BIOECOLOGY AND LIFE-TABLES OF THE PEA APHID *Aphis craccivora* KOCH. AND ITS NATURAL ENEMIES

By

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DECLARATION

I hereby declare that this thesis entitled "BIOECOLOGY AND LIFE-TABLES OF THE PEA APHID *Aphis craccivora* KOCH. AND ITS NATURAL ENEMIES" 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 LIFE-TABLES OF THE PEA APHID *Aphis craccivora* KOCH. AND ITS NATURAL ENEMIES" is a record of research work done independently by Ms. REJI RANI. O.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or accociateship to her.

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INTRODUCTION

1. INTRODUCTION

Pea aphid Aphis craccivora koch. is a very common pest of a variety of plants found throughout India. Lab lab Arachis hypogea, Glyricidia maculata, Phaseolus mungo, Phaseolus radiatus and many other pulses are often seen seriously damaged by the insect. The nymphs and adults infesting gregariously the tender shoots, inflorescence and tender pods cause malformations stunting and even drying up of these parts. A. craccivora is also reported as a vector of cowpea viruses i Africa (Singh, 1978) and mosaic virus of lab lab in India (Nayar et al., 1976).

Being soft bodied and slow moving the insect is amenable to chemical control. But the highly polyphagous nature of the pest and the round the year availability of many of the vegetable and manure crops often results in the continuous abundance of hosts in all agroecosystems. When the persistant effects of the insecticides in the treated plots fades out the pest reestablishes and multiply faster in the absence of natural enemies and assumes more serious levels. At sublethal doses many of the insecticides are known to induce resurgence of aphids (Jayaraj, 1987).

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These limitations necessitiate repeated and frequent application of insecticides for the control of A. craccivora and the technology often becomes economically non viable.

On crops like cowpea the pest reaches the peak populations at flowering and fruiting stages of the crop. The vegetables harvested from crops frequently treated with toxic chemicals for the control of A. craccivora are prone to certain hazardous levels of pesticide residues. This menace has been widely reported and accepted as a serious draw back of chemical control particularly for vegetable and fruit crops. In view of the above limitations, more viable and ecologically sound technologies for the management of the pest is an urgent necessity. Many predators, (Coccinellids, Syrphids, Chrysopids and Hemorobids), parasite (Trioxys indicus) and recently pathogen (Fusarium pallidoroseum) have been reported on A. craccivora under field conditions. Biology and efficacy of some of these biocontrol agents have also been investigated.

For evolving a sound integrated control strategy against a pest a lot of basic information on the ecology of

the pest concerned and on the impact of biotic and abiotic factors on the population build up of the pest are absolutely essential for each agroecosystem. The studies conducted on these aspects relating to A. craccivora in Kerala are very limited (Mathew et al., 1971, Hareendranath, 1987). Hence investigations were taken up with following objectives.

1. To make a preliminary survey to identify the natural enemies of A. craccivora in the Vellayani ecosystem.

2. To assess the population fluctuation of A. craccivora on cowpea and glyricidia during different seasons.

3. To assess the fluctuation of the population of natural enemies of A. craccivora in relation to the population of the pest.

4. To assess the association of the pest population with the abiotic factors in the ecosystem.

5. To study the biology of A. craccivora and its predominant natural enemies in the ecosystem.

6. To assess the feeding potential of the selected natural enemies.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Importance of *Aphis craccivora* Koch. as a pest

The pea aphid *Aphis craccivora* koch. is a sporadic pest of pulses often causing serious damage to the crop. Both the nymphs and adults of the insect feed on leaves, flower buds, pods and branches of cowpea by delivering sap and severely affect the plant growth (Srivastava and Singh, 1976). Serious damage occurs at high populations by greatly reducing pod yield and entire plant may even be destroyed (Kabir, 1978).

Singh and Van Emden (1979) reported that direct damage to host plant was due to the depletion of assimilates by the removal of sap coupled with an increase in respiration rate in the plant while large numbers cause distorted leaves and stunted plants with small poorly nodulated root system, reduced yield and in extreme cases the death of the plants.

A. craccivora was reported as a major pest in Asia causing an estimated loss of twenty to forty per cent in yield and as a minor pest in Africa, sometimes causing an yield loss of 35 per cent (Singh and Allen, 1980).

Rangaswami (1976) found that *A. craccivora* and its predators on lab lab niger had a high population of 246.7 aphids per plant, in August sown crop, 167.11 in October sown crop and 58 in May sown crop. There was a negative correlation between maximum temperature, minimum temperature, relative humidity and aphid population.

Saharia (1980) sampled the populations of aphids and its coccinellid predators at weekly intervals on cowpea for three years in Assam and found that population peak of aphid coincided with pod formation. Population of predators depended on the population of prey. Rainfall, quality of food (host) and predators were considered the three most important factors responsible for fluctuation in the population of the aphid.

The relationship between the aphid and its coccinellid predators on groundnut was studied by Butani and Bharodia (1984). A positive correlation was observed between the aphid index and the population of active stages of predators during March, while in April the aphid population decreased with increased abundance of the coccinellids. The predator population had declined by the first week of May, most of them having migrated to other areas due to decrease in prey abundance.

2.2 Population fluctuation of *A. craccivora*

Mathew *et al.* (1971) investigated the population fluctuations of the aphid and its predators on cowpea at Vellayani. Population of both the aphids and the predators remained high during September to April and was very low during May to August. There was a strong correlation between number of aphids and that of their predators. Temperature and rainfall were also found to influence the aphid population.

Saleh *et al.* (1972) reported a maximum population in August which declined from September in Southern Egypt.

Patel *et al.* (1974) observed at Central Gujarath that the aphids appeared in the second week of August and the population rose to 97 per cent during the third week of the month. The population decreased with the increased population of natural enemies. The population of predators also declined by first week of September indicating that most of them must have migrated to other areas due to the shortage of food.

Selim *et al.* (1987) found that *A. craccivora* and *A. gossypi* attained peak population levels in January and February respectively on *Vigna faba* (broad bean).

Srikanth and Lakkundi (1990) studied *A. craccivora* and its predator population and found a prey dependant predator growth, often predator population lagging behind the prey, pressing for alternate control methods.

The effect of weather (temperature, rainfall, wind speed and sunshine) on population build up of *A. craccivora* was studied by Falerio *et al.* (1990). They observed a negative correlation with maximum temperature, relative humidity and rainfall. Linear regression studies showed that an increase in minimum temperature significantly increased aphid population.

Hijam and Singh (1991) studied the seasonal abundance of *A. craccivora* and several species of predators on cowpea. The predator populations were found to closely follow those of the aphids. On the other hand the aphid population was influenced more by density independent factors than the population of natural enemies.

2.3 Estimation of aphid population in field

Davies (1934) estimated the population of aphid on potato crops by recording the number of aphids on 100 randomly chosen lower leaves.

Thomas and Jacob (1943) counted the aphids on top, middle and bottom leaves of 50 randomly selected potato plants.

Dunn (1951) took 50 cm long tips including the growing point and enclosing leaves and collected 50 to 100 tips per plot in peas.

As the removal of plant parts or whole plants may affect the aphid population of the neighbouring plants, Heathcote (1952) suggested in situ counting if it would be accurate or where only relative estimates of population were required.

Banks (1954) deviced an easy method for estimating populations of *Aphis fabae* Scopli. on field beans. He examined many stems and placed them in one of the five

arbitary classes of infestation viz Zero (0), Very light (V), Light (L), Medium (M) and Heavy (H). Ten samples of each were taken in sealed containers, washed off with 90 per cent ethyl alcohol, the number on each stem was counted and the average of 10 stems was calculated. This average was used to estimate the population of stems in each class recorded in the field.

Swirski (1954) while studying *Hyalopterous pruni* (Geoffroy) in Israel, recorded the number of aphid colonies on each plant and the size of each colony. The number of aphids in different colonies were categorised as from 1 to 5, 6 to 25, 26 to 40 and 41 to 100 and the population was computed assigning the values of 3, 15, 30 and 70 for the categories respectively.

Way and Heathcote (1966) adopted five categories and recorded populations as extremely light, very light, light, medium or heavy based on visual impressions of the length of stem infested, appearance of aphid populations on leaves etc.

Amman (1967) took samples of bark with a 1 1/2 cm cork punch from trees of Fraser fir, *Abies fraseri* for estimating population of *Adeges piceae* (Ratzeburg), and were counted in the laboratory.

Kumar (1971) categorised infested stems and pods of mustard into three classes of infestation viz. heavy, mild and low depending on the density of *Lipaphis erysimi* kalt. Aphid numbers on sample stems and pods were counted in the laboratory and population per unit length of stem or pod was assessed. Aphid population on stems and pods in the field was estimated by using the mean number of aphids per centimetre in each category.

Hanifa *et al.* (1973) recorded the population of aphids per 2.5 cm length of terminal shoot of field bean and Charles Bell (1980) and Dhanorkan and Darvare (1980) also used the same procedure.

Jayappa (1984) placed cowpea plants infested with aphids in one of the five grades viz. Grade 0 - free from aphids; grade 1 - less than 25 per cent of plant area covered

by aphids; grade 2 - 25 to 50 per cent of plant area covered and grade 3-50 to 75 per cent of the plant area covered and grade 4 more than 75 per cent of the plant area covered.

Srikanth (1985) standardised a method for estimating large aphid population on cowpea. He estimated the density of aphids per unit area on different parts of the plant such as stem, leaves and pods after placing samples of infested plant parts into three classes of infestation viz. heavy, medium and low depending on degree of colonisation. The length and circumferance of samples (stems and pod) were measured in laboratory and was calculated. The number of aphids per cm^2 area of plant part was assessed and using these indices population in field samples was estimated.

Srikanth and Lakkundi (1988) estimated the population of aphids on cowpea leaf as the total of the aphid numbers on three leaflets. Aphids on the upper, middle and lower leaves since they were not found in dense colonies. Population of predatory coccinellids were taken by direct counting.

2.4 Natural enemies of *A. craccivora* koch.

2.4.1 Predators

2.4.1.1 Coccinellids

Population of aphids is controlled to a great extent by their predators. Reports on predators of aphids include *Chilomenes sexmaculata* Fabr. (Lefroy, 1909), Bagal and Trahan, 1949), *Scymnus xerampelinus* Muls. (Lefroy, 1909), *S. quadrillum* F., *Brumus suturalis* F. and *Adonia variegata* Goze., *Scymnus nubilis* Muls. and *Scymnus gracilis* Motsch. (Kapur, 1942) and *Coccinella septumpunctala* L. (Lal and Singh, 1947), *Chilocorus nigritus* Fabr. (Rao *et al* 1954), *Rodolia cardinalis* (Subramaniam, 1923), *Brumus* sp (Khan and Hussain 1965). Falerio *et al* (1990) found *Brumus*, *Chnysopa* and *Coccinella* sp in colonies of *A. Craccivora*.

The biology and ecology of predaceous cocconellids viz. *C. Septumpunctata*, *C. Sexmaculata*, *B. Suturalis* and *C. nigritis* were studied by Hagen (1962).

Jacob (1963) worked out the morphology of grub, pupa and adult of *C. Sexmaculata*.

Patel (1974) observed that the population of *A. craccivora* was brought under complete control by *M. sexmaculatus* when the predator population was quite abundant.

Saharia (1980-81) reported that *M. sexmaculatus* was the most abundant and persistant predator of *A. craccivora* because of its short life cycle, larger population and fairly high feeding potential. Other predators reported by him were *Coccinella rependa*, *M. sexmaculata*, *S. bisellata* and *Harmonia dinudata*.

Anand (1983) studied the extent of predation by *C. septumpunctata* and *M. sexmaculata* on five species of aphids. The predators consumed large numbers of *Brevicoryne brassicae*, *A. craccivora*, *Macrosiphum pisum* and *Lipaphis erysimi* while the consumption of *Aphis gossypi* was the least.

Parasuraman (1989) found 8 species of coccinellids feeding on *A. craccivora* in pulses of which *M. sexmaculatus* (43%) and *Scymnus sp* (25%) were the dominant species.

In an experiment conducted in UAS Bangalore Srikanth and Lakkundi (1990) reported that *M. sexmaculatus* was the most predominant predatory coccinellid constituting 77 to 88 per cent in summer and 83 to 95 per cent in kharif.

Sharma (1991) found that *C. septumpunctata* was the most abundant predator of *A. craccivora* on *Lathyrus*, Lentil and Chickpea. Other coccinellid predators observed were *C. divaricata*, *Coccinella. sp*, *Micraspis discolor*, *M. sexmaculatus*, *Menochilus sp* and *C. transversalis*.

2.4.1.2 Syrphids

Lefroy (1909) reported that about 67 species of syrphids were prevalent in India and that the syrphid larvae fed exclusively on aphids. Deoras (1942) reported that a single syrphid larva destroyed about 484 aphids in four hours. According to Khan and Hussain (1965) Syrphids were very important predatory group of insects from the economic point of view since they check groundnut aphid infestation.

According to Sita Raman (1966) *Xanthogramma scutellare* Fb. was the most important Syrphid predator in

Kerala. He also reported that the population peak of these flies were during November and March-April.

Saxena *et al.* (1970) reported the predatory behaviour of the hover fly, *Iscchiodon scutellaris* F. on *A. craccivora* in Yugoslavia.

Rangaswami (1976) studied the ecology of *I. scutellaris* and *A. craccivora*. Peak population of the predator coincided with the peak of prey population.

2.4.2 Parasites

Trioxys indicus (Braconidae) was an important parasitoid of *A. craccivora*. The average fecundity of the parasitoid was 143 per female and the mean period of development was 17.8 and 14.5 days respectively for female and males. (Pandey and Rajendrasingh 1984). A linear relationship was observed between the mortality level of the aphids caused by the parasitoid and the aphid density. Each parasitic female could attack 46.8 aphids in a 15 minute period when host population was 100 and 12 aphids when the

population was 25. The Peak parasitism of 64.6 per cent was observed in mid February resulting in the suppression of the aphid.

2.4.3 Pathogens

Fusarium pallidoroseum was seen pathogenic to *A. craccivora*.(Hareendranath, 1989). The infected insects turned pale in the initial stages and assumed a brownish black colour later on. Complete mortality occured in 48 to 72 hour of inoculation. The mummified cadavers were seen adhering to plants and covered with fluffy growth of mycelium. Application of a spore suspension at the rate of 3.5×10^6 spores per ml and 7×10^6 spores per ml was as effective as the insecticide quinalphos sprayed at 0.05 per cent in controlling the pest.

Faizal (1992) recorded a mortality per cent of 99.57 when the aphids were sprayed with culture filtrate of *F. pallidoroseum* grown in Richard's medium. The formulation of spore as wettable powder with diatomaceous earth as inert material was found more effective than wettable powder with talc. Virulence of the fungal spore decreased with increase

in storage period and it retained substantial virulence upto 4 days of storage.

2.5 Biology of *A. Craccivora* Koch.

Behura (1956) reported that the nymphs of *A. craccivora* had four moults and the interval between two instars was usually 24 hours or less although in some cases it was delayed upto 72 hours. The apterous female began producing broods within 24 hours of the attainment of adult stage. The largest number of young ones produced by a single apterous parthenogenetic female was 29 and the maximum number of broods produced within 24 hours was 12.

According to Dorge *et al.* (1966) the nymphal stage of the insect on goundnut lasted 3 to 8 days in the laboratory and the apterous and alate females produced 54 and 47 nymphs over a period of 13 and 15 days respectively.

Biology of the aphid on groundnut under green house condtions in Punjab was studied by Bakhetia and Sidhu (1977). They observed that the young ones passed through four to five instars to reach the adult stage and the adult aphid started

reproducing within 24 hour. The pre-productive period varied from 4.2 ± 0.1 to 20.8 ± 1 days in different seasons with the peak period between December and March and the minimum between April and May. The reproductive period was 4.4 ± 0.8 to 29.2 ± 1.5 days in different seasons and the mode of reproduction was exclusively through parthenogenesis throughout the year. The number of young ones produced by a single female in its life-time was 15.1 ±2.2 to 123.7 ± 15.4 nymphs. Adults survived for 0.7 ± 0.7 to 3.7 ± 1.9 days after completion of reproduction. The longevity of the aphid was 9.6 ± 3.6 to 68.2 ± 13.2 days which started increasing with the onset of winter and was 16.4 ± 5.8 to 68.2 ± 13.2 days against 9.6 ± 3.6 to 20.4 ± 6.2 days in the rest of the season. The aphid passed through 31 overlapping generations during one year out of which 16 were passed during the seasons of ground nut crop (July to September).

