (1.57)	0.34 (1.16)	0.68 (1.30)	0.62 (1.27)	0.90 (1.38)	2.04 (1.74)
Nimbecidine 2ml l^{-1}	0.70 (1.31)	0.30 (1.14)	1.28 (1.51)	0.89 (1.38)	0.73 (1.32)	0.23 (1.11)	0.23 (1.11)	0.92 (1.38)	1.66 (1.63)	1.26 (1.50)
Imidacloprid 0.005%	0.57 (1.25)	0.63 (1.28)	0.93 (1.39)	0.64 (1.28)	1.06 (1.43)	0.23 (1.11)	0.55 (1.25)	1.01 (1.42)	1.01 (1.42)	1.26 (1.50)
Fenvalerate 0.03%	0.01 (1.00)	0.00 (1.00)	1.31 (1.52)	1.31 (1.52)	1.62 (1.62)	0.11 (1.05)	0.12 (1.06)	0.61 (1.27)	0.97 (1.40)	1.76 (1.66)
Lambda cyhalothrin 0.002%	0.00 (1.00)	0.30 (1.14)	0.31 (1.15)	0.92 (1.39)	1.47 (1.57)	0.04 (1.01)	0.34 (1.16)	0.90 (1.38)	1.30 (1.52)	0.94 (1.39)
Chlorpyrifos 0.03%	0.01 (1.00)	0.63 (1.28)	1.30 (1.52)	0.91 (1.38)	0.89 (1.37)	0.23 (1.11)	0.23 (1.11)	0.92 (1.38)	1.33 (1.53)	1.26 (1.50)
Dimethoate 0.05%	0.30 (1.14)	0.30 (1.14)	0.63 (1.27)	1.31 (1.52)	1.29 (1.51)	0.34 (1.16)	0.34 (1.16)	0.62 (1.27)	0.29 (1.13)	1.68 (1.64)
Malathion 0.05%	0.01 (1.00)	0.00 (1.00)	0.29 (1.14)	0.63 (1.28)	0.61 (1.27)	0.00 (1.00)	0.00 (1.00)	0.65 (1.28)	0.94 (1.39)	1.51 (1.58)
Control	1.07 (1.44)	1.31 (1.52)	1.28 (1.51)	1.63 (1.62)	1.15 (1.47)	1.37 (1.54)	1.06 (1.43)	0.99 (1.41)	1.30 (1.52)	2.04 (1.74)
CD (0.05)	0.227	-	-	-	-	-	-	-	-	-

Figures in parentheses are $\sqrt{x+1}$ values

Table 19. Effect of insecticides on preying mantids in vegetable cowpea observed in the field experiment

Treatments	Mean number per plant									
	Days after first spray					Days after second spray				
	1	3	5	7	15	1	3	5	7	15
Amrutneem 5ml l^{-1}	0.30 (1.14)	0.91 (1.38)	0.29 (1.14)	0.29 (1.14)	0.63 (1.23)	0.07 (1.03)	0.00 (1.00)	0.74 (1.32)	0.30 (1.14)	0.56 (1.25)
Neem Azal 2ml l^{-1}	0.30 (1.14)	0.29 (1.14)	0.29 (1.14)	0.63 (1.28)	0.29 (1.14)	0.29 (1.13)	0.00 (1.00)	0.28 (1.13)	0.29 (1.14)	0.63 (1.28)
Nimbecidine 2ml l^{-1}	0.31 (1.14)	0.00 (1.00)	0.28 (1.13)	0.24 (1.11)	0.24 (1.11)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.92 (1.38)
Imidacloprid 0.005%	0.30 (1.14)	0.00 (1.00)	0.29 (1.14)	0.29 (1.14)	0.29 (1.14)	0.29 (1.13)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.30 (1.14)
Fenvalerate 0.03%	0.00 (1.00)	0.00 (1.00)	0.29 (1.14)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.30 (1.14)	0.00 (1.00)	0.00 (1.00)	0.37 (1.14)
Lambda cyhalothrin 0.002%	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.29 (1.14)	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)	0.00 (1.00)	0.00 (1.00)	0.37 (1.14)
Chlorpyrifos 0.03%	0.00 (1.00)	0.00 (1.00)	0.29 (1.14)	0.29 (1.14)	0.63 (1.28)	0.07 (1.03)	0.00 (1.00)	0.09 (1.04)	0.00 (1.00)	0.56 (1.28)
Dimethoate 0.05%	0.50 (1.24)	0.04 (1.02)	0.31 (1.15)	0.06 (1.03)	0.05 (1.03)	0.00 (1.00)	0.01 (1.00)	0.00 (1.00)	0.00 (1.00)	0.71 (1.28)
Malathion 0.05%	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.63 (1.28)	0.07 (1.03)	0.00 (1.00)	0.40 (1.18)	0.30 (1.14)	0.84 (1.38)
Control	0.60 (1.28)	0.63 (1.28)	0.63 (1.28)	0.91 (1.38)	0.63 (1.28)	0.72 (1.31)	0.29 (1.14)	1.12 (1.46)	0.63 (1.28)	1.22 (1.52)
CD (0.05)	-	-	-	-	-	-	-	-	-	-

Figures in parentheses are $\sqrt{x+1}$ values

4.6.2.5 Effect of botanical and chemical insecticides on the population of preying mantids

The effect of botanical and chemical insecticides on the population of preying mantids is presented in Table 19.

After both the first and second spraying, none of the treatments recorded any significant reduction in the population of preying mantids on the first, third, fifth, seventh and fifteenth day of observation.

4.6.2.6 Effect of botanical and chemical insecticides on the yield of vegetable cowpea

Results are presented in Table 20. On mean weight basis all the treatments recorded yields significantly higher than that of the control (181.50). Imidacloprid 0.005 per cent treated plants recorded the highest yield (372.90) but was on par with dimethoate 0.05 per cent (366.89) and malathion 0.05 per cent (364.85). Fenvalerate 0.03 per cent (325.37), lambda cyhalothrin 0.002 per cent (307.88) gave statistically similar yields. Chlorpyrifos 0.03 per cent (265.11) recorded the lowest yield among all chemical insecticide treatments and was on par with Amrutneem 5 ml l^{-1} and Nimbecidine 2 ml l^{-1}.

Among the botanical insecticides, Amrutneem 5 ml l^{-1} (285.63) and Nimbecidine (278.35) could give significantly higher yields than Neem Azal 2 ml l^{-1} (204.04).

Dimethoate 0.05 per cent yielded the highest number of fresh pods (46.33) followed by malathion 0.05 per cent (44.33) and imidacloprid 0.005 per cent (43.67), fenvalerate (40.67), lambda cyhalothrin 0.002 per cent (37.67), Nimbecidine 2 ml l^{-1} (34.00), Amrutneem 5 ml l^{-1} (33.67), chlorpyrifos 0.03 per cent (32.67). Neem Azal 2 ml l^{-1} yielded the lowest number of fresh pods (24.67)

Table 20. Yield of vegetable cowpea and Benefit Cost ratio of insecticide treatments against pod bugs

Treatments	Yield per plant (g)	Mean number of fresh pods per plant	Benefit Cost ratio
Amrutneem 5ml l-1	285.63	33.67	2.85 : 1
Neem Azal 2ml l-1	204.04	24.67	0.61 : 1
Nimbecidine 2ml l-1	278.35	34.00	2.69 : 1
Imidacloprid 0.005%	372.90	43.67	5.31 : 1
Fenvalerate 0.03%	325.37	40.67	4.02 : 1
Lambda cyhalothrin 0.002%	307.88	37.67	3.55 : 1
Chlorpyrifos 0.03%	265.11	32.67	2.33 : 1
Dimethoate 0.05%	366.89	46.33	5.18 : 1
Malathion 0.05%	364.85	44.33	5.16 : 1
Control	181.50	18.00	--
CD (0.05)	21.203	2.360	

among treatments. The number of pods from all the treatments were significantly superior to control (18.00).

Based on the benefit cost ratio also, imidacloprid 0.005 per cent ranked first (5.31:1) followed by dimethoate 0.05 per cent (5.18:1) and malathion 0.05 per cent (5.16:1). The corresponding values in fenvalerate 0.03 per cent, lambda cyhalothrin 0.002 per cent, chlorpyrifos 0.03 per cent, Amrutneem 5 ml l^{-1} and Nimbecidine 2 ml l^{-1} were 4.02:1, 3.55:1, 2.33:1, 2.85:1, 2.69:1 respectively. Neem Azal 2 ml l^{-1} indicated the lowest benefit cost ratio (0.61:1) of all the treatments.

Discussion

5. DISCUSSION

Many agroecosystems are in a continuous state of change. In such systems new problems often emerge. In Kerala, recently a phenomenal increase in the damage inflicted by hemipteran pod bugs was observed in vegetable cowpea during the post flowering phase of the crop. Call it a reflection of the change, in favour of sucking pests witnessed in many agroecosystems now a days. The single track means of protecting the crop with insecticides though provides instant kill of bugs, seems to be a failure in containing them in the long run. The implicit meaning is that there is a need to evolve sustainable measures. Countering insects is not an overnight task as insect problem is a twin component of agriculture. As opined by Metcalf and Flint (1932) insects evolved varied and insidious ways of survival and establishment calls for an equally varied and vigilant defense to prevent them gaining upper hand. Obviously, it is essential to ponder over some of the basic aspects of the bugs like biology, seasonal occurrence and host range which affect their population build up, besides identifying soft and effective management measures. In this context, a project entitled "Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt" was pursued during 2005-2006 at the College of Agriculture, Vellayani, Thiruvananthapuram.

