BIODIVERSITY AND BIONOMICS OF PREDATORY COCCINELLIDS IN VEGETABLE CROPS

By

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THESIS

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DEPARTMENT OF ENTOMOLOGY
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that the thesis entitled **"Biodiversity and bionomics of predatory coccinellids in vegetable crops"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara
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CERTIFICATE

Certified that the thesis entitled **"Biodiversity and bionomics of predatory coccinellids in vegetable crops"** is a record of research work done independently by Ms. Sheena under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Tim Allen

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Dedicated affectionately to my beloved parents and to my loving husband

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INTRODUCTION

1. INTRODUCTION

Vegetables are one of the cheapest and most important sources of natural nutritive food and have got great demand due to high dietary value and are cultivated throughout the year. Insect pests are the major constraints in the productivity of these crops. To tackle various pests, farmers often resort to frequent and massive application of insecticides even in the reproductive stage of crops, which often culminates in pesticide residues in the harvested produce. Pesticide application may also lead to the destruction of natural enemies and consequent resurgence of pests. Unless a sound alternative to the ecologically destructive pesticides is made available to the growers, a way out of the present situation can never be thought of.

It is now universally recognized that the most effective and acceptable pest management strategies from the point of preservation of environment has biocontrol as the pivotal concern. Biological control has been the core of many successful integrated pest management programmes. Interactions between insects and plants are strongly influenced by higher trophic levels, which include the predators and parasitoids. These natural enemies play a vital role in the regulation of pest population and a large number of coccinellids are known to prey upon several species of economically important phytophagous insects which include aphids and coccids. These predators are potentially useful biocontrol agents checking the population build up of insect pests (Hodek, 1967). Predaceous coccinellids are linked to biological control more often than any other taxa of predatory organisms. The first spectacular success in this method of control was achieved in 1889 in California by employing the vedalia beetle, *Rodolia cardinalis* (Mulsant) for combating the fluted scale *Icerya purchasi* Mask.

Success in applied biocontrol is often dependant on a thorough understanding of the organisms involved both injurious and beneficial and their intricate interactions with each other and with abiotic environment. Basic studies on systematics, biology and ecology of pests and their natural enemies are therefore an integral part of the field of biological control (De Bach, 1964). The control that can be exerted over pests by their natural enemies need to be harnessed and used to its maximum potential in any insect pest management programme. Inevitably the first step in any investigation on the role of natural enemies in pest control involves a field survey to determine the species present and how their numbers vary in relation to those of insect pests.

The present study entitled "Biodiversity and bionomics of predatory coccinellids in vegetable crops" was taken up to study the species diversity and bionomics of predatory coccinellids in vegetable crops like cowpea, bhendi, brinjal, pumpkin and bittergourd and to quantify their suppressive potential.

Review of Literature

2. REVIEW OF LITERATURE

A comprehensive review of the work done on biology, fecundity, predatory potential, and prey preference of predaceous coccinellid beetles and the seasonal fluctuation of aphid and predator population are summarized below.

2.1 PEST STATUS OF APHIDS

Mathew *et al.* (1971) reported that the pea aphid *Aphis craccivora* Koch is a serious pest of cowpea in Kerala during dry periods. According to Singh and Allen (1980) *A. craccivora* is a major pest in Asia causing an estimated loss of 20 to 40 %. Gupta and Singh (1981) stated that *A. craccivora* is a widespread pest of cowpea in India and it caused significant damage by feeding on stems, terminal shoots, petioles of seedlings, pods and flowers. Koshy *et al.* (1987) reported an yield loss of 13.34 to 33.89 % by aphids in cowpea from Kerala

2.2 COCCINELLIDS AS PREDATORS OF APHIDS

Ray (1967) reported that *Cheilomenes sexmaculata* (Fab.) is a well known predator of aphids infesting plants. It has been found to feed on *A. craccivora*, *Lipaphis erysimi* Kalt. and *Brevicoryne brassicae* (Linn.). According to Saharia (1980) *C. sexmaculata* was the most abundant and persistent predator of *A. craccivora* because of its short life cycle, larger populations and fairly high feeding potential. Agarwala and Ghosh (1980) stated that some of the true aphidophagous coccinellids include *Adalia bipuncta* L., *Coccinella transversalis* Fab., *C. sexmaculata* and *Scymnus nubilus* Mulsant. The predator *C. transversalis* is considered as an important natural biocontrol agent of aphids. It has been reported to feed on 15 different aphid species (Agarwala and Saha, 1986). According to Falerio *et al.* (1990) aphid population is controlled to a great extent by their predators. Important predatory coccinellids of aphids include *C. sexmaculata, Coccinella septempunctata* L. and

R. cardinalis. Bhasker (1992) reported the feeding of *B. suturalis* on *Aphis nerii* Boyr. under Bangalore conditions.

2.2.1 *Bromoides suturalis* (Fab.)

It is an important predatory coccinellid species feeding on aphids.

2.2.1.1 *Morphology*

Bhasker (1992) made morphological description of *B. suturalis* in which the adult is oval and long, head and thorax yellow, pronotum yellowish - brown, scutellum black and elytra yellow with a broad longitudinal stripe on each elytron.

2.2.2 *Cheilomenes sexmaculata* (Fab.)

C.sexmaculata is considered as one of the most abundant and persistent predator of *A. craccivora.*

2.2.2.1 *Morphology*

Azim and Ahmed (1966) observed seven colour variations of *C. sexmaculata* in Pakistan. *C. sexmaculata* adult is medium sized, elongate and oval. Head is pale yellow. Dorsal colouration is variable. Pronotum is yellow with a median half moon shaped marking connected with posterior marginal stripe (Bhasker, 1992).

2.2.2.2 *Longevity*

Life history of *C. sexmaculata* was studied by Azim and Ahmed (1966). They stated that at a temperature of 28.7°C, the life cycle of *C. sexmaculata* averaged 18 days. Kawauchi (1979) reported that the duration of development of *C. sexmaculata* decreased with rise in temperature up to 30°C. A study on longevity of *C. sexmaculata* was conducted by Easwaramoorthy *et al.* (1998) at Coimbatore. According to them the mean duration of development of *C. sexmaculata* reared on *Melanaphis indosacchari* (Zehntner) was 11.3 ± 2.4 days. The adults survived for 12.7 ± 3.1 days when fed with aphids.

2.2.2.3 *Predatory potential*

Variation in the feeding capacity of coccinellids was reported by Lefroy as early as 1909. The total consumption of aphids by a single larva of *C. sexmaculata* during its lifetime was found to be 2,400. Begal and Trehan (1949) found it to be 303 aphids for *C. sexmaculata*. Azim and Ahmed (1966) reported from Pakistan that the average daily number of *A. craccivora* consumed by *C. sexmaculata* generally increased with age. It was found to be 17.2 for one day old larva. The number of aphids consumed daily by the adults varied from 12 - 50 with an average of 32.4. Studies on the feeding potential of the grubs and adults of coccinellid predator *C. sexmaculata* were undertaken by Devi (1967) in Kerala and found that the average feeding potential of first, second and third instar larvae of *C. sexmaculata* was 7.11, 38.44 and 70.78 respectively under laboratory conditions. Adult was found to consume 27.22 aphids per day. Verma *et al.* (1983) reported that the feeding potential of *C. sexmaculata* on *A. craccivora* was found to be 28.7, 35.40, 32.20, 32.50 and 30.70 aphids respectively for first, second, third and fourth instar grubs and adult. The average per day consumption of *A. craccivora* by *C. sexmaculata* larva was 8.5 adults and 73.52 nymphs whereas; the adult predator consumed 24.34 adults and 176.15 nymphs (Lokhande and Mohan, 1990). Jayaramaiah *et al.* (1996) reported that *C. sexmaculata* consumed on an average 31.20 aphids per day under Bangalore conditions. The feeding potential of *C. sexmaculata* grub was 220.2 ± 17.4 aphids in the case of *M. indosacchari* and 179.6 ± 40.5 aphids in the case of *Melanaphis sacchari* Zehntner. The adult beetles preyed on an average of 992.8 ± 256.8 *M. indosacchari* and 1403.3 ± 99.9 *M. sacchari* respectively (Easwaramoorthy *et al.*, 1998). Nandakumar (1999) stated that the mean consumption of *Aphis gossypii* Glover by first, second and third instar grubs of *C. sexmaculata* was found to be 11.2, 51.45 and 121.45 aphids respectively. The mean consumption of *A. gossypii* adults by an adult coccinellid during its lifetime was 827.90 and it ranged from 386 to 1494.

2.2.2.4 ***Feeding preference***

Kapur (1940) and Jotwani and Verma (1969) reported that in the absence of aphid host, *C. sexmaculata* and *Veronia discolor* F. were found feeding on *Aleurolobus barodensis* Mask, *Pyrilla perpusilla* Wlk. and few hours old larvae of *Chilo zonellus* Swinhoe. *C. sexmaculata* when reared on *A. craccivora*, *L. erysimi* and *A. gossypii* showed marked differences in growth and development. The size and fecundity of predator was greater when fed on *A. craccivora* (Rao and Rao, 1997)

2.2.3 ***Coccinella septempunctata*** **(L.)**

C.septempunctata is an efficient predator of aphids.

2.2.3.1 ***Longevity***

Sethi and Atwal (1965) noticed that the eggs, larvae and pupae of *C. septempunctata* developed faster at 35°C and 30°C than at 20°C. According to Kawauchi (1979), the duration of development of *C. septempunctata* decreased with rise in temperature up to 30°C. An investigation on the longevity of *C. septempunctata* was conducted by Singh *et al.* (1994) in Bihar. They reported that the minimum, maximum and average duration of the larval stage of *C. septempunctata* varied from 10.0 - 11.0, 16.0 - 17.0 and 13.0 - 14.0 days respectively. The mean longevity of adult coccinellids was greater in February (16.73 days) than in March (13.52 days). Jagdish *et al.* (1996) found that the duration of larval stages of *C. septempunctata* was found to be 8.9 days and that of adult females was 42 days. Veeravel and Baskaran (1996) observed that the developmental period of egg and larval stages of *C. septempunctata* tend to get reduced as the temperature went up. Xia *et al.* (1999) reported that longevity of *C. septempunctata* adult decreased with temperature from 38 days at 20°C to 14 days at 35°C.

2.2.3.2 *Fecundity*

The fecundity of beetles reared and kept at 20°C and 30°C was higher than those of beetles kept at 35°C (Sethi and Atwal, 1965). Jagdish *et al.* (1996) reported that the mean fecundity of *C. septempunctata* was found to be 518. Xia *et al.* (1999) stated that oviposition of *C. septempunctata* was highest at 25°C with a total of 287.4 eggs per female per day.

2.2.3.3 *Predatory potential*

Adult *C. septempunctata* was found to be feeding 42, 49 and 49 aphids at temperature 22.5°C, 26°C and 24.5°C respectively (Hodek, 1967). Lakhanpal *et al.* (1998) reported that the total consumption of *L. erysimi, B. brassicae* and *Myzus persicae* (Sulzer) by *C. septempunctata* was found to be 1435 ± 12.01, 1021.05 ± 8.16 and 628 ± 3.42 aphids respectively.

2.2.3.4 *Feeding preference*

Obryeki (1990) found that no individuals of *C. septempunctata* survived to the second instar when provided with European corn borer eggs. First instar grub did not feed on the eggs and desiccated within three days. Richards and Evans (1998) studied the feeding potential of *C. septempunctata* by providing them with alphalpha weevil and pea aphids. Females fed weevils produced very few eggs. When dissected, females fed weevils had only very small eggs in their ovaries.

2.2.4 *Coccinella transversalis* Fab.

2.2.4.1 *Morphology*

Debaraj and Singh (1990) studied the taxonomic characters of *C. transversalis* and they observed that the freshly emerged adult of *C. transversalis* was yellow in colour and its permanent elytral colouration appeared after three to four hours. Body oval and convex. Head black with two yellow spots on posterior corners. Eyes brownish, antenna clavate and 11 segmented, mouth parts black, elytra orange or red with three transverse black bands. Size of the adult varied from 5.43 - 6.80 mm in length.