Gargav and Verma (1980) in a laboratory study conducted at 31^{o}C and 91 per cent RH observed that the aphids reared on cowpea completed development in 4.3 days, adults lived of 11.5 days and fecundity of female was 81.4. On sprouts of *Dolichos lablab*, the average durations of four nymphal instars were 1.3 days, 1.0 days, 1.1 days and 1.1 day

respectivley. The adult lived for 7.6 days and took 0.6 dyas for maturing and producing young ones. A single female produced on an average 45.7 nymphs during its reproductive phase. Post reproductive phase was 0.3 days. The total life cycle of aphid from birth of nymph to its death averaged 12 days.

Talati and Butani (1980), studied the reproductive rate of the aphid on groundnut in the laboratory and observed that the rate of reproduction varied from one to thirteen for different adults. The total number of nymphs produced varied from 38 to 99 at the prevailing temperature of 22 to 26^{o}C. The type of reproduction of the aphid was found to be parthenogenetic viviparity.

Dharmareddy *et al.* (1983) found that the developmental period and adult longevity of the aphid on bean were 4.3 days and 12.4 days respectively. The fecundity of a single apterous female was 56.9 nymphs.

Radka (1983) reported that fundatrices of bean aphid required almost as long to reach maturity as

parthenogenetic viviparous nymphs under laboratory conditions.

Kaakeh and Dutcher (1993) in a green house study on different hosts found that *A. craccivora* had the shortest development, pre reproductive and generation times on cowpea as compared to the other hosts viz. *I. hirsuta*, *Vicia villosa*, *Sesbania exaltata*, *Trifolium incarnatum* and rye, whereas the mean probe duration was longer on cowpea and *I. hirsuta* as compared to the others.

2.6. Feeding potential of predators

2.6.1. Feeding potential of coccinellids

The coccinellids vary in their feeding capacities both in the adult and larval stages. According to Lefroy (1909) the total conscumption of aphids by a single larva of *C. sexmaculata* during its life time was 2,400 while Bagal and Trehan (1949) found it to be 303 for Chilomenes and 420 for *C. septumpunctata*, adults however being heavy feeders. Maximum number of aphids consumed by a pair of *Chilomenes* was 16,321 and that of *C. septumpunctata* was 22574 during their

life time with an average of 60.84 and 106.29 aphids per adult per day. Jacob (1963) conducted detailed studies on the morphology and ecology of predatory coccinellid, *C. sexmaculata* and worked out the feeding potential of the predator to be 27.2 aphids per day.

Studies on the feeding potential of the grubs and adults of coccinellid predators of *A. craccivora* viz. *C. sexmaculata*, *S. quadrillum* and *P. circumflexa* were undertaken by Sarala Devi (1967). The average feeding potential of the first, second and third instar larva of *Chilomenes* was 7.11, 38.44 and 70.78 under laboratory conditions. The adult under laboratory conditions consumed 27.22 aphids per day and a total of 906.7 aphids during its life time whereas under field conditions the consumption was 92.35 aphids per day and 5611 aphids during its life time. With regard to the other predators *S. quadrillum* and *P. circumflexa* the per day consumption of aphid by adults was 9.26 and 9.83 respectively where as the consumption during entire life period was 473.43 aphids and 276.8.

In a laboratory experiment to asertain the feeding rate of *M. sexmaculata* on three species of aphids, Haque and

Islam (1978) observed that the per day consumption of a single pair of the predator ranged between 23.1 and 91.7, 12.5 and 15.3 and 24 and 63 numbers of *A. craccivora M. perzicae*, and *A. gossypi* respectively.

Ofuya (1986) studied the predation of *Cheilomenes vicina* on *A. craccivora* under laboratory conditions and reported that early aphid instars were consumed in large numbers than later instars. Feeding rates were found to have a significant positive correlation with the population density of the prey.

Lokhande and Mohan (1990) carried out a laboratory test to find out the per day consumption of *A. craccivora* by *M. sexmaculatus*. The average consumption of the predator larva was 8.5 adults and 73.52 nymphs where as the adult predator consumed 24.34 adults and 176.15 nymphs.

Das (1991) reported that the grub of *M. sexmaculatus* consumed 9 to 13 adults of *A. craccivora* on the first day after hatching. Consumption increased to 53.05 $\pm$ 0.93 on second day. After eighth day

consumption fell down sharply. Average consumption during the entire life stage was 270 to 367 aphids.

Predatory efficiency of *C. transversalis* on *A. craccivora* was worked out by Debaraj and Singh (1990). Consumption increased with the instars and reached a maximum in the final (fourth) instar. The total number of aphids consumed by a single larva varied from 401 to 736.

2.6.2. Feeding potential of syrphids

Sita Raman (1966) recorded that a single larva of the predator. *X. scutellare* required on an average 123 *A. craccivora* per day.

Sarala Devi (1967) studied the feeding potential of *X. scutellare* and observed that each of the predator maggot consumed 386.86 aphids during its larval period of 5.07 days.

Patro and Beheras (1993) reported that *Paragus serratus* a syrphid predator of *A. craccivora* consumed 9.2, 33

and 34 number of aphids during the first, second and third instars respectively. The total consumption was 258.3 aphids.

2.7. Life-table

2.7.1. Life-tables in the study of insect population

Deevey (1947) used life-tables in relation to natural populations of animals for the first time. The use of life-tables for the study of natural populations of insect pests has been discussed comprehensively by Moris and Miller (1954), Moris (1963), Harcout (1969) and Southwood (1978).

2.7.2. Life-table studies in India

Atwal and Balraj (1969-74) prepared the budget and life-table of *Chilo partellus* to determine the key mortality factor. Mortality at the egg stage due to sterility was 49.18 per cent. Other mortality factors were predators, diseases and parasites during larval stage. Apparently abiotic factors, particularly high temparatures during summer

were lethal to the survival of the borer larvae during monsoon period.

The generation survival value for pre monsoon period was 0.092. The trend index (1-15) indicated that mortality factors operating during this period were not effective in causing decline in pest population.

During monsoon egg mortality was 68.4 per cent. Over 77 per cent of larvae died in first instar due to rainfall. Natural enemies were responsible for mortality among larvae during the period. Extent of parasitisation of *Apanteles flavipes* was only 0.4, 3.9 and 6.4 per cent during third, fourth and fifth instar. Generation survival for monsoon was 0.028, considerably lower than that in premonsoon. Trend index (0.983) indicated mortality factors were effective in pest decline.

During post monsoon egg mortality was only 20.77 per cent. Mortality during larval stage (93.08 per cent) was the primary cause of reduced generation survival. Maximum contribution towards larval mortality was due to cultural

practices. *A. flavipes* caused 28.94 per cent mortality. Spider predators and diseases contributed 3.14 per cent. Generation survival value was 0.069 and trend index 0.88, indicating effectiveness of mortality factors.

Phadke (1982) compared four different host varieties of *Brassica species* viz. Ys-Pb-24 (Yellow sarson), BSH-1 (brown sarson), T9 (Toria) and variety Pusa bold (rai) through the life-table studies on *Lipaphis erysimi* kalt., a serious pest of the crop. The net reproductive rates (Ro) were 114.377, 94.25, 119.377 and 86.121 respectively. The intrinsic rates of increase (rm) were 0.2018, 0.1552, 0.2062 and 0.1648 per female per day respectively. Yellow sarson and Toria were found favourable to aphid. The finite rate of increase accordingly was found to be 1.224, 1.168, 1.228 and 1.206 respectively.

Life-table studies on *Cotesia orientalis* larval parasitoid of *Exelastis atomosa* Fab. were carried out by Sathe and Nikam (1984). The natality (mx) was found to be 11.7, intrinsic rate (rm) was 0.188 and population multiplied 41.93 times with a mean generation time of 19.87 days.

Life and fertility tables of *Bagrada hilaris* were prepared (1981-82 to 1982-83) at IARI, New Delhi, by Lakshmi Narayana and Phadke (1987). The bug showed a relatively higher rate of natural increase during August to October. The minimum (rm) values was 0.1885 in the first year and 0.2011 during the second year. Afterwards it declined. Maximum and minimum mean temperature showed a significant positive correlation with (rm) while rain and morning and evening humidity showed significant negative correlation. Sixty eight per cent of variation in (rm) was attributed to weather parameters.

Life-table studies on *B. hilaris* (Lakshmi Narayana and Phadke, 1987) showed that the early nymphal stages of the bug were more vulnerable to natural mortalities and rainfall was the key mortality factor.

Mukunthan (1989) found that the key mortality factor of *Scirpophaga expertalis*, sugarcane top borer, was parasitisation of egg mass and failure of neonate larvae to enter into the midrib. The trend index of the insect calculated from life-table was less (0.014) in *Sorghum halepense* as compared to sugarcane and *Saccharum spontaneum*.

Life-table studies of a syrphid predator *Metasyrphus corolae* (F) revealed a high mortality due to a large number of mortality factors. *Bacillus* was the key mortality factor besides parasitisation by *Diplazon laetorius* (F). (Sharma and Bhalla, 1992).

Singh and Jalali (1992) worked out the age specific life-table of *Trichogramma embryophagum* (Htg) and *T. dendrolini* Matsumara. The net reproductive rates (Ro) were 60.23 and 33.98; the intrinsic rates (rm) 0.292 and 0.305; the generation times (T) 14. 03 and 13.25 days for *T. embryophagum* and *T. dendrolini* respectively.

Srinivasaperumal *et al* (1992) constructed life-tables of *Earias vitella* on *Abelmoschus esculentus*, *Gossypium hirsutum* and *Abutilon indicum*. The pest population increased at the rate of 0.124, 0.106 and 0.082 female per day on the three hosts respectively. Generation time of insect was shorter on *Abelmoschus* (34.24 days) than on gossypium (38.24 days) and *Abutilon* (39.22 days). Innate capacity for increase was also high on *Abelmoschus*, thus showing a higher suitability of that host.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field experiments and laboratory studies in the present investigations were carried out at the Instructional farm and the Department of Entomology respectively of the College of Agriculture, Vellayani during the period 1993 to 1994.

3.1. Raising crops

Bulk crop of cowpea variety 'Malika' known to be susceptible to the pea aphid, was maintained during December 1993 to July 1994. The crop was raised in an area of four cents with a spacing of 45 x 15 cm and the recommended package of practices (Kerala Agricultural University, 1989) were followed. No insecticides were used on the crop.

Glyricidia plants of uniform age, height (1.5 m) and canopy selected from the existing plants maintained under uniform cultural practices in the Agricultural College farm were used for the studies. Observations on the pest and its natural enemy populations were recorded from December 1993 to November 1994.

3.2. Estimation of the aphid population on cowpea

3.2.1. Recording the aphid infestation on twigs of the crop at weekly intervals after planting

Incidence of aphids were assessed during the entire crop period commencing from 28 days after sowing. Fifteen plants were selected at random for each observation. In each plant the terminal twig upto 15 cm length with the unopened leaves and two opened leaves were observed for aphid incidence.

Based on the intensity of infestation these twigs were classified following the method of Banks (1954) and the data were recorded. The classes adopted in recording the observation were as follows.

1. Zero (0) : No aphids
2. Very light (V) : From one aphid to a small colony confined to the very yongest leaves of the crown
3. Light (L) : Several aphid colonies present on the stem and not confined to the uppermost leaves.

4. Medium (M) : Aphids present in large numbers not in recognizable colonies but diffuse and infesting a large proportion of leaves and stem

5. Heavy (H) : Aphids present in large numbers, very dense, infesting all the leaves and stem, the latter usually being black with aphids

3.2.2. Estimating the aphid population in different classes of infested twigs mentioned in para 3.2.1

The number of aphids present in different classes of samples were estimated. The collection of samples and estimation of aphid population were done following the method of Srikanth (1985). Ten numbers of the shoots in each class were collected from the experimental field.

The sample shoots were cut with sharp blade ensuring that the number of aphids falling from the shoots was reduced to the minimum. These were then put in plastic containers with provision for ample aeration and were brought to the laboratory.

Each sample shoot was then transferred to a white paper and were gently tapped to dislodge the aphids. A camel hair brush was also used to dislodge the aphids from the twig. Proper care was taken not to rupture the aphids while brushing. The mean number of aphids (all stages) per twig in each class was assessed. Those were 0, 6.8, 57.6, 295.5 and 679 for the classes 0, V, L, M and H respectively.

3.2.3. Computation of aphid population on twigs observed from field

Using the indices given in para 3.2.2. the aphid population in the samples mentioned in para 3.2.1 were computed and the weekly incidence of aphid population on cowpea was recorded.

3.2.4. Aphid population on pods

Incidence of the aphid on pods were recorded in terms of the number on three pods, one each on the upper, middle and lower part of 15 randomly selected plants in the field. The pods selected were of uniform age and size. The observations were made at weekly intervals throughout the yielding stage of the crop.

The portion of the pod infested by aphid all round was measured in centimeters using a scale. When aphids were not present all round the pod, the portion infested (1/2, 1/4, 1/3 area etc.) was assessed and proportionate adjustments were made in the length of infested portion recorded. As done in the case of twigs, number of aphids present per 2.5 cm of the infested pod was estimated in the laboratory observing ten samples collected from the field. The mean number of aphids was 340 per 2.5 cm length. Using this index the population of aphids on the total infested portion of the three pods in each plant was computed and recorded.

3.3. Estimation of aphid population on glyricidia

In the case of glyricidia six plants were randomly selected for weekly observations. On each plant, four branches one from each of the four sides of the plant were selected. The sampling unit consisted of the terminal unopened leaves and the following eight leaves as the aphid infestation was found to concentrate in this region. (Jacob, 1963). The shoots observed were visually classified and recorded.

Number of aphids in different classes of the samples were assessed as done for cowpea. The mean numbers were 0, 38.14, 1101.71, 2727.71 and 47301 for the five classes of O, V, L, M and H respectively. The population in different observations were computed using the above indices.

3.4. Predator population

The predator population on each observational plant was assessed by direct counting at weekly intervals.

3.5. Correlation studies of aphids with predators and weather parameters

Weather data during the period of observation viz maximum and minimum temperature, rainfall, morning and evening humidity and sunshine were gathered from the meteorological observatory of the College of Agriculture Vellayani.

The weekly observations on the population of aphids and their predators viz. coccinellids, syrphids and spiders were correlated with the weather parameters to assess the association of biotic and abiotic factors on the population build up of aphids.

3.6. Biology of *Aphis craccivora* koch. and its promising predators

Field observations revealed that the coccinellid *Chilomenes sexmaculata* Fabr. was the most abundant predator of the aphid, *A. craccivora* followed by the syrphid, *Xanthogramma scutellare* Fb. Hence the biology of the aphid and the two predators was studied in detail.

3.6.1. Biology of *A. craccivora*

Five newly emerged nymphs were confined in microcage on tender leaf of cowpea plant. Ten replications were maintained. The following observations were recorded from the experiment.

1. Duration of each instar
2. Survival percentage of nymphs
3. Adult longevity
4. Pre-reproductive period
5. Reproductive period
6. Fecundity
7. Male : Female ratio

3.6.2. Biology of *C. sexmaculata*

The biology of the test insects was studied by rearing the insect in the laboratory.

Tender terminal twigs of cowpea/glyricidia infested with *A. craccivora* were collected from the field. These were cut to a length of 10 cm and the predators already present were removed from the colonies carefully observing the colonies through a hand lens. The shoots were kept turgid by keeping the cut end of stem dipped in water contained in a vial. The vial along with the infested twig was placed inside a jar.

Male and female adults of *C. sexmaculata* collected from the field were released into the jar. The mouth of the jar was covered with a muslin cloth. The beetles mated readily inside the jar. Eggs laid on the same day were transferred to a petridish.

The first instar grubs emerged on the same day were transferred individually to different petridishes using a camel hair brush. Small twigs infested with aphids were

placed inside the petridish as food for the larvae. Observations on the first instar grub were recorded. After the first moulting the grubs were transferred to another set of petridishes and observations recorded. Similar observations on the third and fourth instar grubs and the pupae were recorded.

Freshly emerged adults of the same age were separated and confined in seperate petridishes and were provided with sufficient number of aphids as food. Observations were recorded on pre-reproductive period, reproductive period, adult longevity, fecundity and percentage of survival. Females and males were counted and male : female ratio worked out.

Ten replications were maintained for each stage of the insect.

3.8.3. Biology of *X. scutellare*

Hurricane chimneys of size 15 x 17 cm were used for rearing the test insect. The top end of chimney was closed with muslin cloth and the other end was placed in a petridish

and this was used as rearing cage. The maggots of *X. scutellare* were collected from the field and placed inside the chimneys at the rate of one per chimney. Twigs containing aphid colonies free from predators were placed inside the chimneys as food for the maggots. Fresh twigs infested with aphids were provided every day for food. The maggots after pupation were transferred to clean specimen tubes (8 x 2 cm) and kept for the emergence of adults.