In the present study conducted, nine species of pod bugs belonging to eight genera and four families have been found to infest the pods of vegetable cowpea. These include two alydids *viz., R. pedestris, R? linearis,* three coreids *viz., C. gibbosa, C. bipunctatus, Homoeocerus* sp., three penatatomids *viz., A. graminea, N. viridula, P. rubrofasciatus* and one plataspidid *viz., C. cribraria* (Plate 1). Of these, except *R. pedestris, C. gibbosa, C. cribraria* and *N. viridula* all others are new records from vegetable cowpea in India. This is also the first record of *A. graminea, C. bipunctatus* and *Homoeocerus* sp. in a pulse crop in

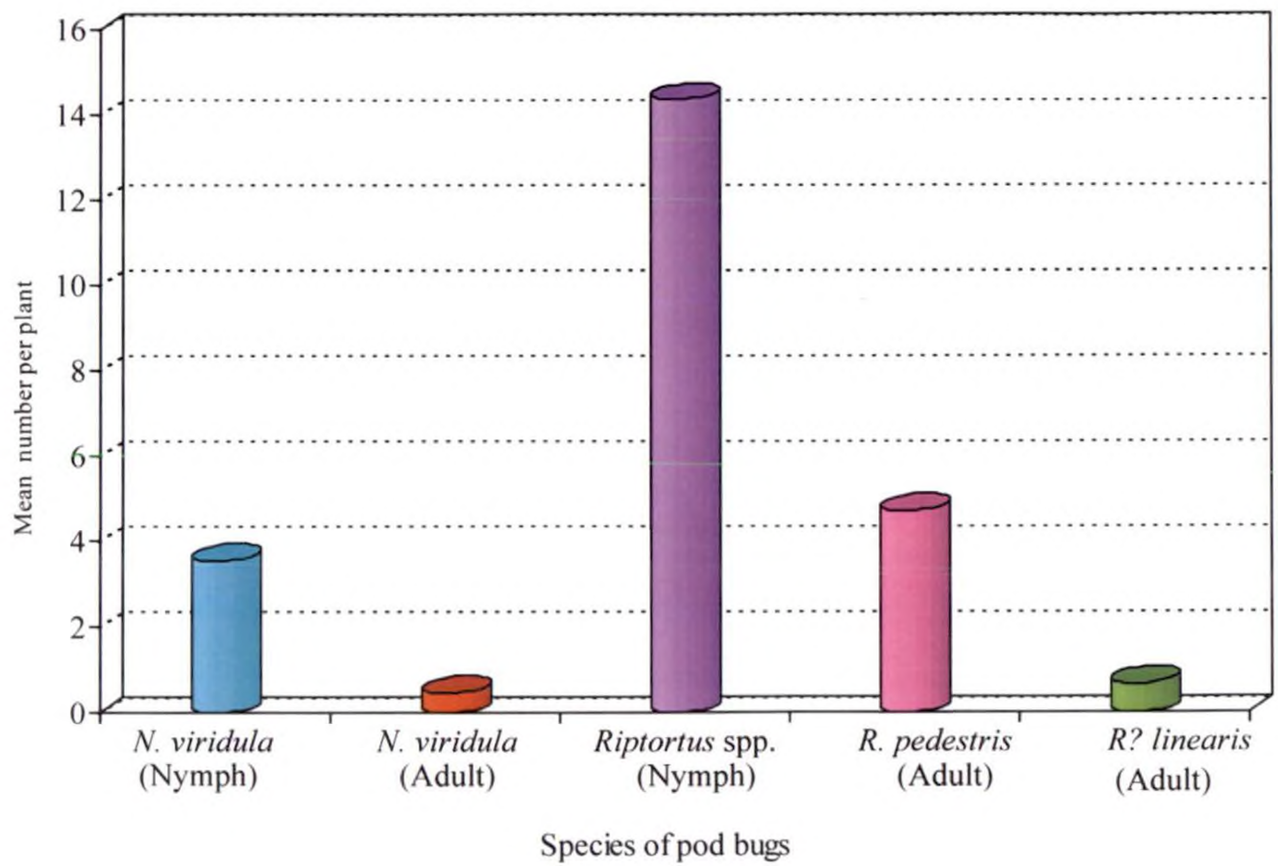


Fig. 2. Population of different species of pod bugs

India. Earlier record of *A. graminea* as an euryphagous pest infesting paddy in Pakistan has been documented (Abbas and Ahmad, 1984). *C. bipunctatus* was earlier recorded as a pest of amaranthus (Jena *et al.*, 2002).

With regard to *Homoeocerus* sp. the only record of the pest in pulses is in soybean from Korea (KeonSoo *et al.*, 1998). Records of the pest in India is from *Acacia* spp. in the Indo Pakistan sub continent (Parveen and Ahamad, 1999). *P. rubrofasciatus,* as an emerging pest of soybean has been previously recorded in India by Singh *et al.* (1989). *R? linearis* was identified from green gram among the pulses. *C. gibbosa, N. viridula* and *R. pedestris* as pests of vegetable cowpea in Kerala has been documented (Visalakshi, *et al.*, 1976; Nair, 1978).

Each of the bugs showed varying preference for reclaimed wet land or garden land ecosystems, crop stage and position of pods in the plant. The time of activity also differed. *R. pedestris* and *N. viridula* were the dominant species among these bugs. The other species of bugs possessed weaker competing abilities and hence were found in low numbers only.

R. pedestris was present in the field throughout the day time, fed from pods, irrespective of their positions in the plant and thus obtained a lion's share of the available food sources which could be one of the reasons for the dominance of the species (Fig. 2). In accordance with competitive exclusion phenomenon stated by Saxena (1992), when competition exists between two or more different species due to overlapping of niches, one species is bound to capture the resource and eliminate the other. Another reason which could be attributed to the dominance of the species is its early colonisation in the crop, coinciding with the pod initiation stage itself unlike most other species which appeared during vegetable pod stage. Yet another reason for the supremacy of *R. pedestris* is its ability to utilize dry pods also. Adults and nymphs fed gregariously on dry pods. They persisted in the field even after the harvest of green pods, when all other species of pods bugs abandoned the crop. Moreover the camouflaging of the nymphs of *R. pedestris* with that of the surrounding dry leaves (Plate 2) and pods and its behavioural adaptations, to drop down immediately on disturbance and take refuge under weed cover also seemed to be contributing factors to its dominance. The nymphs of this bug surpassed the hot periods of the day, by hiding under dry leaves which gave them sufficient insulation from heat.

A closely related species *viz., R? linearis* could persist in the field by choosing to feed only from lowermost pods where aggregated feeding by *R. pedestris* adults was less. This is in accordance with Gillot (1980) stating that competitive displacements could be averted if closely related organisms evolved mechanisms like habitat selection (spatial selection), microhabitat selection, temporal segregation and dietary difference making them to coexist, in almost but not the same niche.

N. viridula and *C. cribraria* showed preference for pods exposed to sunlight. The former was often observed on the upper and middle pods while the latter preferred upper pods generally. Middle most pods irrespective of light or shade were the choice of *P. rubrofasciatus.*

A. graminea, C. bipunctatus, C. gibbosa and *Homoeocerus* sp. were observed to infest the crop during the vegetable pod stage. Their feeding and resting sites were restricted to pods growing amidst dense canopy of leaves, with each of the bugs taking different positions in the middle and lower most regions of the plant. This characteristic, common ecological need of these bugs might probably be an attributed cause of their rarity.

R. pedestris, R? linearis and *N. viridula* were found in moderate numbers in both reclaimed wet land and gardens lands. *A. graminea, C. gibbosa, C. cribraria* and *Homoeocerus* sp. were found only in reclaimed wet lands. *C. bipunctatus* and *P. rubrofasciatus* occurred in very few numbers in reclaimed wet land and seldom observed in garden land. This indicates that the warm, humid air endowed by the rice fields and constant irrigation practices had a bearing on the incidence of these bugs.

The occurrence of *A. graminea* and *Acrosternum heegeri* Fieber in rice in the Indo-Pakistan sub continent and their association with the leguminous weed, *Indigofera oblongifolia* Forssk. has been documented earlier (Ahmad and Rana, 1989). The present record of *A. graminea,* from vegetable cowpea raised only near the wet land rice ecosystem is in tune with the above mentioned feeding habits and habitat observed earlier in Pakistan.

Natural enemies play an important role in hampering the pest population levels to the benefit of the man kind. Hairston *et al.* (1960) deduced that herbivore populations were often controlled by their natural enemies. In the present study, nine species of predators and one ectoparasitic mite were observed to utilize pod bugs as their prey / host. Out of these six were insect predators and three were spider predators.

Four species of preying mantids (Plate 3) *viz., E. tricomaliae, E. pulchra, H. ceylonica, H. ventralis,* one species of ant, *C. compressus* and an unidentified reduviid bug (Plate 3) were the insect predators. Three species of araneae *viz., A. pulchella, P. virdana* and *T. dimidiata* were the spider predators (Plate 4). All the natural enemies of the pod bugs recorded in the present study, except spiders are new reports.

In the present observations made, it was seen that the size difference of the mantids and their prey determined the host range to a certain extent. *E. tricomaliae* and *E. pulchra* were slender bodied, medium sized mantids and they consumed nymphal stages of *R. pedestris, R? linearis* and *N. viridula* excepting the fifth instar nymph of *N. viridula* which was larger sized. The adults of these three bugs, often escaped predation which may be due to the difference in size of the prey and the predator and the quick agility of the prey. Further, the shield shape of *N. viridula* also made it difficult for the slender mantids to clasp them. Similar observations were also made by Clercq *et al.* (2002) who found that the adults of *N. viridula* escaped predation by *P. maculiventris* due to their greater agility.

H. ceylonica and *H? ventralis* could feed on nymphs as well as adults of *R? linearis, R. pedestris* and nymphs of *N .viridula.* These two mantids were much larger than their prey and had tougher spines in their raptorial legs. *N. viridula* adults escaped predation in this case also. Strand and Obrycki (1996) opined that those insects which are not attacked by predators often have large size. The swift flying capability of mantids made them competent enough to secure pod bugs as their prey. Hirose *et al.* (1996) stated that polyphagy and high dispersal ability were the main characteristics of effective natural enemies of mobile pests.

The spiders, *A. pulchella, P. virdana* and *T. dimidiata* were found to prey on the nymphs of pods bugs. *P. virdana* and *T. dimidiata* started feeding on pod bug nymphs immediately after confinement, whereas *A. pulchella* preyed upon pod bug nymphs only after four to five days of starvation when there was no other choice. Manu (2005) observed that *Argiope* spp. are web spinners waiting for their prey even during hot sunny hours. Though the spider showed only slight preference for pod bugs, this character of the spider seems beneficial in arresting the movement of flying adults.