2.2.4.2 ***Longevity***

The total larval period of *C. transversalis* on *A. gossypii* was observed as 7.88 days (Agarwala and Saha, 1986). The biology of *C. transversalis* was studied by Debaraj and Singh (1990). The experiment was conducted under laboratory conditions at 18.23 ± 1.60°C and 55.4 ± 2.38 % relative humidity and observed that the life cycle from egg to adult was completed in 38 - 45 days. Incubation period took 8 - 10 days and the total larval period ranged from 19 - 23 days. Jagdish *et al.* (1996) reported that the duration of larval stage of *C. transversalis* was found to be 7.2 days and the mean longevity of adult was found to be 37 days at 26.4°C and 65% relative humidity. Veeravel and Baskaran (1996) observed that developmental period for egg, larval instars and other stages of *C. transversalis* tend to get reduced as the temperature went up and the fourth instar took more number of days than the earlier instars. According to Singh and Rai (2001) the total life cycle of *C. transversalis* was found to be more in cooler month (January) followed by warmer months of February and March.

2.2.4.3 ***Fecundity***

According to Debaraj and Singh (1990) mated females of *C. transversalis* laid eggs in batches consisting usually of 17 - 45 numbers in three to four rows. Usually one or two egg batches were laid in a day. Occasionally the eggs were laid singly. Jagdish *et al.* (1996) reported that the mean fecundity of *C. transversalis* was found to be 407. Evans (2000) reported that *C. transversalis* females laid most eggs on a diet of aphids.

2.2.4.4 *Predatory potential*

Consumption of *A. craccivora* by *C. transversalis* increased with the instars and reached a maximum in the final instar. The total number of aphids consumed by a single larva varied from 401 - 736 (Debaraj and Singh, 1990). Predatory potential of *C. transversalis* was studied by Patro and Sontakke (1994). According to them, the consumption rate by the first, second, third and fourth instar larvae and adults of *C. transversalis* on *A. craccivora* was found to be 11.4 ± 1.6, 20.7 ± 2.0, 29.2 ± 1.4, 41.2 ± 1.8 and 65.3 ± 8.3 aphids per day respectively. Larvae consumed on an average 222.1 ± 13.4 aphids during their developmental period. Jayaramaiah *et al.* (1996) reported that the larvae of *C. transversalis* consumed on an average 13.40, 37.86, 46.06 and 141.60 *M. persicae* respectively.

2.2.4.5 *Prey preference*

Richards and Evans (1998) reported that aphidophagous coccinellids feed on a variety of prey in addition to preferred aphids. These alternative foods may serve only to maintain the predator but do not permit immature growth or adult reproduction.

Babu (1999) found that *C. transversalis* showed a selective preference for *Aphis fabae* Scopoli in a free choice situation when *A. fabae* and *A. nerii* were provided. He observed that the young ones reared on *A. fabae* emerged into adults quicker than their counterparts raised on *A. nerii*. He also found that the adult longevity ranged from 30 - 40 days on different prey species. George (1999) conducted laboratory studies on the preference of *C. transversalis* for three aphid species *Pentalonia* sp., *A. gossypii* and *A. nerii*. *C. transversalis* consumed more number of *A. gossypii* (41.42) followed by *A. nerii* (38.48) and *Pentalonia* sp. (30.42) within one hour. Consumption of all the three species decreased in later hours.

2.2.5 *Coleomegilla maculata* De Geer

The polyphagous coccinellid *C. maculata* feed on eggs and small larvae of the colorado potato beetle. Prey consumption rates were highly correlated with temperature (Groden *et al.*, 1990).

2.2.6 *Jouravia soror* Weise

J.soror is a small and rare predator of aphids.

2.2.6.1 *Morphology*

J. soror is oval to round, usually small, strongly convex and uniformly brownish - orange with black compound eyes (Bhasker, 1992).

2.3 ESTIMATION OF APHID AND COCCINELLID POPULATION

Davies (1934) estimated the aphid population on potato crop by recording the number of aphids on 100 randomly chosen lower leaves. Thomas and Jacob (1943) recorded the aphid population by counting the number of aphids on top, middle and bottom leaves of 50 randomly selected potato plants. Dunn (1951) worked out aphid population by taking 50 cm long tips including the growing point and enclosing leaves. He collected 50 to 100 tips per plot. Hanifa *et al.* (1973) recorded the population of aphids per 2.5 cm length of terminal shoot of field bean. Bell (1980) and Dhanorkan and Darvare (1980) also used the same procedure. Ombir and Dahya (2001) studied population dynamics of *L. erysimi* and its natural enemies by counting the aphid and its natural enemies. He counted the aphid population on 1.5 cm long central twig and population of coccinellids was counted per plant.

2.4 SEASONAL FLUCTUATION OF APHIDS AND COCCINELLIDS

Mathew *et al.* (1971) reported that temperature affect aphid population and its

Predators differently. According to them aphid population was significantly influenced by rainfall. Radke *et al.* (1973) observed that a change in photoperiod, temperature, humidity and other environmental conditions affect the form and development of the aphid. *Lablab niger* had a high population of *A. craccivora*, 246.7 per plant in August sown crop, 167.11 in October sown crop and 58 in May sown crop. (Rangaswami, 1976). Patel *et al.* (1976) observed at Central Gujarat that the aphids appeared in the second week of August and the population rose to 97 % during the third week of the month. Saharia (1980) reported that population of aphids and coccinellids were found to be influenced by rainfall. Abiotic factors play a vital role in aphid population build up (Singh and Singh, 1986). According to them relative humidity and temperature are the most favourable factors for aphid multiplication.

Selim *et al.* (1987) found that *A. craccivora* and *A. gossypii* attained peak population levels in January and February respectively on *Vigna fabae* (L.). Sharma *et al.* (1990) reported that temperature and relative humidity were found to influence development, survival, fecundity and predatory potential of *Pharoscymnus flexibilis* Mulsant. Aphid population was found to be influenced more by density independent factors than the population of natural enemies (Hijam and Singh, 1991). Rani (1995) observed that the peak population of aphids occurred during second week of January and first week of February in Kerala. She found that the population observed during the first week of January to the fourth week of February was on par and significantly higher. Raetano and Nakano (1994) studied the relationship between climatic conditions and the occurrence of *M. sacchari* during February. A long period of dry weather and a suitable range of temperature resulted in an outbreak of the aphid, despite the presence of natural enemies. Gautam *et al.* (1995) reported that the alate form of safflower aphid *Uroleucon* sp. appeared in first week of February and attained peak population around middle of March. The predator *C. sexmaculata* appeared during third week of February to third week of March. Rana (2001) stated that maximum and minimum temperature; relative humidity, rainfall and sunshine play a crucial role in the establishment of the aphid as well as the predators. Ombir and

Dahya (2001) reported that the *L. erysimi* population was found to be reduced by rains at Ludhiana.

2.5 CORRELATION OF APHID AND COCCINELLID POPULATION WITH WEATHER FACTORS

Rangaswami (1976) observed that aphid population is negatively correlated with maximum and minimum temperature and relative humidity. The effect of 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. Diraviam and Viraktamath (1991) reported that *Curinus coeruleus* Mulsant showed a negative correlation with the wind speed and relative humidity. *C. coeruleus* population was found to be positively correlated with maximum and minimum temperature and sunshine hours. Rana (2001) observed that temperature is positively correlated with increase in number of predators but was negatively correlated with aphid numbers. Meena and Bhargava (2001) reported that significant negative correlation existed between temperature (maximum and minimum) and aphid as well as coccinellids. The aphid and coccinellid population had positive correlation with relative humidity.

2.6 PREY-PREDATOR RELATIONSHIP

Mathew *et al.* (1971) reported that there was a strong positive correlation between number of aphids and their predators. Patel *et al.* (1976) found that the population of aphids decreased with the increased population of natural enemies. In 1980, Saharia observed that prey population is an important factor determining the population build up of predator. The relationship between the aphid and its coccinellid predators on groundnut was studied by Butani and Bharodia (1984). They observed a positive correlation 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. According to Sarma *et al.* (1996) *C. transversalis* population was positively correlated with aphid population. A decline in the prey population was followed by that of predator population. Agarwala and Roy (1999) reported that the number of eggs and adults of *C. transversalis* and *C. sexmaculata* increased in response to the increase in the aphid population. Meena and Bhargava (2001) found that there was a positive and highly significant correlation between aphid and coccinellid population at one per cent level of significance.

Materials and Methods

3. MATERIALS AND METHODS

The field experiments were carried out in the vegetable plots of the Department of Olericulture and laboratory studies were conducted in the insectary of Department of Entomology, College of Horticulture, Vellanikkara during 2001 to 2002.

3.1 COLLECTION OF PREDATORY COCCINELLIDS

Fixed plot surveys and random surveys were carried out for the collection of predatory coccinellids.

3.1.1 Fixed plot survey

For conducting regular surveys, bulk crop of cowpea variety Kanakamoni susceptible to pea aphid, *A. craccivora* was maintained in the field as well as in pots. No plant protection measures were taken in order to maintain the population of natural enemies. Different species of predatory coccinellid adults were collected from the field and were reared in 17 x 25 cm sized plastic containers.

3.1.2 Random survey

Surveys were conducted randomly in the vegetable growing areas of Pattikkad, Madakkathara and Nadathara panchayats and Irinjalakkuda to collect predatory coccinellids and to assess the aphid and predator populations.

3.2 REARING

Mass rearing of predatory coccinellids was done in plastic containers under laboratory conditions. Aphid infested shoots of cowpea was provided as food. The shoots were kept fresh by covering the cut end with moistened cotton and were placed inside the plastic containers. The mouth of the containers were covered with muslin cloth.

3.3 IDENTIFICATION

The coccinellid predators collected were identified based on morphological and other characters of the insects. Identity was confirmed based on the available literature.

3.4 BIOLOGY

The biology of the test insects was studied by rearing the insects in plastic containers under laboratory conditions.

3.5 MORPHOLOGY

Colour and size of different stages of predatory coccinellids were observed by keeping the different instars separately.

3.6 DURATION OF LIFE STAGES

Beetles collected were allowed to mate within the plastic containers. Eggs laid on the same day were transferred to petridishes. Eggs of different species were kept separately to record the incubation period. The first instar grubs emerged on the same day were transferred individually to different containers using camel hair brush. Small shoots with aphids were placed inside the plastic containers as food for the grubs. Grubs were transferred to new containers on alternate days and the aphid infested shoots were replaced daily. Duration of each instar and pupal period were recorded periodically. Freshly emerged adults of uniform age were separated and confined in separate plastic containers having aphid infested shoots to record the adult longevity. Ten replications were maintained for each species.

3.7 FECUNDITY

For studying the fecundity, separate lots of insects were collected and reared. Adults emerged on the same day were kept together. The mating beetles were transferred to different containers and they were provided with sufficient number of aphids as food. Number of eggs laid by the female beetle were counted daily until it stopped laying eggs. Ten replications were maintained for each experiment.

3.8 PREDATORY POTENTIAL

Predatory potential of adult beetles and grubs was worked out under *invitro* conditions to assess their efficiency in managing the aphid population. The grubs were provided with five nymphs and two adults on first and second day, 10 adults on third day, and 20 adults on fourth day. From fifth day onwards 50 adult aphids were given. The known number of aphids along with the shoot of cowpea was kept inside the plastic containers. Difference between the number of aphids supplied and those left over after consumption were recorded daily. The average number of aphids consumed by the predator was thus worked out. Feeding potential of all the four instars and adult were assessed. Per day consumption of each stage was worked out by dividing number of aphids consumed by the stage with duration of the stage. Ten replications were maintained for each stage.

3.9 FEEDING PREFERENCE

Feeding preference was studied by no choice test and multiple choice test.