The freshly emerged adults were sexed and the male : female ratio worked out. One pair of adults was transferred to each rearing jar and the mouth of the jar was covered with moistened muslin cloth. Cotton wools soaked in 1% sugar solution were placed inside the jar as food for the adult flies.

Cowpea pods/glyricidia twigs infested with aphid colonies devoid of predators were kept inside the jar to induce egg laying. The twigs were daily examined for the presence of eggs, and fresh twigs were provided every day.

The number of eggs laid were recorded for each replication and the average number of eggs laid per female was worked out. Observations were also recorded on the duration, survival and incubation period of the eggs.

The maggots emerged on the same day were transferred to individual petridishes and were provided with aphid colonies as food. Observations were recorded on the duration and survival of the first instar, second instar and third instar maggots and of the pupae and adults.

3.7. Assessment of comparative efficiency of the biocontrol agent

Feeding potential of the predominant aphidivorous insects viz. the coccinellid *C. sexmaculata* and the syrphid *X. scutellare* was worked out to assess their comparative efficiency in controlling the aphid populations.

Cowpea seedlings were raised in pots of size 6" x 9". Fifteen days after sowing the potted plants were placed inside cages of muslin cloth fitted on metal frames. Aphids of medium size were specially selected from the colonies for the experiment and known numbers were released on the caged plants.

Freshly emerged grubs and adults of *C. sexmaculata* and maggots of *X. scutellare* were obtained from the laboratory culture. One predator was then introduced into each cage, allowing it to feed on aphids. Every morning the skeletons were counted and removed and fresh aphids of known number was supplied. The difference between the number of aphids supplied and those left over was recorded daily. The average number of aphids consumed by the predator was worked out.

Feeding potential was worked out in seperate experiments for the first, second and third instar larvae and for the adults of *C. sexmaculata* and the first, second and third instar of *X. scutellare*. The adults of *X. scutellare* are not predacious. The number of aphids supplied were 25, 50, 100 and 300 for the first, second and third instar larvae and the adult of *C. sexmaculata* respectively and those for *X. scutellare* were 50, 100 and 150 for first, second and third instar larvae respectively. Ten replications were maintained for each experiment.

Observations were recorded daily at 8.00 am on the number of aphids consumed.

3.8.1. Preparation of life and fertility table of *A. craccivora*

Life and fertility table of *A. craccivora* was prepared following the procedure of Phadke (1987).

Leaves of same age and size were selected from cowpea plants grown in pots. A day earlier, 2 mother aphids had been earmarked. Newly emerged nymphs from the earmarked aphids were transferred using a fine camel hair brush, to the selected leaves at the rate of four per leaf. Nymphs were then enclosed in microcages. Six replications were maintained. The survival of individual nymph was observed daily at 4 pm till the natural death of all the individuals occured. The number of young nymphs reproduced parthenogenetically by the emerging adults were also recorded every day. After counting, the newly emerged nymphs were carefully removed without disturbing the mother aphid and microcages were again put back in position for further observations. All the newly born nymphs were found to be females only.

Survival value (lx) and fecundity rate (mx) at each pivotal age (x) were worked out. The net reproductive rate

(R_o), approximate generation time (T_c), capacity for increase (r_c) and the intrinsic rate of increase 'rm' were calculated using the method of Birch (1948). The intrinsic rate was determined by using the relationship $\leq e^{7 - rm.x} .lx .mx = e^7 = 1097$. From this the finite rate of increase (λ) and true generation time (T) were also worked out.

3.8.2. Age-specific life-table of *A. craccivora* on cowpea

In order to understand the trend in population build up of *A. craccivora*, age specific life-tables were prepared for different generations.

For the preparation of life-tables, detailed observations were made on the population of the aphid, its natural enemies and weather parameters. Population of aphids and predators were recorded from 15 randomly selected cowpea plants by direct counting. Two generations were recorded during the period December '93 and January '94. As it was diffucult to differentiate between instars, counts of aphids were recorded for early instar, late instar and adult. Concurrently the number of eggs, larvae and adults of the predators and the ecological factors were also recorded.

Aphids collected from the field were regularly examined in the laboratory for the presence of parasities and diseases. No parasites or pathogens were observed during the period of observation. Life tables were constructed following the method proposed by Morris and Miller (1954) modified by Morris (1963).

The column headings adopted were the age interval (x), the number surviving at the begining of the stage noted in x column (lx), the number dying within the age interval in the x column (dx), the mortality factors responsible for dx (dxf); the per cent apparent mortality (100 qx), per cent real mortality (100 rx) and age specific mortality (k).

All the lx and dx values of the table represent the number of individuals per plant. The population values for all age intervals (lx) were converted to logarithms, and the 'k' values were determined by subtracting each log population from that of the previous stages.

Statistical analysis of the data

The aphid population recorded from cowpea during December 1993 to July 1994 and from glyricidia during December 1993 to November 1994 were subjected to analysis of variance after effecting [log (x+10)] transformation.

The predator population recorded at weekly intervals were not statistically analysed since in many of the observations the population were at zero level. Therefore the range and mean values were presented.

The associations between aphid and predator populations (coccinellids syrphids and spiders) and weather factors (maximum and minimum temperature, rainfall morning and evening humidity and sunshine) were studied through simple correlation analysis of the data.

RESULTS

4. RESULTS

4.1. Population fluctuation of *A. craccivora* on cowpea and glyricidia during the first season (December 1993 to March 1994)

The relevant data and results of statistical analysis of the same are presented in Table 1.

4.1.1. Population on cowpea twigs

During the first five weeks after sowing there was no incidence of the insect on the crop. The population observed at 6 WAS (Weeks after sowing) (162.42/twig) showed a general increasing trend and it reached the peak (544.7) at 15 WAS. The population observed at 8, 11, 12, 13, 14 WAS and at 16 and 17 WAS were on par with the peak population (262.19 to 515.43). The lowest incidence was observed during 21 WAS (32.5) and the count at 7, 20 WAS (44.9 and 57.86) also came on par with the same. The population at 6, 9, 10 and 19 WAS were on par (159.74 to 262.19) and significantly higher than the lowest population levels.

Table 1. Mean number of *A. craccivora* on cowpea and glyricidia. Season I (December 1993 to March 1994)

W.A.S. Weeks after sowing

Figures inparanthesis are transformed values log (x+10)

CD for comparing weekly population on cowpea

twig = 0.3133488

pod = 0.724156

total = 0.4565023

CD for comparing weekly population on glyricidia = 0.426975

Table 1.

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea			Mean number on glyricidia (Per-twig)
		Per-twig	Per-three pods	Total	
27.10.93 to 25.11.93	0-5	NIL	NIL	NIL	--
01.12.93	6	162.42 (2.23)	22.05 (1.51)	248.36 (2.41)	36.78 (1.67)
07.12.93	7	44.89 (1.73)	174.81 (2.27)	379.36 (2.59)	9.25 (1.28)
14.12.93	8	311.51 (2.5)	237.45 (2.39)	972.98 (2.99)	92.87 (2.01)
21.12.93	9	144.80 (2.18)	70.51 (1.91)	393.35 (2.60)	1007.73 (3.0)
28.12.93	10	205.00 (2.33)	207.86 (2.33)	996.62 (3.00)	6118.70 (3.78)
06.01.94	11	214.33 (2.35)	531.06 (2.73)	1810.32 (3.26)	12807.18 (4.1)
14.01.94	12	307.80 (2.50)	1199.68 (3.08)	2879.15 (3.46)	5432.55 (3.73)
20.01.94	13	461.43 (2.67)	5328.08 (3.73)	5918.30 (3.77)	2178.38 (3.34)
27.01.94	14	461.43 (2.67)	4268.49 (3.63)	4960.49 (3.69)	6620.69 (3.82)
03.02.94	15	544.70 (2.74)	9058.16 (3.96)	9627.76 (3.98)	5231.96 (3.71)
10.02.94	16	515.43 (2.72)	25.07 (1.54)	697.74 (2.84)	1905.60 (3.28)
17.02.94	17	412.92 (2.62)	462.42 (2.67)	2291.12 (3.36)	1050.42 (3.02)
24.02.94	18	262.19 (2.43)	300.48 (2.49)	1192.53 (3.08)	1604.53 (3.20)
02.03.94	19	159.74 (2.22)	48.52 (1.77)	407.19 (2.62)	6849.51 (3.33)
09.03.94	20	57.88 (1.83)	31.31 (1.62)	168.13 (2.25)	3110.90 (3.49)
16.03.94	21	32.50 (1.62)	3.07 (1.12)	39.22 (1.69)	7112.00 (3.82)
23.03.94	22	0.0003 (1.0)	0.0003 (1.0)	0.0003 (1.0)	1124.97 (3.05)
30.03.94	23	0.0003 (1.0)	0.0003 (1.0)	0.0003 (1.0)	388.06 (2.59)
Mean		238.76	1160.50	1651.70	3482.33

The population observed during the second week of December and from the first week of January to the fourth week of February were on par and significantly higher. It was followed by the population observed during first, third and fourth week of December 1993 and first week of March 1994 which were on par. Population at second and third week of march were on par and low. There was no population during the third and fourth week of March 1994.

4.1.2. Population on cowpea pods

On pods also the incidence of *A. craccivora* was first noted at 6 WAS and the population was then low (22.05 per three pods). Then the population showed an increasing trend. Observations at 7 to 10 WAS (70.5 to 237.45) were on par and subsequently there was faster increase in number and the population reached the level of 531.06 at 11 WAS. This was also on par with the populations at 17 and 18 WAS (462.2 and 300.48). There was steep increase in the population at 12 WAS and it reached the peak at 15 WAS and the observations were on par (1199.68 to 9058.16).

The high levels of populations on pods were noted between January second week and first week of February

(4268.49 to 9058.16) and it was closely followed by the population during the first week of January and third and fourth weeks of February. Population during the second week of February was low. The number of aphids observed during the month of December also was high though comparatively lower than the month of January and February. The population observed in March and second week of February were very low (50). No pest was observed during the last two observations in the latter half of March 1994.

4.1.3. Total population of *A. craccivora* on cowpea

The population on twigs and pods considered together revealed that the plants were very intensively infested at 13, 14 and 15 WAS, the number of aphids being 4960.49, 5918.30 and 9627.76 respectively which were statistically on par. This was closely followed by the population observed at 11, 12 and 17 WAS (1810.32, 2879.15 and 2291.12 respectively). Population at 8, 10, 16 and 18 WAS were comparitively lower and on par (972.98, 996.62, 697.74 and 1192.53 respectively). Observations at 6, 7, 9, 19 and 20 WAS were on par and the number ranged from 168.13 to 407.19. The count at 21 WAS was significantly lower than the

rest of the observations and it was 39.22 only. No aphids were noted at the last two observations.

The high population levels of the aphid was observed during third and fourth week of January and first week of February (4960.49 to 9627.76). It was closely followed by the population during the first and second weeks of January and second half of February. During December second week to fourth week also levels of infestation was low. The least infestation was recorded during the second week of February and in March first half. The insect was not noted during the third and fourth weeks of March 1994.

4.1.4. Population on glyricidia

Since the planting time of the crop was not known, the distribution of the pest in relation to growth stages of the crop could not be assessed. The peak population was observed during first week of January 1994 and the population was 12, 807.18 per twig. Population during the last week of December, second and fourth week of January, first week of February, first and third week of March came on par with the peak population in January first week, the number of aphids

per twig being in the range of 7112 to 5231.96. Population in January third week, February second and fourth week and March second week which ranged from 3110.9 per twig to 1604.53 per twig were on par. Population observed during December fourth week, February third week and March fourth week ranged between 1007.73 and 1124.97 and were on par. Least population were noticed during the first, second and third weeks of December 1993, the number being 36.78, 9.25 and 92.87 respectively.

4.2. Survey of natural enemies of *A. craccivora*

A survey conducted in the Instructional Farm, College of Agriculture, Vellayani and in the adjacent farmers fields revealed the presence of coccinellids syphid and spiders. The coccinellids were identified as *Chilomenes sexmaculata* Fabr., *Coccinella septumpunctata* L., *Scymnus sp*, and *Micraspis crocea* L. Syrphid predator was identified as *Xanthogramma scutellare* Fb. The spiders included *Lycosa pseudoannulata* and *Oxya chinensis*. A fungal pathogen *Fusarium pallidoroseum* (Cooke) Sacc. was also noticed occassionally in some colonies in the field. No parasites were observed either in the field or samples collected from field and kept under observation in the laboratory.

4.3. Population fluctuation of *A. craccivora* on cowpea and glyricidia during the second season. April 1994 to July 1994

The relevant data and results of statistical analysis are presentedin Table 2.

4.3.1. Population on cowpea twigs

The insect first appeared at 4 WAS and the population was fairly high then (169.20 per twig). AT 5, 7 and 8 WAS also the population remained on par with it, the numbers being 205.73, 169.90 and 111.27 respectively. The peak population was observed at 6 WAS (393.83). From 9 WAS onwards the population on twig was very low ranging from 45.09 to 1.09 aphids. At 15, 18, 19 and 28 WAS the count was at zero level.

The highest level of aphid population on the twigs was noted during April third week. In the remaining observations in April and in the first week of May also there was significantly high levels of the population. From May second week the population declined to very low levels.

Table 2. Mean number of *A. craccivora* on cowpea and glyricidia. Season II (April 1994 to July 1994)

W.A.S. Weeks after sowing

Figures in paranthesis are transformed values log (x+10)

CD for comparing weekly population on cowpea

twig = 0.2019833

pod = 0.569031

total = 0.5218789

CD for comparing weekly population on glyricidia = 0.3282167

Table 2.

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea			Mean number on glyricidia (Per-twig)
		Per-twig	Per-three pods	Total	
16.03.94 to 30.03.94	0-3	NIL	NIL	NIL	—
06.04.94	4	169.20 (2.25)	Pods nil	169.20 (2.25)	171.50 (2.25)
13.04.94	5	205.73 (2.33)	Pods nil	205.73 (2.33)	71.99 (1.91)
20.04.94	6	393.83 (2.61)	Pods nil	393.83 (2.61)	251.45 (2.41)
27.04.94	7	169.90 (2.26)	Pods nil	169.90 (2.26)	926.20 (2.97)
04.05.94	8	111.27 (2.08)	203.94 (2.33)	572.55 (2.76)	1896.17 (3.28)
11.05.94	9	45.09 (1.74)	190.48 (2.30)	322.37 (2.52)	741.84 (2.86)
17.05.94	10	21.08 (1.49)	4673.56 (3.67)	4705.60 (3.67)	54.89 (1.81)
24.05.94	11	16.14 (1.42)	7942.49 (3.67)	7970.37 (3.90)	27.03 (1.56)
30.05.94	12	1.48 (1.06)	3070.00 (3.49)	3071.69 (3.48)	9.24 (1.28)
06.06.94	13	1.09 (1.05)	3893.39 (3.59)	3893.84 (3.59)	2.99 (1.11)
13.06.94	14	3.50 (1.13)	447.92 (2.66)	448.53 (2.66)	2.17 (1.08)
20.06.94	15	0.0003 (1.0)	172.60 (2.26)	172.60 (2.26)	8.02 (1.25)
27.06.94	16	6.80 (1.23)	26.09 (1.56)	42.96 (1.72)	0.0003 (1.0)
04.07.94	17	3.50 (1.13)	5.37 (1.19)	10.07 (1.30)	0.0003 (1.0)
11.07.94	18	0.0003 (1.0)	2.66 (1.10)	2.67 (1.10)	0.0003 (1.0)
18.07.94	19	0.0003 (1.0)	0.0003 (1.0)	0.0003 (1.0)	0.6770 (1.02)
25.07.94	20	0.0003 (1.0)	0.0003 (1.0)	0.0003 (1.0)	5.81 (1.19)
Mean		64.19	1609.84	1303.05	245.29

4.3.2. Population on cowpea pods

The first incidence of the aphid was observed at 8 WAS since the pods appeared only then. The population noted at 8 and 9 WAS (203.94 and 190.48 respectively) were on par and these were also on par with the aphid count at 14 and 15 WAS (447.92 and 172.60 respectively). At 10 WAS there was twenty three fold increase in the population (4673.56) and the maximum population in the season (7942.49) occurred at 11 WAS. Populations at 12 and 13 WAS (3070 and 3893.39 respectively) were on par between themselves and also with the population at 11 WAS. Population at sixteenth week was very low and the aphid persisted upto eighteenth week (26.09 to 2.66). From nineteenth week *A. craccivora* was not seen on pods.