An ant predator, *C. compressus* was observed to prey on eggs of *N. viridula* but only partial utilization of the egg mass was noticed. Sparse distribution of nymphs of *N. viridula* coincided with the busy activity of these ants. Debach and Rosen (1991) opined that ants constitute one of the most important predatory groups and are important in natural control. Ehler (2002) observed that less than 10 per cent of eggs of *N. viridula,* was generally preyed upon by predators with chewing and biting type of mouth parts. Predators seldom destroyed an entire egg mass, typically eating less than 40 per cent of eggs per exploited mass. This is also the first report of an ant predator of *N. viridula* eggs in India.

An unidentified reduviid predator was observed to prey upon nymphs of pod bugs, *N. viridula* and *Riptortus* spp. Reduviid bugs have been reported as effective predators of *C. gibbosa* (Ambrose *et al.,* 2003), *N. viridula* (James, 1994), *R. clavatus* (Claver and Ambrose, 2003). Clercq *et al.* (2002) opined that adult *N. viridula* was a sub optimal prey for the spined soldier bug, *P. maculiventris* due to its greater agility whereas eggs and nymphs formed an easy prey.

In the present study no parasitoids were recorded on pods bugs. Waage (1992) is of the opinion that parasitoid abundance and time of arrival is related to crop diversity and vegetation adjacent to crops.

An ectoparasitic mite (Plate 5) was found to attack the pods bugs, *N. viridula, R? linearis* and *P. rubrofasciatus.* The mites could kill the nymphs of pod bugs except fifth instar of *N. viridula* and served as debilitating factor of adults. Parasitized adult bugs could not contribute to further generations. This is the first report of an ectoparasitic mite on pod bugs in India.

The different species of the pod bugs caused varying levels of shrinking, shrivelling and discolouration of seeds due to the removal of sap (Plate 6). They desapped from pods, preferably from the seed region. Deep brown lines were observed in the rind portion adjacent to the seeds. Feeding punctures caused by the feeding of all the species of pod bugs except *Homoeocerus* sp. were distributed all over the seed region. The infested pods shrivelled. The contents of the seeds were sucked out leaving only the seed coat inside the pods in severe infestations during the tender stage of the pod. In mature pod, seeds were only partially desapped. *Homoeocerus* sp. preferred to feed from the rind region and a continuous, characteristic browning symptom was observed.

R. pedestris did the worst damage causing 74.96 per cent of weight loss of seeds followed by *R? linearis* (55.17 %) and *N. viridula* (48.89 %) (Fig. 1). Again this capacity of *R. pedestris* to feed more and cause a higher damage within a given period of time when compared to *R? linearis* and *N. viridula* places the bug as the most injurious one. The damage by this bug, resulted in higher levels of shrinking, shrivelling and distortion of seed (Plate 6). Seeds of young cowpea pods left untouched by pod bugs developed fully (Plate 7). Wrinkling of seed coat of *P. vulgaris* due to the attack of *Clavigralla* sp. was attributed to the injection of toxic saliva of the bug (Materu, 1970). The results are in confirmation with Visalakshi *et al.* (1976) stating that the surface of infested pods became rough and uneven with feeding punctures localized in the seed regions. Deterioration of seed quality of soybean due to feeding by *N. viridula* was documented by Turnipseed and Kogan (1976). Nair (1978) stated that pod bug infestation caused shrivelling and discolouration of pulse seeds. Chand (1995) reported that feeding by nymphs and adults of *N. viridula* resulted in necrotic spots on seeds of pulses, which failed to develop.

Alternate hosts serve as sites for oviposition, provide hiding places and also act as sources for carrying the population into the next crop season. The polyphagous nature of pod bugs gives them these advantages, provided by the alternate hosts during crop free periods. According to Panizzi (2000), phytophagous heteropterans are in general polyphagous, feeding on a wide array of plants. The less preferred plants are also explored as food and / or shelter which play an important role in the life history of the bugs. Speight (1983) stated that insects with a wide host range will be able to multiply on a number of host plants and it is likely that the insect will stay longer and become numerous, causing greater damage. *N. viridula*, one of the dominant bugs observed in the present study, is a polyphagous pest known to attack many plant species of agriculture and forest importance (Kumar and Ahmad, 2003). Panizzi and Menegium (1989) opined that since *N. viridula* feeds on fruiting structures, a sequence of host plants may be used by successive generations during the year.

Numerous reports are available on the alternate host range of *N. viridula* (Gupta *et al.*, 1993; Yadav and Rizvi, 1995; Shaw *et al.*, 1998; Sileshi *et al.*, 2000; Odermatt *et al.*, 2000; Biswas *et al.*, 2001; Mitra and Biswas, 2002; Bhagat, 2003; Singh and Joshi, 2004). However, only few reports are available on alternate hosts of *Riptortus* spp.

In the present study, 26 plants out of the 50 plants tested were found to support the survival of adult *R. pedestris*. Out of the eleven vegetables, only four plants supported the bugs' survival and produced symptoms. Nymphs and adults of *R. pedestris* congregated in dry fruits of *A. esculentus* in forsaken fields (Plate 7) and the seeds were emptied of the contents, which later dried with black discolouration. *C. annum* harboured the nymphs and adults soon after the harvest of cowpea crop and supported the survival of the bugs. The other two vegetables that could support the bugs' survival were *C. tetragonoloba* and *P. tetragonolobus*. Shrinking and shrivelling of pods with feeding punctures was evident in these two hosts. *C. annum* was found to host nymphs and adults of the bug soon after harvest of cowpea crop in the adjacent field and hence has a critical role in maintaining the population of *R. pedestris* in the field during off seasons.

All the four pulses evaluated viz., *C. cajan, V. radiata, V. mungo* and *V. unguiculata* were important hosts of *R. pedestris* which emptied the contents of the seeds and produced brown coloured feeding punctures on the pods in all these hosts. None of the oil seeds, fruit crops and spice crop observed in the present study, except *P. gujava* supported the survival of *R. pedestris*.

Seven out of the 13 ornamentals observed could support the survival of adult *R. pedestris*. Dark brown necrotic spots were produced on the leaf lamina of these ornamental plants except *C. pulcherrima* where pods were utilized. Eight out of the 14 weed plants were also observed to support the bugs' survival. Though the symptoms produced by the bug were not much pronounced in *S. nodiflora* and *P. maximum*, these plants sheltered the bugs during the hot sunny hours in large numbers and also during crop free periods. *C. occidentalis* could support the survival and development of *R. pedestris*. Further, this weed also served as ovipositional sites for the bug. These three weeds played the role of pest reservoirs in and around cowpea fields. Ingram (1998) opined that removal of hosts like senna trees and sesbania showed great reduction in field population of *R. serripes*. Like wise, destroying hosts like *C. occidentalis*, *P. maximum* and *S. nodiflora* in the vicinity of cowpea fields would be a positive attempt in checking the population of *R. pedestris*.

An analysis on the preference of the bugs for plants belonging to different families was also made. Plants belonging to the family Leguminosae were the most preferred hosts. Out of the 12 leguminaceous plants including crops, weeds etc. observed, only two, viz., *C. ternatea* and *D. gyrans* were rejected by the bug. The toughness of the pod wall of *C. ternatea* and small, bead shaped fragile pods of *D. gyrans* offered least scope for feeding by the bugs. The bugs successfully completed their development in *C. pulcherrima* and *C. occidentalis* in addition to all the four pulse crops observed.

Though *C. annum* of the Solanaceae family was preferred by the bug, other two members *viz.*, *L. esculentum* and *S. melongena* were untouched by the bug. *G. globosa* (Amaranthaceae), *O. sanctum* (Labiatae), *A. leptopus* (Polygonaceae), *C. bipinnatus* and *A. conyzoides* (Compositae), *C. thompsoniae* (Verbenaceae), *I. chinensis* (Rubiaceae), *K. fruticosa* (Apocynaceae), *B. stricta* (Nyctaginaceae), *P. maximum* (Poaceae) and *C. benghalensis* (Commelinaceae) supported the survival of adult bugs.

Members of the families, Pedaliaceae, Cucurbitaceae, Euphorbiaceae, Moringaceae, Sapotaceae, Anacardiaceae, Asteraceae, Piperaceae, Capparidaceae and Acanthaceae observed were not explored by *R. pedestris* for feeding or resting.

R. pedestris nymphs were reared on vegetable cowpea pods in the laboratory and the adults were released into excised plant parts of the alternate hosts, identified in the above study, for assessing their preference. Though the nymphs were reared in vegetable cowpea, the adults showed no reluctance in accepting the suitable plants for survival. Similar observations were made by Ntonifer *et al.* (1996) who stated that the choice of the host by the adult of another species of the pod bug, *R. dentipes* was unaffected by the nutritional history of the nymphs. This also indicates the probable food switch of adult *R. pedestris* from vegetable cowpea to alternate hosts and vice versa, in the field situations, which in turn promotes their persistence in the environment.

Population growth of any organism will depend upon the action of five components, the physical environment, host or food source, space, population itself and other species of organisms (Southwood and Way, 1970). Weather, constituting an important component of the physical environment has enormous impact on pest population. Earlier research findings also substantiates this. Adipala *et al.* (1999) opined that significance of pod sucking bugs in cowpea, vary from region to region, season to season and might be related to weather fluctuations. Kumar and Nath (2004) observed that the temporal distribution of *C. gibbosa* population on red gram exhibited significant difference. Verma and Henry (2003) noticed lower intensity of *C. scutellaris* in the rainy season crop of pigeon pea.