3.9.1 No choice test

Known number of aphids, leaf hoppers, white flies, mealy bugs and thrips were provided separately to each predatory coccinellids. For this purpose, aphids were collected from cowpea, white flies and thrips from chillies, leaf hoppers and mealy bugs from brinjal. The food was provided by keeping infested shoots of the above plants with their cut end covered with moistened cotton inside the plastic containers.

3.9.2 Multiple choice test

To study the feeding preference, test insects were maintained separately in the laboratory. First day onwards grubs were given seven nymphs of each host insect namely aphids, leaf hoppers, white flies, thrips and mealy bugs. On third and fourth days 10 and 20 adults and from fifth day onwards 50 adults of host insect was provided. Aphids were collected from cowpea, white flies and thrips from chillies, leaf hoppers and mealy bugs from brinjal as the host insects. Food was provided to the beetles by keeping infested shoots of the above plants with their cut end covered with moistened cotton inside the plastic containers. Number of insects consumed by the grubs and beetles were counted. Ten replications were maintained for each test insect.

3.10 ESTIMATION OF APHID AND COCCINELLID POPULATION

Estimation of aphid and predator population was carried out from June 2001 to May 2002. Observations were taken at fortnightly intervals from cowpea, bittergourd, bhendi, brinjal and chilli. Ten plants were selected randomly for recording the data. The top five centimeters of the shoot of selected plants were observed for aphid incidence. The shoots were cut carefully with a sharp blade without disturbing the aphids. Each shoot was then tapped gently with a camel hair brush to dislodge the aphids on a white paper. The mean number of aphids per plant was thus assessed.

Predator population on each observational plant was assessed by direct counting. Here also ten plants at random were selected for fortnightly observation.

3.11 WEATHER DATA

Weather data during the period of observation i.e., maximum and minimum temperature, rainfall, morning and evening humidity and mean humidity were collected from meteorological observatory of College of Horticulture, Vellanikkara.

3.12 CORRELATION ANALYSIS

Correlation of aphid and predator population with weather factors was studied. Correlation between aphid and predator population was also analysed as proposed by Panse and Sukhatme.(1976).

4. RESULTS

Studies were conducted on biology, fecundity, predatory potential and feeding preference of six predatory coccinellids. Observations were made on seasonal fluctuations of aphid and coccinellid populations in the field from June 2001 to May 2002. The results obtained are given below.

4.1 *Coccinella transversalis* Fab. (Plate 1)

C. transversalis is the most common coccinellid predator observed during the present study. Studies on morphology, longevity, fecundity, predatory potential and feeding preference of *C. transversalis* were carried out in the laboratory at 27°C and 79 % relative humidity.

4.1.1 Morphology

Egg: Length 0.8 - 1mm, spindle shaped, yellowish - orange and shiny. They were laid singly or in groups, which turned black just before hatching. Number of eggs laid ranged from 17 - 35 in each group.

Grub: 1st instar: Length 1.7 - 2 mm and pale black.

2nd instar: Length 3.3 - 3.7 mm, black with a pair of yellowish - orange patch on dorsal side near head.

3rd instar: Length 4.7 - 5.1 mm, black with orange patch on dorsal and dorsolateral side.

4th instar: Length 6.8 - 7.1 mm, black with orange coloured patches formed like a ring on the dorsal and dorsolateral side.

Pupa: Length 5 - 5.5 mm. Yellowish – orange with yellow head and black eyes. Five pairs of black spots on the dorsal side.

Adult: Length 5 - 5.5 mm. Body oval and convex with black head. Elytra orange or red with three transverse black bands. Sometimes only one black band is seen.

4.1.2 Longevity

Total life cycle of *C. transversalis* ranged between 14 - 15 days with a mean of 14.3 ± 0.163 days (Table 1). Incubation period was found to be two days. The instar-wise mean durations were 1, 1.8 ± 0.133, 2.7 ± 0.153 and 4.8 ± 0.133 days respectively. Pupal period lasted for two days. Adult longevity was observed to range from 11 - 13 days with a mean of 12.2 ± 0.233 days.

4.1.3 Fecundity

Egg laying started two days after mating and lasted for 8 - 9 days. Out of the 10 beetles observed five beetles showed maximum fecundity on the fourth day and rest five on the fifth day. Mean fecundity was found to be 421.8 ± 4.983 (Table 2).

4.1.4 Predatory potential

The mean predatory potential of first, second, third, fourth instars and adult were found to be 3.2 ± 0.291, 6.2 ± 0.680, 44.6 ± 4.045, 175.1 ± 2.605 and 213.5 ± 4.710 aphids respectively (Table 3). Per day consumption of different instars and adult were found to be 3.2, 3.44, 16.51, 36.48 and 17.79 aphids respectively.

4.1.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test.

4.1.5.1 *No choice test*

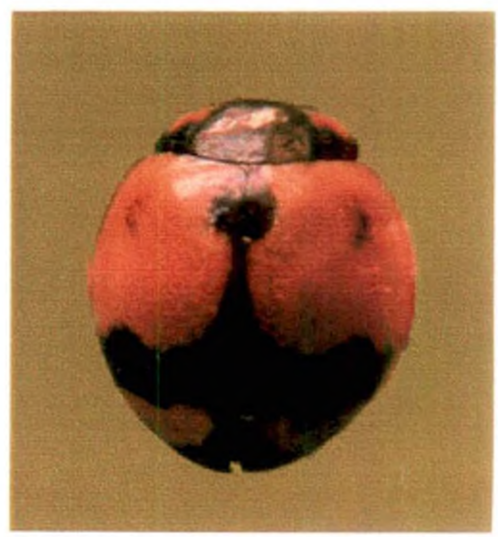
In no choice situation all grubs and beetles except those provided with aphids died of starvation.

4.1.5.2 *Multiple choice test*

All the 10 coccinellids preferred to consume only aphids when they were provided with aphids, mealy bugs, thrips, leaf hoppers and white flies. The mean feeding potential of different instars and adult were found to be 3.3 ± 0.300, 6.6 ± 0.306, 50.2 ± 4.253, 164.6 ± 6.459, 202.5 ± 4.542 aphids respectively (Table 4).

1 A

1 B



1 C

1 D

Plate 1. Different stages of *Coccinella transversalis* Fab.

1 A - Egg
1 B - Grub
1 C - Pupa
1 D - Adult

Table 1. Duration of different stages of *C. transversalis,* days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	2	2	5	2	14	13
2	2	1	2	3	4	2	14	11
3	2	1	1	3	5	2	14	12
4	2	1	2	2	5	2	14	12
5	2	1	2	3	4	2	14	12
6	2	1	1	3	5	2	14	12
7	2	1	2	3	5	2	15	12
8	2	1	2	3	5	2	15	12
9	2	1	2	3	5	2	15	13
10	2	1	2	2	5	2	14	13
Mean	2	1	1.8± 0.133	2.7± 0.153	4.8± 0.133	2	14.3± 0.163	12.2± 0.233

Table 2. Fecundity of *C. transversalis*

Serial No.	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	Total
1	36	50	77	78	87	73	39	13	453
2	19	48	79	77	90	59	38	19	429
3	8	39	67	81	92	79	29	19	414
4	25	36	82	86	92	72	29		422
5	21	47	78	76	89	60	39	14	424
6	18	59	79	96	83	56	29		420
7	31	52	80	91	78	61	22		415
8	17	46	73	88	79	49	39	28	419
9	24	61	78	95	80	70	21		429
10	9	38	57	97	70	73	28	21	393
Mean									421.8 ± 4.983

Table 3. Predatory potential of different stages of *C. transversalis*

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	3	7	29	181	237
2	2	6	49	187	214
3	3	5	57	164	198
4	2	5	28	172	205
5	4	5	58	182	189
6	4	5	38	165	206
7	4	5	56	183	211
8	4	6	50	179	219
9	2	6	54	169	231
10	4	12	27	169	225
Mean	3.2±0.291	6.2±0.680	44.6±4.045	175.1±2.605	213.5±4.710

Table 4. Feeding potential of different stages of *C. transversalis* under multiple choice situation.

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	3	8	35	181	227
2	4	6	55	157	204
3	2	7	63	164	188
4	2	7	34	172	195
5	4	7	64	182	196
6	4	6	44	125	179
7	4	5	62	183	201
8	4	6	56	179	205
9	2	6	60	169	209
10	4	8	29	134	221
Mean	3.3±0.300	6.6±0.306	50.2±4.253	164.6±6.459	202.5±4.542

4.2 *Cheilomenes sexmaculata* (Fab.)

C. sexmaculata showed pronounced variation in body colour. Three morphotypes of *C. sexmaculata* were observed and studied during the present investigation.

4.2.1 *C. sexmaculata* morphotype I (Plate 2)

Adult beetle is yellow with three wavy markings on each elytron. Studies on morphology, longevity, fecundity, predatory potential and feeding preference were carried out in the laboratory at 27°C and 79 % relative humidity.

4.2.1.1 Morphology

Egg: Length 0.8 - 1 mm, spindle shaped, yellow and shiny. They were laid singly and in groups.

Grub: 1st instar: Length 1.7 - 2 mm and pale black.

2nd instar: Length 2.3 - 2.6 mm. Black with grayish - black ring shaped marking on abdomen and two pale spots on thoracic region.

3rd instar: Length 4.2 - 4.5 mm. Black with yellow marking near head. A pair of yellowish - orange patch on dorsal side of thoracic region.

4th instar: Length 6.7 - 7 mm. Black with orange tinge on dorsal side near head and an yellow ring shaped marking in the area above thorax.

Pupa: Length 5 - 6.5 mm. Yellow coloured with black eyes and five pairs of black spots on dorsal side.

Adult: Length 4.5 - 5mm. Body oval and convex. Elytra yellow with three wavy markings on each elytron. Pronotum yellow with a median half moon shaped marking connected with posterior marginal stripe.

4.2.1.2 Longevity

Total duration of life cycle ranged between 12 - 15 days with a mean 13.4 ± 0.291 days (Table 5). Incubation period was found to be two days. The instar wise mean durations were 1, 1.3 ± 0.153, 2.6 ± 0.163 and 4.5 ± 0.167 days respectively. Pupal stage lasted for two days. Adult longevity was observed to range from 10 - 12 days with a mean of 11.2 ± 0.306 days.

4.2.1.3 Fecundity

Egg laying started two days after mating and lasted for 7 - 8 days. Out of the 10 beetles observed six beetles showed maximum fecundity on the fourth day and rest four on the fifth day. Mean fecundity was found to be 295.6 ± 8.069 (Table 6).

4.2.1.4 Predatory potential

The mean predatory potential of first, second, third, fourth instars and adult were found to be 5.2 ± 0.433, 8.5 ± 0.778, 50.6 ± 1.408, 160.4 ± 1.614 and 212.6 ± 4.517 respectively (Table 7). Per day consumption of first, second, third, fourth instars and adult were recorded as 5.2, 6.53, 19.46, 35.64 and 18.98 aphids respectively.

4.2.1.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test.

4.2.1.5.1 *No choice test*

In no choice situation all beetles except those provided with aphids died of starvation.

4.2.1.5.2 *Multiple choice test*

All the test insects ate only aphids when they were provided with aphids, mealy bugs, thrips, leaf hoppers and white flies. The mean feeding potential of different instars and adult were found to be 4.8 ± 0.327, 7.6 ± 0.267, 49.4 ± 0.447, 156.8 ± 1.659 and 224.6 ± 4.517 aphids respectively (Table 8).