The high population level observed were in the second half of May and first half of June 1994. During the first and second weeks of May and third and fourth weeks of June, the population were on par and significantly lower than those of May second half and first half of June 1994. The incidence during the remaining period of the crop was very low.

4.3.3. Total population of *A. craccivora* on cowpea

Based on the total population on twigs and pods the peak was at 11 WAS (7970.37 per twig and three pods) and the number of aphids noted at 10, 12 and 13 WAS (4705.6, 3071.69 and 3893.84) were also on par with the same. These were followed by the population at 8, 14, 6 and 9 WAS, the number of aphids being in the range of 572.55 to 322.27. Population during remaining period of the crop was low.

The total population also were at high levels in April second half and first week of May 1994. These were followed by the population observed in May first week, June second week, April third week and May second week. The population observed during the remaining periods, were very low.

4.3.4. Population on glyricidia

The high population level was observed at the last week of April and first week of May 1994 (926.20 and 1896.19 per twig respectively) and it was closely followed by population in May second week (741.84). These were followed

by the population in April third and first week (251.45 and 171.50 respectively) which were on par and in April second and May third weeks (71.99 and 54.89 respectively) which were again on par with each other. Low population ranging from 27.03 to 0.68 were observed at May last week and in the month of June and July 1994.

4.4. Population fluctuation of *A. craccivora* on glyricidia during season III (August 1994 to November 1994)

The data relating to the experiment and results of statistical analysis of the same are presented in Table 3.

The high population of 10097.86 per twig was observed during fourth week of August and it was on par with the population observed in August third week (9366.55). These were followed by the population observed during August first and second week and September first week, the number being 4073.94, 2484.58 and 2611.52 respectively. These levels were on par. The population in September second week (479.08) and September third week (95.50) were significantly lower than those of the earlier occasions.

Table 3. Mean number of A. craccivora on glyricidia. Season III (August 1994 to November 1994)

Date of observation	Aphid population (per-twig)	Date of observation	Aphid population (per-twig)
09.08.94	2484.58 (3.39)	04.10.94	10.55 (1.31)
16.08.94	4073.94 (3.6)	11.10.94	8.02 (1.25)
23.08.94	9366.55 (3.97)	18.10.94	16.70 (1.42)
30.08.94	10097.86 (4.0)	25.10.94	10.55 (1.31)
06.09.94	2611.52 (3.42)	01.11.94	16.70 (1.42)
13.09.94	479.08 (2.68)	08.11.94	8.02 (1.25)
20.09.94	95.50 (2.02)	15.11.94	22.50 (1.51)
22.09.94	35.06 (1.6)	22.11.94	13.42 (1.36)
Mean	---	---	1834.41

Figures in paranthesis are transformed values log (x+10)

CD for comparing weekly populations = 0.3217085

Populations observed from fourth week of September to fourth week of November ranged between 35.06 and 8.03 only and observation did not show statistically significant variations.

4.5. Fluctuation in the population of coccinellid predators of *A. craccivora* on cowpea and glyricidia in season I (December 1993 to March 1994)

The data relating to the studies are presented in Table 4.

4.5.1. Fluctuation of coccinellid predators on cowpea

As seen from the mean of weekly observations during the whole season *C. sexmaculata* was the most predominant of the three predators.

Population was 40 times more than *Scymnus* sp. While *C. septumpunctata* was 3 times more than of *Scymnus sp.* Out of 16 observations (when aphid were available on the crop) *C. sexmaculata* were present in the 15 observations, *C. septumpunctata* in 13 and *Scymnus* sp in 9 observations only.

Table 4. Mean number of different coccinellid predators on cowpea and glyricidia. Season I (December 93 to March 94)

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea (per-plant)			Mean number on glyricidia (per-plant)		
		C. sexma-culata	*C. septum-punctata*	*Scymnus Sp*	*C. sexma-culata*	*C. septum-punctata*	*Scymnus Sp*
27.10.93 to 24.11.93	0-5	NIL	NIL	NIL	---	---	---
1.12.93	6	0.8 (0-4)	0.13 (0-1)	0	0.13 (0-1)	0	0
7.12.93	7	2.87 (0-7)	0.25 (0-2)	0.20 (0-1)	0.04 (0-1)	0	0
14.12.93	8	6.0 (5-11)	0.95 (1-2)	0.04 (0-1)	0.08 (0-1)	0.04 (0-1)	0
21.12.93	9	3.20 (3-8)	0.20 (0-1)	0.13 (0-1)	0.04 (0-1)	0	0
28.12.93	10	3.46 (0-10)	0	0	0.04 (0-1)	0.24 (0-1)	0
6.1.94	11	4.45 (3-14)	0.20 (0-1)	0.13 (0-1)	0.83 (0-3)	0.20 (0-1)	0
14.1.94	12	4.00 (2-11)	0.40 (0-2)	0.26 (0-2)	0.54 (0-2)	0.50 (0-2)	0.30 (0-1)
20.1.94	13	7.00 (7-15)	0.33 (0-2)	0.33 (0-2)	1.42 (0-3)	0.42 (0-2)	0.04 (0-1)
27.1.94	14	6.53 (7-18)	0.33 (0-2)	0.20 (0-2)	1.29 (0-2)	0.45 (0-2)	0.08 (0-1)
3.2.94	15	7.33 (7-18)	0.60 (0-2)	0.20 (0-2)	1.04 (0-3)	0.60 (0-2)	0.36 (0-2)
10.2.94	16	3.86 (0-10)	0.20 (0-1)	0	1.45 (0-3)	0.60 (0-1)	0.04 (0-1)
17.2.94	17	3.75 (3-9)	1.04 (0-2)	0	0.66 (0-1)	0.32 (0-2)	0.04 (0-1)
24.2.94	18	3.20 (3-10)	0.80 (1-2)	0.04 (0-1)	0.58 (0-2)	0.04 (0-1)	0
2.3.94	19	2.54 (2-7)	0.33 (0-1)	0	1.25 (0-3)	0.04 (0-1)	0
9.3.94	20	3.75 (2-10)	0	0	0.54 (0-2)	0.04 (0-1)	0
16.3.94	21	0	0	0	0.16 (0-1)	0	0
23.3.94	22	0	0	0	0.45 (0-3)	0.30 (0-2)	0.04 (0-1)
30.3.94	23	0	0	0	0.87 (0-2)	0.25 (0-1)	0
Mean		3.48 (0-18)	0.26 (0-2)	0.08 (0-2)	0.63 (0-3)	0.22 (0-2)	0.05 (0-1)

W.A.S - Weeks after sowing.
Figures in parenthesis are the ranges in replications

The number of *C. sexmaculata* varied, highest being 7.33 per plant observed in the first week of February and the close intensity of 7.0, 6.53 and 6.0 in the third and fourth week of January and second week of December respectively. In the first and second week of January populations were 4.45 and 4.0 respectively. Least population (0.8) was in the first week of December 1993. In the second week of December and first week of March population levels were 2.87 and 2.54 respectively. In the remaining observations the number of predators ranged from 3.2 to 3.86 per plant.

Mean number of *C. septumpunctata* were 1.04, 0.95, 0.80, 0.60 and 0.40 during third week of February, second week of December, fourth week of February and second week of January respectively. In the remaining period the population ranged between 0.4 to 0.33 only.

Mean population of *Scymnus* ranged between 0.04 to 0.33 per plant only. In a number of observations the population recorded was at zero level.

4.5.2. Fluctuation of coccinellids on glyricidia

On glyricidia also the most predominant coccinellid predator was found to be *C. sexmaculata*, mean number being 3 times and 12 times that of *C. septumpunctata* and *Scymnus sp*

C. sexmaculata was present in all the observations where as *C. septumpunctata* was seen in 14 and *Scymnus* in 7 out of the 20 observations made during the period of the experiment.

The highest population of *C. sexmaculata* was recorded in the second week of February (1.45 per plant). The close intensity of 1.42, 1.29, 1.25 and 1.04 were observed in the third and fourth week of January first week of March and first week of February respectively. In the fourth week of March population recorded was 0.87. This was closely followed by the population in the first week of January (0.83). The populations were 0.66, 0.58, 0.54 and 0.45 during third week of February, fourth week of February, second week of January and fourth week of March respectively. During all other observations the populations of *C. sexmaculata* were negligible mean number varying between 0.04 and 0.13 per plant only.

C. septumpunctata reached the peak during the first half of February (0.60 per plant) followed by second half of January (0.42-0.50). In the third week of February the population was 0.32 per plant only. During the last week of December and first week of January the counts were 0.24 and

0.20 per plant respectively. The population thereafter decreased to 0.30 and 0.25 during the second half of March. Observations during rest of the periods were negligible ranging from 0 to 0.04.

Scymnus population attained the highest (0.36 per plant) in the first week of February followed by 0.30 per plant in the second week of January. Population recorded during rest of the period were negligible ranging from 0 to 0.08 per plant.

4.6. Fluctuation in the population of *X. scutellare* on cowpea and glyricidia in the first season

4.6.1. Fluctuation of *X. scutellare* on cowpea

Data regarding the population fluctuation of *X. scutellare* are presented in Table 5.

The peak population was noticed in the third week of February (5.13 per plant) followed by first week of March and first week of February (3.8 and 3.53 respectively). In the second week of January and second week of March populations were 3.20 and 3.13 respectively.

Table 5. Mean number of *X. scutellare* and spider on cowpea and glyricidia. Season I - (December 1993 to March 1994)

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea (per plant)		Mean number on glyricidia (per-plant)	
		X. scutellare	Spider	*X. scutellare*	Spider
27.10.93 to 25.11.93	(0-5)	NIL	NIL	---	---
01.12.93	6	1.0 (0-3)	0	0	0.04 (0-1)
07.12.93	7	0.86 (0-3)	0.13 (0-1)	0	0
14.12.93	8	2.13 (1-7)	0.26 (0-2)	0.08 (0-2)	0.12 (0-1)
21.12.93	9	2.66 (1-7)	0.20 (0-2)	0.04 (0-1)	0.08 (0-2)
28.12.93	10	0.33 (0-2)	0.20 (0-1)	0.54 (0-2)	0.08 (0-1)
06.01.94	11	1.73 (0-5)	0.13 (0-1)	0.54 (0-2)	0.04 (0-1)
14.01.94	12	3.20 (1-8)	0.33 (0-2)	0.45 (0-2)	0.12 (0-1)
20.01.94	13	2.46 (2-5)	0.40 (0-2)	0.45 (0-3)	0.08 (0-1)
27.01.94	14	1.80 (0-6)	0.53 (0-2)	1.08 (0-4)	0.04 (0-1)
03.02.94	15	3.53 (2-10)	0.60 (0-2)	1.04 (0-4)	0.04 (0-1)
10-02.94	16	2.60 (1-9)	0.26 (0-2)	1.0 (0-2)	0
17.02.94	17	5.13 (1-9)	0.53 (0-2)	0.29 (0-1)	0
24.02.94	18	2.80 (4-12)	0.33 (0-2)	0.29 (0-2)	0.04 (0-1)
02.03.94	19	3.80 (1-10)	0.40 (0-2)	0.25 (0-2)	0.04 (0-1)
09.03.94	20	3.13 (4-10)	0.06 (0-1)	0.13 (0-1)	0
16.03.94	21	0	0	0.13 (0-1)	0
23.03.94	22	0	0	0.37 (0-2)	0.04 (0-1)
30.03.94	23	0	0	0.29 (0-1)	0
Mean		2.06 (0-12)	0.24 (0-2)	0.39 (0-4)	0.04 (0-1)

W.A.S - Weeks after sowing
Figures in paranthesis are the ranges in replications

The populations were 2.8, 2.66, 2.60, 2.46 and 2.13 during the fourth week of February, fourth week of December, second week of February, third week of January and third week of December respectively. A low population level ranging from 0.86 to 1.0 insect/plant was observed during first half of December. The population again decreased to 1.73 and 1.80 in the first and fourth week of January respectively. There was no incidence of *X. scutellare* during the second half of March.

4.6.2. Fluctuation of *X. scutellare* on glyricidia

On glyricidia the population attained the peak (1.08 per plant) in the last week of January, followed by first half of February (1-1.04). In the last week of December and first week of January the population remained at the level of 0-0.54 and then decreased to 0.45 in the second and third week of January. The population was still low in the second half of February (0.29) and again went down to the level of 0.25 in the first week of March. Population went on decreasing to the level of 0.13 during second and third week of March. Then there was an increase to 0.29 and 0.37 during second half of March. Population recorded during third and

fourth week of December were negligible (0.08 and 0.04). During the first half of December the population reached zero level.

4.7. Fluctuations in the population of spiders on cowpea and glyricidia in the first season

4.7.1. Fluctuation of spider on cowpea

It is seen that the population was very low ranging from 0 to 0.6 per plant. Highest population was recorded in the first week of February followed by fourth week of January and third week of February (0.53). Population was very low during rest of the periods (0 to 0.04).

4.7.2. Fluctuation of spider on glyricidia

The peak population of spider was noticed during third week of December and second week of January (0.12 per plant). The population recorded throughout the season were negligible when compared to other predators, the range being 0 to 0.08 per plant.

4.8. Fluctuations in the population of coccinellid predators of *A. craccivora* on cowpea and glyricidia in the second season (April 1994 to July 1994)

The data relating to the studies are presented in Table 6.

4.8.1. Fluctuation of coccinellids on cowpea

In the second season also *C. sexmaculata* was predominant among other coccinellid predators, the mean of the weekly observations being 5 and 30 times greater than *C. septumpunctata* and *Scymnus* respectively. Out of 17 observations (when aphids were available on the crop) *C. sexmaculata* were on 15 observations where as *C. septumpunctata* and *Scymnus* were present on 13 and 7 observations respectively.

Highest population of *C. sexmaculata* was recorded in the third week of June (6.75 per plant) followed by fourth week of May and first week of June (6.66 and 6.07 respectively). The populations recorded during second half of May were 5.33 and 5.73 respectively.

Table 6. Mean number of different coccinellid predators on cowpea and glyricidia. Season II (April 93 to July 94)

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea (per-plant)			Mean number on glyricidia (per-plant)		
		C.sexma-culata	*C.septum-punctata*	*Scymnus Sp*	*C.sexma-culata*	*C.septum-punctata*	*Scymnus Sp*
16.3.94 to 30.3.94	0-3	NIL	NIL	NIL	---	---	---
6.4.94	4	1.0 (0-5)	0.06 (0-2)	0	0.50 (0-2)	0.20 (0-1)	0
13.4.94	5	1.13 (0-3)	0	0	0.20 (0-2)	0.20 (0-1)	0
20.4.94	6	0.33 (0-2)	0.13 (0-1)	0.04 (0-1)	0.95 (0-3)	0.65 (0-3)	0.08 (0-1)
27.4.94	7	0.80 (1-2)	0.25 (0-2)	0.13 (0-2)	0.54 (0-1)	1.00 (0-4)	0.36 (0-3)
4.5.94	8	3.90 (2-9)	0.83 (0-3)	0.33 (0-2)	0.66 (0-2)	0.12 (0-1)	0
11.5.94	9	2.60 (2-6)	0.73 (0-2)	0.33 (0-2)	0.12 (0-1)	0.12 (0-1)	0
17.5.94	10	5.33 (5-15)	1.33 (0-6)	0.40 (0-1)	0.25 (0-1)	0	0
24.5.94	11	5.73 (5-15)	1.33 (0-5)	0	0.16 (0-1)	0	0
30.5.94	12	6.66 (4-15)	1.06 (0-5)	0.26 (0-2)	0.04 (0-1)	0.04 (0-1)	0
6.6.94	13	6.00 (4-12)	1.06 (0-5)	0	0.08 (0-1)	0	0
13.6.94	14	2.75 (3-9)	0.41 (0-2)	0.13 (0-1)	0.04 (0-1)	0.04	0
20.6.94	15	6.75 (4-15)	0.33 (0-2)	0	0	0	0
27.6.94	16	3.33 (0-8)	0.73 (0-2)	0	0	0	0
10.7.94	17	3.33 (3-7)	0.41 (0-2)	0	0	0	0
11.7.94	18	0.06 (0-1)	0	0	0	0	0
18.7.94	19	0	0	0	0	0.04 (0-1)	0
25.7.94	20	0	0	0	0	0.04 (0-1)	0.04 (0-1)
Mean		2.69 (0-15)	0.51 (0-5)	0.09 (0-2)	0.21 (0-3)	0.15 (0-3)	0.03 (0-3)

W.A.S Weeks after sowing
Figures in parenthesis are the ranges in replications.

In the first week of May the population was 3.6. The population remained at the level of 3.33 per plant during the fourth week of June and first week of July. During second week of June and second week of May, populations were 2.75 and 2.6 respectively. Populations recorded during first half of April were 1.0 and 1.13 where as in the second half it went down to the levels of 0.33 and 0.80 per plant. *C. sexmaculata* were absent during the second half of July.