In the present study conducted from October 2005 to September 2006, the population of *N. viridula* showed sudden hikes and falls (Para 4.4.1). The nymphal population was completely absent in the field during October 2005, second fortnight of November 2005 and first fortnight of December 2005 but attained its peak level during the first fortnight of March 2006 (10.35). The nymphs of *N. viridula,* especially the first two instars, were highly susceptible to rain. The first instars once washed away could not right themselves and resume feeding. Heavy rainfall during the first and second fortnights of October 2005 and

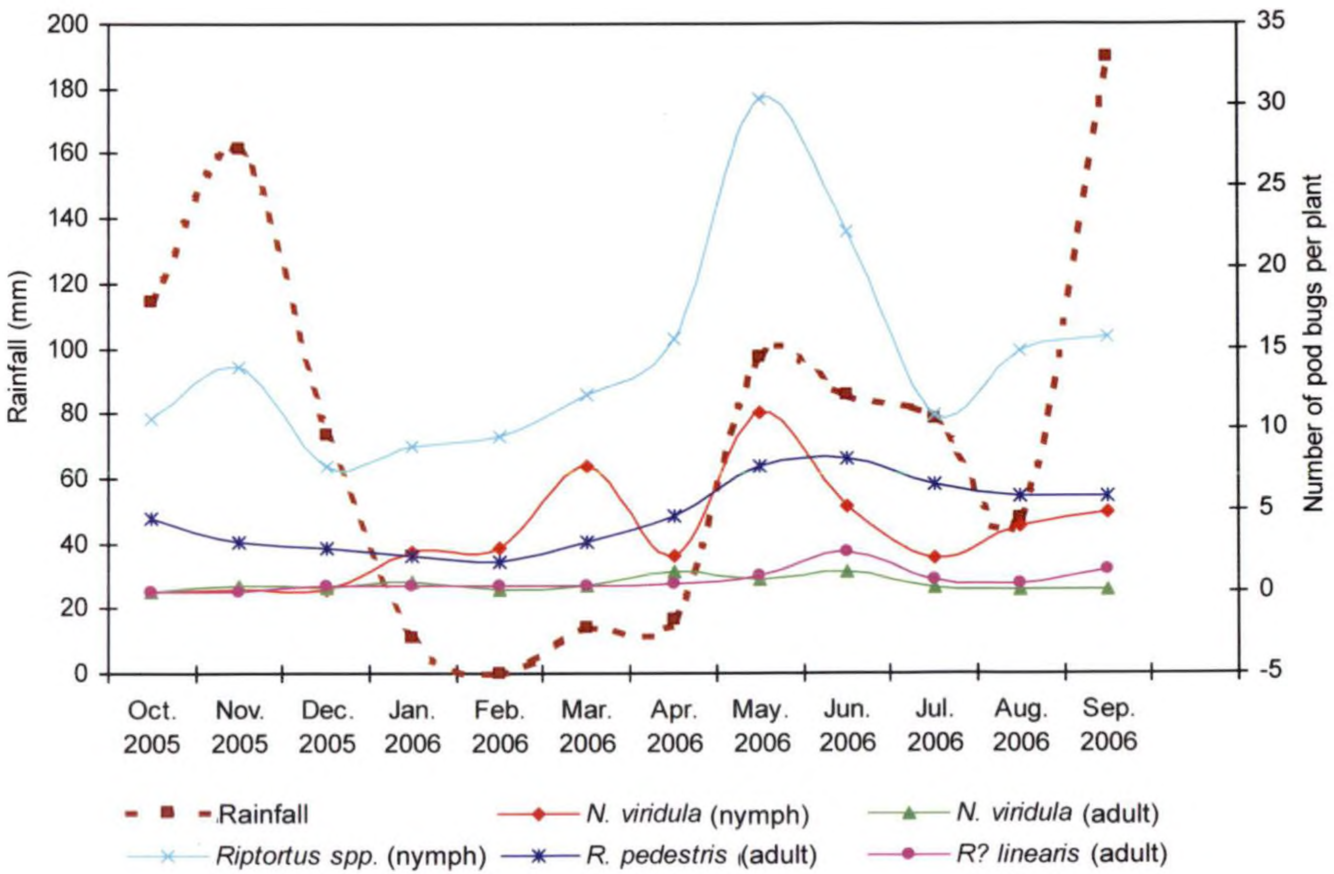


Fig. 3. Effect of rainfall on the population of pod bugs

second fortnight of November 2005 (49.50 mm and 65.00 mm and 103.70 mm respectively) might be the probable reason for the absence of nymphs of *N. viridula* during this period. A negative correlation was observed between nymphal population of *N. viridula* and rainfall as well as number of rainy days during the fortnight of observation (Fig. 3) as well as the previous fortnight though it was not significant. The nymphal population was significantly lower during October 2005 and December 2005 than in May 2006. Similarly, significantly lower populations of adult *N. viridula* was observed during October 2005 and December 2005.

Rainfall and number of rainy days, however, exerted a weak positive influence on the population of adults of *R. pedestris* and *R? linearis* during the fortnight of observation (Fig. 3) but a negative correlation was observed between rainfall of previous fortnight and population of *R? linearis.* Even during heavy rains, *R. pedestris* adults as well as nymphs of *Riptortus* spp. were seen resting on pods without being washed away. Adults and nymphs took a firm grip on the twigs, leaves or pods even when heavy rain drops striked and flowed over them. This characteristic feature helped this pod bug to maintain a steady population throughout the year except for slight rise and fall in population. Again, this is one more strengthening advantage to the dominance of *R. pedestris.* The population of nymphs of *Riptortus* spp. peaked during the first fortnight of May 2006 (36.07) which was significantly higher than in any other fortnight of observation except the immediate succeeding three fortnights which were on par. Adult population of *R. pedestris* reached the maximum value during the first fortnight of June 2006 (9.02) and was significantly higher than the population observed during November 2005 to March 2006. Adults of *R? linearis* reached a maximum population of 3.30 bugs per plant during the second fortnight of June 2006 which was significantly higher than that observed in any other fortnight.

The results of the present study revealed that maximum temperature during previous fortnight was positively associated with the population of *N. viridula*

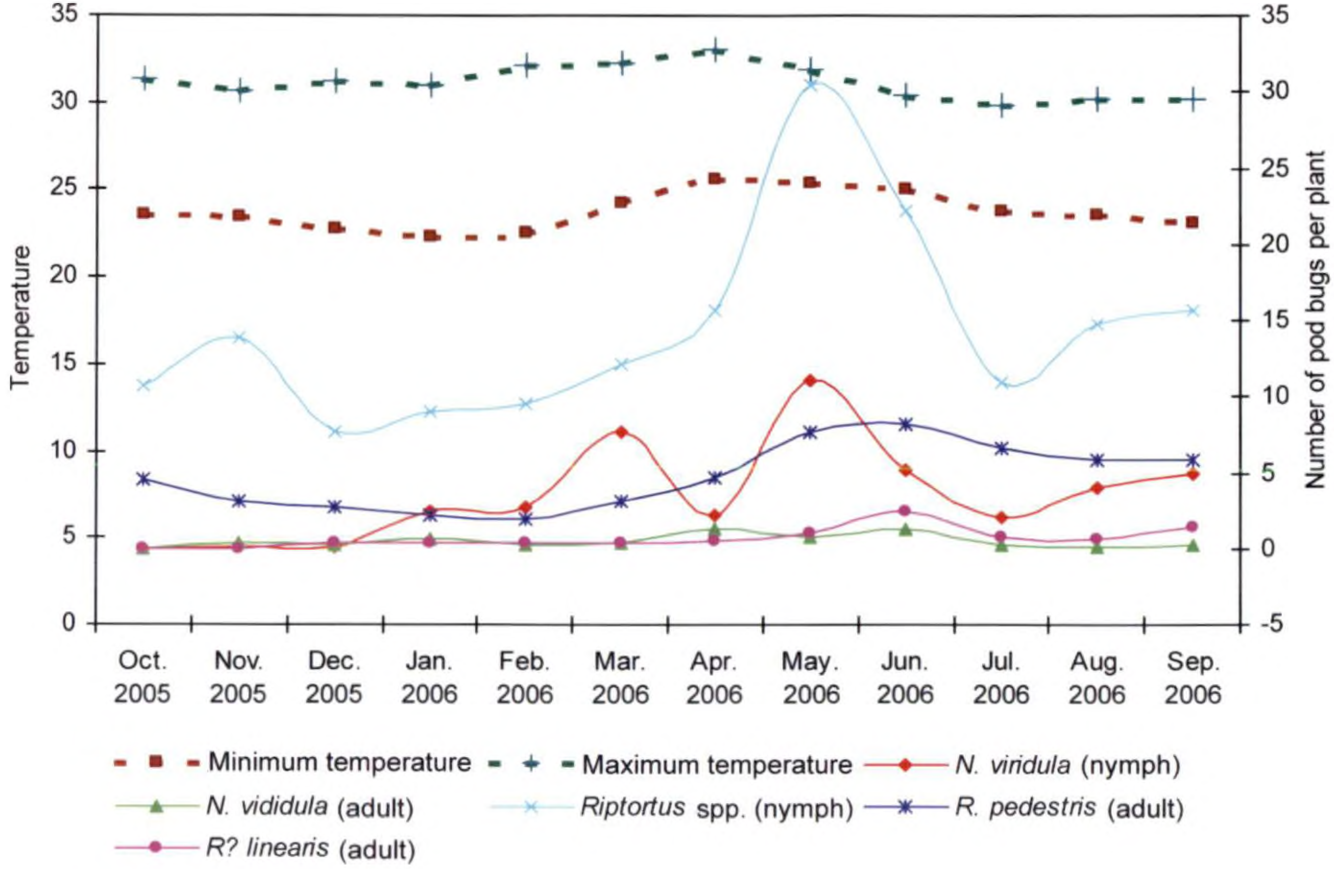


Fig. 4. Effect of maximum and minimum temperature on the population of pod bugs

adults. Minimum temperature exerted significant positive effect on nymphal and adult population of *N. viridula* and nymphs of *Riptortus* spp. during the fortnight of observation (Fig. 4). Minimum temperature of the previous fortnight also had significant positive effect. The findings are in conformation with Sarma and Dutta (1996a) who deduced a positive correlation between minimum temperature and population build up of *N. viridula* in green gram. Singh *et al.* (2002) reported that maximum and minimum temperature were positively correlated with population increase of *N. viridula* in cowpea. Contrasting results have been presented by Nayak *et al.* (2004) who observed a negative correlation between peak numbers of *N. viridula* and *Riptortus* spp. and minimum temperature in black gram. Kumar and Nath (2004) found that most of the weather parameters had only a weak influence on pod bug populations. According to Kumar and Ahmad (2003) increase in population of *N. viridula* coincided with high temperature.