2 A 2 B

2 C 2 D

Plate 2. Different stages of *Cheilomenes sexmaculata* morphotype I

2 A - Egg
2 B - Grub
2 C - Pupa
2 D - Adult

Table 5. Duration of different stages of *C. sexmaculata* morphotype I, days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	1	3	4	2	13	11
2	2	1	1	3	4	2	13	12
3	2	1	2	3	4	2	14	10
4	2	1	2	3	5	2	15	10
5	2	1	2	3	5	2	15	10
6	2	1	1	2	5	2	13	12
7	2	1	1	2	4	2	12	12
8	2	1	1	3	4	2	13	12
9	2	1	1	2	5	2	13	12
10	2	1	1	2	5	2	13	11
Mean	2	1	1.3± 0.153	2.6± 0.163	4.5± 0.167	2	13.4± 0.291	11.2± 0.306

Table 6. Fecundity of *C. sexmaculata* morphotype I

Serial No.	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	Total
1	18	29	50	67	87	49	14		314
2	16	52	50	67	36	39	25	14	299
3	15	50	50	63	38	25	23		264
4	25	48	39	41	53	33	25		264
5	19	25	37	53	72	49	28		283
6	28	21	39	67	58	47	24	22	306
7	11	38	47	69	64	53	29	20	331
8	9	14	29	77	54	53	28		264
9	27	41	38	59	75	57	29		326
10	17	28	49	74	58	28	27	23	304
Mean									295.6± 8.069

Table 7. Predatory potential of different stages of *C. sexmaculata* morphotype I

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	7	49	158	235
2	3	7	45	155	216
3	4	12	58	163	214
4	4	11	49	162	196
5	5	13	49	152	214
6	7	7	50	165	203
7	6	7	50	162	216
8	4	7	59	169	235
9	6	7	50	156	194
10	7	7	47	162	203
Mean	5.2±0.433	8.5±0.778	50.6±1.408	160.4±1.614	212.6±4.517

Table 8. Feeding potential of different stages of *C. sexmaculata* morphotype I under multiple choice situation

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	8	48	152	247
2	5	9	44	149	228
3	6	8	57	157	226
4	4	9	48	166	208
5	6	7	48	146	226
6	5	7	49	159	215
7	5	7	49	156	228
8	4	7	58	163	247
9	4	7	48	160	206
10	3	7	45	160	215
Mean	4.8±0.327	7.6±0.267	49.4±0.447	156.8±1.659	224.6±4.517

4.2.2 *C. sexmaculata* morphotype II

It is having orange - yellow elytra without any wavy marking. Studies on morphology, longevity, fecundity, predatory potential and feeding preference were carried out in the laboratory at 27°C and 79 % relative humidity.

4.2.2.1 Morphology

Egg: Length 0.7 - 1 mm, spindle shaped, yellow and shiny. They were laid singly or in groups.

Grub: 1st instar: Length 1.6 - 2 mm and pale black.

2nd instar: Length 1.7 - 1.9 mm. Black with grayish - black ring shaped marking on abdomen and two pale spots on thoracic region.

3rd instar: Length 4.2 - 4.6 mm. Black with yellow marking near head and a pair of yellowish - orange patch on dorsal side of thoracic region.

4th instar: Length 6.7 - 7 mm. Black with orange patch on dorsal side near head and an yellow ring shaped marking on dorsal side of thorax.

Pupa: Length 5.5 - 6 mm. Yellow with black eyes and five pairs of black spots on dorsal side.

Adult: Length 4.5 - 4.8mm. Body oval and convex. Elytra yellowish - orange without any wavy marking on elytra. Pronotum yellow with a median half moon shaped marking.

4.2.2.2 Longevity

Total duration of life cycle ranged between 13 - 15 days with a mean of 14.1 ± 0.149 days (Table 9). Incubation period was found to be two days. The instar wise mean durations were 1, 1.6 ± 0.163, 2.9 ± 0.100 and 4.6 ± 0.163 respectively. Pupal stage lasted for two days. Adult longevity was observed to range from 11 - 13 days with a mean 12 ± 0.180 days.

4.2.2.3 Fecundity

Egg laying started two days after mating and lasted for 6 - 7 days. Out of the 10 beetles observed three beetles showed maximum fecundity on the fourth day and rest seven on the fifth day. Mean fecundity was found to be 291.7 ± 11.031 (Table 10).

4.2.2.4 Predatory potential

The mean predatory potential of first, second, third, fourth instars and adult were found to be 5.2 ± 0.359, 7.8 ± 0.396, 48.3± 1.153, 138.8 ± 2.973 and 226.2 ± 2.772 aphids respectively (Table 11). Per day consumption of first, second third, fourth instars and adults were found to be 5.2, 4.87, 16.62, 30.17 and 18.85 aphids respectively.

4.2.2.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test.

4.2.2.5.1 *No choice test*

In no choice situation all beetles except those provided with aphids died of starvation.

4.2.2.5.2 *Multiple choice test*

All the 10 coccinellids devoured only aphids when they were provided with aphids, mealy bugs, thrips, leaf hoppers and white flies. The mean feeding potential of different instars and adult were found to be 4.9 ± 0.314, 7.2 ± 0.277, 46.8 ± 1.191, 146.2 ± 2.772 and 210.8 ± 2.820 aphids respectively (Table 12).

3 A

3 B

3 C

3 D

Plate 3. Different stages of *Cheilomenes sexmaculata* morphotype II

3 A - Egg
3 B - Grub
3 C - Pupa
3 D - Adult

Table 9. Duration of different stages of *C. sexmaculata* morphotype II, days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	2	3	5	2	15	12
2	2	1	1	3	5	2	14	12
3	2	1	2	3	4	2	14	12
4	2	1	2	2	4	2	13	12
5	2	1	2	3	4	2	14	13
6	2	1	1	3	5	2	14	12
7	2	1	2	3	4	2	14	11
8	2	1	2	3	5	2	15	12
9	2	1	1	3	5	2	14	12
10	2	1	1	3	5	2	14	12
Mean	2	1	1.6± 0.163	2.9± 0.100	4.6± 0.163	2	14.1± 0.149	12.0± 0.180

Table 10. Fecundity of *C. sexmaculata* morphotype II

Serial No.	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Mean
1	19	43	63	66	70	43		304
2	17	51	58	71	37	36	24	294
3	14	49	39	73	39	29	25	268
4	23	49	37	43	59	35	29	275
5	24	23	34	50	75	47	26	279
6	23	22	48	67	73	48	23	304
7	12	39	45	55	81	55	28	315
8	8	13	27	53	70	57	28	256
9	24	43	41	56	74	59	31	328
10	18	28	49	74	68	29	28	294
Mean								291.7± 11.031

Table 11. Predatory potential of different stages of *C. sexmaculata* morphotype II

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	4	8	44	134	236
2	6	7	45	130	224
3	6	7	51	146	223
4	5	7	46	148	213
5	4	7	54	142	237
6	4	7	48	149	226
7	4	10	43	148	238
8	6	10	52	140	214
9	6	8	50	127	226
10	7	7	49	124	225
Mean	5.2±0.359	7.8±0.396	48.3±1.153	138.8±2.973	226.2±2.772

Table 12. Feeding potential of different stages of *C. sexmaculata* morphotype II under multiple choice situation

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	4	7	43	141	221
2	5	7	44	137	209
3	5	6	50	153	208
4	5	6	45	155	198
5	4	7	53	149	222
6	4	8	47	156	211
7	4	8	42	155	223
8	5	9	51	147	199
9	6	7	49	134	211
10	7	7	44	135	206
Mean	4.9±0.314	7.2±0.277	46.8±1.191	146.2±2.772	210.8±2.820

4.2.3 *C. sexmaculata* morphotype III (Plate 4)

It is a brownish - black beetle without any marking. Studies on morphology, longevity, fecundity, predatory potential and feeding preference were carried out in the laboratory at 27°C and 79 % relative humidity.

4.2.3.1 Morphology

Egg: Length 0.8 - 1 mm. They were laid singly and in groups.
Grub: 1st instar: Length 1.7 - 1.9 mm and pale black.
2nd instar: Length 2.3 - 2.5 mm. Black with grayish - black ring shaped marking on abdomen and two pale spots on thoracic region.
3rd instar: Length 4.2 - 4.5 mm. Black with yellow marking near head and a pair of yellowish - orange patch on dorsal side of thoracic region.
4th instar: Length 6.5 - 6.8 mm. Black with orange patch on dorsal side near head and an yellow ring shaped marking on dorsal side of thorax.
Pupa: Length 5 - 6.5 mm. Yellow with black eyes and five pairs of black spots on dorsal side.
Adult: Length 5 - 5.5mm. Body oval and convex. Elytra brownish - black without any marking.

4.2.3.2 Longevity

Total life cycle of insect ranged between 13 - 15 days with a mean of 14.3 ± 0.153 days. Incubation period was found to be two days. The instar wise mean durations were found to be 1, 1.8 ± 0.133, 2.8 ± 0.133 and 4.7 ± 0.141 days respectively. Pupal stage lasted for two days. Adult longevity was observed to range from 11 - 12 days with a mean of 11.6 ± 0.163 days (Table 13).

4.2.3.3 Fecundity

Egg laying started two days after mating and lasted for 6 - 7 days. Out of the 10 beetles observed three beetles showed maximum fecundity on the fourth day, six beetles on the fifth day and one on the sixth day. Mean fecundity was observed as 290.8 ± 7.728 (Table 14).

4.2.3.4 Predatory potential

The mean predatory potential of first, second, third, fourth instars and adult were found to be 5.6 ± 0.213, 7.8 ± 0.269, 46.2 ± 0.371, 142.8 ± 2.917 and 218.6 ± 2.551 aphids respectively (Table 15) and the per day consumption of first, second, third, fourth instars and adult were found to be 5.6, 5.44, 16.5, 30.38 and 18.84 aphids respectively.

4.2.3.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test.

4.2.3.5.1 ***No choice test***

In no choice situation all beetles except those provided with aphids died of starvation.

4.2.3.5.2 ***Multiple choice test***

All the 10 coccinellids consumed only aphids when they were provided with aphids, mealy bugs, thrips, leaf hoppers and white flies. The mean feeding potential of different instars and adult were found to be 4.8 ± 0.213, 8.6 ± 0.581, 42.6 ± 2.741, 156.4 ± 2.821 and 224.8 ± 3.884 aphids respectively (Table 16).

4 A

4 B

4 C

4 D

Plate 4. Different stages of *Cheilomenes sexmaculata* morphotype III

4 A - Egg
4 B - Grub
4 C - Pupa
4 D - Adult

Table 13. Duration of different stages of *C. sexmaculata* morphotype III, days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	2	3	5	2	15	12
2	2	1	2	3	5	2	15	11
3	2	1	2	3	5	2	15	12
4	2	1	1	3	4	2	13	12
5	2	1	2	2	5	2	14	12
6	2	1	2	3	4	2	14	12
7	2	1	2	2	5	2	14	11
8	2	1	1	3	5	2	14	12
9	2	1	2	3	5	2	15	11
10	2	1	2	3	4	2	14	11
Mean	2	1	1.8± 0.133	2.8± 0.133	4.7± 0.141	2	14.3± 0.153	11.6± 0.163

Table 14. Fecundity of *C. sexmaculata* morphotype III

Serial No.	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Mean
1	18	45	64	58	79	41		305
2	16	52	57	53	60	33	26	297
3	13	48	45	69	33	28	24	260
4	19	47	38	58	44	34	28	268
5	25	25	35	59	61	65	27	297
6	24	21	39	65	52	71	21	293
7	13	29	44	60	86	54	29	315
8	9	15	28	71	53	51	29	256
9	26	45	43	53	77	57	32	333
10	18	27	48	65	79	28	19	284
Mean								290.2± 7.728

Table 15. Predatory potential of different stages of *C. sexmaculata* morphotype III

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	10	42	135	222
2	5	8	63	137	217
3	4	8	43	141	191
4	5	6	62	150	220
5	5	8	41	143	218
6	7	8	37	153	228
7	6	7	39	137	235
8	6	7	43	130	208
9	6	8	42	151	220
10	6	8	50	151	227
Mean	5.6±0.213	7.8±0.269	46.2±0.371	142.8±2.917	218.6±2.551

Table 16. Feeding potential of different stages of *C. sexmaculata* morphotype III under multiple choice situation

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	5	10	38	148	228
2	4	10	59	150	223
3	4	10	39	154	197
4	5	11	58	163	226
5	4	9	45	156	224
6	6	8	37	166	234
7	5	7	35	150	241
8	4	9	39	143	214
9	6	6	38	164	226
10	5	6	46	170	235
Mean	4.8 ± 0.213	8.6 ± 0.581	42.6± 2.741	156.4± 2.821	224.8 ± 3.884

4.3 *Brumoides suturalis* (Fab.) (Plate 5)

This was observed during cooler months of January and February. Studies on morphology, longevity, fecundity, predatory potential and feeding preference were carried out in the laboratory at 28°C and 50 % relative humidity.