The highest population of *C. septumpunctata* was observed in second half of May (1.33 per plant) followed by fifth week of May and first week of June (1.06). The population during first week of May was 0.83. During the second week of May and fourth week of June the population was 0.73 per plant. In the second week of June and first week of July population was 0.41 and it was 0.33 in the third week of June. In the second half of April population ranged from 0.25 to 0.31. Least population was 0.06 observed in the first week of April. Population was at zero level in the second week of April, second, third and fourth week of July.

Scymnus population on cowpea reached the maximum of 0.40 per plant in the third week of May followed by 0.33 in

the first half of May. The population level was 0.26 during last week of May and 0.13 in the second week of June and fourth week of April. Least population of 0.04 per plant was recorded in the third week of April and the population reached zero levels during first half of April, fourth week of May, second half of June and in the month of July.

4.8.2. Fluctuation of coccinellids on glyricidia

As seen from the means of observations in season II, *C. sexmaculata* predominates, the population being 1.5 and 7 times greater than that of *C. septumpunctata* and *Scymnus sp* respectively.

The highest population of *C. sexmaculata* was recorded in the third week of April (0.95 per plant) followed by 0.66 and 0.54 during first week of May and fourth week of April respectively. Population recorded during first week of April and third week of May were 0.50 and 0.25 respectively. During the second week of April population recorded was 0.20. A low population ranging from 0.12 to 0.16 per plant was observed during second and fourth week of May. There after the population reached the lowest level of 0.04 to 0.08 from

fourth week of May and first half of June and it was absent in the second half of July.

Highest population of *C. septumpunctata* was observed in the fourth week of April (1.0 per plant) followed by third week of April (0.65 per plant). Population was low during the first half of April (0.20) and still lower (0.12) during the first half of May. Least population (0.04) was recorded in the fifth week of May, second week of June and second half of July. During second half of May, first, second and third week of June, and first half of July population was at zero levels.

Scymnus population recorded during the second season on glyricidia were negligible. Incidence was noticed only in three occasions in second and fourth week of April (0.08 and 0.36 respectively) and fourth week of July (0.04).

4.9. Fluctuation in the population of *X. scutellare* on cowpea and glyricidia in the second season

The relevant data are given in Table 7.

Table 7. Mean number of X. scutellare and spider on cowpea and glyricidia. Season II - (April 1994 to July 1994)

Date of observation	Growth stage of cowpea (W.A.S)	Mean number on cowpea (per-plant)		Mean number on glyricidia (per-plant)	
		X. scutellare	Spider	*X. scutellare*	Spider
16.03.94 to 30.03.94	(0-3)	NIL	NIL	---	---
06.04.94	4	1.0 (0-4)	0	0.33 (0-2)	0
13.04.94	5	1.70 (0-5)	0	0.33 (0-2)	0
20.04.94	6	0.86 (1-3)	0.06 (0-1)	0.79 (0-3)	0
27.04.94	7	0.53 (0-2)	0.13 (0-1)	0.79 (0-3)	0.04 (0-1)
04.05.94	8	0.25 (0-1)	0.20 (0-1)	0.29 (0-1)	0
11.05.94	9	0.13 (0-2)	0	0.16 (0-1)	0
17.05.94	10	0	0.40 (0-1)	0.08 (0-2)	0
24.05.94	11	0	0	0.12 (0-3)	0.08 (0-1)
30.05.94	12	0.20 (0-2)	0.04 (0-1)	0.04 (0-1)	0
06.06.94	13	0.06 (0-1)	0.40 (0-2)	0	0.04 (0-1)
13.06.94	14	0	0.20 (0-1)	0.08 (0-2)	0
20.06.94	15	0	0.13 (0-1)	0	0
27.06.94	16	0.06 (0-1)	0.13 (0-1)	0	0
04.07.94	17	0	0.33 (0-1)	0.04 (0-1)	0
11.07.94	18	0	0.13 (0-1)	0	0
18.07.94	19	0	0	0.04 (0-1)	0
20.07.94	20	0	0	0	0
Mean		0.28 (0-5)	0.13 (0-2)	0.18 (0-3)	0.01 (0-1)

W.A.S - Weeks after sowing
Figures in paranthesis are the ranges in replications

4.9.1. Fluctuation of *X. scutellare* on cowpea

Highest population of *X. scutellare* in season II was during second week of April (1.70 per plant) followed by first week of April (1.0). Population there after decreased from 0.86 to 0.13 to during third week of April to second week of May. Population observed at fourth week of May was 0.20. Least population was in the first and fourth week of June (0.06). During rest of the period the insect was not present.

4.9.2. Fluctuation of *X. scutellare* on glyricidia

Population of *X. scutellare* was maximum during third and fourth week of April (0.79 per plant), followed by the population level of 0.33 during first half of April. Population during May ranged only from 0.04 to 0.29 per plant. Population was very low ranging from 0.04 to 0.08 in the second week of June, first and third week of July. During rest of the period population was at zero level.

4.10. Fluctuation in the population of spider on cowpea and glyricidia in the second season

Relevant data are presented in Table 7.

4.10.1. Fluctuation of spider on cowpea

Peak population was observed in the third week of May and first week of June (0.4 per plant) followed by the first week of July (0.33). The count was 0.20 per plant in first week of May and second week of June. A low population level of 0.13 was observed in the third and fourth weeks of June and second week of July. The population during April was very low ranging from 0 to 0.13. Population was at zero level during second half of May and second half of July.

4.10.2. Fluctuation of spider on glyricidia

The spider populations on glyricidia were observed only in three weeks. Populations were negligible as they ranged from 0 to 0.08 per plant.

4.11. Fluctuation of population of predators on glyricidia in the third season

Data regarding the same are given in Table 8.

Table 8. Mean number of different species of predators on glyricidia. Season III (August 1994- November 1994)

Date of observation	Coccinellids (per-plant)			*X. scutellare* (per-plant)	Spider (per-plant)
	C. sexma-culata	*C. septum-punctata*	*Scymnus sp*		
09.08.94	0.91 (0-4)	0	0	0.54 (0-2)	0
16.08.94	0.63 (0-2)	0	0	0.63 (0-3)	0.08 (0-1)
23.08.94	1.16 (0-3)	0	0	0.87 (0-4)	0.08 (0-1)
30.08.94	1.16 (0-4)	0	0	1.08 (0-4)	0.04 (0-4)
06.09.94	1.2 (0-2)	0	0	0.54 (0-2)	0
13.09.94	1.2 (0-3)	0	0	0.71 (0-3)	0
20.09.94	0.54 (0-1)	0	0	0.66 (0-3)	0.04 (0-1)
27.09.94	0.12 (0-1)	0	0	0.45 (0-2)	0.08 (0-1)
04.10.94	0.12 (0-1)	0	0	0	0.04 (0-1)
11.10.94	0.2 (0-1)	0.04 (0-1)	0	0.12 (0-2)	0
18.10.94	0.2 (0-1)	0.04 (0-1)	0	0.08 (0-1)	0.12 (0-1)
25.10.94	0.33 (0-2)	0	0	0.12 (0-1)	0
01.11.94	0.2 (0-1)	0	0	0	0.04 (0-1)
08.11.94	0.16 (0-1)	0	0	0	0
15.11.94	0.16 (0-1)	0	0.3 (0-2)	0	0
22.11.94	0.12 (0-1)	0	0.04 (0-1)	0	0.04 (0-1)
Mean	0.53 (0-4)	0.005 (0-1)	0.02 (0-2)	0.36 (0-4)	0.04 (0-4)

Figures in parenthesis are the ranges in replications

4.11.1. Fluctuation of coccinellids

In the third season also *C. sexmaculata* was predominant when compared to other species, the mean of weekly population being 100 times and 26 times more than those *C. septumpunctata* and *Scymnus sp* respectively.

C. sexmaculata were present throughout the season whereas *C. septumpunctata* and *Scymnus* were recorded only during two occassions each.

Population of *C. sexmaculata* reached the peak of 1.2 per plant during the first half of September followed by second half of August (1.16). The population ranged between 0. 63 and 0.91 in August first and second weeks and 0.54 per plant in the third week of September. The population decreased from fourth week of September to fourth week of November the range being 0.12 to 0.33 only.

C. septumpunctata was very rare, the population ranging from 0 to 0.04 only during second and third week of October and was absent during rest of the period.

Scymnus was also rare, populations ranging from 0 to 0.3 per plant during the third and fourth week of November and at 0 level during the rest of the period.

4.11.2. Fluctuation of *X. scutellare*

During the third season population of *X. scutellare* reached the maximum level of 1.08 per plant in the fourth week of August followed by 0.87 in the third week of August and 0.71 in the second week of September. In the third week of September the population was 0.66 per plant, closely followed by 0.63 in the second week of August. The population was 0.54 in the first week of August and first week of September. During the last week of September the population recorded was 0.45 per plant. There after the population decreased, ranging from 0.12 to 0.08 during the period of second week of October to last week of October. *X. scutellare* was absent in the month of November.

4.11.3. Fluctuation of spider on glyricidia

The peak population of spider was observed during third week of October (0.12 per plant). Population level

during rest of the observations were considerably lower ranging from 0.04 to 0.08. There was no population during first week of August, first and second week of September, second and fourth week of October and second and third week of November.

4.12. Association of the population of *A. craccivora* on cowpea with the biotic and abiotic factors in the ecosystem

4.12.1. Season I

The relevant data are presented in Table 9 and Fig. 1. The population of coccinellid predators *C. sexmaculata*, *C. septumpunctata* and *Scymnus sp*, syrphid (*X. scutellare*) and spiders were seen significantly and positively correlated with the population of aphids, their correlation coefficients being 0.8142, 0.4499 and 0.7911 respectively. The total predator population also showed a significant positive association with the aphids (r = 0.7857). The maximum temperature showed significant negative association with the coccinellid predators (r= -0.4896) while the minimum temperature was negatively and significantly associated with the population of the predators

independently (-0.5930, -0.6786, -0.7151 and -0.7047 respectively) and in combination (-0.7724). Though the rainfall, morning and evening humidity showed a negative association with the predators independently, the correlation coefficient were not statistically significant.

4.12.2. Season II

The relevant data are presented in Table 10 and Fig. 2. Here the coccinellid predators alone showed significant positive association with the aphid population (r=0.7677). The coccinellid predators and spiders showed positive and significant correlation with rainfall (r=0.5682 and 0.4962 respectively). Evening humidity showed a significant positive correlation with aphid population (r=0.6213) and coccinellid predators (r=0.6213).

4.12.3. Season I and II

The correlation matrix of the analysis of the data relating to the two seasons combined is presented in Table 11. Only significant correlation seen was between the total predator population and morning humidity (r=0.5975).

Table 9. Correlation between aphids on cowpea, its predators and weather factors during December 1993 to March 1994 (Season I)

Table 10. Correlation between aphids on cowpea, its predators and weather factors during April 1994 to July 1994 (Season II)

Table 11. Correlation between aphids on cowpea, its predators and weather factors during December 1993 to July 1994 (Season I and II)

Parameters

X_1 - Aphid population

X_2 - Coccinellid population

X_3 - Sryphid population

X_4 - Spider population

X_5 - Total population

X_6 - Maximum temperature

X_7 - Minimum temperature

X_8 - Rainfall

X_9 - Morning humidity

X_{10} - Evening humidity

X_{11} - Sunshine

Table 9.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.000	0.8142*	0.4499*	0.7911*	0.7857*
X_6	-0.3900	-0.4896*	-0.0750	-0.2692	-0.3715
X_7	-0.5930*	-0.6786*	-0.7151*	-0.7047*	-0.7724*
X_8	-0.2889	-0.3252	-0.4016	-0.3992	-0.3722
X_9	0.4349	-0.4486	-0.1914	-0.2656	0.3901
X_{10}	-0.2343	-0.3671	-0.5925	-0.4514	-0.5069
X_{11}	0.0464	-0.0051	0.3640	0.3024	0.1401

Table 10.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.0000	0.7677*	-0.3007	0.4120	-0.0684
X_6	0.1108	-0.1140	0.4660	-0.0100	-0.1279
X_7	0.1093	-0.0306	0.2462	0.0713	0.1243
X_8	0.3808	0.5682*	-0.3504	0.4962*	-0.0814
X_9	0.2353	0.1608	0.0001	0.0281	0.1485
X_{10}	0.6213*	0.6213*	-0.0896	-0.1463	0.1991
X_{11}	-0.4501	-0.3427	0.3525	0.1223	0.2659

Table 11.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.0000	0.0872	-0.1107	-0.0422	-0.1197
X_6	-0.1337	-0.0454	-0.0901	-0.0909	-0.10000
X_7	-0.1117	-0.0966	-0.0762	-0.0677	-0.0863
X_8	0.0684	-0.1029	-0.0852	0.0079	-0.0581
X_9	-0.0835	-0.2338	-0.2129	-0.1560	0.5975*
X_{10}	-0.1896	0.0783	-0.2159	-0.1725	-0.1383
X_{11}	0.3384	-0.1715	0.0471	-0.1755	-0.2019

* Significant at 5% level

4.13. Association of the population of *A. craccivora* on glyricidia with the biotic and abiotic factors in the environment

4.13.1. Season I

The relevant data are presented in Table 12 and Fig. 1. The aphid population was significantly and positively correlated with spiders (r=0.5613) and coccinellid predators (r=0.6181) while the spider population showed a negatively significant correlation with maximum temperature (r= -0.5454). The aphid, coccinellid and syrphid population as well as total predators showed a significant negative correlation with the minimum temperature, the r values being -0.4279, -0.73900, -0.6249 and -0.7286 respectively. With rainfall the population of aphids (-0.4915) coccinellids (-0.4797) and total predators (-0.4772) showed significant negative correlation.

4.13.2. Season II

The relevant data are presented in Table 13 and Fig 2.

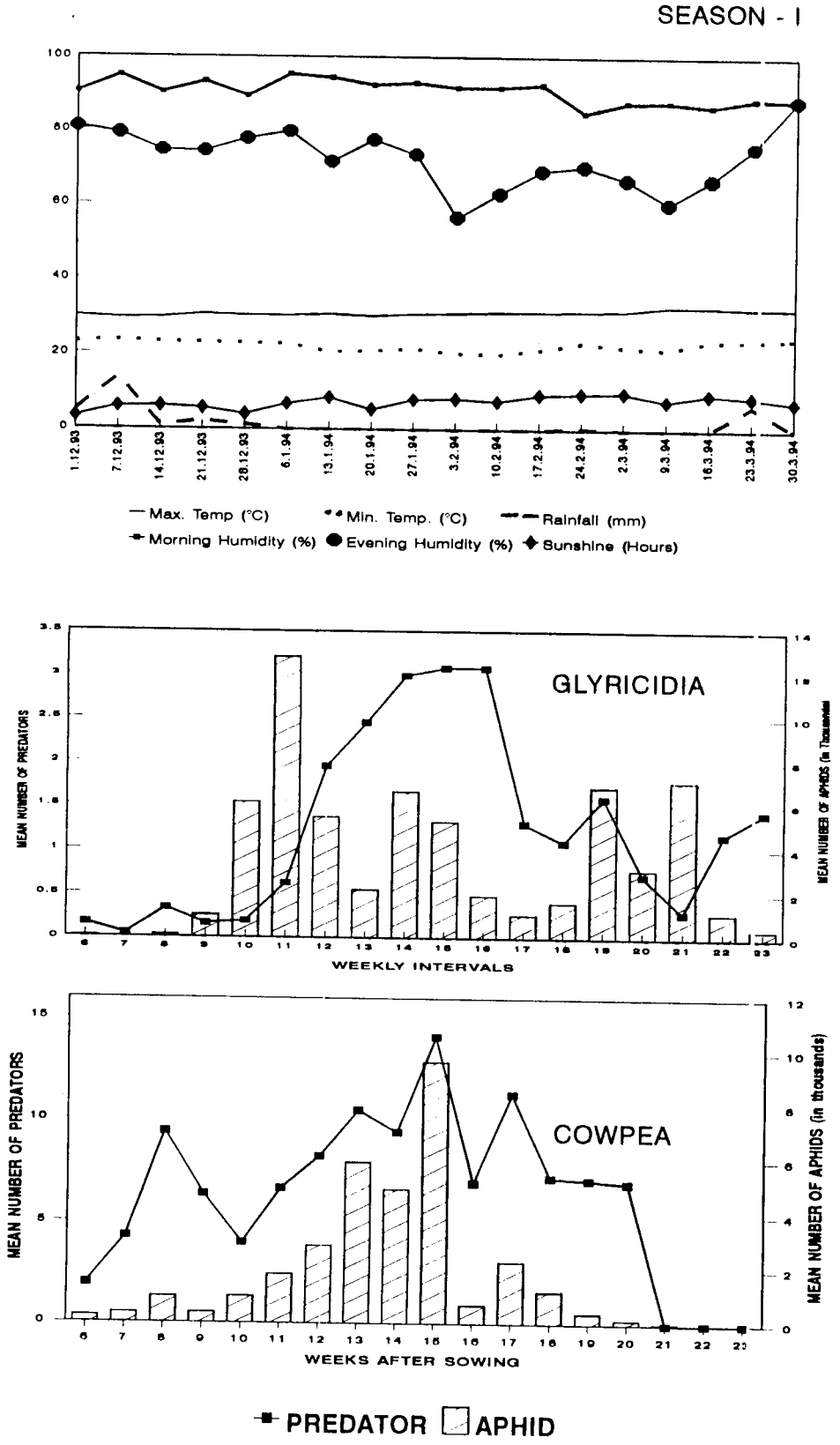

Fig. 1. Association of pea aphid population on cowpea and glyricidia with biotic and abiotic factors in the environment

