BIOCONTROL OF MITES ON YARD LONG BEAN (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt) AND CHILLI (*Capsicum annuum* (L.))

BY

ABHILASH B.

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DECLARATION

I hereby declare that this thesis entitled **"Biocontrol of mites on yard long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt) and chilli (*Capsicum annuum* (L.))"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
29-05-2001

Abhilash B.

CERTIFICATE

Certified that this thesis entitled **"Biocontrol of mites on yard long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt) and chilli (*Capsicum annuum* (L.))"** is a record of research work done independently by Mr. Abhilash B. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellayani,
29-05-2001

Dr. K. Sudharma
(Chairman, Advisory Committee)
Associate Professor
Department of Entomology
College of Agriculture, Vellayani
Thiruvananthapuram

APPROVED BY:

CHAIRMAN

Dr. K. SUDHARMA

MEMBERS

1. **Dr. K. SARADAMMA**

2. **Dr. SUSAMMA MATHAI**

3. **Dr. C. GOKULAPALAN**

EXTERNAL EXAMINER

3/07/01

(P. Reghunath)

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INTRODUCTION

1. INTRODUCTION

The great proliferation of strains in the subclass Acari and the phenomenal increase in the extent of damage by phytophagous mites in the last two decades can be attributed to the acute selection pressure exerted by wide use of pesticides. Today, the management of these minute acarine pests has become inevitable for achieving economic returns especially in vegetables, like yard long bean and chilli. Considering the mounting problems associated with pesticide use, an ecologically sustainable management strategy is to be adopted for the management of mites too. In this context, biocontrol assumes special meaning since it is regulatory and gives the advantage of permanency.

It is an established fact that the most important factor which prevents acarine pests from gaining overwhelming dominance is the activity of their natural enemies. Augmentation of natural enemies is followed under situations where the existing natural enemies fail to achieve control in time. Inundative releases of natural enemies in a sense is application of 'biotic insecticides' and this can be accomplished by periodic colonization of mass reared entomophages.

'Know your insect' is of relevance in mass rearing of natural enemies using natural or factitious hosts and artificial diets. An insight into the biology of the entomophage and interrelations of the entomophage with its hosts is essential prior to adopting technologies involving releases of mass reared natural enemies.

Among the natural enemies of phytophagous mites, the most dominant are the acarine predators. Evidences indicate that releases of phytoseiid mites established a balance between phytophagous mites and their predators (McMurtry *et al.*, 1970; Krishnamoorthy and Mani, 1989).

Insect predators also act as natural enemies of phytophagous mites. The green lacewing, *Chrysoperla carnea* Stephens, a voracious feeder of soft bodied insects is also known to feed on mites (Gupta, 1985). The importance of *C. carnea* in integrated pest management is much appreciated in view of its general tolerance to pesticides (Canard *et al.*,1984 ; Pree *et al.*, 1989). Currently the predator is employed for pest management in cotton ecosystems in India. Before translating this technology for pest management into a different ecosystem, assessment of the suitability of the predator in the new ecosystem is of paramount importance.

Kerala with a rich flora offer scope for management of mites using botanical pesticides. But only very few studies exploiting the potential regional flora are known (Reghunath and Gokulapalan, 1996; Santhoshkumar, 1999).

A single tactic alone cannot hold the key for management of mites in future. An array of tools should be made available to farmers for adopting technologies suited to specific situations. Combination of biotic agents or combination of biotic agents and botanical pesticides may enhance the success of the biological control programmes. With the above facts in mind the project entitled "Biocontrol of mites on yard long bean

(*Vigna unguiculata* ssp *sesquipedalis* (L.) Verdcourt) and chilli (*Capsicum annuum* (L.))" was chalked out with the following objectives.

1. To develop mass multiplication techniques for predatory mites and the green lace wing *Chrysoperla carnea* Stephens
2. To determine the predatory potential and prey preference of predators
3. To assess the effect of pesticides on the predators
4. To evolve management techniques for the spider mite, *Tetranychus ludeni* Zacher infesting yard long bean (vegetable cowpea) and the broad mite, *Polyphagotarsonemus latus* Banks infesting chilli.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The red spider mite, *Tetranychus ludeni* Zacher and the broad mite *Polyphagotarsonemus latus* Banks are the two important mite pests of cowpea and chilli respectively in Kerala. The literature on the nature of damage, crop loss, biology and management of these phytophagous mites and the mass multiplication, biology and feeding potential of their natural enemies viz., the phytoseiid mites and the chrysopid predators is briefly reviewed below.

2.1 *Tetranychus ludeni*

Nearly thirty species of plants were recorded as natural hosts of this spider mite (Jeppson *et al.*, 1975; Gupta, 1985; Karuppuchamy and Mohanasundaram, 1987; Sathiamma, 1991).

2.1.1 Nature of damage and crop loss

T. ludeni was reported to cause direct as well as indirect damages. The Dolichos enation mosaic virus was reported to be transmitted by *T. ludeni*.(Rajagopalan, 1974) Puttasamy and ChannaBasavanna (1979) reported that feeding by *T. ludeni* in French beans induced white stippling at the feeding points which later coalesced and produced necrotic patches on the leaves.

Dhooria (1983) found that even five female *T. ludeni* in a young french bean plant bearing 5-7 leaves could cause significant damage to leaves resulting in low vitality of plants.

2.1.2 Biology

According to Mallik (1974) *T. ludeni* females took 222 hours and males took 200 hours to complete the life cycle. On an average, each stage viz., egg, larva, protonymph and deutonymph lasted for 106 hours, 32.5 hours, 34.5 hours and 44 hours respectively. Preoviposition period was 26 hours and a female laid about 72 eggs on an average and its longevity was 17 days.

Puttasamy (1978) observed that under field conditions in Bangalore, the total development time was 12.48 days for females and 11.96 for males. His studies also revealed that development was faster and fecundity higher in okra when compared to beans, brinjal and castor.

Sathiamma (1991) reported arrhenotokous reproduction in *T. ludeni*. The female of this mite completed its egg to adult period in 9.73 ± 0.52 days. The male was reported to be complete its development in 9.50 ± 0.24 days at 24-30^{0}C temperature and 41-96 per cent relative humidity.

Ansari and Pawar (1992) found that each *T. ludeni* female laid 30-90 eggs individually within the webs on leaves and the incubation period was 2-2.7 days on *Eichornia crassipes*.

Morros and Aponte (1994) studied the biology and life table of *T. ludeni* on blackgram, *Phaseolus vulgaris* L. The mean duration of different stages viz., egg, larva, protonymph and deutonymph were 4.68, 1.75, 1.31 and 1.85 days respectively . The total life cycle lasted 9.98 and 9.25 days for females and males respectively. Studies conducted by Malaviya and Rai (1995a) on the bionomics of *T. ludeni* on Indian bean in the laboratory revealed that incubation period was

4.6 ± 0.7 days irrespective of sexes and males emerged as adults earlier than females and mated males produced male and female progeny in ratio of 1 : 4.05.

Sudharma (1996) observed that the egg, larval, protonymphal and deutonymphal periods of *T. ludeni* on *Rosa* sp. were 4.7 ± 0.44, <24 hours, 2.18 ± 0.25 and 1.21 ± 0.21 days respectively.According to Silva *et al.* (1999) at 30 ^{0}C and 35 ^{0}C *T. ludeni* completed its life cycle in 8.45 and 6 days respectively.

2.2 *Polyphagotarsonemus latus*

P. latus, known by different names such as chilli murnai mite, broad mite, yellow tea mite and tropical mite was reported to be distributed throughout the tropics and the temperature regions on vegetables and ornamental plants (ChannaBasavanna and Puttarudriah, 1959; Jeppson *et al.*, 1975; Mote, 1976; Dhooria and Bindra, 1977; Kareem *et al.*, 1977; Sandhu *et al.*, 1974; Kandasamy *et al.*, 1987).

2.2.1 Nature of damage and crop loss

Kulkarni (1922) conducted detailed studies on leaf curl infestation of chilli and reported that malformation was due to the feeding of mite. He found that the symptom made its appearance first in the terminal and axilliary tender shoots of chilli plant. Further in 1938 ,Hambleton recorded *P. latus* as the causative agent of leaf curl of chilli in Los Angeles, USA.

According to Ningappa (1972) the mite caused downward curling of leaf margin and cupping of leaves on 14th day after infestation and was accompanied by dropping of flowers.

Under laboratory conditions, Dhooria and Bindra (1977) observed that *P. latus* infested chilli leaves first curled downwards at margin and tips. Kareem *et al.* (1977) reported that chilli crop failed to yield if *P. latus* infested at the flowering and fruiting

stage of the crop. Nandihalli (1979) found that feeding of the mite resulted in the development of shining spots on the lower surface of leaves.

Saradamma *et al.* (1981) first reported this mite, as a pest of chilli and cowpea in Kerala.

According to Karmakar (1995) when chilli plants were inoculated with *P. latus*, the young leaves curled downwards, in an inverted boat shaped manner and presented a silvery lining on their ventral surface.

Sudharma (1996) reported that even though *P. latus* infested a number of crops like chilli, ridgegourd, bittergourd, pumpkin etc., infestation was most serious in chilli. Crop loss studies on chillies showed that even 24 mites/plant when released three weeks after planting could cause significant reduction in yield.

2.2.2 Biology

According to Lavioperse (1940) life cycle of *P. latus* was completed in 6-10 days in winter and four days in summer. The larval period was observed as two days. At the end of the larval period the mites were reported to enter the quiescent pupal stage. Often the quiescent stages of the female were carried on their backs by the males.

Schoonhoven *et al.* (1978) reported the duration of the immature stages as 2-3 days and the longevity of the male and female as 11-14 days and 7-8 days respectively.

Kabir (1979) found that when females came in contact with males they stopped moving and remained stationary for copulation. Further, he found that oviposition period ranged from 7-11 days and during this period each female laid 30 to 76 eggs.

In 1986, Almaguel *et al.*, observed the duration of immature stages as 2.55 to 4.4 days. He reported that oviposition and pre-oviposition periods were longer in wet season than dry season and the fecundity as 24 eggs/female. According to Karuppuchamy and Mohanasundaram (1987) *P. latus* completed its life cycle in 6.5-8.0 days.

Nagaraja (1988) found that *P. latus* took 113.61 ± 27.9 hours for female, 93.04 ± 21.55 hours for male to complete their development and each stage viz., egg, larva, nymph lasted for 49.53 ± 9.1 hour, 36.22 ± 7.41 hours and 27.86 ± 11.39 hours respectively for the female and 46.06 ± 7.67 hours, 22.80 ± 4.94 hours and 24.18 ± 8.64 hours respectively for the male. Female adult started laying eggs after a preoviposition period of 35.4 ± 9.3 hours and continued for 4.61 ± 1.07 days. Fecundity ranged from 10-34 eggs with an average of 13.14 ± 8.19 eggs. Karmakar (1997) studied size, shape and behaviour of *P. latus* on chilli and duration of life cycle from egg to egg was reported as 74.05 hours.

2.3 Management of mite pests

2.3.1 Bioagents in the management of mites

2.3.1.1 Predators

Acarine predators as well as insect predators were observed as important natural enemies of phytophagous mites in India and abroad (Singh and Ray, 1977; Dhooria, 1982 ; Sudharma, 1996).

2.3.1.1.1 Acarine predators

The discovery of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot in 1958 against *T. urticae* in glasshouse of Netherlands led to new interests in biological control programme (Bravenboer and Dosse, 1962).