4.3.1 Morphology

Egg: Length 0.5 - 0.8 mm, spindle shaped yellow and shiny. They were laid singly and in batches.

Grub: 1st instar: Length 1 - 1.5 mm and pale black.

2nd instar: Length 1.5 - 2 mm. Pale black with two yellow spots near head.

3rd instar: Length 2.5 - 3 mm. Black with two yellow spots near head and one yellow ring shaped marking on abdominal region.

4th instar: Length 3.5 - 4.5 mm. Black with two yellow spots near head and one yellow ring shaped marking on abdominal region.

Pupa: Length 2.5 – 3 mm.Yellowish - white with black eyes.

Adult: Length 4 - 4.5 mm. Body oval, longer than broad, pronotum yellowish - brown, elytra yellow with a broad longitudinal stripe on each elytron.

4.3.2 Longevity

Total life cycle ranged between 10 - 11 days with a mean of 10.4 ± 0.224 days. Incubation period was found to be two days. The instar wise mean durations were 1, 1, 2.2 ± 0.133 and 2.2 ± 0.133 days respectively. Pupal period lasted for two days. Adult longevity was observed to range from 7 - 9 days with a mean of 8.5 ± 0.163 days (Table 17).

4.3.3 Fecundity

Egg laying started two days after mating and lasted for 6 - 7 days. Out of the 10 beetles observed one beetle showed maximum fecundity on the third day, six beetles on the fourth day and three on the sixth day. Mean fecundity was found to be 278.3 ± 8.439 (Table 18).

4.3.4 Predatory potential

The mean predatory potential of first, second, third, fourth instars and adult were found to be 5.9 ± 0.233, 6.6 ± 0.224, 31.8 ± 2.835, 58.3 ± 1.789 and 118.0 ± 3.473 aphids respectively (Table18). Per day consumption of first, second, third, fourth instars and adult were found to be 5.9, 6.6, 14.45, 26.5 and 13.88 aphids respectively.

4.3.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test

4.3.5.1 *No choice test*

In no choice situation all beetles except those provided with aphids died of starvation.

4.3.5.2 *Multiple choice test*

All the 10 coccinellids consumed only aphids when they were provided with aphids, mealy bugs, thrips, leaf hoppers and white flies. The mean feeding potential of different instars and adult were found to be 5.8 ± 0.221, 6.9 ± 0.200, 34.8 ± 2.835, 62.4 ± 1.849 and 122.6 ± 3.481 aphids respectively (Table 20).

Table 17. Duration of different stages of *B. suturalis*, days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	1	2	3	2	11	8
2	2	1	1	3	2	2	11	9
3	2	1	1	2	2	2	10	9
4	2	1	1	2	2	2	10	8
5	2	1	1	2	2	2	10	9
6	2	1	1	2	2	2	10	9
7	2	1	1	2	3	2	11	8
8	2	1	1	2	2	2	10	9
9	2	1	1	2	2	2	10	9
10	2	1	1	3	2	2	11	7
Mean	2	1	1	2.2± 0.133	2.2± 0.133	2	10.4± 0.224	8.5± 0.163

Table 18. Fecundity of *B. suturalis*

Serial No.	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Mean
1	18	43	72	67	58	39		297
2	17	51	55	63	39	32	27	284
3	13	37	48	60	65	25		248
4	18	43	39	50	42	35	27	254
5	24	26	42	58	72	43	28	293
6	25	21	38	63	70	51	22	290
7	12	37	53	71	65	53		291
8	8	16	23	63	54	50	28	242
9	25	43	42	61	63	61	31	326
10	19	26	43	68	53	31	18	258
Mean								278.3± 8.439

Table 19. Predatory potential of different stages of *B. suturalis*

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	7	28	53	121
2	5	7	49	55	115
3	6	6	29	59	120
4	5	6	24	61	123
5	7	7	26	63	112
6	6	7	27	71	110
7	6	7	28	53	105
8	7	6	29	55	125
9	5	7	30	54	120
10	6	6	48	59	129
Mean	5.9 ± 0.233	6.6 ± 0.224	31.8± 2.835	58.3± 1.789	118.0 ± 3.473

Table 20. Feeding potential of different stages of *B. suturalis* under multiple choice situation

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	8	31	64	129
2	6	8	52	58	140
3	5	6	51	59	125
4	6	7	27	57	105
5	6	7	29	75	110
6	5	7	30	67	112
7	6	7	31	65	123
8	6	6	32	63	122
9	6	7	33	59	135
10	6	6	32	57	125
Mean	5.8 ± 0.221	6.9 ± 0.200	34.8± 2.835	62.4± 1.849	122.6 ± 3.481

4.4 *Jouravia soror* Weise (Plate 6)

J. soror was observed only during February. Studies on morphology, longevity, fecundity, predatory potential and feeding preference were carried out in the laboratory at 28°C temperature and 50 % relative humidity.

4.4.1 Morphology

Egg: Length 0.5 - 0.8 mm, Spindle shaped, yellow and shiny eggs.
Grub: 1st instar: Length 1 - 1.5 mm and pale black.
2nd instar: Length 2 - 2.5 mm, pale black with two yellow spots near head and one yellow broken ring shaped marking on abdominal region.
3rd instar: Length 2.5 - 3 mm, black with two yellow spots near head and yellow ring shaped markings on thoracic and abdominal regions.
4th instar: Length 3 - 3.8 mm, black with two yellowish spots and a yellow ring shaped marking near head. Yellow ring shaped markings were present on thoracic and abdominal regions.
Pupa: Length 2.5 – 3 mm, yellow with three pairs of black spots on dorsal region.
Adult: Length 3 - 3.5 mm, Small, oval to round insect with strongly convex body and brownish - orange elytra.

4.4.2 Longevity

Total life cycle of the insect ranged between 9 - 10 days with a mean of 9.6 ± 0.163 days. Incubation period was found to be two days. The instar wise mean durations were 1, 1, 1.8 ± 0.133 and 1.8 ± 0.133 days respectively. Pupal stage lasted for two days. Adult longevity was observed to range from 4 - 5 days with a mean of 4.6 ± 0.269 days (Table 21).

4.4.3 Fecundity

Egg laying started two days after mating and lasted for 4 - 5 days. Out of the 10 beetles observed six beetles showed maximum fecundity on the second day and rest four on the third day. Mean fecundity was observed as 84.5 ± 3.153 (Table 22).

4.4.4 Predatory potential

The predatory potential of first, second, third, fourth instars and adult were found to be 5.5 ± 0.348, 5.9 ± 0.384, 23.8 ± 2.525, 32.9 ± 2.351 and 88.7 ± 2.970 aphids respectively (Table 23). Per day consumption of first, second, third, fourth instars and adult were found to be 5.5, 5.9, 13.2, 18.2 and 19.28 aphids respectively.

4.4.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test.

4.4.5.1 *No choice test*

In no choice situation all insects except those provided with aphids died of starvation.

4.4.5.2 *Multiple choice test*

All the ten insects consumed only aphids when they were provided with aphids, mealy bugs, white flies and thrips. The mean feeding potential of different instars and adult was found to be 4.8 ± 0.200, 5.6 ± 0.267, 26.2 ± 1.114, 31.8 ± 2.413 and 82.6 ± 2.963 aphids respectively (Table 24).

Table 21. Duration of different stages of *J soror,* days

Serial No.	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total life cycle	Adult
1	2	1	1	1	2	2	9	5
2	2	1	1	2	2	2	10	5
3	2	1	1	2	2	2	10	4
4	2	1	1	2	2	2	10	4
5	2	1	1	2	2	2	10	5
6	2	1	1	2	2	2	10	5
7	2	1	1	2	2	2	10	4
8	2	1	1	1	2	2	9	5
9	2	1	1	2	1	2	9	5
10	2	1	1	2	1	2	9	4
Mean	2	1	1	1.8± 0.133	1.8± 0.133	2	9.6± 0.163	4.6± 0.269

Table 22. Fecundity of *J. soror*

Serial No.	1st day	2nd day	3rd day	4th day	Total
1	18	38	31	18	105
2	11	23	35	12	81
3	16	31	24	17	88
4	16	38	22		76
5	21	19	34	12	86
6	24	39	17		80
7	22	27	33	15	97
8	24	38	19		81
9	18	35	19		72
10	19	23	25	12	79
Mean					84.5 ± 3.153

Table 23. Predatory potential of different stages of *J. soror*

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	6	7	10	33	89
2	4	7	28	38	86
3	6	7	27	38	77
4	6	6	30	33	76
5	6	5	20	34	81
6	5	5	27	36	93
7	6	6	27	41	99
8	4	5	10	39	106
9	6	4	30	18	89
10	6	7	29	19	91
Mean	5.5±0.348	5.9±0.384	23.8±2.525	32.9±2.351	88.7 ± 2.970

Table 24. Feeding potential of different stages of *J. soror* under multiple choice situation

Serial No.	1st instar	2nd instar	3rd instar	4th instar	Adult
1	5	6	22	32	83
2	4	7	29	37	80
3	5	6	28	36	71
4	5	6	27	32	70
5	6	5	25	33	75
6	4	5	28	35	87
7	5	6	30	30	93
8	4	5	23	27	100
9	5	4	20	38	83
10	5	6	30	18	84
Mean	4.8±0.200	5.6±0.267	26.2±1.114	31.8±2.413	82.6 ± 2.963

Plate 5. ***Brumoides suturalis*** **(Fab.) adult**

Plate 6. ***Jouravia soror*** **Weise adult**

4.5 SEASONAL FLUCTUATION OF APHID AND PREDATORY COCCINELLID POPULATION

Seasonal fluctuation of aphids and coccinellids was studied during June 2001 to May 2002. Observations were taken from 10 plants each of cowpea, bhendi, pumpkin, brinjal and bittergourd.

4.5.1 Cowpea

Aphids and coccinellids were present in cowpea during the entire course of study (Table 25). The aphid, coccinellid ratio was maximum during the 1st and 2nd fortnight of January and the mean population values were 221.5 and 1.2 respectively. Population of aphids and coccinellids were least during 2nd fortnight of July and the mean population values recorded were 32.5 and 0.2 respectively.

4.5.2 Bhendi

In bhendi, occurrence of aphid and coccinellid population were observed during December, January and February and were absent during the other months (Table 26). Maximum population of aphids and coccinellids were recorded during 1st fortnight of February and the values recorded were 32.4 and 0.5 respectively.

4.5.3 Pumpkin

Population of aphids and coccinellids was present during December, January and February (Table 27). Maximum population of aphids (29.8) and coccinellids (0.5) were seen during the 2nd fortnight of January. Aphids and coccinellids were absent during the other months of study.

4.5.4 Brinjal

Aphid and coccinellid population were present only during January and February. Maximum population of aphids (22.4) and coccinellids (.2) were recorded during the 2nd fortnight of January.

4.5.5 Bittergourd

Aphid and coccinellid population were present only during January and February (Table 29). Aphid population was maximum during the 1st fortnight of January (22) whereas coccinellid population was maximum during 1st fortnight of February (0.4).