A non significant positive correlation was observed between evening relative humidity and nymphal population of *N. viridula* (Fig. 5). Hirose *et al.* (2006) stated that relative humidity, greatly affected nymphal emergence and survivorship upto the second instar. They found that when relative humidity was greater than 80 per cent, the survival of nymphs was 90 per cent. In the present observations, evening relative humidity went above 80 per cent only during the first fortnight of July 2006 (82.55 per cent), first and second fortnight of September 2006 (80.35 and 80.20 per cent respectively). During all other periods the evening relative humidity was less than 80 per cent. This weather parameter might have been the possible cause for the fluctuating population levels of *N. viridula*. The adult population of *N. viridula* attained the maximum value during the second fortnight of June 2006 (1.31) and was completely absent during October 2005 and the first fortnight of August 2006. In the case of *Riptortus* spp. nymphs, morning relative humidity showed significant negative correlation wih the population of the current fortnight.

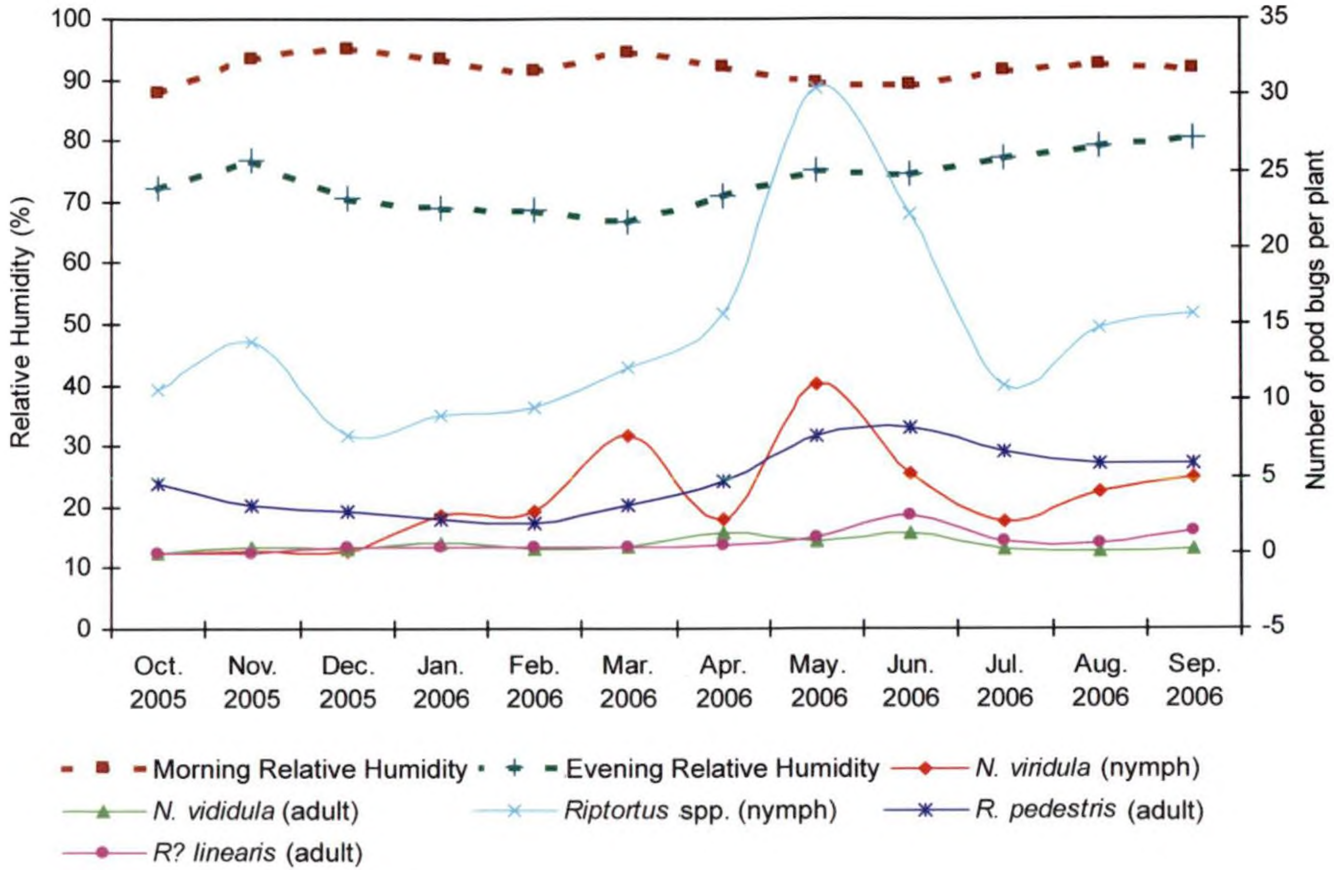


Fig. 5. Effect of morning and evening relative humidity on the population of pod bugs

An assessment of the relationship between weather parameters and population of predators showed significant negative correlation between population of preying mantids and morning relative humidity of the previous fortnight whereas maximum temperature of the previous fortnight exhibited highly significant positive correlation with the population of spiders. Minimum temperature during the fortnight and the previous fortnight showed highly significant positive correlation with the population of spiders. The findings are in contrast to the results presented by Manu (2005). According to her, spider population was influenced by prey availability alone.

The density dependent forces which frequently result from the action of parasitoids, predators and pathogens in some cases can be identified as one of the key factors which is largely responsible for determining the population size (Huffacker, 1957). In the present study, preying mantids, exerted a weak negative impact on the population of nymphs of *N. viridula*, *Riptortus* spp. and adults of *R? linearis*. According to Strand and Obrycki (1996) predators like preying mantids, are less likely to be selective about their prey and restrict their hiding sites to particular habitats, plants or plant communities. The non significant negative correlation observed in the present observation may be attributed to this low prey selectivity of preying mantids. Further, it may be noted that this relationship was obtained for nymphs of *N. viridula* as well as with *Riptortus* spp. and adults of *R? linearis*. The nymphs were fragile and soft bodied and made an easy prey for the preying mantids. So also, the adults of *R?. linearis* were slender, with less sharper pronotal and femoral spines, which weakened the chances of escape from predation by preying mantids. Fagan *et al.* (2002) also stated that preying mantids exhibited only weak negative effects on density for most taxa of insects.

However, the spiders did not exert negative influence on the population of any of the pod bugs. Arora and Monga (1993) found that spiders in pigeon pea fields showed only moderate feeding preference for the pod bug, *Clavigralla* spp.

Similarly, Manu (2005) reported that spiders showed lesser preference for nymphs of *R. pedestris* and *Clavigralla* spp. compared to nymphs of cowbugs. Riechert and Lockley (1984) had the opinion that spiders can have a strong stabilizing influence on prey as they rely on a complex assemblage of prey and maintain a fairly constant numerical representation that exert considerable control on associated prey population without extinction of their prey. Thereby, spiders act as buffers that limit the initial exponential growth of given prey populations.

Knowledge on the biology of the pest concerned is absolutely essential for identifying the vulnerable stages and behavioural characters. These crucial factors of survival, have to be targeted while evolving pest management programmes. Hence, the biology of four bugs *viz., N. viridula, P. rubrofasciatus, R? linearis* and *R. pedestris* was studied in vegetable cowpea. Being the dominant species, the biology of *R. pedestris* was studied in grain cowpea and coffee senna weed also. This is the first report of biology of *R. pedestris* on a weed host in India.

R? linearis and *R. pedestris* resembled each other very closely during most of the life stages. The eggs of these two species could never be distinguished with naked eye (Plate 10 and Plate 11) but microscopic examination revealed size differences. The egg of *R? linearis* measured 1.13 $\pm$ 0.03, 1.08 $\pm$ 0.03 and 0.76 mm while the egg of *R. pedestris* measured 1.37 $\pm$ 0.01, 1.13 $\pm$ 0.01 and 0.63 mm respectively.

Both *R? linearis* and *R. pedestris* laid eggs singly which were firmly glued to the substratum. Eggs were sub globular in shape and dull green coloured when freshly laid. Eggs turned to chocolate brown colour, two to four days after oviposition. Congregated deposition of eggs was observed in muslin cloth and dry pods whereas in green pods, eggs were sparsely distributed. In case of *R. pedestris* eggs, an incubation period of 7.88, 7.55 and 8.15 days were observed in vegetable cowpea, grain cowpea and coffee senna weed respectively. This is in contrast to the observation made by Visalakshi *et al.* (1976) who reported 3-4 days of incubation period for the egg in grain cowpea.

R? linearis completed its nymphal period in 14.61 ± 0.26 days in vegetable cowpea. The findings are in conformation with Baruah and Dutta (1994) reporting 14.86 –17.57 days of nymphal period in green gram. *R. pedestris* took 13.52, 16.69 and 15.84 days to complete its nymphal period in vegetable cowpea, grain cowpea and coffee senna weed respectively. In vegetable cowpea, the duration of the different nymphal instars were 1.58, 2.77, 2.41, 2.68 and 4.08 days respectively. The findings of the present study are in slight contradiction with that of Visalakshi *et al.* (1976) who noted the durations of different nymphal instars as 3, 3.6, 3, 3.75 and 3.16 days in grain cowpea. In the present study the fifth instar was observed as the longest of all the nymphal instars (4.08 days). Significant differences were observed in the duration of life stages of *R. pedestris* reared in vegetable cowpea, grain cowpea and coffee senna weed. The total nymphal period and total life cycle was shortest (13.52 and 21.40 days respectively) on vegetable cowpea. Also the longest oviposition period (9.20 days) and the highest fecundity (94.40) was observed on this host. Hence it is inferred that vegetable cowpea is the most suitable host of *R. pedestris* compared to grain cowpea and coffee senna weed. Khaemba (1984) opined that purple and dark green poded cultivars of cowpea were more resistant to pod bugs than those with light green pods. Chiang and Jackai (1988) considered tough pod wall as an important contributing factor to the lower feeding damage by pod bugs. The light green shade and the succulent nature of vegetable cowpea pods might have made it a superior host for *R. pedestris.* Grain cowpea pods were darker green in colour with tougher pod wall. Coffee senna pods possessed the toughest pod wall and the darkest green shade among the three hosts. Gerard (1978) stated that pubescence and vigorous growth were effective defenses against pest complexes attacking cowpea cultivars. The glabrous nature of vegetable cowpea pods might have been yet another appealing factor to *R. pedestris*.