Among the predatory mites, phytoseiid mites have been recognized as one of the most valuable groups of predators of phytophagous mites (McMurtry *et al.*, 1970; Van De Vrie and Boersma, 1970). *Amblyseius finlandicus* (Oudemans) occurred in the ecosystem of many phytophagous mites and was reported as a promising predator on eggs and larvae of *Eutetranychus orientalis* (Gupta *et al.*, 1971) Studies conducted by Croft and McMurtry (1972) revealed that mass release of phytoseiid mites was promising on apple trees to control *T. mcdanielli.*

In sweet pepper grown in glasshouse in Netherlands *Phytoseiulus* was used for the control of *T. urticae* (Ramakers, 1980; 1983). Jagdish and Nageshchandra (1982) reported the potential of *Typhlodromips tetranychivorus* Gupta as a predator and as a biocontrol agent of red palm mite *Raoiella indica* Hirst.

The occurrence of *Amblyseius rhododendronis* Gupta as a predator of *T. ludeni* on okra was reported by Krishnamoorthy (1983). Very low population of the predatory mite was reported to be present on plants in the absence of prey mites.

Gupta and Gupta (1985) reported the occurrence of *Amblyseius largoensis* (Muma) and *Amblyseius ovalis* Evans as predatory mites of *T. cinnabarinus* and *T. neocaledonicus* respectively in West Bengal. Krishnamoorthy and Mani (1989) studied the effect of releases of *P. persimilis* in the control of *T. urticae* in French beans and found that 10 predators per plant would be ideal in suppressing *T. urticae* in french beans.

. The natural enemy complex of coconut pest, *R. indica* was studied in West Bengal by Somchoudhury and Sarkar (1989). They reported that *Phytoseius* sp. and *Amblyseius* sp. were the dominant predatory mites.

Gupta and Gupta (1992) gave an account of the predatory mites in India, their hosts and importance in biological control. The predatory mites *A. finlandicus*, *A. ovalis*, *A. longispinosus*, *A. largoensis*, *A. multidentatus*, *A. tetranychivorous* were reported to be highly effective in checking population of *E. orientalis*, *O. coffeae*, *O. mangiferus*, *T. neocaledonicus* and *T. ludeni* respectively.

Studies conducted by Karuppuchamy *et al.* (1994) revealed that the adult predation of *A. ovalis* were the most efficient in devouring the chilli mites. Fan and Petitt (1994) reported *Neoseiulus barkeri* Hughes as an important predator of *P. latus*.

2.3.1.1.2 Insect predators

2.3.1.1.2.1 Coccinellid predators

The coccinellid, *Sthethorus* spp. identified as important predators of tetranychid mites are distributed throughout the world (McMurtry *et al.*, 1970; Singh and Ray, 1977). Dhooria (1982) observed *Stethorus pauperculus* Weise to prey on *E. orientalis* under field situations. Among the various insect predators of tetranychid mites in cassava, *Stethorus gilvifrons* Muls was the most effective one. *Stethorus picipes* Casey was identified by McMurtry (1989) as a voracious feeder of spider mites in citrus. The females consumed upto 50 adult spider mites per day and several thousands during their lifetime.

2.3.1.1.2.2 Chrysopid predators

The grubs of Chrysopids having mandibulo-suctorial mouthparts are well adapted to predatory life. Chrysopids feed on more than eighty species of insects and ten species of tetranychid mites (Kharizanov and Babrikova, 1978).

C. carnea has been successfully utilised in release programmes for the control of European red mite on apple (Miszczak and Niemezyk, 1978); spider mites on cotton (Gurbanov, 1982).

The general tolerance of chrysopids to many insecticides commonly used against pests of crops has led to considerable interest in the use of chrysopids in Integrated Pest Management Programme (Canard *et al.*, 1984; Pree *et al.*, 1989).

In Tamil Nadu ,*C.carnea* is recommended for the management of the aphid ,*A.craccivora* in ground nut @ 2000/acre/week.(Reghupathy *et al.*, 1997).

2.3.2 Botanicals in the management of mites

According to Malaviya and Rai (1995b) the plant products Neemate and Replin were found to be as effective as methyl-o-demeton, ethion, quinalphos and triazophos and these plant products may be taken advantage for control of *T. ludeni* on Indian bean.

Patel *et al.* (1995) studied the acaricidal effects of botanical pesticides in comparison to conventional acaricides / pesticides against red spider mites on brinjal and Indian bean and found Neemark 0.5 per cent had considerable effect on population of *T. cinnabarinus* and *T. mcfarlanei*. In another study conducted by Ramaraju *et al.* (1995) to test the effect of plant products on *T. ludeni* in brinjal, the overall efficiency was highest for neem oil five per cent. It was followed by *Vitex negundo* leaf extract and NSKE five per cent.

Mironova *et al.* (1997) studied the effect of NeemAzal-T/S on *Tetranychus urticae* Koch. The laboratory studies revealed that the botanicals caused cent per cent mortality of adults of *T. urticae*. He also found that at all the concentration tested, 0.1, 0.3 and 0.5 per cent there was significant reduction in the reproductive capacity of

mites. The survival of progeny of treated females were greatly reduced in comparison with untreated control.

According to Momen *et al.* (1997) Neemazal, F had high repellency, toxicity and oviposition deterrence to *T. urticae*. Field experiments conducted by Santhoshkumar (1999) revealed that ten percent extracts of *Andrographis paniculata* and garlic gave effective control of *P. latus* on chilli. He also found that neem seed oil 10 per cent was equally effective in controlling this mite.

2.4 Natural enemies

2.4.1 Phytoseiid mites

2.4.1.1 Predatory potential and prey preference

According to Mallik (1974), *A. longispinosus* is an efficient predator of *T. ludeni*. During the development of the predator, the protonymph, deutonymph and adult females consumed 3,4 and 26 eggs/day respectively.

Nangia (1980) reported that *T. tetranychivorus* consumed *T. ludeni* and the most preferred stage was adults and it was followed by the nymphal stages. McMurtry *et al.* (1984) studied the feeding behaviour of mites, *Typhlodromus rickeri* Chant and *Typhlodromus porresi* on broad mite, *P.latus* and found that the predators preferred larvae to other stages. Nakagawa (1985) reported that adult females of *A. longispinosus* consumed 15.8 eggs of *T. kanzawai* at 25^0C and 10.4 eggs at 20^0C per day.

Biasi *et al.* (1988) found that consumption of eggs of *T. ludeni* by *Neoseiulus fallacis* Garman was directly proportional to quantity offered. Hariyappa and Kulkarni (1988) studied the feeding potential of *A. longispinosus* on chilli mite *P. latus* and found that the adult predator consumed 11.72 larvae, 9.33 nymphs or 5.07 adults/day

while the larvae of the predator consumed 3.76, 1.38 and 0 prey larvae, nymphs and adults respectively. They studied interaction of predatory mite *A. ovalis* and chilli mite *P. latus* in laboratory and found that at predator prey ratio of 1 : 25, 1 : 50 and 1 : 100 *P. latus* was eliminated on ninth, twelfth and seventeenth day respectively.

2.4.1.2 Biology

Though usually four developmental stages have been reported in phytoseiids, Ballard (1954), working on the biology of *A. fallacis* found that the males did not pass through a deutonymphal stage. The preoviposition period of this mite was observed to be 24 hours and female laid on an average 2.2 eggs per day. According to Burell and McCormik (1964) this predatory mite took 8-10 days to complete its life cycle on the eggs of *Eutetranychus carpini* (Oudemans).

Kinsley and Swift (1971) who worked on the biology of *Amblyseius umbraticus* Garman and McGregor, a predator of *T. urticae* found that a total of 154.5 hours was taken by the female to complete its development, egg, larvae, protonymph, deutonymph taking 45.6, 23.0, 41.8 and 43.7 hours respectively. The females showed a longevity of 24 days and deposited 36 eggs per female.

Chandrasekharappa *et al.* (1995) studied the biology of predatory mite, *A. longispinosus* reared on *T. urticae* and found that the adult life span averaged 33.77 days at 25^0C, mated female laid 53 ± 729 eggs and the most favourable temperature for reproduction of the mite was between 25^0C and 30^0C. They also found that the average developmental period was 99.0 ± 11.46 hours at 25^0C.

2.4.1.3 Effect of pesticides on phytoseiid mites

Croft and Nelson (1972) evaluated toxicity of twenty three commonly used pesticides against *A. fallacis* and reported that dimethoate and imidan were less toxic

compared to carbaryl and phosalone The phytoseiid mites, the principal natural enemy of the spider mites, are generally known to be very much susceptible unlike the spider mites to many pesticides (Watve and Lienk, 1976; Roush *et al.*, 1980).

Krishnamoorthy (1982a) tested fourteen pesticides against gravid females of *A. tetranychivorus*, and found that the predator was least affected by wettable sulphur and Zineb one day after spraying and its residue was also innocuous. Though endosulfan 0.07 per cent was highly toxic on the day of spraying subsequently its, residue had little mortality to predatory mite and all other chemicals tested remained toxic even after nine days of treatment.

Jagdish and ChannaBasavanna (1989) conducted toxicity studies on *A. tetranychivorus* , an effective predator of *T. ludeni.* Slide dip method was followed for testing the mortality (F.A.O., 1984) and according to them, the predator was more susceptible to quinalphos and malathion at 0.05 and 0.01 per cent concentration followed by dicofol at 0.05 per cent at 12 hours after treatment. Rai *et al.* (1995) tested toxicity of pesticides including neem products on *Amblyseius alstoniae* Gupta and found that monocrotophos, dicofol were toxic. NSKE had least effect on this predator.

2.4.1.4 Mass multiplication

Phytoseiids can be divided into two main groups; monophagous species such as *P. persimilis* or *M. occidentalis* that can be reared on their natural hosts, the tetranychid mites only and those polyphagous species of *Typhlodromus, Amblyseius* and *Euseius* that can be reared on pollen, alternate prey or artificial diets (Gilkeson, 1992).

2.4.1.4.1 On natural hosts

2.4.1.4.1.1 On leaf arena

Techniques for rearing host mites on leaf arena were developed by Ristich (1956). In this technique, host mites were reared on bean leaves laid on filter paper in petridishes. A modification of above method was adopted by Gilstrap (1977) where he placed cut bean leaves on moist cotton as arenas for rearing phytoseiids. Theaker and Tonks (1977) reared *P. persimilis* on blotting papers kept in plastic lids floating in trays of water. Each lid was centered by a magnet on the bottom of the lid, which was attracted to another magnet glued to centre of water tray. Rearing on cut leaves infested with tetranychids was frequently used in laboratory (Bakasova, 1978).

2.4.1.4.1.2 In rearing cages

Tanigoshi *et al.* (1975) developed a cage for rearing *M. occidentalis* using cardboard cartons. Another rearing technique for *P. persimilis* was developed by Fournier *et al.* (1985) in which predacious mites were maintained in rearing units composed of cylinders which contained bean leaves heavily infested with *T. urticae.*

Zhurba *et al.* in 1986, devised a method for mass rearing *P. persimilis* and its host *T. urticae* for large scale utilization in greenhouses. Here predators were reared in transparent perspex boxes and with introduction of 1000 predators into the box in which tetranychid infested leaves were provided, predators multiplied and productivity per box in one week was about 20 000-25000 mites.

Karuppuchamy *et al.* (1988) developed another mass rearing technique using tetraychid mites as prey. They used a glass vial which had a rubber cork at its open end and spider mite infested leaf was inserted through the cork and mass rearing of predator and prey were done.

2.4.1.4.3 On plants

Ristich (1956) reared spider mites on kidney bean plants, and then reared *A. fallacis* on these plants once they were well infested with spider mites. The phytoseiid, *P. persimilis* preyed exclusively on spidermites, *Tetranychus* spp. Therefore, the common method for rearing *P. persimilis* is on plants infested with tetranychids (Bravenboer, 1975).