Table 25. Mean population of aphids and coccinellids in cowpea at fortnightly intervals (June 2001 to May 2002)

Month	Aphid population		Coccinellid population	
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight
June	68.4	55.8	0.4	0.3
July	34.6	32.5	0.6	0.2
August	131.0	97.0	0.6	0.3
September	126.4	97.0	0.5	0.4
October	124.0	111.0	0.5	0.3
November	134.8	134.5	0.6	0.4
December	145.0	150.0	0.8	0.3
January	221.5	196.5	0.8	1.2
February	193.0	219.0	1.0	0.6
March	86.0	75.7	0.5	0.3
April	95.7	88.0	0.6	0.4
May	102.0	88.0	0.5	0.4

Table 26. Mean population of aphids and coccinellids in bhendi at fortnightly intervals (June 2001 to May 2002)

Month	Aphid population		Coccinellid population	
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	20.4	18.5	0.2	0.3
January	26.5	23.8	0.4	0.2
February	32.4	18.2	0.5	0.1
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0

Table 27. Mean population of aphids and coccinellids in pumpkin at fortnightly intervals (June 2001 to May 2002)

Month	Aphid population		Coccinellid population	
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	24.5	20.6	0.4	0.2
January	23.0	29.8	0.4	0.5
February	28.1	15.7	0.2	0.1
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0

Table 28. Mean population of aphids and coccinellids in brinjal at fortnightly intervals (June 2001 to May 2002)

Month	Aphid population		Coccinellid population	
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
January	18.8	22.4	0.1	0.2
February	15.3	11.9	0.1	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0

Table 29. Mean population of aphids and coccinellids in bittergourd at fortnightly intervals (June 2001 to May 2002)

Month	Aphid population		Coccinellid population	
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
January	22.0	4.8	0.2	0.2
February	8.2	3.1	0.4	0.1
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0

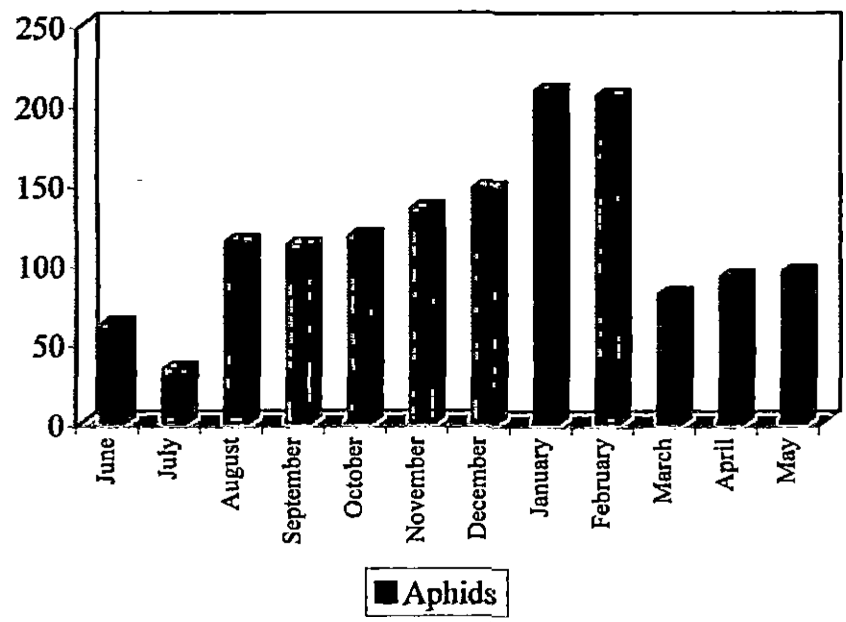


Fig. 1. Population fluctuation of Aphids in cowpea from June 2001 - May 2002

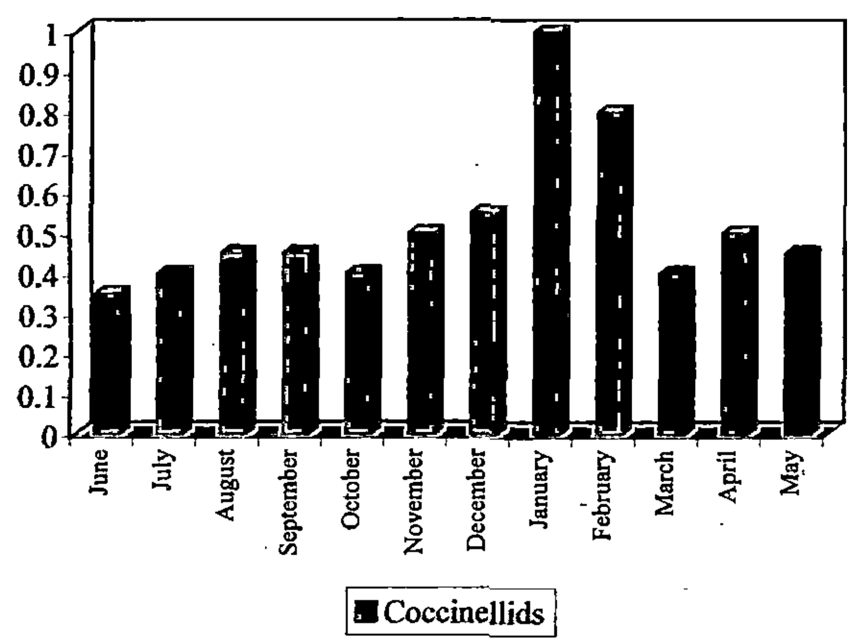


Fig. 2. Population fluctuation of Coccinellids in cowpea from June 2001 - May 2002

4.6 INFLUENCE OF WEATHER FACTORS ON APHID AND COCCINELLID POPULATION

4.6.1 Influence of rainfall

Aphid and coccinellid populations were having significant negative correlation with rainfall in the case of cowpea (Table 30). Aphids and coccinellids were present in bhendi and pumpkin during the months of December, January and February. In brinjal and bittergourd their populations were seen during January and February only. Rainfall was absent during these three months. So correlation of aphid and coccinellid populations with rainfall cannot be worked out in bhendi, pumpkin, brinjal and bittergourd.

4.6.2 Influence of temperature

Significant negative correlation was observed between aphid population and maximum and minimum temperature in cowpea, bhendi and pumpkin (Table 31). Aphid population was not having any correlation with maximum and minimum temperature in brinjal and bittergourd. There was no significant correlation between coccinellid population and maximum and minimum temperature in all the five crops (Table 31).

4.6.3 Influence of relative humidity

In cowpea and bittergourd, aphid population was having significant positive correlation with relative humidity. But only negative correlation was observed between relative humidity and aphid population in bhendi and pumpkin. In brinjal there was no significant correlation between relative humidity and aphid population (Table 32). Coccinellid population was not having any correlation with relative humidity (Table 32).

4.7 PREY - PREDATOR RELATIONSHIP

Significant positive correlation was seen between aphid and coccinellid population in cowpea, bhendi and pumpkin. Correlation between aphid and coccinellid population was not significant in brinjal and bittergourd (Table 33).

Table 30. Correlation of aphid and coccinellid population with rainfall

Crop	Correlation between aphid and rainfall	Correlation between coccinellid and rainfall
Cowpea	-0.576**	-0.164*

** - Significant at 1% level

* - Significant at 5% level

Table 31. Correlation of aphid and coccinellid population with minimum and maximum temperature

Crop	Correlation between aphid and minimum temperature	Correlation between aphid and maximum temperature	Correlation between coccinellid and minimum temperature	Correlation between coccinellid and maximum temperature
Cowpea	-0.364*	-0.264**	-0.084^{NS}	-0.136^{NS}
Bhendi	-0.169*	-0.294**	-0.028^{NS}	-0.140^{NS}
Pumpkin	-0.069*	-0.256**	-0.586^{NS}	-0.124^{NS}
Brinjal	-0.184^{NS}	-0.184^{NS}	0^{NS}	0^{NS}
Bittergourd	-0.289^{NS}	-0.174^{NS}	-0.118^{NS}	-0.109^{NS}

** - Significant at 1% level

* - Significant at 5% level

NS - Non significant

Table 32. Correlation of aphid and coccinellid population with relative humidity

Crop	Correlation between aphid and RH	Correlation between coccinellid and RH
Cowpea	0.141*	0.066^{NS}
Bhendi	-0.290**	-0.093^{NS}
Pumpkin	-0.222*	-0.138^{NS}
Brinjal	0.173^{NS}	0^{NS}
Bittergourd	0.397*	0.109^{NS}

** - Significant at 1% level

* - Significant at 5% level

NS - Non significant

Table 33. Correlation between aphid and coccinellid population

Crop	Correlation between aphid and coccinellid
Cowpea	0.302**
Bhendi	0.362**
Pumpkin	0.247*
Brinjal	0.121^{NS}
Bittergourd	0.480^{NS}

** - Significant at 1% level

* - Significant at 5% level

NS - Non significant

Discussion

5. DISCUSSION

Coccinellids have been widely used in biological control programmes for over a century. The increasing interest in the study of predaceous coccinellids is undoubtedly due to the harmful side effects of toxic chemicals and the intensiveness of research on biological and integrated control of pests. In the present investigation coccinellids like *C. transversalis, C. sexmaculata, B. suturalis* and *J. soror* were persistent in the vegetable ecosystem and hence an attempt was made to quantify the biotic and suppressive potential of these predatory coccinellids.

5.1 *Coccinella transversalis* Fab.

5.1.1 Morphology

Eggs were laid singly or in groups. They were spindle shaped, yellowish - orange and shiny. Just after hatching the grubs were pale black and after first moult they turned black with a pair of yellowish - orange patch on dorsal side near head. After third moult orange coloured patches turned to a ring like pattern on the dorsal and dorsolateral side. Pupae were yellowish - orange with yellow head and black eyes. Adults were orange or red with three transverse bands. Morphological similarities were reported by Debaraj and Singh (2000). In their description also eggs were spindle shaped and grubs black with two reddish - orange spots on the mid - dorsal line. Pupae were yellowish - orange and adults were having orange or red elytra with three transverse bands.

5.1.2 Longevity

Total life cycle of *C.transversalis* ranged between 14 - 16 days with a mean of 14.3 ± 0.163 days under the laboratory conditions at a temperature of 27°C and 79% relative humidity. Incubation period was found to be two days. The instar wise mean durations were 1, 1.8 ± 0.133, 2.7 ± 0.153 and 4.8 ± 0.133 days respectively, i.e., larval stage lasted for 10.3 days. Pupal period was found to be two days. The observations on the life cycle of *C. transversalis* reported from Sambalpur by Patro and Sontakke (1994) at a temperature of 28.3 ± 1.1 °C and 57.9 ± 10.4 % relative humidity agree with the present investigation. According to them the egg, larval and pupal stages of *C. transversalis* lasted for 2.03 ± 0.22, 8.23 ± 0.66 and 2.48 ± 0.21 days when fed with *A. craccivora*. The life cycle of *C. transversalis* observed at Manipur by Debaraj and Singh (1990) ranged between 38 - 45 days when fed with *A. craccivora* at a temperature of 18.23 ± 1.60°C and 55.4 ± 2.38% relative humidity. Incubation period took 8 - 10 days. The total larval period ranged from 19 - 23 days. This increase in duration may be due to the low temperature prevailing there. Veeravel and Baskaran (1996) reported that increase in temperature from 18-30°C resulted in faster development of coccinellids. The duration of larval stages of *C. transversalis* reported by Jagdish *et al.* (1996) from Bangalore at 26.4°C and 65% relative humidity was 7.2 days when fed with the aphid *Hysteroneura setariae* (Thomas). According to Agarwala and Saha (1986) the total larval period of *C. transversalis* was 7.88 days on *A. gossypi* at 25.5°C and 65 % relative humidity. Even though the climatic factors are almost same, the variation observed may be due to host variation. Rao and Rao (1997) reported that size, fecundity and longevity of coccinellids vary with host species.

Adult longevity was observed to range from 11 - 13 days with a mean of 12.2 ± 0.233 days. Nagalingam *et al.* (1996) got similar observation and it was found to be 11.5 days at 26.8°C and 65% relative humidity.