Table 12. Correlation between aphids on glyricidia, its predators and weather factors during December 1993 to March 1994 (Season I)

Table 13. Correlation between aphids on glyricidia, its predators and weather factors during April 1994 to July 1994 (Season II)

Table 14. Correlation between aphids on glyricidia, its predators and weather factors during December 1993 to July 1994 (Season I and II)

Parameters

X_1 - Aphid population

X_2 - Coccinellid population

X_3 - Sryphid population

X_4 - Spider population

X_5 - Total population

X_6 - Maximum temperature

X_7 - Minimum temperature

X_8 - Rainfall

X_9 - Morning humidity

X_{10} - Evening humidity

X_{11} - Sunshine

Table 12.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.0000	0.6181*	0.1305	0.5613*	-0.378
X_6	-0.0378	0.0874	-0.0194	-0.5454*	0.0310
X_7	-0.4279*	-0.7300*	-0.6249*	-0.1162	-0.7286*
X_8	-0.4915*	-0.4797*	-0.3975	-0.1656	-0.4772*
X_9	0.2265	0.2124	0.2446	0.2287	0.2415
X_{10}	-0.2491	-0.3319	-0.3452	0.1670	-0.3406
X_{11}	0.1705	0.3509	0.1948	-0.3175	0.2960

Table 13.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.0000	0.7060*	0.6370*	-0.1007	0.6857*
X_6	0.6408*	0.6525*	0.6636*	-0.1129	0.6560*
X_7	0.5804*	0.4012*	0.3923*	-0.0124	0.4005*
X_8	-0.3509	-0.3595	-0.3805	0.1761	-0.3621
X_9	-0.6140*	-0.2786	-0.2554	0.3181	-0.2623
X_{10}	-0.3200	-0.4755*	-0.4329*	0.4117*	-0.4513*
X_{11}	0.5138*	0.5231*	0.5461*	-0.2617	0.5237*

Table 14.

Parameters	X_1	X_2	X_3	X_4	X_5
X_1	1.0000	-0.2563	-0.0341	0.88166*	0.8029*
X_6	-0.0256	-0.1143	-0.0378	-0.0075	-0.0190
X_7	-0.5514*	0.5693*	0.3036*	-0.5320*	-0.7697*
X_8	-0.4622*	0.5393*	0.3944*	-0.4463*	-0.6331*
X_9	0.4541*	-0.4712*	-0.3136	0.4000*	-0.6570*
X_{10}	-0.4198*	0.5064*	0.2719	-0.5809*	-0.6793*
X_{11}	-0.4253*	0.5822*	0.5093*	-0.3996*	-0.6329*

* Significant at 5% level

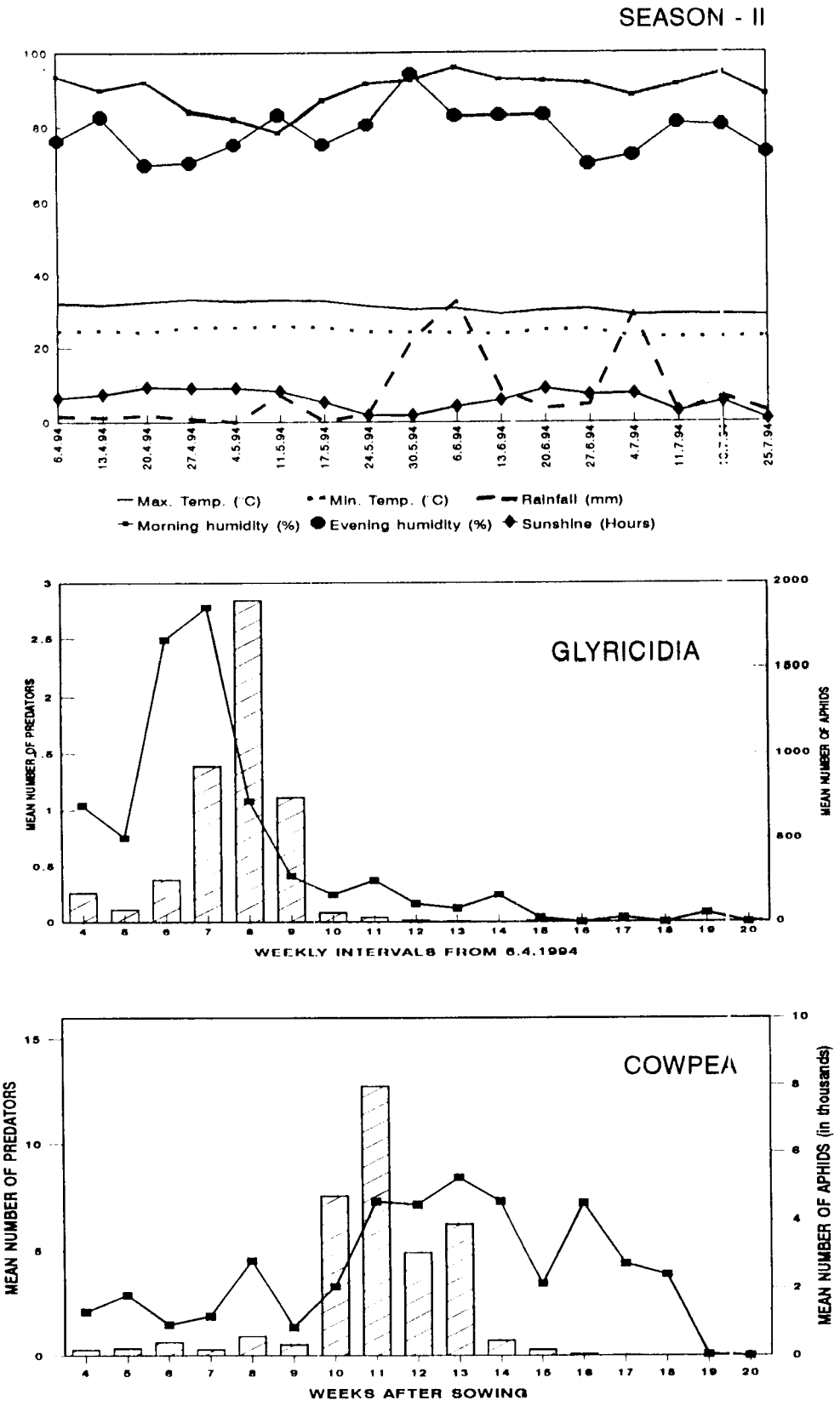

Fig. 2. Association of pea aphid population on cowpea and glyricidia with biotic and abiotic factors in the environment

The aphid population showed a significant positive association with coccinellids (0.7060) syrphids (0.6370) and total predator population (0.6857). The aphids, coccinellids, syrphids and total predator population showed positive significant correlation with maximum temperature (0.6408, 0.6525, 0.6636 and 0.6560) and minimum temperature (0.5804, 0.4012, 0.3923 and 0.4005). While aphid population showed significant negative correlation (-0.6140) with morning humidity. Evening humidity was significantly and negatively associated with coccinellid and syrphid predators (-0.4755, -0.4329) as well as total predator population (-0.4513). During this season sunshine hours also showed significant positive association with populations of aphids (0.5138), coccinellids (0.5231), syrphids (0.5461) and total predators (0.5237).

4.13.3. Seasons I & II

The relevant data are presented in Table 14. Analysis of the pooled data of the two seasons showed a highly significant positive association between the aphid population and the population of spiders (0.8816) as well as total predators (0.8029). The minimum temperature showed a

significant negative association with the population of aphids (-0.5514) spiders (-0.5320) and total predators (-0.7697). Its association with coccinellids (0.5693) and syrphids (0.3036) were positive and significant. Same was the correlation with rainfall (-0.4622, -0.4463, -0.6331, 0.5393 and 0.3944 respectively). Morning humidity showed significant positive correlation with population of aphids (0.4541) and spiders (0.4000) while its correlation with coccinellids (-0.4712), syrphids (-0.3136) and total predators (-0.6570) were negative and significant. Regarding evening humidity its correlation with coccinellids (0.5064) alone was positive and significant while with population of aphids (-0.4198) spiders (-0.5809) and total predators (-0.6793) it showed significant negative correlations. Sunshine was seen negatively correlated with population of aphids (-0.4253), spiders (-0.3996) and total predators (-0.6329) while the factors positively and significantly correlated with the population of coccinellid (0.5822) and syrphids (0.5043).

4.14. Biology of *A. craccivora* observed in the laboratory when reared on cowpea

The relevant results are presented in the Table 15.

Table 15. Biology of A. craccivora observed in the laboratory when reared on cowpea

Stage of the insect	Number observed	Number surviving till moulting	Percentage of survival	Duration (days)
I instar	50	45	90.00	1.4 (1-2)
II instar	45	37	82.22	2.2 (2-3)
III instar	37	27	72.97	2.1 (1-3)
IV instar	27	16	58.25	1.6 (1-2)
Total				7.3 (5-10)

Adult longevity = 6.2 days (4-9)

Pre-reproductive period = 1 day

Reproductive period = 2.2 days (1-4)

Fecundity = 11.5 (7-14)

Figures in parenthesis are ranges in replications

All females observed during the period of study were viviparous and the emerging first instars moulted to the second instars within a mean period of 1.4 days (range 1-2 days). The second, third and fourth instars took 2.2 (2-3 days), 2.1 (1-3 days) and 1.6 (1-2 days) to moult as third instar, fourth instar and adult respectively. The nymphal duration ranged from 5-10 days with a mean of 7.3 days.

The survival was showing a descending trend from the first to the fourth [illegible] with percentages of 90, 82.22, 72.97 and 58.25 respectively.

The adult longevity of the insects ranged from 4-9 days, the mean being 6.2 days. The pre-reproductive period extended upto 24 hours and the mean reproductive period was 2.2 days with a range of 1-4 days. Fecundity recorded was within a range of 7-14 nymphs with a mean number of 11.5.

4.15. Biology of predators of *A. craccivora*

4.15.1. Biology of *C. sexmaculata* reared on aphids on cowpea maintained in the laboratory

The relevant results are presented in the Table 16.

Table 16. Biology of C. sexmaculata and X. scutellare reared on A. craccivora on cowpea

Stage of the insect	Number observed	Number surviving till moulting	Percentage of survival	Duration (days)
C. sexmaculata				
Egg	50	48	96.00	2.5 (2-3)
I instar	48	34	70.83	2.3 (1-3)
II instar	34	27	79.41	3.75 (3-4)
III instar	27	22	81.48	3.75 (2-5)
Pupa	22	22	100	3.6 (3-5)
Total				15.9 (11-20)
X. scutellare				
Egg	50	40	80.00	3.9 (3-5)
I instar	40	36	90.00	2
II instar	36	32	88.00	2.5 (2-3)
III instar	32	29	90.62	3.6 (3-4)
Pupa	29	20	71.42	3.7 (3-5)
Total				13.7 (13-19)

		C. sexmaculata	X. scutellare
Male longevity	=	30.2 days (18-44)	9.3 days (9-10)
Female longevity	=	32.8 days (20-40)	11.3 days (10-12)
Male : Female ratio	=	2:3	2:1
Pre-reproductive period	=	3 days (2-4)	2.5 days (2-3)
Reproductive period	=	1.2 days (1-2)	2.4 days (2-3)
Fecundity	=	15.27 (9-25)	33.00 (30-40)

Figures in parenthesis are ranges in replications

The hatching percentage of eggs was high and the percentage emergence of first instar larvae was 96. The mean period of incubation was 2.5 days with a range of 2-3 days. The duration of the first, second and third instar larvae were 2.3 (1-3 days), 3.75 (3-4 days) and 3.75 (2-5 days) respectively. The mean pupal period was 3.6 days with a range of 3-5 days. The survival of first, second and third instar larvae were 70.83, 79.41 and 81.48 per cent respectively. There was no pupal mortality. Duration of the immature stages lasted for 11-20 days with a mean of 15.9 days.

The male and female lived for 18-44 days (30.2 days) and 20-40 days (32.8 days) respectively. The life cycle from egg to adult lasted for a period of 13.7 days with a range of 13-19 days. Male female ratio was 2:3. The pre-reproductive period of the beetle ranged between 2-4 days with a mean of 3 days. The reproductive period lasted for 1-2 days with a mean of 1.2 days. Each female laid a mean number of 15.27 eggs during its life time and the range was 9-25.

4.15.2. Biology of *X. scutellare* reared on aphids on cowpea maintained in the laboratory

Details relating to the biology of *X. scutellare* are presented in Table 16.

As seen in Table 16, the mean incubation period was 3.9 days with a range of 3-5 days. The mean duration of first, second and third instar larvae were 2, 2.5 (2-3) and 3.6 (3-4) days respectively. The pupal duration was 3.7 days with a range of 3-5 days. The duration of immature stages lasted for 13.7 days with a range of 13-19 days. The life cycle from egg to adult had a mean duration of 13.7 days with a range of 13-19 days.

The egg mortality was comparatively higher, hatching percentage being 80 only. The survival of first, second and third instar larvae were 90, 88 and 90 per cent respectively. In the case of pupae, 71.42 per cent moulted as adults.

The mean longevity of male and female *X. scutellare* were 9.3 (9-10) and 11.3 (10-12) days respectively.

The sex ratio of male to female was 2:1. Pre-reproductive period was 2.5 (2-3) days and reproductive period was 2.4 (2-3) days. Fecundity was 33 eggs per female, range being 30-40.

4.16. Feeding potential of *C. sexmaculata* and *X. scutellare*

4.16.1. Feeding during larval stages

The relevant data are presented in Table 17.

The mean number of aphids consumed by the first, second and third instar larvae of *C. sexmaculata* were 8.10, 22.50 and 56.18 respectively and the total consumption during the whole larval period was 86.78 aphids. The duration of active feeding of the three instars were 2, 4 and 4 days respectively. The range in the daily mean consumptions were 0.71 to 4.30, 3.75-6.87 and 1.42-18.11. Low levels of feeding was observed on the last day due to the non-feeding behaviour of the larvae prior to moulting.

Table 17. **Feeding potential of C. sexmaculata and X. scutellare at larval stages**

Predator	Stage	Number of aphid provided on each day	Mean number of aphids consumed during different periods after emergence (days)					Total consumption
			1	2	3	4	5	
C. sexmaculata	I instar	25	3.10 (2-6)	4.30 (2-6)	0.71 (0-5)	—	—	8.10
	II instar	50	6.33 (4-11)	5.55 (2-13)	6.87 (4-10)	3.75 (0-7)	—	22.50
	III instar	50	13.80 (7-25)	18.11 (15-30)	16.25 (0-27)	6.62 (0-15)	1.4 (0-14)	56.18
	Total	—	—	—	—	—	—	86.78
X. scutellare	I instar	50	15.9 (8-23)	33.55 (20-45)	—	—	—	49.45
	II instar	100	53.8 (28-77)	50.60 (11-74)	34.71 (9-70)	—	—	139.11
	III instar	150	92.20 (74-110)	103.90 (70-122)	63.80 (0-128)	—	—	259.90
	Total	—	—	—	—	—	—	448.46

Figures in paranthesis are ranges in observations

In the case of *X. scutellare* the mean number of aphids consumed by first, second and third instar larvae were 49.45, 139.11 and 259.90 aphids respectively, the total consumption for the entire larval duration being 448.46 aphids. The duration of active feeding of the three instars were 2, 3 and 3 days respectively. In the case of first instar the consumption during the second day was much higher than that of the first day (15.9 and 33.55 respectively) while the variations in the case of second instar (53.8, 50.6 and 34.71) and third instar (99.20, 103.90 and 63.80) were not high except that there was reduction in feeding at the last phase towards the moulting.