Early rearing systems in Glasshouse Crops Research Institute, England were based on inoculation of *P. persimilis* into potted French bean plants infested with spider mites. Using this system each pot of beans produced 1500-4000 or about 22,500-60,000 predators weekly from a 7.5 m^2 greenhouse.

2.4.1.4.2 On alternate hosts/pollen

Experiments done by Kennett and Hamai (1980) proved that many phytoseiids predators can be reared on natural diets containing pollen. Rearing phytoseiids on insects, on eggs and crawler stages of mealy bugs, armoured scales, aphids and their honey dews revealed that nutritional value of these foods were low and rearing could not be carried out effectively (Kamburov, 1971)

Krishnamoorthy (1982b) standardised rearing of phytoseiid mite *P. persimilis* on castor pollen. The polyphagous species, *A. cucumeris* could be efficiently mass reared on tyroglyphid mites and are now inexpensively mass produced on *Acarus* and *Tyrophagus* spp. for application against thrips in greenhouses (Ramakers, 1984).

According to Rasmy *et al.* (1987), *Amblyseius gossypii* Elbadry, can also be reared on the tyroglyphid, *Tyrophagus casei* Oudemans mixed with pollen.

2.4.1.4.3 On artificial diet

The advantages of rearing phytoseiids on artificial diets are that it is cheaper and more predictable and require less labour and space than rearing on tetranychids.

McMurtry and Scriven (1966) found that a mixture of 20 per cent yeast and 20 per cent sucrose provided enough nutrients to sustain oviposition in *A. limonus* and *E. hibisci* . He further stated that though oviposition rates were low and immature development was poor when compared to earlier natural diets, artificial diets could be developed, particularly for species having polyphagous habits.

Shehata and Weismann (1972) obtained viable eggs from *P. persimilis* when fed with three artificial diets. Immature development also occurred with the diets but the resulting female adults were smaller in size and failed to produce viable eggs. The adults had shorter longevity than predators fed on mite prey.

Hassan and Hagen (1978) developed and tested a number of diets for phytoseiids and found that a diet consisting of 5g honey, 5g yeast flakes, 6g yeast hydrolysate, 1g casein hydrolysate, 10 g egg yolk and 68 ml water performed effectively in multiplication.

Kennett and Hamai (1980) tested the above diet on many phytoseiids and found that, the feeding resulted in immatures only. Their modified diet consisted of honey, sugar, yeast, yeast hydrolysate, casein hydrolysate, egg yolk, Wesson's salt and water. Another artificial diet consisting of mite powder, honey, eggyolk, Wesson's salt and water was developed for *Amblyseius teke* Pritchard and Baker (Ochieng *et al.*, 1987) and mites were reared for 25 generations on this diet.

2.4.2 The Green Lace Wing, *Chrysoperla carnea*

2.4.2.1 Biology

The biology of Chrysopidae has been well documented by Canard *et al.* (1984). Zaki (1987) observed the optimum temperature for larval development of *C. carnea* as 30^0C.

Nicole *et al.* (1991) studied the biology of *C. carnea* in different temperature regimes of 10, 14, 18, 22 and 27^0C and found that survival of first instar larvae was only 14 per cent at the lowest temperature. According to Bakthavalsalam *et al.* (1994) out of the four chryropids tested, reproductive rate was highest for *C. carnea* which was 558.78 and was identified as the most suitable one for laboratory rearing.

Yolda (1994) studied the biology of *C. carnea* on two different prey. The mean larval periods of *C. carnea* larvae feeding on *Macrosiphum euphorbiae* and *Trialeurodes vaporarium*.Westwood were9.93 days and 11.4.The longevity of adult females fed on *M. euphorbiae* during larval stage was 46.16 days and fecundity 750.66 eggs per female.

Balasubramani and Swamiappan (1994) studied the developmental period of *C. carnea* on *C. cephalonica* and *Aphis gossypi* and found that the total developmental period was 19.35 and 20.15 days respectively .The larval development was rapid on eggs of *C. cephalonica* which was 8.2 days.

Kundu *et al.* (1998) reported that larval period of *C. carnea* was more (11.2 ± 0.98 days) when fed on adults of *A. craccî vora* where as it was less (7.5 ± 0.67 days) when fed on eggs of *C. cephalonica*. The fecundity of the predator was more when fed on aphids (156.7 ± 23.1 / female), whereas it was only 128.5 ± 18.6 on *C. cephalonica* eggs.

2.4.2.2 Predatory potential and prey preference

Quantity of prey eaten by chrysopids in a situation may vary, for example, *Chrysoperla formosa* Braner larva consumed on an average 2000 *Brevicorne brassicae* (Linnaeus), to complete it's development (Okamato, 1919). On the other hand *Chrysoperla septempunctata* Wesmae larvae can develop by eating less than 100 *Aphis rumicis* L. (Withycombe, 1923).

Gikorashvili (1983) reported that *C. carnea* consumed 33 *P. ulmi* per day under laboratory conditions. Sengonca and Coepicus (1985) worked out the feeding activity of *C. carnea* on *T. urticae* and reported that during development in laboratory the individuals of *C. carnea* consumed a mean total of 12567.3 eggs of *T. urticae*. The predator consumed 7.5 per cent, 20.9 per cent and 71.6 per cent in the first, second and final larval instar respectively. In 24 hours, first second and third instar larva consumed 132.8, 237 and 542.8 protonymphs respectively.

Gupta (1985) reported that the last instar larvae of the predator consumed 1000-1500 citrus mites daily. According to Balasubramani, (1991) *C. carnea* consumed more *C. cephalonica* eggs (732.35) followed by *Helicoverpa armigera* Hubner (662.53), aphids of different species (374.28 to 419.18), whitefly nymphs and pupae (329.7) and leaf hoppers (288.45) in its larval period

Sarode and Sonalkar (1998) reported that when *C. carnea* was reared on *C. cephalonica* eggs the number of eggs consumed by larvae of predator was 53.29 at 125 eggs / day. Studies conducted by Sharanabasava and Manjunatha (1998) showed that during larval development, a single larva of *C. carnea* consumed a mean total of 10968.1 eggs, 3793.7 nymphs and 2889.4 adults of *T. neocaledonicus*.

2.4.2.3 Effect of pesticides on *C. carnea*

Bartlett (1964) studied toxicity of some pesticides to eggs, larvae and adults of green lace wing *C. carnea* and found that malathion 0.1 per cent had no effect on eggs but had lethal effects on larvae and adults.

According to Lingren and Ridgeway (1967) *C. carnea* was least affected by trichlorfon where as methyl parathion and bidrin were more toxic to the predator.

Krishnamoorthy (1985) studied the effect of several pesticides on eggs, larvae and adults of *C. carnea* and found that on treatment with dicofol, quinalphos and malathion, at 0.05, 0.0.5 and 0.1 per cent eggs and larvae were unaffected.

The larvae of C.carnea were found unaffected by cypermethrin 0.014 per cent, phosalone 0.015 per cent, carbaryl 0.36 per cent, fenvalerate 0.014 per cent (Singh and Varma, 1986), dicofol, endosulfan, oxydemeton, monocrotophos, phosalone (Balasubramani and Swamiappan, 1993) endosulfan, phosalone and neem oil (Senthamil Selvan, 1989).

Direct and indirect effects of some insecticides on *C. carnea* Stephens was studied by Badawy and Elnarouty (1999). The chemicals tested against larvae of *C. carnea* in laboratory were organophosphates,carbamates and biocides. In the study, biocides proved safer than carbamates and organophosphates.

2.4.2.4 Mass multiplication

2.4.2.4.1 Larval rearing

2.4.2.4.1.1 On lepidopteran eggs

C. carnea are both highly predaceous and cannibalistic in the larval stages which makes it difficult to hold and feed them in high density cultures. Finney (1948,

1950) used wooden trays covered with white muslin cloth for larval rearing. Larvae were reared on eggs of *Pthorimaea operculella*.Zeller.

Ridgeway *et al.* (1970) used hexcel for larval isolation. One side of hexcel was covered with organdy and other side was covered using a glass plate to which honey and eggs of Angumois grain moth were attached.

Morrison *et al.* (1975) also used this method in a modified manner where by he was successful in obtaining pupae in 93 per cent of rearing cells. The adult emergence was 95 per cent. Krishnamoorthy and Nagarkatti (1981) developed mass rearing technique for *Chrysopa scelestes* Baules under Indian conditions.

Patel *et al.* (1988) utilised eggs of rice moth *C. cephalonica* in group rearing of *C. carnea* larvae.A hot melt glue system for preparation of larval rearing units for green lacewings, (*C. carnea* and *C. rufilabris*) was suggested by Nordlund (1993).

2.4.2.4.1.2 Natural food

The larvae of *P. operulella* ,*Sitotroga cerealella* (Oturer), adults of *Myzus persicae* (Sulzer), and larvae of *Plodia interpunctella* (Hubner) were used as food for rearing *C.carnea*.(Finney, 1948; Morrison *et al.*, 1975; Tulisalo and Korpela 1973; Hassan, 1975).

Krishnamoorthy and Nagarkatti, 1981 used eggs of *C. cephalonica* for mass rearing *C. scelestes*. The large scale laboratory rearing of *C. carnea* larvae has been attempted on *S. cerealella* also (Karpacheva, 1991).

2.4.2.4.1.3 Artificial diets

Hagen and Tassan (1965) were the first to report the use of artificial diets for rearing *C. carnea* successfully. The insects were reared on diets encapsulated in a thin layer of paraffin. Vanderzant (1969) reported a diet that when fed to the larvae

via saturated pieces of cellulose sponge produced 50-65 per cent yields of adults from larvae.

Ridgeway *et al.* (1970) developed a technique of encapsulation of larval diet to reduce cost of mass rearing. Pomonareva (1971)devoloped diet for *C. carnea* larvae which consisted of dried ground adults of *S. cerealella,* honey, autolysed brewers yeast and fresh milk.

Hassan and Hagen (1978) developed and tested a number of diets and found that a diet consisting of honey, sugar, food yeast flakes, yeast hydrolysate, casein hydrolysate, egg yolk and water performed better. According to Yazlovetskij *et al.*, (1990) liquid artificial diets were found suitable for larval rearing.

In India an artificial diet was developed for *C. scelestes* by Gautam and Navarajan Paul (1987) using *C.cephalonica* egg paste, agar agar, cholesterol and yeast powder. McEwen *et al.* (1993a, 1993b) developed on artificial honey dew consisting of yeast autolysate, sugar and water for rearing *C. carnea.*

Puspalatha *et al.* (1994) used laboratory wastes like spent moths or dead adults of *C .cephalonica, Spodoptera litura, H. armigera,* mealy bugs and bees for rearing *C. carnea* larvae. Venkatesan *et al.* (2000) reported that a hydrolysed soyabean. based diet was effective for mass rearing *C. carnea* larvae.

2.4.2.4.2 Adult rearing

Mass culturing techniques for chrysopid adults were developed by many workers which consisted of gadgets for rearing and oviposition (Ridgeway *et al.*, 1970; Morrison and King, 1977). Geeta(1994) developed modified galvanized iron cage and card board cylinder cages for rearing *C.carnea* adults

2.4.2.4.2.1 Natural food source

The adults of chrysopidae are attracted to natural diets like pollen, nectar and honey dew of certain homopteran bugs (Coppel and Mertins, 1977; Rousset, 1980).