All the nymphal instars of *R. pedestris* and *R? linearis* closely resembled each other. The second instar nymph of *R? linearis* could be easily distinguished from *R. pedestris*. The nymph of *R? linearis* was black in colour with greyish green coloured abdomen whereas *R. pedestris* was brick red coloured with olive green coloured abdomen (Plate 10 and Plate 11). However, this difference could be made only in the laboratory reared cultures. Under field conditions blackish brown coloured second instar nymphs of *R. pedestris* were also noticed. Even then, the greyish green coloured abdomen of the second instar nymph of *R? linearis* was a characteristic feature enabling their identification. The first, third, fourth and fifth instars of *R? linearis* and *R. pedestris* could not be easily distinguished under field conditions. The third instar nymphs of *R. pedestris* were either brick red coloured or blackish brown coloured. All the nymphal instars of *R? linearis* were brown/blackish brown coloured. But these nymphs could be clearly distinguished under the microscope. The terminal segment of the antenna is a distinguishing character. It was highly flattened and ribbon shaped in the first four instars of *R? linearis* whereas it was slightly sickle shaped and tapering bluntly in *R. pedestris* nymphs. In the fifth instar nymphs of *R? linearis* and *R. pedestris,* the terminal segment of the antennae were flattened and ending abruptly and could not be clearly distinguished. The adults of *R? linearis* and *R. pedestris* could be easily distinguished. *R? linearis* adults were slender bodied and smaller than *R. pedestris*.

The sternum of the abdomen of *R? linearis* adults showed a black center with a deep yellow border which was broader in males and narrow in females. The abdominal sternum of *R. pedestris* was dull white/yellow coloured with a black band in female and 'U' shaped black markings in male. The pronotal spines and the femoral spines of hind leg were sharper and tougher in *R. pedestris* than in *R? linearis*.

Successful mating which resulted in oviposition occurred only when the bugs received sunlight during the morning hours. The oviposition periods of

R? linearis was 11.10 $\pm$ 2.35 days. Baruah and Dutta (1994) observed an oviposition period of 8.67 to 40 days. The oviposition period of *R. pedestris* was 9.20, 8.70 and 6.10 days in vegetable cowpea, grain cowpea and coffee senna weed respectively. The female longevity observed was 61.40, 59.70, 44.00 days in vegetable cowpea, grain cowpea and coffee senna weed respectively. The fecundity and longevity of *R? linearis* was markedly low when compared to *R. pedestris*. This might have attributed to the sparse occurrence of *R? linearis* in the field.

The morphometrics and characters of the green shield bug *N. viridula* are detailed in para 4.5.1. Eggs of *N. viridula* were pale yellow in colour and laid in hexagonal masses (Plate 8). The mean incubation period was 4.50 days. The total life cycle was completed in 22.59 $\pm$ 0.41 days and five nymphal instars were observed. The results of the present study are in confirmation with Kariya (1961) who reported that the development of *N. viridula* from egg to adult took 23.2 days at 30°C. Kiritani (1964) found that *N. viridula* developed through five nymphal instars. Mukhopadhyay and Roychoudhary (1987) reported that *N. viridula* took an average of 44.4 days to complete its life cycle on *Vigna umbellata* (Thunb.) and Bhalani and Bharodia (1988) observed a total life cycle period of 53 days in pigeon pea. DerChien *et al.* (1997) observed a total life cycle period of 40.3 days in *V. unguiculata* ssp., *sesquipedalis*. The mean fecundity observed in the present study was 81.80 $\pm$ 17.76 eggs. Contrastingly, higher fecundity of 260 eggs were observed by Bhalani and Bharodia (1988) in pigeon pea.

The first instars of *N. viridula* hatched almost simultaneously from an egg mass, congregated over the egg shells for a day before they moved to feed on pods. Similar observations were made by Susanne and Sailer (1999) and Kumar and Ahmad (2003). Efforts made to segregate the first instar nymphs lead to cent per cent mortality. Hokyo and Kiritani (1963) observed that aggregation of *N. viridula* nymphs, worked as defense because mortality was less in gregarious feeders. Derr and Ord (1979) opined that improvement of feeding efficiency in heteroptera was related to gregariousness in nymphs due to more efficient use of saliva in groups. Lockwood and Story (1986) observed that aggregation of first instar nymphs of *N. viridula* was reported to speed development and reduce mortality. Hence it may be concluded that a single first instar nymph, could not survive when confined alone due to desiccation as well as inability to utilize the pod with its fragile rostrum and meagre quantity of salivary secretion. However, feeding effort exerted by a group of nymphs enabled the efficient usage of saliva and the survival of the nymphs. Rapid size increase was noticed during the fifth instar which was almost one and a half time of the previous instar. Fourth instars measured 6.91 $\pm$ 0.11 mm and 5.48 $\pm$ 0.06 mm length and width wise. This indicates the possibility of increased feeding activity and damage to the pods by the fourth instar nymphs. Adult female measured 13.60 $\pm$ 0.49 mm and 7.00 mm length and width wise which is conformation with the description given by Nair (1978). Female adults of *N. viridula* did not oviposit even after several matings and died shortly when subjected to more than 12 hours of light exposure. Saxena (1992) stated that light has a great influence on insect life with regard to egg laying and longevity. Feeding and mating are regulated by the daily cycle of dark and light with dawn and dusk periods in between which serve as clock.

Biological parameters and description of *P. rubrofasciatus* is given in detail in para 4.5.2. *P. rubrofaciatus* laid pale green coloured eggs, arranged in two horizontal rows (Plate 9). The eggs of a single egg mass hatched almost simultaneously and the first instar nymphs congregated over the egg shells for a day before feeding. The total nymphal period was completed in 15.60 $\pm$ 0.20 days. The mean fecundity was 52.00 $\pm$ 8.77 eggs. The incubation period of the eggs was 4.58 days. Joseph (1953) observed that during winter season, the incubation period of *P. rubrofasciatus* extended for six days in lucerne. Singh *et al.* (1989) observed fecundity ranging from 48-80 eggs which were laid in paired elongated rows. The incubation period observed in summer was two days and the nymphal period was 15.70 days in soybean.

Oviposition and egg laying pattern observed in this bug was different from the other bugs studied. It mated and laid eggs on alternate days. The observation are in conformation with Singh *et al.* (1989) who observed that the female bug laid eggs 24 hours after mating. As in *N. viridula*, here again a rapid increase in size, of about one and a half times, was observed between the fourth and fifth instar. After the first four days of oviposition period, often sterile eggs were laid by this bug species.

The cardinal principle behind pest management today is sustainable production, by keeping the pest population at low levels, utilizing varied techniques. The most sought after methods at present, include the use of botanical insecticides and entomopathogens as they are in tune with nature. So, in the present attempt to evolve management strategies against pod bugs also, thrust was given to the identification of suitable botanical insecticides and entomopathogens, besides chemical insecticides. Initially, laboratory screening of three botanicals, three entomopathogens and six insecticides was done against laboratory cultured second generation, third instar nymphs of *R. pedestris* by adopting dry film technique. Among the botanicals, Amrutneem 5 ml l^{-1} proved significantly superior, causing 60.13 per cent mortality followed by Nimbecidine 2 ml l^{-1} and Neem Azal 2 ml^{-1} with 39.87 and 19.67 per cent mortality. The superiority of Amrutneem was indicated even from 12 hours of exposure. After 48 hours, no further mortality was observed in any of the botanicals. The survivors in each of the three botanical treatments, moulted into pale coloured, weakened adults and were lethargic. Dhaliwal and Arora (1998) have stated that neem products affect insect vigour, longevity and fecundity.

All the chemical insecticides evaluated, showed cent per cent mortality within 150 minutes of exposure. Malathion 0.05 per cent was significantly superior and caused cent per cent mortality within 90 minutes. The action of dimethoate 0.05 per cent and fenvalerate 0.03 per cent was quicker when compared to imidacloprid 0.005 per cent and chlorpyrifos 0.03 per cent (para 4.6.1.2).

The fungal pathogens *B. bassiana* @ 2.5 x 10^7 spores ml^{-1} and *R. oryzae* @ 7 x 10^6 spores ml^{-1} could produce only very low mortality levels (0 % to 16.67 %) (Para 4.67.1.3). The nymphs that were sprayed with the spore suspensions, moulted within 2 days as against the normal nymphal period of 2.41 days for the third instar. *P. fluorescens* @ 20 gl^{-1} neither affected the behaviour nor produced any lethal effects on nymphs. The attributes of a good pathogen are virulence and infectivity. Moreover, the susceptibility of the host to the pathogens is also important for their use as biocontrol agents.

Based on the preliminary laboratory evaluation, excluding the three entomopathogens, nine treatments were further tested for their efficacy under field situations.

All the treatments evaluated were significantly superior to control in reducing the population of adult *R. pedestris* upto seven days. However, the treatments better controlled the nymphs of *R. pedestris* than adults and the effect of the treatments were noted upto fifteen days after the first spraying. Quick knockdown of adult *R. pedestris* and further persistent effect was evidently higher for the synthetic pyrethroids viz., fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent in both the sprayings. Marked supremacy of synthetic pyrethroids was also seen in checking the nymphal population of *Riptortus* spp.