4.16.2. Feeding of adults of *C. sexmaculata*

The adults of *X. scutellare* are not predaeous and the data on the feeding potential of adult *C. sexmaculata* are presented in Table 18.

The mean consumption of aphids during life time was found to be 748.9 per individual. The mean consumption during the first three weeks showed a range of 118-150, 106-151, 180-233 aphids per day per individual.

Table 18. Feeding potential of adult C. sexmaculata

Replications	Mean daily consumption per adult during different periods after emergence (weeks)							Total consumption
	1	2	3	4	5	6	7	
1	150	151	233	196	218	243	41(2)*	1232
2	144	110	195	160	215	259	61(2)*	1144
3	142	122	180	213	262	259	—	1178
4	149	150	115(5)*	—	—	—	—	410
5	147	158	196	177	34(1)*	—	—	712
6	120	139	50(2)*	—	—	—	—	309
7	146	136	180	—	—	—	—	462
8	124	148	178	18(1)*	—	—	—	468
9	137	134	210	24(2)*	—	—	—	505
10	118	106	189	193	212	251	—	1069
Mean	137.7	135.4	172.6	98.10	94.10	101.2	10.2	748.9

* Days upto which the insect survived during the week

4.17. Life-table studies

4.17.1. Life and fertility table of *A. craccivora* on cowpea

Age-specific survivorship (lx) and age-specific natality (mx) are presented in Table 19. There was 29.2 per cent mortality during the nymphal period of six days and hundred per cent mortality at the 18^{th} day. Age-specific natality was maximum (10) on the 12^{th} day followed by 3.8, 2.66, 2 and 2 on the 14^{th}, 6^{th}, 15^{th}, 8^{th} and 13^{th} day respectively. Reproduction continued upto the 17^{th} day.

The net reproductive rate was 14.308 during an approximate generation time of 10.82 days and the true generation time was worked out to be 9.78 days.

The intrinsic rate of increase (rm) was 0.272 and finite rate of increase (λ) was 1.87 per female per day.

Table 19. Life and fertility table of A. craccivora on cowpea

x	lx	mx	lx.mx	x.lx.mx
0	1	0	--	--
1	0.9583	0	--	--
2	0.8750	0	--	--
3	0.8750	0	--	--
4	0.750	0	--	--
5	0.750	0	--	--
6	0.708	2.66	1.880	11.28
7	0.708	0.66	0.467	3.26
8	0.666	2.0	1.320	10.56
9	0.666	1.66	1.090	9.81
10	0.580	1.83	1.060	10.60
11	0.458	1.50	0.687	7.55
12	0.416	10	4.160	49.92
13	0.416	2	0.832	10.81
14	0.416	3.8	1.580	22.12
15	0.333	2.66	0.877	13.15
16	0.333	1.0	0.330	5.28
17	0.166	0.16	0.025	0.43
18	0	0	0	0
			$\sum$ 14.308	$\sum$ 154.765

Net reproductive rate (R_0) = 14.308

Approximate generation time (T_c) = $\frac{\sum x.lx.mx}{R_0}$ = 10.82 days

Capacity for increase (rc) = $\frac{\log_e R_0}{T_c}$ = 0.245

Intrinsic rate of increase (rm) = 0.272

Finite rate of increase (λ) = antilog e ^{rm} = 1.87

True generation time (T) = $\frac{\log_e R_0}{rm}$ = 9.78 days

4.17.2. Age specific life-table of *A. craccivora* reared on cowpea during December 1993

The life-table for the month of December is presented in Table 20. The mortality of 48.41 per cent observed among early instar nymphs (fist and second) and 48.75 per cent observed during the late instar nymphs (third and fourth) showed that the mortality factors did not vary significantly during the entire life cycle. The 'k' values were 0.293 and 0.291 for the two life stages considered in the investigation. The real mortality was observed to be very heavy ie. 74.07 per cent. The generation survival (SG) was very low (0.259). The negative value of trend index (0.755) indicated that the mortality factors operating during the period were effective in causing a significant decline in the pest population.

Table 20. Age-specific life-table of A. craccivora on cowpea during December 1993

x	lx	dxf	dx	100qx	100rx	log no:	k's
Early instar nymphs (N_1)	16,725	Unknown factors	8,265	49.41	49.41	4.220	0.293
Late instar nymphs	8,460	Unknown factors	4125	48.75	24.66	3.927	0.291
Adult (N_3)	4,335		--	--	--	3.636	--
Total					74.07		K= 0.584

Real mortality = 74.07 per cent

Fecundity = 11.5

Expected number of early instars in the next generation = 11.5 x 4335
= 49,85.25

Actual number of early instars in the next generation (N_2) = 12,627

$$\text{Trend index (I)} = \frac{N_2}{N_1} = 0.755$$

$$\text{Generation survival (SG)} = \frac{N_3}{N_1} = 0.259$$

4.17.3. Age specific life-table of *A. craccivora* reared on cowpea during January 1994

The mean life-table for the month of January is presented in Table 21. The high mortality of 63.44 per cent observed among the early instar nymphs declined to a very low level of 6.73 per cent among the late instar during the season. The corresponding 'k' values were 0.44 and 0.03 respectively. This showed that the mortality factors were not active during the later part of the life-cycle. The real mortality was 65.90 per cent. The generation survival period was 0.340. The positive value of the trend index 1.095 showed that the mortality factors operating during the period were not effective in suppressing the pest population.

Table 21. Age-specific life-table of *A. craccivora* on cowpea during January 1994

x	lx	dxf	dx	100qx	100rx	log no:	k's
Early instar nymphs (N_1)	9225	Unknown factors	5853	63.44	63.44	3.96	0.44
Late instar nymphs	3372	Unknown factors	227	6.73	2.46	3.52	0.03
Adult (N_3)	3145		--	--	--	3.49	--
Total				70.17	65.90		K = 0.47

Real mortality = 65.90 per cent

Fecundity = 11.5

Expected number of early instars in the next generation = 11.5 x 3145
= 36,167.5

Actual number of early instars in the next generations (N_2) = 10,110

$$\text{Trend index (I)} = \frac{N_2}{N_1} = 1.095$$

$$\text{Generation survival (SG)} = \frac{N_3}{N_1} = 0.340$$

DISCUSSION

5. DISCUSSION

5.1. Fluctuation of *A. craccivora* population on cowpea and glyricidia

Results presented in para 4.1 showed that the population on twigs representing foliar infestation builds up only from 8 WAS (weeks after sowing) and reached high levels at 12 WAS . The highest population observed at 15 WAS was on par with the population at 12 to 15 WAS. On pods population observed at 12 to 15 WAS remained high and were on par. When the data on pods and twigs were combined and analysed, the population at 13,14 and 15 WAS remained on par and were at the peak levels. It was closely followed by the population at 11,12 and 17 WAS.

The fluctuation in the population of *A. craccivora* on a perennial plant viz. glyricidia was also assessed concurrently and it was observed that the peak period of population on this crop extended from the last week of December to the first week of February and after significant decline in the first to third week of February, it again rose to second peak extending from the last week of February to

the third week of March. The peak period on cowpea was at the growth stage of 12 to 18 WAS which coincided with the second week of January extending up to the fourth week of February. During the second peak period of the pest population on glyricidia, the population on cowpea was very low. During the later period cowpea crop was in the drying phase. This difference in the population intensity on two different crops during the same period in the same ecosystem indicate that the host condition and its nutritional status influence the population build up of *A. craccivora* more than the other ecological factors in the nische.

During the second season of the crop (para 4.3) significantly higher level of population was observed on cowpea twigs between 4 and 8 WAS (middle of March to last week of July) while the population on the pods reached the peak between 10 and 13 WAS. On total population basis the growth stage of 10 to 13 WAS were found to be the period of occurrence of peak level of the pest. The period of 4 to 8 WAS extended from first week of April to the first week of May and the 10 to 13 WAS ie. the peak period of incidence on pods, extended from the middle of May to first week of June. Incidence of the insect on glyricidia showed a distinct hike

from the fourth week of April to the third week of May. Thus, during the second season also the occurrence of the peak population of the pest on the vegetative and reproductive parts of the cowpea crop and on glyricidia did not coincide.

A comparison of levels of population of *A. craccivora* in the two seasons showed that the vegetative part of cowpea and glyricidia plants were very unfavorable to the pest in the second season. The mean weekly population during the first season were 238.76 and 3982.33 per twig of cowpea and glyricidia respectively, while in the second season the corresponding means were 64.19 and 245.29 only. But on cowpea pods the mean weekly population level were 1160.5 per three pods during the first season and 1303.05 during the second season. This shows that there is no significant influence of the seasons, in the population build up of the pest. While the population build up on the vegetative and reproductive parts of cowpea plants during the first season overlapped (January first week to end of February and January second week to first week of February) in the second season it was rather sequential (first week of April to first week of May and third week of May to June

first week respectively). Comparatively lower level of population during the second season of cowpea with the sequential distribution of the insect on foliage and pods indicated a migration of the pest from vegetative to reproductive part of the crop in the season. The dirth of some essential nutrients in the vegetative portion of the plant during this season and its availability in the pods might have induced the migration. The rapid increase of population on pods during the period also indicated the nutritional stability of the pods. This observation and the fact that the population on glyricidia also was very low during the second season further showed that the nutritional status and the vegetative growth of the crops during the two seasons might have influenced the population build up of *A. craccivora*, than the other components in the ecosystem.

During the third season (August to November) the population build up of the pest on glyricidia alone could be presented since most of the cowpea plants were affected by a viral disease and died at different occasions. Aphid population was very low and highly erratic.

In season three, population of the pest on glyricidia showed a single peak extending from first week of August to first week of September. During the rest of the period the population was negligible.

In summing up the above observations it may be stated that, on cowpea the population *A. craccivora* remained at a peak level during pod yielding phase of the crop and weekly observations on the population were on par during the period. Crop sown in October 1993 had the peak population during January and February 1994 and the crop sown in March had lesser infestation on vegetative parts and peak was during April and early May. On pods the peak was from May middle to early June.

On glyricidia, a perennial crop, four peaks in the population of *A. craccivora* were found viz. December last week end to February first week, March first week to March third week, May third week to June first week and August first week to September first week. The period December to February (population - 2178 to 12807 per twig) was most favourable and it was followed by August - September (2611 - 10097), March (1604 - 7112) and May - June (251 - 1896).

Lack of coincidence in the period of the peak incidence of the pest on the vegetative and reproductive parts of cowpea and on glyricidia strongly indicated that the growth stages of the crop, its physiological condition and nutritional status influenced the population build up of the pest more than any other factors in the ecosystem.

The occurrence of *A. craccivora* on cowpea grown in different months of one calendar year was studied at Vellayani earlier (Hareendranath Nair, 1989) and the data showed that irrespective of the month of sowing or month of the calender year, the incidence (as assessed from shoot population) reached the peak during the flowering and yielding stages of the crop, falling between the fifth and eleventh week after sowing. In an earlier work done at the same location (Mathew et al., 1971) incidence of *A. craccivora* on cowpea planted repeatedly at monthly intervals within same plot was assessed and it was concluded that the population in the month of September to April of succeeding year remained comparatively higher than those during the months of May to August. The authors did not sample the population with reference to the growth stages of the crop at the time of observation. Srikanth and Lakkundi (1990) raised two crops

of cowpea in March and August and found that the population reached high levels in April - May and September - October. But they further observed that the peak population coincided with the pod formation stage and probably the hike was due to better nutritional quality of the plant. Selim (1987) recorded January - February as the peak season for aphid. These observations generally agreed with the present finding that the stage of the cowpea crop and its nutritional status were influencing the population build up its *A. craccivora* more than the season of the year. Butani and Bharodia, (1984) observed March as the peak season on groundnut and August was observed as the peak season (Saleh, (1971); Patel, (1976); Rangaswamy, (1976) for the build up of *A. Craccivora*.

The population of *A. Craccivora* on glyricidia had been studied at coimbatore by Jacob (1963). He reported high population of insect in the last week of December, first week of May, third week of July, third, fourth and fifth week of October. These peaks did not agree with those recorded at Vellayani. The first and third peaks followed the North East monsoon showers and South West monsoon showers at Coimbatore, were the studies were carried out. In Kerala the December - January season and August - September season followed the two rainy seasons and probably it have caused a better crop stand and consequent population build up.

Separate assessment of *A. Craccivora* on the vegetative and reproductive parts of cowpea and the concurrent assessment of population build up of a perennial and seasonal crop in the same ecosystem were done for the first time. The variations in the pattern of pest build up on different host and in the peak seasons in the incidence of pest indicated the need for host war studies on the population of a polyphagous pest in each ecosystem while evolving integrated pest management strategies.

5.2. Occurrence of natural enemies of *A. craccivora* in the Vellayani ecosystem

The findings included in the para 4.2 revealed a wide spread occurrence of the coccinellid predators - *C. sexmaculata*, *C. septumpunctata*, *Scymnus sp*, *M. crocea*, the syrphid predator - *X. scutellare*, spiders like *L. pseudoannulata* and *O. chinensis* as well as the rare occurrence of the fungal pathogen *F. pallidoroseum* (infesting all the life stages of the pest).

Population fluctuation of coccinellid predators on cowpea and glyricidia

The population of the predators vis-a-vis the population of *A. craccivora* were assessed on cowpea and glyricidia. The results presented in para (4.5.1 to 4.11.3)

showed that all the predators except *M. crocea* detected in the survey were present on both the crops and throughout the season. The mean weekly population of different predators during the first season of cowpea crop revealed that *C. sexmaculata* (33.66 per cent) alone had significant impact on the pest population. In the second season also the same predator predominated with mean percentage of 47.37. On glyricidia also *C. sexmaculata* was the most predominant predator which accounted for 72.7 per cent and 36.21 per cent of the total predator population during the first and second season respectively. *X. scutellare* accounted only 7.57 per cent during the first season while it was 31.03 per cent in the second season. Compared to cowpea the population of *C. septumpunctata* was higher on glyricidia, the percentages being 13.78 and 25.86 of the total population in the two seasons. On glyricidia aphids also *Scymnus* and spiders played a comparatively lesser predatory role. In general the occurrence of the predatory fauna of aphids on cowpea were almost double than those of the population predating aphids on glyricidia.

The predominance of *C. sexmaculata* among the predators of *A. craccivora* has been reported earlier by several workers (Jacob, 1963; Patel, 1976; Saharia 1980, Parasuraman, 1989; Srikanth and Lakkundi, 1990; Sharma, 1991). Sita Raman (1966) observed *X. scutellare* as the most important Syrphid predators in the Vellayani ecosystem of Kerala.

In cowpea the population of *C. sexmaculata* was found to be high (3.2 to 7.3/plant) during December 1993 to January and February 1994 when the population of aphid also was at peak level. During the second crop season also, the population of the predator (5.33 to 6.75) was seen related to the peak level of aphid population in May-June. The highest population level of (2.13 to 5.13/plant) of *X. scutellare* also coincided with high incidence of the aphid population in the months of December, January and February. In this case the high level of population continued in the month of March also when the pest population had declined significantly.

In the case of glyricidia also the population of *C. sexmaculata* remained high (0.54 to 1.45/plant) during the first peak season of aphid extending from December to

early February. A similar relationship could be observed between the predator (0.95 to 2.0 /plant) and pest population during the peak in April-May in the second season. The population of *X. scutellare* ranging from 0.45 to 1.08/plant occured during the first peak of the aphid population on glyricidia during December to February. In the second season, the higher population of the predator (0.12 to 0.79) coincided with the higher incidence of the pest in April-May.

During the third season the higher population level of 0.63 to 1.2/plant of *C. sexmaculata* and 0.54 to 1.08/plant of *X. scutellare* were noticed during August-September when the population of *A. craccivora* was also at a high level.

Thus in overall assessment, the population of the two important predators of *A. craccivora* infesting cowpea as well as glyricida showed a density dependent increase.

The level of predator population found in this investigation were higher than those reported earlier on cowpea aphid (Mathew, 1971; Hareendranath, 1989; Srikanth and Lakkundi, 1990.

5.3. Association of *A. craccivora* with the biotic and abiotic factors

As presented in para 4.12 to 4.13 the predators separately and in combination had a significant positive association with the population of *A. craccivora* during the first season. But during the second season population of coccinellids alone showed a significant association with *A. craccivora* and when the data relating to the two seasons were pooled and analysed, none of the factors were seen associated with the pest population.