Gautam and Navarajan Paul (1988) studied the effects of natural diets like pollen on increasing longevity and reproductive potentiality of *C. scelestes*

2.4.2.3.2.3 Artificial diets

Hagen and Tassan (1966) developed artificial diets containing enzymatic protein hydrolysate of yeast, choline chloride, carbohydrate and combination of brewer's yeast with sugars for adults of *C. carnea*. Artificial diets containing casein hydrolysate, protein hydrolysate, sugars, vitamins, pollen and minerals have been also developed for adult of *C. carnea* (Hagen, 1950; Vanderzant, 1969; Canard, 1973; Elkarmi *et al.*, 1987).

MATERIALS AND METHODS

3.MATERIALS AND METHODS

The mass culturing of predatory mites, *Amblyseius* spp. and *Macrochelus merdarius* and the predatory insect, *Chrysoperla carnea* were done in the laboratory. The predatory potential and prey preference of these predators and the effect of pesticides on them, were assessed. The performance of the predators were further evaluated through field experiments.

3.1. Mass culturing of predators

3.1.1 Mass culturing of predatory mites

Attempts were made to mass multiply predatory mites on phytophagous mites, storage mites and on artificial diets.

3.1.1.1 Mass culturing of *Amblyseius longispinosus*

3.1.1.1.1 On red spider mite, *Tetranychus ludeni*

The mass multiplication of the prey mite, *T. ludeni* was done by a method similar to that followed by Karuppuchamy *et al.* (1988) but with modifications. The rearing unit consisted of glass vial 6 x 2 cm size with a thermocol cork tightly fitted to its mouth. A small glass tube was then inserted through a hole made on the cork and water poured into the vial to about half the length of the vial. The petiole of an excised mature trifoliate leaf of vegetable cowpea was then inserted through the hole into the vial so that the petiole tip remained immersed in water. The vial with trifoliate leaf was then placed in a petridish in which water was poured to about 0.5 cm height. Twenty pairs of gravid females of *T. ludeni* were released on to this trifoliate leaf and the unit was then covered with a bell jar and allowed to multiply. Field collected predatory *Amblyseius* sp. from cowpea plants were subsequently

released on to the same leaf one day after the release *of T. ludeni* @ 10,15 and 20 mites per trifoliate leaf. The predatory mites which multiplied on these leaves were used for the experiments in the present study.

3.1.1.2 Mass multiplication of *Amblyseius* sp. on chilli mite, *Polyphagotarsonemus latus*

The chilli mite, *P. latus* was found to infest vegetable cowpea under field situations. Hence the prey mite, *P. latus* was at first multiplied on excised cowpea leaves as mentioned in 3.1.1.1.1. Thirty adults of *P. latus* were then introduced into each leaf and one day after the release of prey mite *Amblyseius* sp. was also released and the mites were allowed to multiply on the leaf for a period of two weeks.

3.1.1.3. Mass culturing of *Macrochelus merdarius* Berlese on Bran mites

In the laboratory, bran mites were mass multiplied in rice bran. For this 10 g of rice bran was heat sterilized at 70 ^{o}C for one hour and transferred to glass bottles with bakelite screw cap and 400-500 bran mites were introduced into each bottle with bran. To this bottle, 40 predatory mites, *M.merdarius* which were found to feed on *P. latus* were introduced the next day after the release of bran mites. One week after the release of mites the bottle was loosely capped and placed in petridish with water maintained at a height of 0.5 cm. After one hour bran mites and predatory mites moved upward and came to the surface of the cap. Then the cap was removed along with the mites and another cap replaced in its position for further collection of mites.

3.1.1.4 Mass multiplication of predatory mite, *A. longispinosus* on alternate diet

Artificial diets and pollen were evaluated as food for the predatory mite. The development of *A. longispinosus* on the following diet were studied.

1. Pollen of *Acacia auriculiformis* Cunn. Ex. Benth.

2. Pollen of *Hibiscus rosa-sinensis* Linn.

3. Yeast extract + 20 % sucrose (1:1)

4. Yeast extract + 10 % Honey + Casein protein (5:5:1)

5. Yeast extract + Egg yolk + 10 % Honey (1:2:1)

6. Egg yolk + 10% Honey + Casein protein (10:5:1)

7. Egg yolk + 10 % Honey + protinex (2:1:1)

8. Water

Gravid females of the predator were used for the study. The number of eggs laid and the development of the young ones on the different diet was assessed.

3.1.1.4.1 Method of feeding diet

An open glass tube 12 x4 cm dia. was taken. One end of it was covered using klin film on which pin pricks were made. A small sponge piece was taken and swabbed with the prepared diet and placed on the top of the klin film. Using another layer of klin film, the sponge was again covered. It was also ensured that the diet could pass through the holes as fine droplets.

On the other end a plastic cap was tightly fixed and a hole made in it and a 0.5 x 0.75 cm plastic tube inserted through the cap hole into the glass tube. Through this end using a fine camel hair brush 5 numbers adult predatory females were released into each tube and the hole was closed by a cork piece. Cotton strands were also provided inside the tube for collecting eggs as predatory mite use it as substratum for egg laying. In control, water soaked sponge bits were provided in leaf arenas in petriplates.

The pollen of *A. auriculiformis* and *H. rosa-sinensis* were collected in the morning hours. Diet was changed at three days interval.

3.1.1.5 Biology of *Amblyseius* spp.

The biology of predatory mites *A. longispinosus* and *Amblyseius* sp. preying on *T. ludeni* and *P. latus* respectively were studied separately on their host mites, reared on excised leaflets of cowpea and chilli. The development of *A. longispinosus* preying on *T. ludeni* was studied on its eggs, nymphs and adults while for the species of *Amblyseius* preying *P. latus* the development was studied only on the adults of the host mite. Observations were recorded on the developmental period, adult longevity and fecundity of the predators. The experiment was conducted in CRD with five replications.

3.1.2 Mass culturing of *C. carnea*.

Eggs of rice moth, *Corcyra cephalonica* Staint; cowpea aphid, *Aphis craccivora* Koch and spider mite, *Tetranychus* ludeni Zacher were used as food for *C. carnea*. The nucleus culture of *C. carnea* and *C. cephalonica* were obtained from the culture maintained at the Department of Entomology, College of Agriculture, Vellayani.

3.1.2.1 Mass culturing of *C. carnea* on eggs of *C. cephalonica*

3.1.2.1.1 Mass culturing of *C. cephalonica*

2.5 kg wheat flour mixed with 0.05% streptomycin sulphate and 5 g sulphur served as substratum for rearing *C. cephalonica*. Wheat flour was heat sterilized at 100^0C for one hour prior to inoculation of eggs of *C. cephalonica*. One cc eggs of *C. cephalonica* was then mixed with 2.5 kg of substratum taken in 30 cm diameter plastic basins. The basins were covered with kora cloth and kept aside for adult

emergence. The adults that emerged were transferred to oviposition cages for egg laying. The adults of *C. cephalonica* were fed with 10 per cent honey in cotton.

3.1.2.1.2 Mass culturing of *C. carnea* on *Corcyra* eggs

Individual rearing of *C. carnea* was adopted. In individual rearing, the first instar larvae of *C. carnea* on emergence from eggs were transferred separately to clean vials of 10 x 2 cm size using a camel hair brush and mouth of the vial covered with muslin cloth and fastened by rubber band. To each vial, eggs of *C. cephalonica* were sprinkled. On pupation, the pupae were collected and transferred to wide mouthed glass bottle of 15 x 8 cm size. The freshly emerged adults of *C. carnea* were transferred to plastic containers of 45 cm diameter for oviposition. Adults were provided with a semisolid diet consisting of honey, fructose, protinex and water in 1:1:1:1 mixed with water. Water was also provided in sponge bits for the adults. Observations were recorded on the developmental period, adult longevity, and fecundity.

3.1.2.2 Mass culturing of *C. carnea* on cowpea aphids, *Aphis craccivora*

The stock culture of the host insect, *A. craccivora* was maintained in potted cowpea plants, raised in a phased manner and infested periodically with field collected aphids. Individual rearing of *C. carnea* in glass vials was done. To each vial, aphids were provided as prey till pupation. The adult rearing was as mentioned in 3.1.2.1.2.

3.1.2.3 Mass culturing of *C. carnea* on spider mite, *T. ludeni*

As mentioned in 3.2.1.2, the stock culture of *T. ludeni* was also maintained in potted plants. Larval rearing of *C. carnea* was in glass vials with *T. ludeni* as hosts.

3.2. Assessment of predatory potential

3.2.1 Assessment of predatory potential of *A. longispinosus,Amblyseius.sp and M.merdarius*

Feeding potential of predatory mite, *A. longispinosus* feeding on *T. ludeni* was studied in the laboratory using eggs, nymphs and adults of *T. ludeni* separately. The eggs of spider mite were obtained on excised leaves by releasing 10 adult females of *T. ludeni* for one day. The following day, mites were removed and eggs counted. One newly emerged larvae of *A. longispinosus* was introduced on the leaf arena containing 30 eggs of *T. ludeni* in a petridish.

To assess the predatory potential of the predatory larvae on nymphs and adults of *T. ludeni*, each predator was released into leaf arena containing 30 numbers of nymphs and 20 number of adults of *T. ludeni* separately.

In the case of *Amblyseius* sp. and *M. merdarius* preying on *P. latus* ,the predatory potential of the predatory mites was assessed only on adult stage of the host. The experiments were conducted in CRD with six replications. Observations were recorded on daily prey consumption of the predators.

3.2.2 Assessment of predatory potential of *C. carnea*

The culture of *C. carnea* was maintained on eggs of *C. cephalonica* in the laboratory. From this culture, newly hatched predatory larvae were transferred and confined individually in glass vials (7.5 x 2.5 cm). Each first instar larvae was provided with 100 numbers of *T. ludeni*, the second and third instars provided with 150 *T. ludeni* daily *A. craccivora* was supplied @ 30, 40 and 60 for the first, second and third instar larvae respectively.

Observations were made at intervals of 24 h on the number of mites and aphids preyed. Mites and aphids left unpreyed were removed and fresh supply of prey ensured till cocoons were formed. Each treatment was replicated five times.

3.3 Assessment of prey preference of predators

3.3.1 Prey preference of *A.longispinosus*

Different mites viz., *T. ludeni, P. latus* and *Tyrophagus* were evaluated as prey for the adult female of *A. longispinosus*. Test mites were provided together and separately in cowpea leaf maintained in 9 cm petri dishes. To each leaf 20 numbers each of the larvae of *T. ludeni*, adults of *P. latus* and *Tyrophagus* mites were introduced. Observations were taken after 24 h on the number of each prey consumed by the predator.

3.3.2 Prey preference of *C. carnea*

Both insects and mites were evaluated as prey for *C. carnea*. The different hosts tested were *Aleurodicus dispersus*, *Amrasca biguttula biguttula*, *A. craccivora*, *P. latus*, *Scirtothrips dorsalis* and *T. ludeni*. The test organisms were provided either separately or together to the second instar larva of *C. carnea* in petridishes. Prior to the release of the predator it was starved for twelve hours. Twenty numbers of each prey were provided in multiple choice test. In single choice test forty numbers of each of the prey was provided. Experiment was conducted in CRD with five replications. Observations were recorded on number of prey consumed

3.4 Effect of pesticides on predators

Stock culture of predators *A. longispinosus* and *C. carnea* were maintained in the laboratory as mentioned in 3.1.1 and 3.1.2.

The following chemical / botanical pesticides were evaluated for their toxicity against these two predators.

T_1 Malathion 0.05%

T_1 Quinalphos 0.03%

T_2 Dicofol 0.05%

T_3 Triazophos 0.05%

T_4 Garlic emulsion 2%

T_5 Neem oil emulsion 2%

T_6 Neem garlic emulsion 5%

T_7 Emulsified extract of *Andrographis paniculata* 10%

T_8 Emulsified extract of *Hyptis suaveolens* 10%

T_9 Fish oil insecticidal soap 2.5%

T_{10} *Fusarium pallidoroseum* @ 7 x 10^6 spores/ml

T_{11} Control

The chemical pesticides were diluted with water to get the required concentration of spray solutions. The other extracts were prepared as follows.