Among the botanicals, the supremacy of Amrutneem 5 ml l^{-1} was indicated in the observations at one and five days after both the sprayings and it came on par with the effect of fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent on the seventh day after first spraying. Consistent effect of Amrutneem 5 ml l^{-1} was noticed after the second spray also. Though initially, on the first and third day after sprayings, the population was higher than fenvalerate

0.03 per cent and lambda cyhalothrin 0.002 per cent, the effect on nymphs of *Riptortus* spp. was statistically on par on the fifth and seventh days after the second spraying. The effect of Nimbecidine 2 ml l^{-1} was next to Amrutneem 5 ml l^{-1} and was on par with the same on first, third and seventh days. The performance of Amrutneem 5 ml l^{-1} was the best with respect to population reduction and yield but its effect was on par with Nimbecidine 2 ml l^{-1} and with the insecticide chlorpyrifos 0.03 per cent. Neem Azal 2 ml l^{-1} was significantly inferior.

Plants treated with imidacloprid 0.005 per cent harboured significantly higher population of adult *R. pedestris* on fifth and seventh days after both sprayings, compared to fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent. But imidacloprid was on par with these synthetic pyrethroids on first, third and fifteenth day after both the sprayings in checking the population of nymphs of *Riptortus* spp. Malathion 0.05 per cent proved equally good in population reduction of adult *R. pedestris* except on the fifth and seventh day after second spraying. However, in the case of nymphal population of *Riptortus* spp., imadacloprid 0.005 per cent and dimethoate 0.5 per cent showed superiority over malathion 0.05 per cent. Imidacloprid 0.005 per cent and dimethoate 0.05 per cent recorded significantly lower population counts of 3.49 and 4.02 nymphs per plant for a much prolonged duration of fifteen days after the first spraying. Chlorpyrifos 0.03 per cent also had prolonged effect upto fifteen days and was on par with imidacloprid 0.005 per cent in reducing the nymphal population. The effect of chlorpyrifos 0.03 per cent on adult *R. pedestris* was as good as malathion 0.05 per cent in the seventh day after both the sprayings but was significantly lower than synthetic pyrethroids.

Imidacloprid 0.005 per cent which recorded the lowest number of nymphs until the fifteenth day after spraying recorded the highest yield (372.90). However, the yield was on par with dimethoate 0.05 per cent and malathion 0.05 per cent. The percentage increase in yield over control in these treatments were

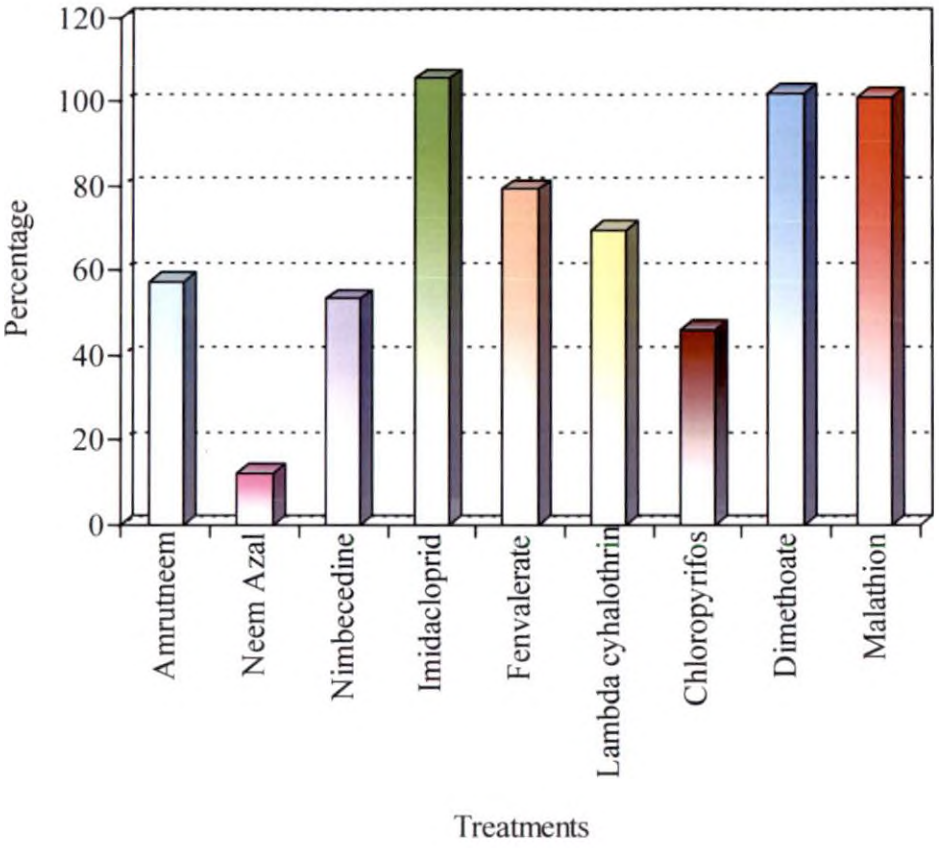


Fig. 6. Percentage increase in yield over control in different treatments

105.45 per cent, 102.14 per cent and 101.01 per cent respectively (Fig. 6). The toxic effect of imidacloprid, chlorpyriphos and malathion (Varghese, 2003) and dimethoate (Ivibijaro and Balaji, 1990; Amatobi, 1995; Decri *et al.*, 2000; Minja *et al.*, 2000) to *R. pedestris* has been documented.

Based on the benefit-cost ratio, imidacloprid 0.005 per cent ranks as the best treatment for the management of the pod bug *R. pedestris* (5.31 : 1). This was followed by dimethoate 0.05 per cent (5.18 : 1), malathion 0.05 per cent (5.16 : 1); fenvalerate 0.03 per cent (4.02 : 1), lambda cyhalothrin 0.002 per cent (3.55 : 1), Amrutneem 5ml l^{-1} (2.85 : 1), Nimbecidine 2 ml l^{-1} (2.69 : 1), chlorpyrifos 0.03 per cent (2.33 : 1) and Neem Azal 2 ml l^{-1} (0.61 : 1).

Further these insecticides did not affect the population of spiders except on the first day after the first spray. Nimbecidine 2 ml l^{-1} and imidacloprid 0.005 per cent were significantly superior to all other treatment in supporting the population of spiders. Manu (2005) observed that dimethoate (0.05 per cent), malathion (1 per cent) were highly toxic to spiders when applied topically. Imidacloprid 0.02 per cent was less toxic to spiders. In the present findings, the population of the predatory preying mantids was unaffected.

Considering the various aspects influencing the population of the pod bugs, to keep the pests at bay and to obtain economically sound returns, the following suggestions are made.

* Monitoring the population of pod bugs
* Collection and destruction of egg masses of *N. viridula*
* Collection and destruction of adult bugs using sweep nets. Destruction of nymphs by crushing, especially those clustering in the dry leaves

* Wetting the crop canopy thoroughly while irrigating to wash of the first instars of *N. viridula*

* Removal of weeds in the vicinity of cowpea plant especially, *C. occidentalis, P. maximum* and *S. nodiflora*

* Complete harvest of pods including dry pods in vegetable cowpea after the crop period and removal of crop trash to avoid carry over of pests to next crop season

* Trash removal after harvest in bhendi and chilli crop adjacent to cowpea

* Application of Amrutneem 5 ml l^{-1} / Nimbecidine 2 ml l^{-1} / Neem Azal 2 ml l^{-1} / imidacloprid 0.005 per cent / dimethoate 0.05 per cent / malathion 0.05 per cent / fenvalerate 0.03 per cent / lambda cyhalothrin 0.002 per cent / chlorpyrifos 0.03 per cent

* Use of the correct dosage of the above botanical / chemical insecticide

Inspite of the low benefit cost ratio obtained in botanical treatments compared to chemical insecticides, considering their environmental safety, due to importance is to be given to botanical insecticides in the management of pod bugs. Though the benefit cost ratio was higher in fenvalerate 0.03 per cent and lambda cyhalothrin 0.002 per cent than botanicals, contemporary problems of pest resurgence posed by synthetic pyrethroids in other ecosystems (Rajak and Diwakar, 1987; Kumar *et al.*, 2002), consequent to its continuous use are to be borne in mind while recommending these chemicals in management of pod bugs.

Further, the situational importance of each of the above elements is to be given due importance to avoid over reliance on a single tactic and to mitigate the pod bug infestation in vegetable cowpea.

Summary

6. SUMMARY

Pod bugs have emerged as major pests in vegetable cowpea ecosystems in Kerala in spite of the continuous insecticide applications given by the farmers. This reiterates the need for adopting sustainable measures in its management. Information pertaining to the species, pest status and other contributory factors of population build up of pod bugs are to be gathered. Hence, the present project entitled "Bioecology and management of pod bugs infesting vegetable cowpea *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt" was undertaken at the College of Agriculture, Kerala Agricultural University, Vellayani during 2005 to 2006 and the gist of the results are presented.

- Nine species of pod bugs belonging to eight genera and four families were found to infest vegetable cowpea. They were *Acrosternum graminea* (Fab.), *Clavigralla gibbosa* Spinola, *Cletus bipunctatus* Westw., *Coptosoma cribraria* Fab., *Homoeocerus* sp., *Nezara viridula* (L.), *Piezodorus rubrofasciatus* (Fab.), *Riptortus? linearis* (Fab.) and *Riptortus pedestris* Fab. *R. pedestris* was the dominating species. *N. viridula* and *R?linearis* were the next important species. Occurrence of *C. bipunctatus, Homoeocerus* sp., *P. rubrofasciatus* and *R? linearis* are reported for the first time from vegetable cowpea in India.

- Early colonization of *R. pedestris* on pods irrespective of their position in the plant, occurrence throughout the day, ability to utilize dry pods, camouflaging of nymphs with dry leaves are the attributing factors for the dominance of the bug.

- *R. pedestris* caused maximum feeding damage of 74.96 per cent seed weight loss within a given period of time when compared to *R? linearis* (55.17 per cent) and *N. viridula* (48.89 per cent).