5.1.3 Fecundity

Egg laying started two days after mating in majority of insects. The pre-reproductive period reported by Rani (1995) is somewhat similar and it was found to be 24 hours. Debaraj and Singh (2000) reported a pre - reproductive period of seven days at 18.23 ± 1.6°C and 55.4 ± 2.38 % relative humidity. This increased period may be due to increased life duration at lower temperature. The reproductive period of 8 - 9 days observed in the present investigation was much lower than the results reported by Dorge *et al.* (1966). He recorded the fecundity period as 13 - 27 days at a temperature of 18.5°C and 68% relative humidity. This difference may be due to the low temperature and host variation. Bakhetia and Sidhu (1977) observed variation in fecundity and reproductive period of coccinellids with variation in host.

Mean number of eggs laid was found to be 421.8 ± 4.983. The observation made by Jagdish *et al.* (1996) from Bangalore at 26.4°C temperature and 65 % relative humidity agree with the present investigation. He reported that mean number of eggs produced by adult *C. transversalis* was found to be 407.

5.1.4 Predatory potential

Consumption of *A. craccivora* by *C. transversalis* increased with the instars and reached maximum in the final instar. The mean consumption of aphids during larval stage was found to be 229.1 under laboratory conditions at 27°C and 79 % relative humidity. The present finding is supported by the observations of Jagdish *et al.* (1996) who reported the feeding potential of *C. transversalis* on *A. craccivora* at 26.4°C and 65 % relative humidity as 226 aphids.

The mean consumption values of first, second, third and fourth instars were found to be 3.2 ± 0.291, 6.2 ± 0.680, 44.6 ± 4.045 and 175.1 ± 2.605 aphids respectively. Contrary to the present finding, Jayaramaiah *et al.* (1996) reported that the larvae of *C. transversalis* consumed on an average 13.0, 37.86, 46.06 and 141.60 *M. persicae*. This difference may be due to host variation. Rao and Rao (1997) suggested that the feeding potential of coccinellids varies with host.

Per day consumption of first, second, third, fourth instars and adult were found to be 3.2, 3.44, 16.51, 36.48 and 17.79 aphids respectively. Patro and Sontakke (1994) reported that fourth instar grubs were the most voracious feeders and the consumption rate of fourth instar grub was 41.2 ± 1.8 aphids per day at 28.3 ± 1.1°C and 57.9 ± 10.4 % relative humidity. The present observation also agree with this statement.

5.1.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test. In both the cases known number of aphids, leaf hoppers, white flies, mealy bugs and thrips were provided. In no choice situation all beetles except those provided with aphids died of starvation. In multiple choice situation all the 10 coccinellids preferred to ate only aphids. Richards and Evans (1998) mentioned that aphidophagous coccinellids feed on a variety of prey in addition to preferred aphids. These alternative foods may serve only to maintain the predators but do not permit immature growth or adult reproduction. Joshi (1999) reported that *A. craccivora* is the most preferred host for all the coccinellids.

5.2 *Cheilomenes sexmaculata* (Fab.)

5.2.1 Morphology

Three morphotypes of *C. sexmaculata* were studied during the present investigation. Body colour of the adult beetle was found to be varying in these three morphotypes. Morphotype I was with yellow pronotum and elytra. Three wavy markings were seen on each elytron. Pronotum was having a median half moon shaped marking connected with posterior marginal stripe. Morphotype II was with orange elytra without any wavy marking. Pronotum yellow with a median half moon shaped marking. Morphotype III was having brownish - black elytra without any marking. Azim and Ahmed (1966) recorded seven colour variants in *C. sexmaculata*. Bhasker (1992) reported that the dorsal colouration of *C. sexmaculata* is variable and also reported that pronotum was having a median half moon shaped marking connected with posterior marginal stripe. Morphotype II and Morphotype III are being reported for the first time from Kerala.

Egg, larval and pupal characters were same in all the three morphotypes. Eggs were spindle shaped and were laid singly and in groups. First and second instar grubs were black. Third instar grubs were black with a pair of yellowish - orange patch on dorsal side of thoracic region. Fourth instar grubs were having an yellow ring shaped marking in the area above thorax. Pupae were yellow coloured.

5.2.2 Longevity

The life cycle of morphotype I, II and III ranged between 12 - 15, 13 - 15 and 13 - 15 days respectively. The mean duration of life cycle was found to be 13.4 ± 0.291, 14.1 ± 0.149 and 14.3 ± 0.153 days for morphotypes I, II and III respectively at 27°C and 79 % relative humidity. Observations made by Azim and Ahmed (1966) from Pakistan broadly agree with the present investigation who suggested that at a temperature of 28.7°C, life cycle of *C. sexmaculata* averaged 18 days. Easwaramoorthy *et al.* (1998) reported that the mean duration of development of *C. sexmaculata* reared on *M. indosacchari* was 11.3 ± 2.4 days at 25.6°C and 62 % relative humidity.

The mean adult longevity of morphotypes I, II and III were found to be 11.2 ± 0.306, 12 ± 0.180 and 11.6 ± 0.163 days respectively. Easwaramoorthy *et al.* (1998) observed that *C. sexmaculata* survived for 12.7 ± 3.1 days when fed with *M. indosacchari* at 25.6°C and 62 % relative humidity.

5.2.3 Fecundity

Egg laying started 2-3 days after mating in three morphotypes. The reproductive period lasted for 7 - 8 days in morphotype I and 6 - 7 days in II and III morphotypes. Mean number of eggs laid were found to be 295.6 ± 8.069, 291.7 ± 11.031 and 290.2 ± 7.728 in morphotypes I, II and III. Previous reports are not available regarding this observation.

5.2.4 Predatory potential

The mean consumption values of *A. craccivora* by a single larva of morphotype I, II and III during the developmental period were found to be 224.7, 200 and 202.4

respectively. Nandakumar (1999) noticed that the mean consumption of *A.gossypii* by a single larva of *C. sexmaculata* was 184.1.Verma *et al.* (1983) found the mean consumption of *A.craccivora* by a single larva of *C. sexmaculata* as 128.8.

The per day consumption of adult beetles were found to be 18.98, 18.85 and 18.84 aphids by morphotypes I, II and III respectively. Devi (1967) observed that the C. *sexmaculata* adult under laboratory condition consumed 27.22 *A. craccivora* per day. Azim and Ahmed (1967) reported that the number of aphids consumed daily by the adults varied from 12 - 50 with an average of 32.4. Jayaramaiah *et al.* (1996) suggested that *C. sexmaculata* consumed on an average 31.20 *A. craccivora* per day. *C.sexmaculata* was found to be showing wide variations in feeding potential. Variation in the feeding capacity was reported by Lefroy as early as 1909.

5.2.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test. In both cases known number of aphids, leaf hoppers, white flies, mealy bugs and thrips were provided. In no choice situation all the beetles except those provided with aphids died of starvation. In multiple choice situation all the 10 coccinellids consumed only aphids. Joshi (1999) observed *A. craccivora* as the most preferred host for all the coccinellids. Feeding preference of *C. sexmaculata* was studied by Bindu (1997) and observed that *A. craccivora* is the most preferred host of *C. sexmaculata*

5.3 *Brumoides suturalis* (Fab.)

5.3.1 Morphology

Eggs were spindle shaped and laid singly or in batches. Grubs were pale black just after hatching. Second instar grubs were also pale black with two yellow spots near head. After second moult they turned black with a ring shaped marking on abdominal region. Fourth instar grubs were black with two yellow spots near head and one yellow ring shaped marking on abdominal region. Pupae were yellowish - white.

Adult beetle was with yellow pronotum and elytra. A broad longitudinal stripe was present on each elytron. A similar observation was made by Bhasker (1992) who described that the beetle is oval, longer than broad and elytra yellow with a broad longtitudinal stripe.

5.3.2 Longevity

Life cycle of the beetle ranged between 10 - 11 days with a mean of 10.4 ± 0.224 days when it was studied in the lab condition at 28°C and 50 % relative humidity. Incubation period was observed as two days. The instar wise mean durations were 1, 1, 2.2 ± 0.133 and 2.2 ± 0.133 days respectively. Pupal period lasted for two days. Adult longevity was observed to range from 7 - 9 days with a mean of 8.5 ± 0.163 days. No previous reports were available regarding this observation.

5.3.4 Fecundity

Egg laying started 2 - 3 days after mating and lasted for 6 - 7 days. Mean fecundity was found to be 278.3 ± 8.439. No previous reports were available on fecundity of *B. suturalis.*

5.3.5 Predatory potential

The mean consumption of aphids by first, second, third, fourth instar and adult were found to be 5.9 ± 0.233, 6.6 ± 0.224, 31.8 ± 2.835, 58.3 ± 1.789 and 118.0 ± 3.473 aphids respectively. Per day consumption of first, second, third, fourth instars and adult were found to be 5.9, 6.6, 14.45, 26.5 and 13.88 aphids respectively. Previous records were not available regarding the feeding preference of *B. suturalis.*

5.3.6 Feeding preference

Feeding preference was studied by no choice test and multiple choice test. In no choice situation all the beetles except those provided with aphids died of starvation. In multiple choice situation all the 10 coccinellids ate only aphids. Periyappa (1997) observed *A. craccivora* as the preferred host of *B. suturalis* when *A. craccivora* and *A. nerii* were provided.

5.4 *Jouravia soror* Weise

5.4.1 Morphology

Eggs were spindle shaped, yellow and shiny. Newly emerged grubs were pale black in colour. After first moult, grubs were having two yellow spots near head and one yellow broken ring shaped marking on abdominal region. Third and fourth instar grubs were having yellow ring shaped markings on thoracic and abdominal region and two yellow spots near head. Pupae were yellow with three pairs of black spots on dorsal region. Adult beetles were brownish - orange with strongly convex body. Bhasker (1992) reported that *J. soror* is oval to round and usually small, brownish - orange beetle with black compound eyes.

5.4.2 Longevity

Total life cycle of the insect ranged between 9 - 10 days with a mean of 9.6 ± 0.163 days. Incubation period lasted for two days. The instar wise mean durations were 1, 1, 1.8 ± 0.133 and 1.8 ± 0.133 days respectively. Pupal stage took two days. Adult longevity was observed to range from 4 - 5 days with a mean of 4.6 ± 0.269 days. No reports are available on the biology of *J. soror*.

5.4.3 Fecundity

Egg laying started 2 - 3 days after mating and lasted for 4 - 5 days. Mean fecundity was observed as 84.5 ± 3.153.

5.4.4 Predatory potential

The predatory potential of first, second, third, fourth instar and adult were found to be 5.5 ± 0.348, 5.9 ± 0.384, 23.8 ± 2.525, 32.9 ± 2.351 and 88.7 ± 2.970 aphids respectively. Per day consumption values of first, second, third, fourth instar and adult were found to be 5.5, 5.9, 13.2, 18.2 and 19.28 aphids respectively.

There were no previous reports on longevity, fecundity and predatory potential of *J. soror.*

5.4.5 Feeding preference

Feeding preference was studied by no choice test and multiple choice test. In the former all the 10 coccinellids died of starvation and in the latter all the beetles ate only aphids. Joshi (1999) reported *A. craccivora* as the most preferred host for all the coccinellids.

5.5 SEASONAL FLUCTUATION OF APHID AND COCCINELLID POPULATION

Aphid and coccinellid population were recorded from cowpea, bhendi, pumpkin, brinjal and bittergourd at fortnightly intervals from June 2001 to May 2002. In cowpea, aphid and coccinellid population were present during the entire course of study. Bhendi and pumpkin were having aphid and coccinellid population during December, January and February, but in brinjal and bittergourd population of aphids and coccinellids were present only during January and February. Periyappa (1997) observed cowpea *Vigna unguiculata* sub sp. *sesquipedalis* (L.) as the most favoured host of *A. craccivora*. He was of the opinion that in cowpea aphid population reached peak during January and there was migration of aphids to other hosts during January and February.