Neem garlic emulsion

Dissolved 5 g ordinary bar soap in 50 ml luke warm water. To this 20 ml. neem oil was added and stirred vigorously to get a proper emulsion. 20 g garlic was made into a paste and mixed with 30 ml water and sieved through a muslin cloth. This garlic extract was added to the neem oil emulsion. 0.9 litres of water was further added to the above emulsion to get 1 litre of 2 per cent neem garlic emulsion.

Neem oil emulsion

Ten gram ordinary bar soap was dissolved in 50 ml water. The soap solution was mixed with 100 ml neem oil. The resultant neem oil emulsion was made upto two litres to obtain 5 per cent spray solution.

Garlic emulsion

20 g garlic was crushed and mixed with one litre water in which 5 g soap was dissolved to get 2 per cent garlic emulsion.

Spore suspension of *F. pallidoroseum*

The fungus was multiplied in rice bran. Eight day old fungus was suspended in water and then sieved through a muslin cloth and spore count estimated using a haemocytometer. The spore suspension was standardized to get 7×10^6 spores/ml.

Fish oil insecticidal soap

To get 2.5 per cent of fish oil insecticidal soap 25 g of the material was dissolved in 1 litre warm water. The experiments were conducted in CRD with five replications for *A. longispinosus* and six replications for *C. carnea*. Observations on the mortality of the predator were taken at 6, 24 and 48 hours after exposure to the pesticides. The mortality was corrected using Abbot's formula (Abbot, 1925).

3.4.1 Effect of pesticides on *Amblyseius longispinosus*

In 9 cm diameter petridishes, dry films of the pesticides at the test concentrations were made by swirling 2 ml each of the test solution and then shade drying for one hour. In addition, cowpea leaf was taken and dipped in the test solution and shade dried. The treated leaf was placed inside the petridish and six adult female were released into each petridish and the petridish was sealed using a klin film.

Mortality of the predator were recorded at 6, 24 and 48 hours. After 6 hours fresh leaf with *T. ludeni* were also provided into the petridishes as food for the predator.

3.4.2 Effect of pesticides on *C. carnea*

A dry film of the pesticide was made on a 9 cm petridish as described in 3.4.1 Ten well fed one day old first instar larvae were released into the petridishes. Observations on mortality were recorded 6 h, 24h and 48h. After six hours of exposure, eggs of *Corcyra* were provided in paper strips. After 48 hours live larvae were transferred to fresh vials and allowed to complete its development.

3.5 Field experiment

3.5.1 Cowpea

Vegetable cowpea variety Sharika was raised during March to June 2000 in the Instructional farm, College of Agriculture, Vellayani. The crop was raised in an area of 15 m x 8 m plot with a spacing of 45 x 15 cm. Each row consisting of seven numbers of plants formed one treatment, out of which five plants in the centre were observational plants. Buffer rows were maintained between treatment rows. The recommended package of practices of Kerala Agricultural University (1996) was followed excepting the pesticide application.

The experiment was laid out in Randomised Block Design with three replications and 15 treatments as follows.

T_1 *C. carnea* @ 5/plant at fortnightly intervals

T_2 *C. carnea* @ 10/plant at fortnightly intervals

T_3 *A.longispinosus* @ 10/plant at fortnightly intervals

T_4 *A.longispinosus* @ 20/plant at fortnightly intervals

T_5 (T_1 + T_3)

T_6 (T_2 + T_4)

T_7 (T_1 + T_3 + Neem garlic emulsion 2 % at fortnightly intervals)

T_8 Neem garlic emulsion 2 % at fortnightly intervals

T_9 Neem oil emulsion 5 % at fortnightly intervals

T_{10} Garlic emulsion 2 % at fortnightly intervals

T_{11} *Fusarium pallidoroseum* @ 7 x 10^6 spores / ml

T_{12} (T_1 + T_3 + T_{11})

T_{13}(T_2 + T_4 + T_{11})

T_{14} Fish oil insecticidal soap 2.5 %

T_{15} Control

The first application of pesticides / release of predators was done 45 days after planting and second 60 days after planting. Observations were recorded on population of cowpea mite, *T. ludeni*, and its predators at one, five, ten and fifteen days after treatment and the data obtained were subjected to analysis of covariance. Yield of cowpea at harvest was recorded. Economics of control operations was also analysed by working out the benefit cost ratio.

3.5.2 Chilli

Chilli crop was raised from June to October 2000 using variety Jwalasakhi in an area of 20 m x 8 m and with a spacing of 45 cm x 45 cm. Each row consisted of seven plants. Observations were taken from all the plants except the border two plants. In the experiment in chilli also the treatments were as in 3.5.1 excepting T_{11},

T_{12} and T_{13}. The treatments were given on 30 and 45 days after transplanting. Observations on the population of chilli mite ,*P. latus* and its predators were recorded at one, five, ten and fifteen days after treatment. The data obtained were subjected to analysis of covariance. Yield of chilli was recorded at harvest. The economics of control operations was also analysed by working out the benefit cost ratio.

RESULTS

4. RESULTS

4.1 Mass multiplication of predators

4.1.1 Mass multiplication of *Amblyseius* spp.

Mites belonging to the genus *Amblyseius* were observed as the major predatory mites of *T. ludeni* and *P. latus*. However, the species found preying on *T. ludeni* and *P. latus* were different. *A. longispinosus* was identified as the predator of *T.ludeni* . The species level identification of the predator found to prey on *P. latus* could not be obtained.

4.1.1.1 Mass multiplication of *Amblyseius longispinosus* on *T. ludeni*

Mass multiplication of the prey mite, *T. ludeni* (Plate 1&2) and the predatory mite, *A. longispinosus* (Plate 3& 4)could be done on leaves of vegetable cowpea in the laboratory (Plate 5). It was found that green, and mature trifoliate leaf of vegetable cowpea when placed in a vial with water remained turgid for two weeks. Rooting was seen to occur from the basal portion of the petiole. Root initiation was seen from the third day onwards as white callus at the base of petiole.

It was observed that when twenty adults of *T. ludeni* were placed on a trifoliate leaf and ten adults of predatory mite released into the same leaf one day after the release of prey mite, the predator multiplied and, on the seventh day 24 eggs, 19.4 immature stages and adults of the predator could be harvested from a leaf (Table 1). The eggs were laid singly by the predator usually on the sides of the mid rib and sometimes aside the colony of the prey mite. Occasionally the predatory mites also showed tendency to congregate

Plate 1 Tetranychid mite *Tetranychus ludeni* (cleared specimen)

Plate 2 Colony of *Tetranychus ludeni* in cowpea leaf

Plate I

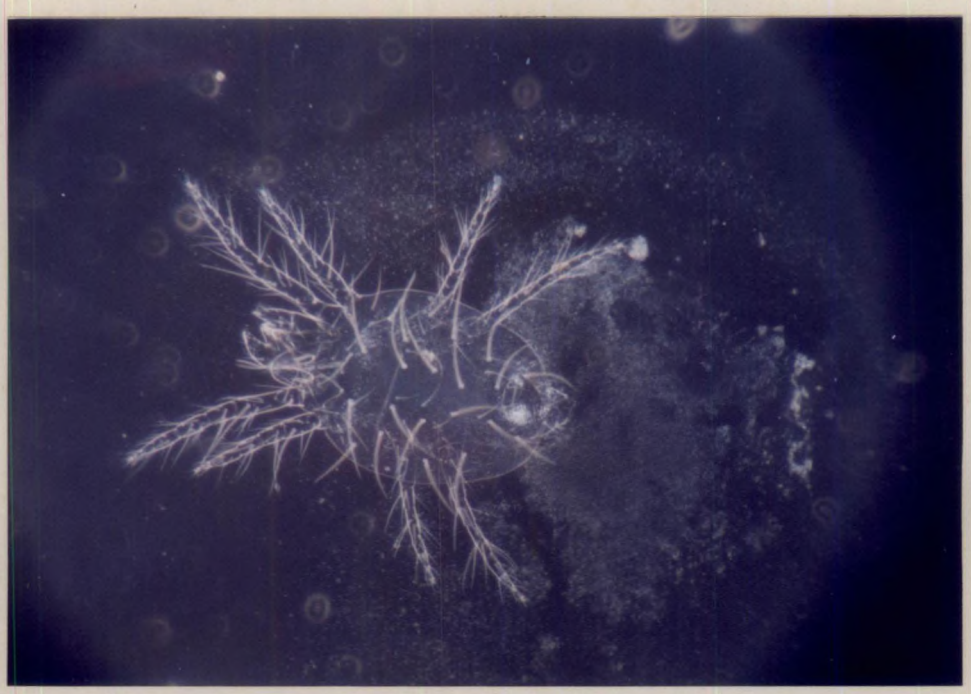


Plate 2

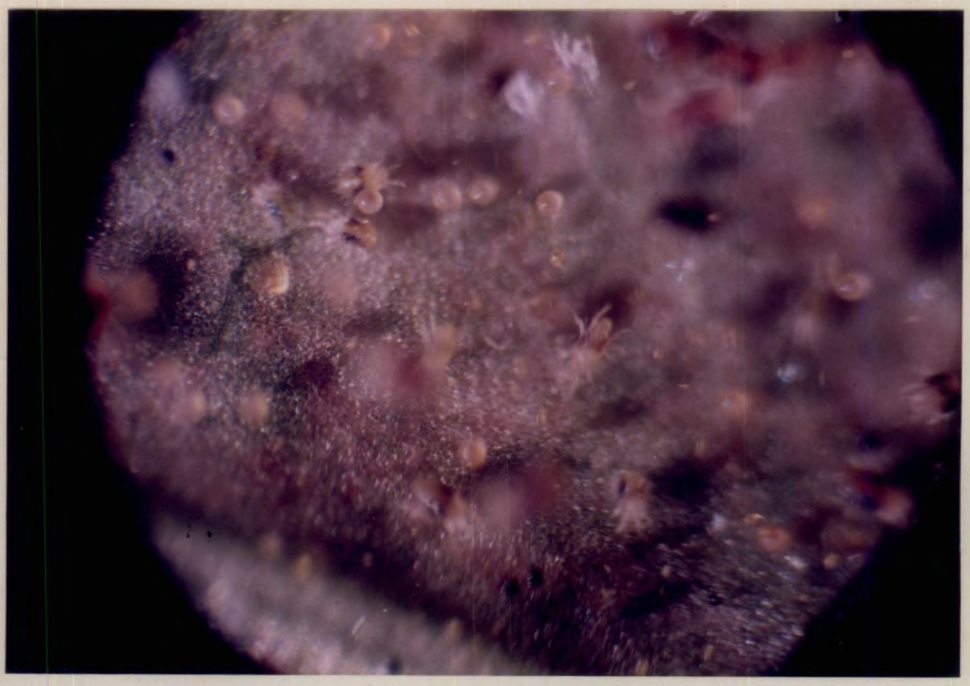


Plate 3 Predatory mite, *Amblyseius longispinosus* (cleared specimen)

Plate 4 Predatory mite, *Amblyseius longispinosus* in cowpea leaf

Plate 3

Plate 4

1. Population build up of *Amblyseius longispinosus* and *Amblyseius* sp. in excised cowpea leaves

Predatory mite	Prey mite No. provided	No. of predators released	No. of predators obtained			
			7 days		12 days	
			Eggs	Immature stages + adults	Eggs	Immature stages + adults
A. longispinosus	*T. ludeni* 20	10	24	19.4	39.6	32.2
"	15	10	10.6	16.2	26.8	23.4
"	10	10	7.2	14.8	20.8	22.6
Amblyseius sp.	*P. latus* 200	10	23	20.2	31.2	25.4

Plate 5 Multiplication of *Amblyseius longispinosus* in excised cowpea leaf

Plate 5

and make their own colonies when the population of the predator increased. Crowding of the predator was checked by removing ten adults of the predator from the leaf seven days after the release. Twelve days after release 39.6 eggs and 32.2 immature stages and adults of the predator could be obtained. When ever the population of the predatory mite exceeded thirty in a trifoliate leaf signs of dispersal were exhibited by the predator even though prey mite was available. When fifteen members of the prey mite were placed in a trifoliate leaf and ten predators released into it on the seventh day the predator increased to the tune of 16.2 immature stages and adults and 10.6 eggs. After removing ten adults of the predator from the leaf on the seventh day. The predator multiplied to 26.8 eggs and 23.4 immature stages and adults on the twelfth day.