- Nine predators of pod bugs were identified. All of them excepting spiders are being reported for the first time as predators of pod bugs. The predators include four preying mantids *viz., Elmantis tricomaliae* (Mukharji-Hazra), *Euantissa pulchra* (Fabricius), *Humbertiella ceylonica* (Saussure) and *Heirodula? ventralis* Giglio-Tos, an ant predator of *N. viridula* eggs, *viz., Camponotus compressus* Fabricius, an unidentified reduviid bug and three spider predators *viz., Argiope pulchella* (Thorell), *Peucetia virdana* (Stoliczka) and *Telamonia dimidiata* (Simon).

- One ectoparasitic mite (unidentified) caused the death of nymphs of *N. viridula* (except fifth instars), *P. rubrofasciatus* and *R? linearis*. This is the first report of an ectoparasitic mite on pod bugs in India.

- Twenty six plants were found to support the survival of *R. pedestris*. The bug successfully completed its biology in six of them. Leguminosae was the most preferred family. *Cassia occidentalis* (L.), *Panicum maximum* (L.) and *Synedrella nodiflora* (L.) Gaertn. were the important weed plants that hosted *R. pedestris.*

- Minimum temperature showed significant positive correlation with the population of *N. viridula* nymphs, *N. viridula* adults and nymphs of *Riptortus* spp.

- *N. viridula* completed its life cycle in 22.59 $\pm$ 0.41 days in vegetable cowpea var. Sharika, by undergoing five nymphal instars.

- *P. rubrofasciatus* underwent five nymphal instars and completed its life cycle in 20.19 $\pm$ 0.20 days in vegetable cowpea var. Sharika.

- *R? linearis* took 22.05 $\pm$ 0.25 days to complete its life cycle on vegetable cowpea var. Sharika. *R. pedestris* completed its life cycle in 21.40, 24.24, 24.00 days in vegetable cowpea var. Sharika, grain cowpea var. Pusa Komal and coffee senna weed (*C. occidentalis*) respectively. Vegetable cowpea was the most suitable host of *R. pedestris.* This is the first report of biology of *R. pedestris* on a weed host in India.

- Based on the laboratory bioassay, using *R. pedestris* nymphs, Amrutneem 5 ml l^{-1} ranked first among the botanicals causing 60.13 per cent mortality. Malathion 0.05 per cent caused rapid mortality of cent per cent within 90 minutes of exposure.

- The fungal pathogens *Beauveria bassiana* @ 2.5 x 10^7 spores ml^{-1} and *Rhizopus oryzae* @ 7 x 10^6 spores ml^{-1} produced only very low mortality levels in *R. pedestris* nymphs. *Pseudomonas fluorescens* P.F.I. @ 20 gl^{-1} was totally ineffective on the pest.

- The supremacy of Amrutneem 5 ml l^{-1} among the botanicals was pronounced in the field experiment also.

- Imidacloprid 0.005 per cent and dimethoate 0.05 per cent recorded significantly lower populations of *Riptortus* spp.

- Imidacloprid 0.005 per cent recorded the highest yield and also it was on par with dimethoate 0.05 per cent and malathion 0.05 per cent. The benefit cost ratio of these chemicals followed the same trend as in yield. The treatments *viz.,* Amrutneem 5 ml l^{-1}, Neem Azal 2 ml l^{-1}, Nimbecidine 2 ml l^{-1}, fenvalerate 0.03 per cent, lambda cyhalothrin 0.002 per cent, chloropyrifos 0.03 per cent were also superior to control.

- Monitoring pod bugs, mechanical destruction of eggs, nymphs and adults, wetting the crop canopy during irrigation to wash off the first instar nymphs of *N. viridula*, removal of alternate hosts *viz., C. occidentalis, P. maximum, S. nodiflora,* removal of crop trash in bhendi and chilli fields, adjacent to cowpea crop and application of Amrutneem 5 ml l^{-1} / Nimbecidine 2 ml l^{-1} / Neem Azal 2 ml l^{-1} / imidacloprid 0.005 per cent / dimethoate 0.05 per cent / malathion 0.05 per cent / fenvalerate 0.03 per cent / lambda cyhalothrin 0.002 per cent / chlorpyrifos 0.03 per cent are the suggested management measures for pod bugs in vegetable cowpea.

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Appendix

Appendix

Weather parameters recorded during October 2005 – September 2006

Period	Temperature °C		Relative humidity (%)		Rainfall (mm)	Rainy days
	Max.	Min.	Morning	Evening		
I FN October 2005	31.70	23.60	83.15	70.10	49.50	2
II FN October 2005	31.05	23.50	92.95	74.45	65.00	6
I FN November 2005	30.80	23.70	92.85	77.50	57.50	7
II FN November 2005	30.50	23.30	93.80	75.80	103.70	5
I FN December 2005	31.10	23.07	94.77	74.93	70.87	6
II FN December 2005	31.35	22.50	95.10	66.45	2.45	1
I FN January 2006	32.15	23.25	92.45	67.10	6.60	1
II FN January 2006	29.90	21.30	94.50	70.55	4.65	1
I FN February 2006	31.85	22.25	90.65	74.20	0.00	0
II FN February 2006	32.35	22.90	92.55	62.85	0.00	0
I FN March 2006	31.95	23.75	93.65	67.75	14.15	3
II FN March 2006	32.50	24.77	95.43	65.43	0.70	0
I FN April 2006	33.20	25.45	92.80	72.00	4.45	1
II FN April 2006	32.85	25.85	91.40	69.90	12.70	2
I FN May 2006	33.25	26.35	85.25	70.25	16.50	0
II FN May 2006	30.67	24.33	93.67	79.77	80.70	9
I FN June 2006	31.60	24.75	90.40	74.50	0.25	1
II FN June 2006	29.30	25.45	88.05	74.20	85.90	6
I FN July 2006	29.45	23.45	93.15	82.55	76.65	7
II FN July 2006	30.20	24.10	90.00	71.45	1.65	0
I FN August 2006	29.80	23.53	93.67	78.43	47.23	6
II FN August 2006	30.60	23.55	91.45	79.65	0.75	3
I FN September 2006	30.40	23.30	89.65	80.35	52.95	6
II FN September 2006	30.00	22.90	94.00	80.20	136.55	10

BIOECOLOGY AND MANAGEMENT OF POD BUGS INFESTING VEGETABLE COWPEA, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt

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Abstract of the thesis submitted in partial fulfillment of the requirement for the degree of

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ABSTRACT

The mounting problems posed by pod sucking bugs recently in the vegetable cowpea ecosystem is emblematic of the changing pest status in favour of sucking pests in many agro ecosystems. To devise management strategies against the bugs, a project entitled "Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt" was undertaken during 2005-2006 at the College of Agriculture, Vellayani.

Nine species of pod bugs *viz.*, *Acrosternum graminea* (Fab.), *Clavigralla gibbosa* Spinola, *Cletus bipunctatus* Westw., *Coptosoma cribraria* Fab., *Homoeocerus* sp., *Nezara viridula* (L.), *Piezodorus rubrofasciatus* (Fab.), *Riptortus? linearis* (Fab.) and *Riptorus pedestris* Fab. were recorded. *A. graminea, C. bipunctatus, Homoeocerus* sp., *P. rubrofasciatus*, *R? linearis* are new reports from vegetable cowpea in India. *R. pedestris* was the dominating pod bug followed by *N. viridula* and *R? linearis.*

Nine predators including four preying mantids, one black ant, a reduviid bug, three species of spiders and one ectoparasitic mite were documented as natural enemies of pod bugs. Record of the mantids, *Elmantis tricomaliae* (Mukharji-Hazra), *Euantissa pulchra* (Fabricius), *Humbertiella ceylonica* (Saussure), *Hierodula? ventralis* Giglio-Tos, the black ant *Camponotus compressus* Fabricius and the ectoparasitic mite are new reports of natural enemies of pod bugs in India.

Plants belonging to the family Leguminosae were the most preferred hosts of *R. pedestris. Cassia occidentalis* (L.), *Panicum maximum* (L.) and

Synedrella nodiflora (L.) Gaertn. served as important weed hosts. Minimum temperature exerted significant positive effects on the population of *N. viridula* and nymphs of *Riptortus* spp.

N. viridula, P. rubrofasciatus and *R? linearis* completed their life cycle in 22.59 $\pm$ 0.41, 20.19 $\pm$ 0.20 and 22.05 $\pm$ 0.25 days respectively on vegetable cowpea var. Sharika *R. pedestris* took 21.40, 24.00, 24.40 days to complete its development in vegetable cowpea var. Sharika, grain cowpea var. Pusa komal and coffee senna weed (*C. occidentalis*) respectively.

Amrutneem 5 ml l^{-1} proved superior among the botanical insecticides tried against *R. pedestris* in the laboratory bioassay and field experiment and it was followed by Nimbecidine 2 ml l^{-1} and Neem Azal 2 ml l^{-1}. *Beauveria bassiana* @ 2.5 x 10^7 spores ml l^{-1} and *Rhizopus oryzae* @ 7 x 10^6 spores ml^{-1} was pathogenic to *R. pedestris* but the infectivity was low. *Pseudomonas fluorescens* P.F.I @ gl^{-1} showed no lethal effects on *R. pedestris*.

Imidacloprid 0.005 per cent and dimethoate 0.05 per cent were significantly superior in suppressing the nymphal population of *Riptortus* spp. All the insecticide treatments evaluated were significantly superior to control in reducing the population of *Riptortus* spp. Imidacloprid 0.005 per cent gave the highest benefit cost ratio.

Monitoring the population of pod bugs, mechanical destruction of eggs, nymphs and / or adults, wetting the crop canopy thoroughly during irrigation, removal of weed hosts *viz., C. occidentalis, P. maximum* and *S. nodiflora* in vicinity, trash removal after harvest in cowpea, bhendi, chilli and application of Amrutneem 5 ml l^{-1} / Nimbecidine 2 ml l^{-1} / Neem Azal 2 ml l^{-1} / imidacloprid 0.005 per cent / dimethoate 0.05 per cent / malathion 0.05 per cent / fenvalerate 0.03 per cent / lambda cyhalothrin 0.002 per cent / chlorpyrifos 0.03 per cent are suggested as management measures against pod bugs.