In the case of glyricidia during thr first season the population of coccinellids and spiders were seen positively associated with the aphid population while the syrphids and total predator population did not show any significant correlation with the pest population. But in the second season significant positive associations were seen between the population of coccinellids, syrphids and their totals and aphid population. When the data for the two seasons were pooled, significance was observed in the correlation between aphid, spider and total predator population. The only earlier report on the correlation

between aphids on glyricidia and its predators was that of Jacob (1963). He also reported a positive significant association between *C. sexmaculata* and aphid population. Butani and Bharodia (1984) studied the correlation between *A. craccivora* and the coccinellid predators, and found a significant positive association between the two. Mathew et al. (1971) and Hareendranath (1989) studied the correlation between *A. craccivora* and its predators collectively and found a significant positive association between them. A prey dependent fluctuation in the population of coccinellid predators was observed by Saharia (1980) and with the total predators by Rangaswami (1976), Srikanth and Lakkundi (1990) and Hijam and Singh (1991). Patel (1976) observed a significant negative correlation between the pest and predator population.

The association of the population of *A. craccivora* and its predators, as well as the total population of the predators with different abiotic factors, viz. maximum and minimum temperature, rainfall, morning and evening humidity and sunshine did not show consistent results either in the two seasons of the cowpea crop and in the analysis of the pooled data of two seasons. In fact the analysis of pooled

data show statistical significance for correlation coefficient between the total predator population and the evening humidity alone.

The inconsistency in the correlation obtained during different seasons and the pooled data may be due to numerous factors interacting among the components of the biotic system and their interaction with numerous abiotic factors. These are widely changing from season to season and even within a season. The relative contribution of these components in the population of the pest and natural enemies is bound to vary significantly from season to season and one factor may mask the effect of the other component. Such masking effect had also been reported earlier (Mathew et al. 1971). The manipulation of these components for achieving reduction in the pest population especially on polyphagous pest species like *A. craccivora* is extremely complex. For consistent conclusions these correlation studies may have to be extended over a number of seasons and for all the hosts separately.

5.4. Biology of *A. craccivora, C. sexmaculata, X. scutellare* and the feeding potential of the predators

Among the predators detected in the vellayani ecosystem *C. sexmaculata* and *X. scutellare* alone were

peristantly significant in occurrence and hence the biology of the pest and these predators as well as their feeding potential were investigated in detail. As seen from para 4.15 the duration of the first and the fourth instar were slightly shorter than those of the second and third instar nymphs. Behura (1956) and Gargav and Verma (1980) studied the duration of instars on cowpea and Dolichos respectively and they did not find significant variations among the duration of the different instars.

Total duration of life cycle of the insect noted in the present studies ranged between 5 to 10 days with a mean of 7.3 days. Earlier reports of Behura (1956) on cowpea was 5 to 15 days, generally agreeing with the present findings. The duration on groundnut (Dorge et al., 1966), on Dolichos (Gargav and Verma, 1980) and beans (Dharamareddy et al., 1983) ranged between 4 and 8 days. Slightly longer duration observed on cowpea may be the effect of the host plant.

The nymphal mortality observed in the first to fourth instar showed an upward trend. The percentage being 10,18,27 and 42 respectively. The instarwise mortality of the insect has not been reported earlier.

The adult longevity was observed to range from 4 to 9 days on cowpea in the present investigations with a mean of 6.2 days. The mean duration reported by Gargav and Verma (1980) under laboratory conditions was 11.5 days and it was also on cowpea. On beans Dharmareddy (1984) found a mean longevity of 4.4 days. Bakhetia and Sidhu (1977) studied the longevity on groundnut under green house condition in Punjab and reported a long duration of 9.6 to 68.2 days. This may be due to the highly variable climatic conditions in Punjab. In general it may be observed that the host as well as the climate influences the adult longevity significantly.

The pre-reproductive period extended up to 24 hours under laboratory conditions. Earlier reports also agrees with this observation (Behura, 1956, Bakhetia and Sidhu, 1977; Gargav and Verma, 1980). The reproductive period 2.2 days (1 - 4 days) observed in the present investigation was much lower than the reported results of Dorge et al., (1976) and Bakhetia and Sidhu (1977); on groundnut ranging from 13 to 27 days. This variation may be attributed to host difference and climatic factors.

The mean fecundity observed in cowpea in the present investigation was 11.5. The earlier report of Gargav and Verma (1980) was very high (81.4). Other reports on groundnut (Talati and Butani, 1980 - 1- 13), Dolichos (Gargav and Verma, 1980 - 45.7) and beans (Dharmareddy, 1983 - 56.9) were found comparatively much higher.

Regarding *C. sexmaculata* (para 4.15.1) incubation period and first instar duration were lower than the duration of second and third instar as well as the pupa. The mean total duration was 15.9 days. The instar wise duration in the life-cycle of *C. sexmaculata* has not been reported earlier. Bagal and Trehan (1949) reported that the number of instars vary with season and Jacob (1963) observed 4 larval instars in the life-cycle. His studies were conducted on aphids of glyricidia. The mortality observed in the egg, three larval instars and the pupa were 4,29,21,19 and 0 respectively, with a total mortality (from egg to adult) of 44 per cent. There is no reference on the this aspect. The longevity of the adult observed did not show much difference between male and female and it had a range of 18 to 44 days with a mean of 31.5 days. Begal and Trehan (1949) observed a long longevity of 2 months for this predator. The mean fecundity was 15.27 eggs per female.

In the case of *X. Scutellare* (para 4.15.2) incubation period, duration of three instars and pupa was 3.9,2,2.5,3.6 and 3.7 respectively with a total of 13.19 days. The mortality in the corresponding developmental stages were 20,10,12,9 and 29 respectively, the total mortality being 40 per cent. The longevity of male and female differed by two days only. The mean fecundity was 33 eggs per female. The data on the life-cycle of this predator reported by Sita Raman (1966) broadly agree with the observations in the present investigation. There are no earlier reports on the longevity and fecundity of this insect.

The larva of *C. sexmaculata* consumed around 87 aphids in its life time (para 4.16.1) and the percentage consumption in the three larval instars were 9,20 and 64 respectively. Sarala Devi (1967) observed the total consumption as 116 insects and the percentage consumption by different larval instars were 6,33 and 60 respectively. These two observations do not show wide variations. Lokhande and Mohan (1990) observed the consumption as 73.52 nymphs per predator. But Bagal and Trehan (1949) observed the consumption to be 303 per larva. The consumption by the

adult was 750 individual in the present observation and the mean consumption per day (longevity 31.5 days) was worked out to be 23.77 aphids/day. On this criteria the consumption reported by earlier workers did not show significant differences. The consumption reported by Jacob (1963), Sarala Devi (1967) and Lokhande and Mohan (1990) were 29, 27 and 27 aphids/day respectively. The consumption reported by Haque and Islam (1978) was on the higher side (57/day). The daily consumption from the time of emergence till death did not show wide variations. The total consumption by larvae and adult was around 835 aphids and in an assessment made by Das (1991) the consumption was reported as 270 to 367 aphids.

The individual total consumption during the larval stages of *X. scutellare* (para 4.16.1) was around 450 aphids. Sita Raman (1960) and Sarala Devi (1967) observed the consumption as 450 and 383 respectively. The consumption by the three larval instars were 11, 31 and 59 percent of the total number and the corresponding percentages reported in the work of Sita Raman (1966) were 12,22 and 56 respectively. Thus the present findings broadly agree with earlier reports also.

A comparison of the biology of *A. craccivora* and the two predators revealed that the former with its shorter duration relatively lower mortality in the immature stages is bound to have a much more rapid rate of population increase than those of the predators. Fecundity of the aphid is slightly less than that of *C. sexmaculata* and (11.5 and 15.7 respectively) the fecundity of *X. scutellare* was found to be quite high (33.0). But the actively moving predators often distribute their eggs in low density among the aphid colonies thus resulting in low population build up. The field observation is in overall agreement with this conclusion. Allthrough the observations the population of the predators showed a positive association with that of aphids. In many occassions these relationships was statistically significant. But frequent sudden hikes and falls in the aphid population occured without corresponding hike or fall of predator population, in the immediately preceeding periods. The predators did not play an important role in pest regulation. Srikanth and Lakkundi (1990) also made parellel conclusions. Of the two predators *X. scutellare* had a shorter life-cycle, higher longevity and fecundity thus indicating a superiority over *C. sexmaculata*. But the field observations revealed that the latter was more predominant on aphid

colonies. Though the feeding potential of he immature stages of *X. scutellare* was higher, the adult *C. sexmaculata* consumed very large number of aphids and hence the latter has to be treated beneficial in controlling the pest.

5.5. Life-tables studies

Age-specific life-tables for *A. craccivora* could be prepared for the first time, following the methods adopted by Morris (1963) and Phadke (1987). The intrinsic rate of increase and true generation time were observed as 0.272 and 9.78 days respectively. Based on similar life-tables of *Lipaphis erysimi* Phadke (1987) reported that the intrinsic rate of increase of the pest on four different host ranged from 0.1690 to 0.2172. The true generation time ranged from 22.78 to 29.30 days. Obviously the population increase of *A. craccivora* will be much faster than *L.erysimi*.

The age-specific life-tables of *A. craccivora* prepared in December 1993 and January 1994 revealed a low generation survival (0.254) and trend index (0.755) in December compared to the corresponding values for January (0.34 and 1.095 respectively.) During the first season the

mortality at early and late nymphal instars did not show any variation, whereas in the second life table mortality of later instar nymphs were very low (k = 0.03). The abiotic factors in the ecosystem during the two different periods do not show significant variations. The predator population also showed a linear increase in January and hence cannot be attributed to the high mortality in early instar and low mortality in later instar nymphs. Towards the later portion in the period of observation there was profuse pod setting and an increase in the Vigor of the plants. This might have favored the better survival of the late instar nymphs and hence a comparatively higher generation survival.

Construction of a series of life-tables covering different hosts, seasons and ecosystems will help in developing models for the forecast of pests outbreaks and management of the pest in different agro ecosystem.

SUMMARY

SUMMARY

The seasonal incidence of pea aphid, an important peristant pest of cowpea in Kerala and its natural enemies and their occurrence on a perennial alternate host glyricidia in the same ecosystem at the college of Agriculture, Vellayani were studied during 1993-'94. The detailed biology of the pest and two predators prevalent in the ecosystem was studied under laboratory condition and the feeding potential of the latter also was ascertained with a view to evaluate them as the biocontrol agents in pest management strategy. Attempts were also made to prepare the life table of *A. craccivora* with a view to assess the intrinsic rate of increase, generation time, generation survivals and trend indices.

On cowpea during the first season the incidence of the pest on the vegetative parts (terminal twig) commenced at 6 WAS (week after sowing) and gradually increased reaching a peak level on 15^{th} week, the latter being on par with the population levels from 12^{th} to 18^{th} WAS. The population on pods remained high and on par between 12^{th} and 15^{th} week. When the data on the twigs were pooled and analysed high

levels of population were from 13th to 15th week. The peak periods occurred between January first week and end of February 1994.

On glyricidia two peak levels were found in the population during first season one in the last week of December to the first week of February and the second from last week of February to the third week of March.

In the Second season (April - July) peak periods on cowpea twigs were at 4 to 8 WAS and on pods at 10 to 13 WAS. These periods were April first week to May first week and May third week to June first week respectively. On glyricidia peak incidence occured from April 4th week to May third week. During the third season (August - November) population on glyricidia alone was studied since cowpea crop failed due to the incidence of an unidentified viral disease. The peak season of aphid incidence was from first week of August to the first week of September.

Results showed that (1) the period of population build up on cowpea and glyricidia in the same ecosystem varied significantly. (2) During the second season

population of aphids on twigs of cowpea and on glyricidia were much lower than the population during the season. (3) On pods the population in the second season was slightly higher. (4) On cowpea only a single peak occured in the population in both the seasons while on glyricidia two peaks were noticed in the first season. (5) On cowpea during the first season when the vegetative growth was good, peak on twigs and pods occured concurrently while in the second season (summer) the population on twigs fell to negligible levels compared to pod bearing stage, indicating a migration.

The above observations indicate the strong influence of crop stage and nutritional status on the population of *A. craccivora* compared to other ecological components.

Survey of the predators in the locality led to the identification six predators viz *C. sexmaculata*, *C. septumpunctata*, *Scymnus sp*, *M. Crocea*, *X. scutellare*, *L. Pseudoannulata* , *O. chinensis* and a pathogen, *F. pallidoroseum*.

The seasonal fluctuation of these predators showed that *C. sexmaculata* and *X. scutellare* alone were important

in regulating the pest population. Their population levels were on par with the incidence levels reported by earlier workers. The predator population on cowpea and glyricidia showed a pest dependent increase. The sudden rises and decline in the aphid population observed were not preceeded by corresponding depression and rise in predator population and hence the density dependent increase in predator population did not appear to cause pest increase or reduction.

Correlation studies revealed that pest/predator and abiotic factors did not show consistent association in the first and second seasons and in the analysis of the pooled data. The relative importance of different factors acting on the pest in different seasons may vary, one masking the effect of another resulting in variations in correlation coefficients from season to season. Data from long periods of study alone may lead to consistent conclusions.

Detailed studies on the biology of the pest and predators and feeding potential of the latter are scanty and instar wise data on the survival percentage, duration as well as longevity and fecundity of the adults were gathered. Such detailed data are essential for preparing proper models for pest forecasting and adopting integrated control of the pest. Data revealed that the short life cycle and

higher fecundity of the pest in comparison with the predator might result in rapid build up of the pest than the predators in the field and hence the failure of the predators in exerting control effect on pest population. Biological data indicated higher potential of *X. Scutellare* than *C. sexmaculata* in controlling *A. craccivora*. In field the latter was however seen better established. This effect may be due to other factors in the ecosystem adverse to the *X. scutellare*. The feeding potential of the grub of *X. scutellare* was higher but since the adults of the insect are not feeding and the adults of *C. sexmaculata* lived up to 31 days with an mean daily consumption of 24 aphids per day, the latter was more promising in controlling *A. craccivora*.

Age specific tables of *A. craccivora* were constructed for the first time. The intrinsic rate of increase and true generation time of the pest were found conducive to its population build up than those of other aphids reported earlier. In the life tables of the pest for December 1993 and January 1994 a higher generation survival and trend index and were seen during the latter period. Though the tables were successfully prepared for the first time, mortality factors in the field could not be precisely assessed.

BIOECOLOGY AND LIFE-TABLES OF THE PEA APHID *Aphis craccivora* KOCH. AND ITS NATURAL ENEMIES

By

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ABSTRACT

The seasonal distribution of pea aphid *Aphis craccivora* and its predators on twigs and pods of cowpea and a perennial alternate host of the insect, glyricidia were assessed during 1993-94 at the College of Agriculture, Vellayani, Kerala. On cowpea peak population of the pest during the first season, on twig and pods were noted in January/February while on glyricidia two peaks were noted in the season first from December and early February and the next from February to end to early March. In the second season also one peak period each were seen on twigs and pods of cowpea and on glyricidia, but the three did not coincide in the periods of occurrence. In glyricidia a fourth peak was observed in August/September 1994. Studies thus revealed vital indifference in the trend of population build up on cowpea and glyricidia and even on the twigs and pods of the same plant. The growth stages of the crops and their nutritive status are suggested as the major factor influencing the population build up of *A. craccivora* than any other factor in the ecosystem. Survey of natural enemies in the region revealed the occurrence of six

predators and one insect pathogen. Among them *C. sexmaculata* and *X. scutellare* were found to be the important ones. A pest dependent increase in the population of predators were observed but the trends of the population build up of the pest and the natural enemies did not show any effective role of the predators in suppressing the pest population under field condition. The detailed biology of *A. craccivora* and the two predators were studied in the laboratory conditions. The duration and percentage survival of each larval instar, adult longevity and fecundity were studied and the data indicated that short duration and higher fecundity od *A. craccivora* when compared to predators account for the successful establishment of the pest in field even with higher levels of predator population. The parameters of biology in laboratory were found more favourable for the population of *X. scutellare* than for *C. sexmaculata*. But in field latter was more successful. Feeding potential of *C. sexmaculata* (larvae and adult) was much higher than that *X. scutellare* (larvae) only. Hence *C. sexmaculata* was found to be a better bicontrol agent for the control of *A. craccivora*. The exhaustive information gathered will be useful in constructing models for integrated pest control programmes of *A. craccivora*. Age specific life-tables were consctucted

for *A. craccivora* for assessing the intrinsic rate of increase and generation time of pest and these were found suitable for fast population build up. Life tables were prepared during, December 1993 and January 1994 and the 'Generation Survival' and 'Trend Index' were found increasing in January. The lower mortality percentage of the late instar nymphs were found as the reason for the variations. But the mortality factors could not be precisely determined in the investigations. Series of such life tables developed for different seasons, hosts and different ecosystems may be necessary for constructing suitable models for integrated pest management practices.

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