When ten predatory mites were released along with ten adults of *T.ludeni* the predator multiplied to 14.8 immature stages plus adults and 7.2 eggs on the seventh day and in the twelfth day the corresponding figures were 22.6 and 20.8 respectively.In this case it was necessary to supplement fresh prey on the fourth day @10 adult mites per leaf.

4.1.1.2 Mass multiplication of *Amblyseius* sp. on *P. latus*

On releasing 10 predatory *Amblyseius* sp. (Plate 6) preying on *P. latus* into a trifoliate consisting of 200 numbers of the prey, the population of the predator doubled in a week (20.2 immature stages and adults). The prey was completely extinguished on the twelfth day. The mean count of the predator increased to 25.4 immature stages and adults and 31.2 eggs.

Plate 6 Predatory mite of chilli, *Amblyseius* sp.

Plate 6

Plate 7 Predatory mite, *Macrochelus merdarius*

Plate 8 Rice bran mite, *Tyrophagus* sp.

Plate 7

Plate 8

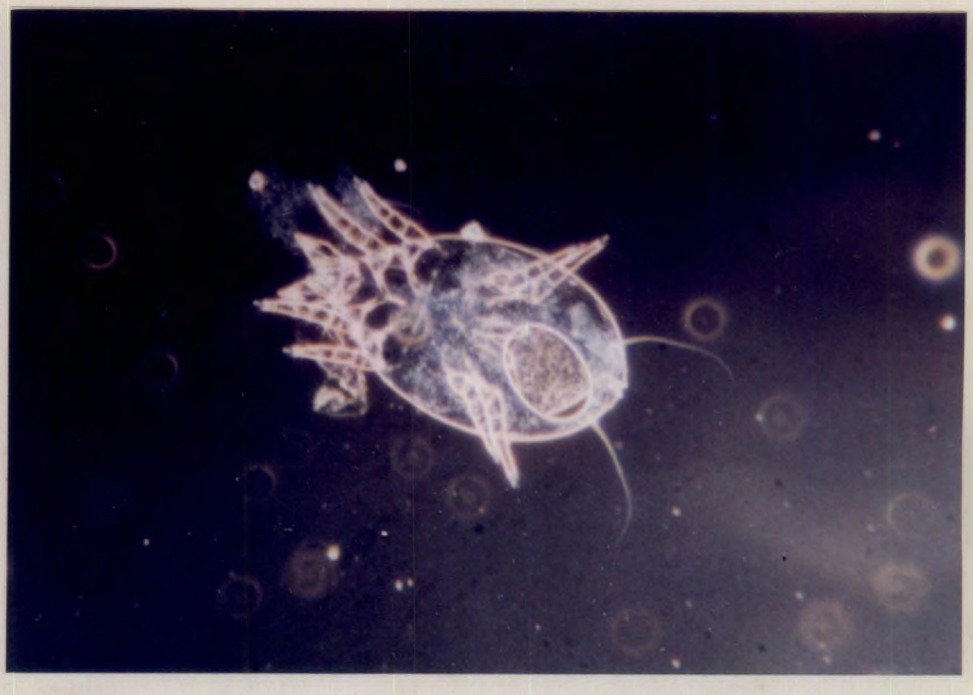
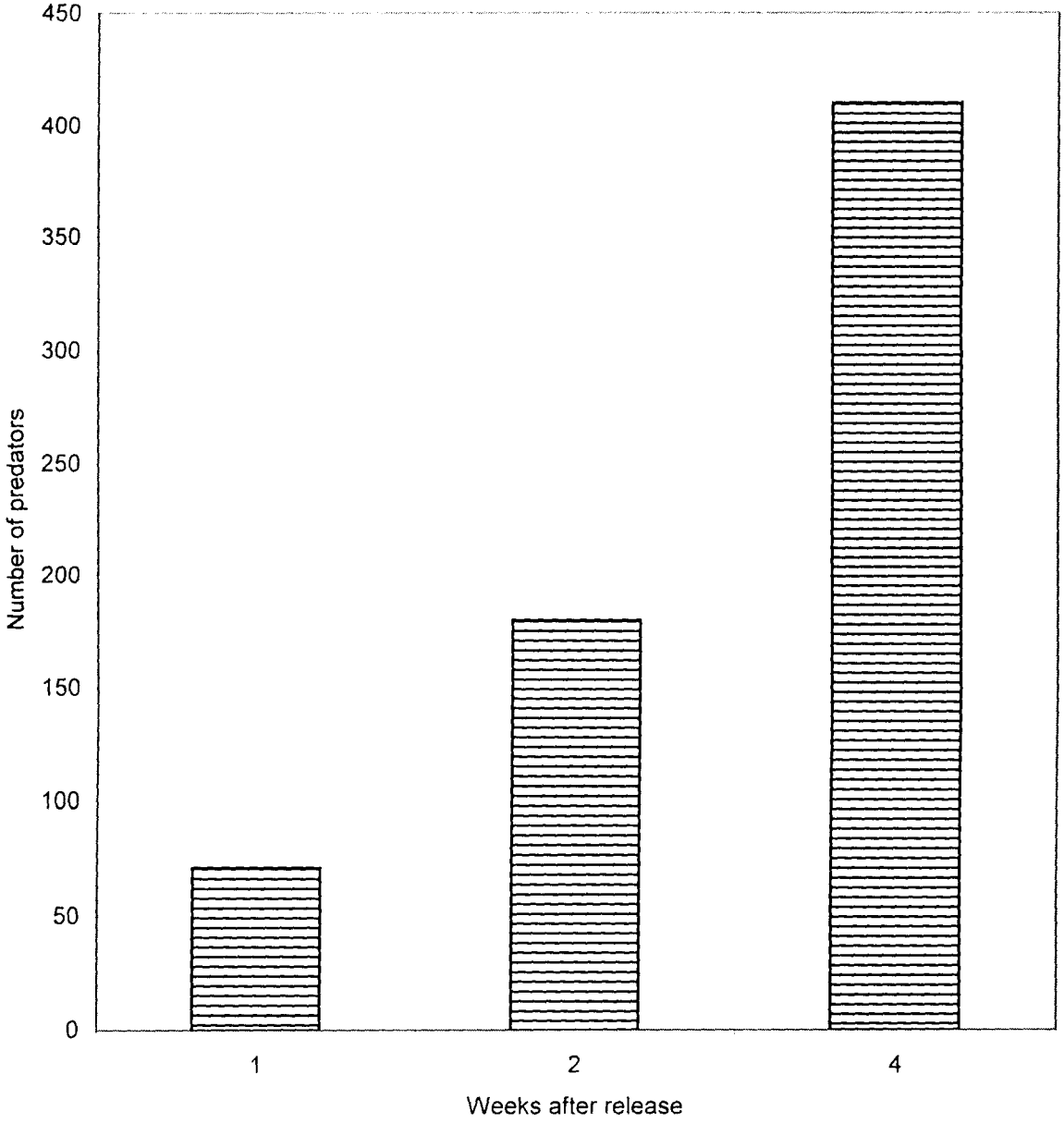


Fig. 1 Rate of multiplication of *Macrochelus merdarius* on *Tyrophagus* sp.



4.1.1.3 Mass multiplication of *Macrochelus merdarius* (Berlese) on rice bran mites

A Macrocheyletid mite, associated with rice bran mite was observed as an efficient predator of chilli mite, *P. latus* in the laboratory. This predator and rice bran mite were identified as *M. merdarius* (Plate 7) and *Tyrophagus* sp.(Plate 8) respectively. *Caloglyphus* and *Suidasia* mites of the family Acaridae were occasionally seen associated with *Tyrophagus* sp. in rice bran.

Attempts made to mass culture *M. merdarius* on *Tyrophagus* sp had given encouraging results. The results showed that by releasing forty *M. merdarius* into a bottle containing 500 numbers of *Tyrophagus* sp., on the seventh day the predator multiplied to a mean population of 71.25 (Fig 1). The release of another 500 numbers of *Tyrophagus* into the same bottle increased the number of predators to 180 during the second week and to 410 during the fourth week respectively .

4.1.1.4 Mass multiplication of predatory mite *A. longispinosus* on alternate diet

Data relating to the fecundity and developmental periods of *A.longispinosus* in alternate diet is provided in Table2. There was significant difference in the number of eggs laid by the predatory mite fed on different diets . Maximum number of eggs were laid by the predator which was fed on pollen. While hibiscus pollen fed adults laid a mean number of 10 eggs per female, Acacia pollen fed adults laid eight eggs per female. Eggs were also laid by adult females fed only on water but the number of eggs laid was much less (2.33). The mean number of eggs laid per day was also high for pollen

Table 2 Developmental period and fecundity of *Amblyseius longispinosus* on alternate diets

Treatment	Predators released	Mean No. of eggs laid	Mean longevity of adults (days)	Mean No. of eggs per day	Mean percent egg Hatch	Duration (days) and stage upto which the first generation survived
1. Pollen of *Acacia auriculiformis*	5	8^{ab}	7.00^{bcdef}	1.14	75	9.3 (Adult)
2. Pollen of *Hibiscus rosa-sinensis*	5	10^{a}	12.00^{a}	0.83	80	9.0 (Adult)
3. Yeast extract + 20 % sucrose (1:1)	5	4^{d}	6.33^{defg}	0.63	57.7	Protonymph
4. Yeast extract + 10 % Honey + Casein protein (5:5:1)	5	4^{dc}	10.33^{ab}	0.39	75	Protonymph
5. Yeast extract + Egg yolk + 10 % Honey (1:2:1)	5	8^{abc}	10.33^{abc}	0.77	62.5	Deutonymph
6. Egg yolk + 10% Honey + Casein protein (10:5:1)	5	3^{def}	7.66^{bcde}	0.39	66.66	Protonymph
7. Egg yolk + 10 % Honey + protinex (2:1:1)	5	2^{defgh}	5.66^{defgh}	0.35	100	Larva
8. Water	5	2.33^{defg}	8.00^{bcd}	0.29	40	Protonymph
CD (0.05)		3.60	3.73			

Means accompanied by common letters are not significantly different.

fed adults. A mean number of 1.14 and 0.833 eggs per day were laid by adults fed on pollen of *Acacia* and pollen of *Hibiscus* respectively.

The eggs laid by adults fed on *Hibiscus* and *Acacia* pollen showed 75 and 80 per cent hatching and the young ones developed from these eggs completed development to adults in 9 and 9.3 days respectively.

None of the larvae fed on artificial diet surpassed the protonymphal stage except in the diet with yeast extract + egg yolk + Honey (1:2:1) where 60 percentage survived till deutonymphal stage.