5.6 INFLUENCE OF WEATHER FACTORS ON APHID AND COCCINELLID POPULATION

5.6.1 Influence of rainfall

Significant negative correlation was seen between aphid and coccinellid population with rainfall in cowpea. Observations made by Falerio *et al.* (1990) and Ombir and Dahya (2001) agree with the present study. According to Falerio *et al.* (1990) aphid and coccinellid population were having negative correlations with rainfall. Ombir and Dahya (2001) reported that *L. erysimi* population was found to be reduced by rain. Climatic factors including rainfall play a major role in the establishment of the aphid as well as the predators (Rana, 2001). Radke *et al.* (1973) observed that aphid population was significantly influenced by rainfall. Saharia (1980) mentioned that rainfall, predators and host plant influence fluctuation in aphid population.

Aphids and its predators were present in bhendi and pumpkin during December, January and February. In brinjal and bittergourd they were seen only during January and February. There was no rainfall during these months. So correlation of aphid and coccinellid population with rainfall was not determined.

5.6.2 Influence of temperature

Aphid population was negatively correlated with maximum and minimum temperature in cowpea, bhendi and pumpkin. No significant relation existed between maximum and minimum temperature and aphid population in brinjal and bittergourd. The present finding is supported by the observations of Rangaswami (1976) and Meena and Bhargava (2001). They also reported negative correlation between aphid population and minimum and maximum temperature. Falerio *et al.* (1990) also observed negative correlation between aphid population and maximum temperature. Coccinellid population did not show any significant relation with maximum and minimum temperature. Mathew *et al.* (1971) reported that temperature affects the aphids and its predators differently.

5.6.3 Influence of humidity

The present study revealed positive correlation between aphid population and relative humidity in cowpea and bittergourd. This is in conformity with the findings of Meena and Bhargava (2001). They reported that fenugreek aphid *Acyrthosiphon pisum* (Harris) population was having positive correlation with relative humidity. In bhendi and pumpkin, it was found to be negatively correlated with relative humidity. Rangaswami (1976) and Falerio *et al.* (1990) observed negative correlation between *A. craccivora* population and relative humidity.

The influence of humidity and predatory coccinellids show no persistent relationship. Matching statement was made by Sethi and Atwal (1964). According to them the influence of relative humidity was not so pronounced and persistent in the development of *C. septempunctata*.

The influence of weather factors on *A. craccivora* did not show consistent results. The inconsistency in the correlation obtained may be due to numerous factors interacting among the components of the biotic system and their interaction with numerous abiotic factors. Rani (1995) noticed that the pest and natural enemy population varied with weather factors from season to season. She also suggested that the manipulation of these components for achieving reduction in the pest population especially *A. craccivora* is extremely complex. For consistent conclusions these correlation studies may have to be extended over a number of seasons.

5.7 PREY-PREDATOR RELATIONSHIP

The aphid and predatory coccinellid population were found to be having significant positive correlation between them. This finding was already confirmed by many workers. Mathew *et al.* (1971) reported that there was a strong positive correlation between number of aphids and their predators. Butani and Bharodia (1984) observed positive correlation between the aphid index and the population of active stages of predators. Meena and Bhargava (2001) found positive and highly significant correlation between aphid and coccinellid population.

Summary

6. SUMMARY

Biocontrol is now universally recognized as the most effective and acceptable pest management strategy from the point of preservation of environment. Basic studies on systematics, biology and ecology of pests and their natural enemies are integral parts in the field of biological control. Inevitably the first step in any investigation on the role of natural enemies in pest control involves a field survey to determine the species present and how their numbers vary in relation to pest and environmental factors.

The detailed biology of the coccinellid predators prevalent in the vegetable crops like cowpea, bhendi, brinjal, pumpkin and bittergourd was studied under laboratory condition. Fecundity, predatory potential and feeding preference of these predators were also ascertained with a view to evaluate them as the biocontrol agents in pest management strategy. Attempts were also made to find out the seasonal fluctuation of aphid pests and their coccinellid predators.

Coccinellids like *Coccinella transversalis* Fab., *Cheilomenes sexmaculata* (Fab.), *Brumoides suturalis* (Fab.) and *Jouravia soror* Weise were persistent in the vegetable ecosystem.

During the present study *C. transversalis* was the most common coccinellid predator observed. It was having orange or red elytra with three transverse black bands. Total life cycle ranged between 14-15 days with a mean of 14.3 ± 0.163 days. Adult longevity ranged from 11-13 days and the mean value was 12.2 ± 0.233 days. The mean predatory potential of first, second, third, fourth instars and adult were found to be 3.2 ± 0.291, 6.2 ± 0.680, 44.6 ± 4.045, 175.1 ± 2.605 and 213.5 ± 4.710 aphids respectively. Mean fecundity was 421.8 ± 4.983.

Pronounced variation in body colour was observed in *C. sexmaculata*. Three morphotypes of *C. sexmaculata* were studied in detail during the period.

Morphotype II and morphotype III are being reported for the first time from Kerala. Morphotype I is yellow coloured with three wavy markings on each elytron. Life cycle ranged between 12-15 days with a mean of 13.4 ± 0.291 days.

Adult longevity ranged from 10-12 days with a mean of 11.2 ± 0.306 days. Mean fecundity was found to be 295.5 ± 8.069. Mean predatory potential were observed as 5.2 ± 0.433, 8.5 ± 0.778, 50.6 ± 1.408, 160.4 ± 1.614 and 212.5 ± 4.517 aphids for different instars and adults respectively.

Morphotype II is orange-yellow without any wavy marking. Life cycle ranged between 13-15 days with a mean of 14.1 ± 0.149 days. Adult longevity ranged from 11-13 days with a mean of 12 ± 0.180 days. Mean fecundity was found to be 291.7 ± 11.031 eggs. First, second, third, fourth instars and adult were having a mean predatory potential of 5.2 ± 0.359, 7.8 ± 0.396, 48.3 ± 1.153, 138.8 ± 2.973 and 226.2 ± 2.772 aphids respectively.

Morphotype III is a brownish-black beetle without any marking. Life cycle ranged between 13-15 days with a mean of 14.3 ± 0.153 days. Adult longevity ranged from 11-12 days with a mean of 11.6 ± 0.163 days. Mean fecundity was 290.2 ± 7.728 eggs. Four instars and adult were having a mean predatory potential of 5.6 ± 0.213, 7.8 ± 0.269, 46.2 ± 0.371, 142.8 ± 2.917 and 218.6 ± 2.551 aphids respectively.

Total life cycle of *B. suturalis* ranged between 10-11 days with a mean of 10.4 ± 0.224 days. Adult longevity ranged from 7-9 days with a mean of 8.5 ± 0.163 days. Mean fecundity was found to be 278.3 ± 8.439. Mean predatory potential of first, second, third, fourth instars and adult were found to be 5.9 ± 0.233, 6.6 ± 0.224, 31.8 ± 2.835, 58.3 ± 1.789 and 118.0 ± 3.473 aphids respectively.

Life cycle of *J. soror* ranged between 9-10 days with a mean of 9.6 ± 0.163 days. Adult longevity ranged from 4-5 days with a mean of 4.6 ± 0.269 days. Mean fecundity was observed as 84.5 ± 3.153. The predatory potential of first, second, third, fourth instars and adult were found to be 5.5 ± 0.348, 5.9 ± 0.384, 23.8 ± 2.525, 32.9 ± 2.351 and 88.7 ± 2.970 aphids respectively.

Feeding preference of four predatory coccinellids collected was studied under no choice situation and multiple choice situation. In no choice situation all the beetles except those provided with aphids died of starvation. In multiple choice situation all the coccinellids ate only aphids when they were provided with aphids, mealy bugs, leaf hoppers, white flies and thrips.

Biological data indicated higher feeding potential of *C. transversalis* (213.5 ± 4.710) and *C. sexmaculata* (226.2 ± 2.772) in controlling *A. craccivora*. In field also they were seen better established.

Seasonal fluctuation of aphid and coccinellid population was studied from June 2001 to May 2002. The population of aphids and coccinellids vary widely in different crops. In cowpea, aphid and coccinellid population were present throughout the course of study. Maximum population of aphids was seen on first fortnight of January in cowpea and bittergourd whereas the maximum coccinellid population was seen during second fortnight of January and first fortnight of February. In crops like pumpkin and brinjal, peak population of aphids and coccinellids were observed on the second fortnight of January and in bhendi it was on first fortnight of February. In the correlation studies it was found that aphid and coccinellid population were positively correlated. The influence of weather factors on aphid and coccinellid population did not show consistent results. Rainfall and temperature was found to be negatively correlated with aphid population. Coccinellid population did not show any significant relation with weather factors except in cowpea. Influence of relative humidity varies widely. The inconsistency in the correlation obtained may be due to numerous factors interacting among the components of the biotic system and their interaction with numerous abiotic factors.

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* Originals not seen

Appendices

APPENDIX 1

Mean monthly weather data for the period from June 2001 to May2002

Months	Mean (°C) maximum temperature	Mean (°C) minimum temperature	Mean relative humidity (%)	Rainfall (mm)
June	28.4	23.1	87	676.2
July	29	22.7	85	477.7
August	27.5	23.1	87	256.2
September	30.8	23.2	79	206.1
October	30.7	23	81	215.8
November	31.6	23.1	72	115.8
December	31.3	22.2	60	0.0
January	32.8	22.7	62	0.0
February	34.3	22.4	50	0.0
March	36.2	24.1	63	16.2
April	34.2	24.7	88	50.8
May	32.3	24.5	81	308.4

BIODIVERSITY AND BIONOMICS OF PREDATORY COCCINELLIDS IN VEGETABLE CROPS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The role of biocontrol in keeping the natural balance of the ecosystem is universally accepted. However, the use of insecticides, interventions by man viz. cropping patterns, other methods of control, resistant varieties etc. may cause changes in natural enemy population. No information is available on the number and suppressive potential of predatory coccinellids and their effect on pest population and the present study is intended to meet the aforesaid desideratum.

In the present investigation the detailed biology of the coccinellid predators prevalent in the vegetable crops like cowpea, bhendi, brinjal, pumpkin and bittergourd was studied under laboratory condition. Fecundity, predatory potential and feeding preference of these predators were also ascertained. Seasonal fluctuation of aphid and coccinellid predators was studied from June 2001 to May 2002 in cowpea, bhendi, pumpkin, brinjal and bittergourd.

Coccinellids like *Coccinella transversalis* Fab. , *Cheilomenes sexmaculata*, (Fab.) *Brumoides suturalis*(Fab.) and *Jouravia soror* Weise were persistent in the vegetable ecosystem. Biological data indicated higher feeding potential of *C. transversalis* (213.5 ± 4.710 aphids) and *C. sexmaculata* (226.2 ± 2.77 aphids), which shows that they can effectively control *A. craccivora*. Higher fecundity of *C. transversalis* (421.8 ± 4.983 eggs) account for the successful establishment of these predators in the field: Feeding preference study was conducted by no choice test and multiple choice test. Coccinellids ate only aphids in both the situations.

The population of aphids and coccinellids vary widely in different crops.In cowpea, aphid and coccinellid population were present throught the course of study. Maximum aphid population (221.5 and 22) was seen on the first fortnight of January in cowpea and bittergourd respectively, whereas the maximum coccinellid population was noticed during the second fortnight of January (1.2) in the former and first fortnight of February (0.4) in the latter. In pumpkin and brinjal, peak population of aphids (29.8, 22.4) and coccinellids (0.5, 0.2) were observed on the second fortnight of January and in bhendi on the first fortnight of February (aphids 32.5, coccinellids 0.5). Correlation studies between aphid and coccinellid

coccinellid population with weather factors was also studied. Rainfall and temperature was having negative correlation with aphid population. Coccinellid population did not show any significant relation with weather factors except in cowpea. Influence of relative humidity on aphids and coccinellids vary widely in all the five crops. The inconsistency may be due to numerous factors interacting among the components of the biotic systems and their interaction with numerous abiotic factors. For consistent conclusions these correlation studies may have to be extended over a number of seasons.