4.1.1.5. Biology *of Amblyseius* spp.

4.1.1.5.1 Biology *of Amblyseius longispinosus* on *T. ludeni*

The data relating to the developmental period of *A. longispinosus*. When reared in a colony consisting of different stages of *T. ludeni* is presented in Table 3. The predatory mite completed its development in 6.85 ± 0.46 days on *T. ludeni*. The mean duration of the egg, larva, protonymph and deutonymph of the predator was 3 ± 0.35, 0.88 ± 0.13, 1.43 ± 0.18 and 1.55 ± 0.14 days respectively. The adult *A. longispinosus* was found to live for a period of 13.2 ± 3.7 days during which a single female laid 25.2 ± 3.83 eggs. The mean daily oviposition was 2.02 ± 0.59 eggs.

The biology of the predator *A.longispinosus* preying *T ludeni* was studied on each stage of the prey mite also. The data relating to the study is presented in Table 4.It is seen from the data that the predatory mite completed its life cycle on *T. ludeni* with in a week. The total time taken for completing its life cycle ranged from 6.2 ± 0.27 to 7.3 ± 0.57 on the different stages of the host mite.

Table 3 Duration of life stages of *Amblyseius longispinosus* on *Tetranychus ludeni* and *Amblyseius* sp. on *Polyphagotarsonemus latus*

Stage of the predator	Developmental period (days)	
	A.longispinosus mean ± SE	*Amblyseius* sp. mean ± SE
Egg	3 ± 0.35	2.71 ± 0.19
larvae	0.88 ± 0.13	0.78 ± 0.09
Protonymph	1.43 ± 0.18	1.17 ± 0.16
Deutonymph	1.55 ± 0.14	1.13 ± 0.09
Total duration (days)	6.85 ± 0.46	5.79 ± 0.44
Adult longevity (days)	13.2 ± 3.7	14.2 ± 2.28
Fecundity	25.2 ± 3.83	29.2 ± 7.25
Mean No. of eggs/day	2.02 ± 0.59	2.17 ± 0.05

SE - Standard error

Table 4 Developmental period of *Amblyseius longispinosus* on different stages of *Tetranychus ludeni*

Stage of prey	Duration in days
Egg	6.6 ± 0.54
Larva	6.2 ± 0.27
Nymph	7.3 ± 0.57
Adult	7.00 ± 0.61

SE - Standard error

4.1.1.5.2 Biology of *Amblyseius* sp. on *P. latus*

The data with respect to the developmental period of *Amblyseius* sp. *on P. latus* is also presented in Table 3. It was seen that the predatory mite completed its development on chilli in less than a week (5.79 ± 0.44). However, the adult of the predator was found to thrive on chilli mite for about a fortnight (14.2 ± 2.28 days). The mean number of eggs laid by a female was 29.2 ± 7.25 and the mean daily egg production was 2.17 ± 0.05.

4.1.2 Mass multiplication of *C. carnea*

The development of *C. carnea* (Plate 9) on different hosts viz., *A. craccivora*, *T. ludeni* and *Corcyra* eggs were studied and the data is presented in Table 5.

Among the three hosts tested, developmental period was shortest when reared on eggs of *C. cephalonica* (Table 5). The mean number of days required to complete the larval development on this host was 8.3 ± 0.67. The next preferred host was *A. craccivora* with a developmental period of 9.4 ± 0.54 days.

The adult longevity was also higher on *Corcyra* eggs (51.22 ± 6.97) compared to *T. ludeni* (24.3±6.34). There was significant difference in the number of eggs laid by *C. carnea* when reared on different hosts. A mean number of 219.53 eggs were laid when reared on *Corcyra* eggs while it was only 41.53 when reared on *T. ludeni*. Evidently the oviposition period was also lower on *T. ludeni* (14.4 ± 0.89) compared to *Corcyra* eggs (35.6 ± 1.34).

Plate 9 Larvae of *Chrysoperla carnea*

Plate 9

Table 5. Biology of *Chrysoperla carnea* reared on different prey

Prey	Devolopmental period(days)				Pupa Mean ± SE	Oviposition Period (days)	Adult longevity (Days)	Fecundity Eggs/female
	Larval instars			Total larval period				
	First Mean± S.E	Second Mean± SE	Third Mean± SE	Mean± SE		Mean± SE	Mean± SE	
Aphis craccivora	2.8 ± 0.44	3.8 ± 0.44	2.6 ± 0.55	9.4 ± 0.54	6.7 ± 0.71	25.8 ± 0.83	41.4± 8.7	117
Tetranychus ludeni	3.00	3. 4 ± 0.55	4.2± 0.83	10.6 ± 1.14	8.6 ± 0.84	14.4 ± 0.89	24.3 ±6.34	41.53
Corcyra cephalonica	2.1 ± 0.22	3.00	3.2 ± 0.57	8.3 ± 0.67	5.8 ± 0.63	35.6 ± 1.34	51.22 ± 6.97	219.53
CD. (0.05)								19.44

SE – Standard error

4.2 Predatory potential

4.2.1.1 Predatory potential of *A. longispinosus* on *T. ludeni*

All the stages of the predatory mite viz. The larva, protonymph, deutonymph and adults preyed on *T. ludeni*. The data relating to the feeding potential of different instars on *T. ludeni* is presented in Table 6. It was observed that the larvae of the predatory mite preyed on all stages of the spider mite excluding the adults. However the most preferred stage was eggs and it was followed by larvae and nymphs. The mean number of eggs, larvae and nymphs consumed by a single predatory larva was 0.8 ± 0.84, 0.6 ± 0.55 and 0.4 ± 0.54 respectively.

Compared to the larvae, the protonymph and deutonymphs had higher feeding potential on *T. ludeni* but the most voracious stage of the predator was adults. While the protonymphs and deutonymphs consumed 4.4 ± 1.14 and 5.8 ± 0.84 eggs during a span of 1.5 and 1.6 ± 0.54 days; the adults consumed 118. 8 ± 11.8 eggs during a span of 12 ± 2.55 days. The nymphal stages and adults of the predatory mite was also observed to feed on adults of *T. ludeni*, in addition to the egg, larval and nymphal stages of the prey. Here also the adults exhibited a higher feeding potential and each adult *A.longispinosus* consumed 37.2 ± 6.3 adults of *T. ludeni*.

4.2.1.2 Predatory potential of *Amblyseius* sp. *and M. merdarius* on *P. latus*

The relevant data is presented in Table 7. All the stages of the predator excepting the larvae fed on the adults of the prey mite, *P. latus*. The larval stage of the predator was seen to feed only on the prey larvae. The mean consumption during the larval period was 1.16 ± 0.75 mites per larvae.

Table 6 Predatory potential of *Amblyseius longispinosus* on *Tetranychus ludeni*

Prey / Predator	Mean number of different stages of prey consumed			
	Egg Mean ± SE	Larva Mean ± SE	Nymph Mean ± SE	Adult Mean ± SE
Larva	0.8 ± 0.84	0.60 ± 0.55	0.4 ± 0.54	0.00
Protonymph	4.4 ± 1.14	1.4 ± 0.55	0.4 ± 0.54	1.2 ± 0.48
Deutonymph	5.8 ± 0.84	1.8 ± 0.83	0.8 ± 1.3	1.4 ± 1.14
Adult	118.8 ± 11.8	37.2 ± 6.3	23.8 ± 4.81	18.2 ± 2.68

SE – Standard error

Mean of five replications

Table 7 Predatory potential of *Amblyseius* sp. and *Macrochelus merdarius* on *Polyphagotarsonemus latus*

Prey / Predator	Mean number of different stages of prey consumed		
	Larva Mean ± SE	Nymph Mean ± SE	Adult (per day) Mean ± SE
Amblyseius sp.			
Larva	1.16 ± 0.75	0.00	0.00
Nymph	7.00 ± 1	6.66 ± 1.42	4.55 ± 0.77
Adult	9.66 ± 1.91	8.66 ± 0.76	16.36 ± 2.62
M. meridarius (Adult)	-	-	43.35 ± 1.82

SE – Standard error

Mean of six replications

Both the first and second stages of the predatory nymph together consumed 7.0 ± 1.00, 6.66 ± 1.42 and 4.55 ± 0.77 adults. Each adult predator consumed 9.66 ± 1.91 larvae, 8.66 ± 0.76 nymphs and 16.36 ± 2.63 adults of the prey mite during a period of three days.

The predatory mite *M. merdarius* was also found to be an efficient predator of *P.latus* in the laboratory .The adult female predator consumed 43.35 ± 1.82 adult *P.latus* during a period of three days.

4.2.2 Assessment of predatory potential of *C. carnea*

C. carnea was observed to feed on two important pests of cowpea viz. *A. craccivora* and *T. ludeni*. The data relating to the predatory potential of *C. carnea* and developmental periods on two these two pests, studied under laboratory conditions is presented in Table 8.

4.2.2.1 Predatory potential on *A. craccivora*

C. carnea was observed to feed on both nymphs and adults of *A. craccivora*. The total number of *A. craccivora* consumed by the predaceous larva during its developmental period was 419 ± 9. 14. The number of aphids consumed varied with the different instars and the mean number of aphids consumed by the first, second and third instar larvae were 73.60 ± 15.8, 184 ± 18.27 and 161.4 ± 23.5 respectively. The mean daily consumption was highest for the third instar larvae. Each third instar larvae consumed 57.9 ± 4.26 aphids daily. While the first and second instar larvae consumed 48.65 ± 3.81 and 26.11 ± 2.6 aphids daily.

Table 8. Predatory potential of *Chrysoperla carnea* on different prey

Stage of *C.carnea*	Mean number of prey consumed			
	Aphis craccivora		*Tetranychus ludeni*	
	Total Mean ± SE	**Mean No. per day** Mean ± SE	**Total** Mean ± SE	**Mean No. per day** Mean ± SE
1- Instar	73.60 ± 15.80	26.11 ± 2.60	164.2 ± 10.82	54.72 ± 3.59
2- Instar	184 ± 18.270	48.65 ± 3.81	297.8 ± 46.87	87.58 ± 2.40
3- Instar	161.4 ± 23.50	57.9 ± 4.26	602.6 ± 129.90	136.82 ± 5.71
Total	419. 0 ± 9.14	44.22 ± 2.77	1064.6 ± 135.70	93.06 ± 8.59

SE – Standard error

Mean of five replications

4.2.2.2 Predatory potential on *T. ludeni*

The feeding potential of *C. carnea* was found to be high when *T. ludeni* was provided as prey. Each *C. carnea* consumed 1064.6 ± 135.7 adults of *T. ludeni* during its developmental period. Out of this 164.2 ± 10.82 were consumed during the first instar. Corresponding with the growth of the larvae the subsequent instars showed a higher feeding potential and the mean number of *T. ludeni* consumed were 297.8 ± 46.87 and 602.6 ± 129.9 during the second and third instars respectively. The mean daily consumption was also highest for the third instar (136.82 ± 5.71) compared to 54.72 ± 3.59 and 87.58 ± 2.40 for first and second instar larvae(Table 8)

4.3 Prey preference of predators

4.3.1 Prey preference of predatory mite, *A. longispinosus*

The data on prey preference of *A. longispinosus*, evaluated by single choice and multiple choice tests are presented in Table 9. The predatory mite fed on both the phytophagous mites and completely avoided the *Tyrophagus* mites. Even though the predatory mite fed on both the phytophagous mites provided there was significant difference in their preference .The adult predator consumed 30.43 percent of *T.ludeni* supplied in 24 hours where as only 6.73 percent of *P.latus* were consumed during period in the multiple choice test. In the single choice test also the predator consumed only 20.32 percent of *P.latus* supplied where as 51.43 percent of *T.ludeni* supplied were consumed.

Table 9. Mean percentage of prey consumed by *Amblyseius longispinosus* in multiple choice and single choice tests

Prey	No. of mites supplied	Mean percentage of prey consumed in 24 hours	
		Multiple choice	Single choice
T. ludeni	20	30.43 (5.60)[a]	51.43 (7.24)[a]
P. latus	20	6.73 (2.78)[b]	20.32 (4.61)[b]
Tyrophagus sp.	20	0 (1)[c]	0 (1)[c]
CD (0.05)		1.38	1.68

Means followed by same letter are not significantly different

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

Table 10 Mean percentage of prey consumed by *Chrysoperla carnea* at different intervals in multiple choice and single choice tests

Sl. No.	Prey	No. of prey provided	Mean percentage of prey consumed		
			Multiple choice		Single choice
			Period after release (h)		
			24	48	24
1	*Aphis craccivora*	40	67.98 (8.31)[a]	100 (10.04)[a]	86.50 (9.35)
2	*Tetranychus ludeni*	40	23.14 (4.91)[b]	66.22 (8.19)[b]	96.80 (9.88)
3	*Aleurodicus dispersus*	40	2.07 (1.75)[cdc]	5.28 (2.50)[e]	26.00 (5.16)
4	*Scirtothrips dorsalis*	40	7.74 (2.95)[c]	40.80 (6.46)[c]	68.50 (8.31)
5	*Amrasca biguttula biguttula*	40	3.75 (2.17)[cd]	23.14 (4.91)[d]	48.00 (6.98)
	CD (0.05)		1.47	1.24	0.66

Means accompanied by common letters are not significantly different

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

4.3.2 Prey preference of *C. carnea*

The results on the prey preference of *C. carnea*, evaluated by single choice and multiple choice tests are presented in Table 10. The predator was observed to feed on all the prey supplied viz. *A. craccivora*, *T. ludeni*, *A. dispersus*, *S. dorsalis* and *A. biguttula biguttula* ,but there was significant difference in the preference shown towards the prey. The most preferred host was *A. craccivora*. The larvae consumed all the aphids supplied (40 numbers.) within 48 hours. Next preference was shown for the mite, *T. ludeni*. The mean percentage consumption of the mite was 23.14 and 66.22 within 24 and 48 hours respectively. The preference was least for the spiralling white fly, *A. dispersus*. In the single choice tests also the predator consumed only 10.4 per cent of the white fly where as 86.5 per cent and 96.8 per cent of the aphids and mites were consumed.

4.4 Effect of pesticides on the predators

4.4.1 Effect of pesticides on the predatory mite, *A.longispinosus*

The data on the contact toxicity of pesticides to the adults of the predatory mite, *A. longispinosus* is presented in Table 11. In the observations recorded six hours of exposure to the recommended dose of pesticides, 7.28 to 100 per cent mortality was seen in the different treatments. Cent percent mortality of the predatory mite was noted in triazophos 0.05 per cent. This was followed by dicofol, quinalphos and malathion with mean values of 79.77, 60.84 and 57.21 respectively.

Among the botanical pesticides evaluated, neem oil emulsion five per cent showed the highest mortality (42.30). This was closely followed by

Table 11 Toxicity of pesticides to *Amblyseius longispinosus* at different intervals after exposure

Treatments	Percentage mortality		
	6h	24h	48h
Malathion (0.05%)	60.84 (7.86) ^{bc}	100 (10)^{a}	100 (10)^{a}
Quinalphos (0.03%)	57.21 (7.62)^{bcd}	100 (10)^{ab}	100 (10)^{ab}
Dicofol (0.05%)	79.77 (8.98)^{ab}	100 (10)^{abc}	100 (10)^{abc}
Triazophos (0.05%)	100 (10)^{a}	100 (10)^{abcd}	100 (10)^{abcd}
Garlic emulsion (2.0 %)	26.50 (5.24)^{fg}	37.71 (6.22)^{efgh}	37.71 (6.22)^{efghi}
Neem oil emulsion (5.0 %)	42.30 (6.58)^{cde}	42.30 (6.58) ^{e}	42.30 (6.58)^{ef}
Neemgarlic emulsion (2.0%)	40.02 (6.4)^{cdef}	41.58 (6.52)^{ef}	41.58 (6.52)^{efg}
Emulsified extract of *Andrographis paniculata* (10 %)	10.63 (3.41)^{ghij}	28.83 (5.46) ^{efghi}	38.73 (6.30)^{efgh}
Emulsified extract of *Hyptis suaveolens* (10 %)	14.22 (3.90)^{ghi}	40.42 (6.43)^{efg}	47.63 (6.97)^{e}
Fish oil insecticidal Soap (2.5 %)	16.3 (4.15)^{gh}	27.22 (5.31)^{efghij}	27.22 (5.31) ^{fghij}
Fusarium pallidoroseum @ 7 x 10^{6} spores /ml	7.28 (2.87)^{ghijk}	6.10 (2.66)^{k}	6.10 (2.66)^{K}
CD (0.05)	1.81	1.46	1.44

Means accompanied by common letters are not significantly different

Figures in parenthesis are transformed using $\sqrt{x+1}$

neem garlic emulsion with 40.02 per cent mortality. Only 7.28 per cent mites were found dead when exposed to spore suspension of *F. pallidoroseum* @ 7 x 10^6 spores/ml and this treatment was on par with the mortality observed in fish oil insecticide soap 2.5 per cent (16.3).

All the synthetic insecticides evaluated were observed to be highly toxic to the predatory mites. All the mites were found dead in the subsequent observation recorded 24 hours after exposure to the insecticide. An increase in the mortality of mites was observed in the botanicals too. However, the mortality was much less than that in synthetic insecticides and the maximum mortality was only 47.63 per cent (*H. suaveolens* 10 per cent extract) after 48 hours of exposure.

4.4.2 Effect of pesticides on *C. carnea*

The data on the contact toxicity of pesticides to the first instar larvae of *C. carnea* are presented in Table 12.

There was significant difference in the mortality of *C. carnea* in the observations taken 6, 24 and 48 hours after exposure to the pesticides.Triazophos 0.05 per cent showed the highest mortality of *C. carnea* (87.67). This was followed by quinalphos 0.03 per cent (47.92) and malathion 0.05 per cent (27.92). All the botanicals tested showed less mortality when compared with chemical pesticides except dicofol 0.05 percent. However, mortality to the range of 0.92 percent (garlic emulsion 2 per cent) to 14.59 per cent (Neem oil 2 per cent and *H. suaveolens* 10 per cent) was observed when the larvae were exposed to botanicals for six hours.

Table 12 Toxicity of pesticides to *Chrysoperla carnea* at different intervals after exposure

Treatments	Percentage mortality		
	6h	24h	48h
Malathion 0.05%	27.92 (5.37)^{C}	79.27 (9.55) ^{abc}	86.66 (9.33) ^{abc}
Quinalphos 0.03%	47.92 (6.99)^{b}	96.55 (10.4) ^{ab}	96.12 (10.39) ^{ab}
Dicofol 0.05%	0 (1)^{J}	4.78 (4.09)^{ghi}	5.82 (4.22) ^{ghi}
Triazophos 0.05%	87.67 (9.41)^{a}	100 (10.58) ^{a}	100 (10. 58)^{a}
Garlic emulsion (2. %)	0.92 (1.38)^{hi}	2.24 (3.77)^{ghij}	0.75 (3.35)^{k}
Neem oil emulsion (5 %)	14.59 (3.94)^{de}	8.55 (4.50)^{defg}	15.84 (5.28) ^{defg}
Neemgarlic emulsion (2.5%)	7.79 (2.96)^{defg}	22.52 (5.87)^{d}	20.88 (5.73) ^{d}
Emulsified extract of *Andrographis paniculata* (10 %)	10.79 (8.43)^{def}	18.96 (5.56)^{def}	17.80 (5.45) ^{def}
Emulsified extract of *Hyptis suaveolens* (10 %)	14.59 (3.95)^{d}	20.09 (5.66)^{de}	18.50 (5.52) ^{de}
Fish oil insecticidal Soap (2.5 %)	0 (1)^{k}	7.31 (4.39)^{efg}	6.40 (4.28) ^{fgh}
Fusarium pallidoroseum @ 7 x 10^{6} spores /ml	0 (1)^{h}	1.11 (3.62) ^{ghijk}	0.11 (3.48)^{J}
CD (0.05)	1.31	1.88	1.73

Means accompanied by common letters are not significantly different

Figures in parenthesis are transformed using $\sqrt{x+1}$ second and third column being transformed using $\sqrt{x+12}$

In general, there was an increase in the mortality of *C. carnea* in the observations taken 24 and 48 hours after exposure in all the treatments. While cent per cent mortality was recorded in triazophos 0.05 per cent, the mortality in quinalphos 0.03 per cent and malathion 0.05 per cent were 96.12 and 86.66 per cent respectively after 48 hours of exposure. Dicofol continued to show lowest toxicity to *C. carnea* in the subsequent observations also. There was no significant difference in the mortality of *C. carnea* recorded in dicofol 0.05 per cent, garlic emulsion 2 per cent, fish oil insecticides soap2.5 percent and in *F. pallidoroseum* 7 x 10^6 spores/ml. The mortality in these treatments ranged from 0.75 to 6.40 per cent only.

4.5 Field experiments to study the role of bioagents and botanical pesticides in the management of mites infesting vegetable cowpea and chilli

4.5.1 Effect of bioagents and botanical pesticides on cowpea mite, *T. ludeni* ,predators and on yield

4.5.1.1 Effect on *T. ludeni*

The data relating to the effect of bioagents and botanical pesticides on *T. ludeni* is presented in Table 13. One day after treatment, the mean number of *T. ludeni* in treated plants ranged from 1.37 to 11.04 mites per square centimeter leaf area. The lowest incidence was in neem garlic emulsion 2 per cent + *A.longispinosus* @ 10 per plant + *C. carnea* @ 5 per plant (1.37). This was followed by neem garlic emulsion 2 per cent with a mean population of 2.35 and these treatments were on par and significantly superior to control. The mean population of *T. ludeni* in neem oil emulsion 5 per cent treated plants and garlic emulsion 2 per cent treated plants were also significantly

Table 13. Mean number of *Tetranychus ludeni* per leaf at different intervals after the release of bioagents / application of botanical pesticides

Treatments	Pre-count	Days after application/release			
		1	5	10	15
T_1 *C. carnea* @ 5/plant	6.32 (2.71)	7.05 (2.84)	3.25 (2.06)	7.64 (2.94)	6.08 (2.66)
T_2 *C. carnea* @ 10/plant	6.84 (2.80)	5.45 (2.54)	3.13 (2.03)	4.81 (2.41)	6.02 (2.65)
T_3 *A. longispinosus* @ 10/plant	6.45 (2.73)	8.49 (3.08)	7.70 (2.95)	6.13 (2.67)	5.60 (2.57)
T_4 *A. longispinosus* @ 20/plant	6.29 (2.70)	7.24 (2.87)	7.41 (2.90)	4.38 (2.32)	7.29 (2.88)
T_5 (T_1 + T_3)	8.49 (3.08)	8.12 (3.02)	8.92 (3.15)	7.01 (2.83)	6.13 (2.67)
T_6 (T_2 + T_4)	10.76 (3.43)	11.04 (3.47)	9.89 (3.30)	4.90 (2.43)	7.70 (2.95)
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	4.71 (2.39)	1.37 (1.54)	4.20 (2.28)	3.62 (2.15)	9.37 (3.22)
T_8 Neem garlic emulsion 2 %	6.40 (2.72)	2.35 (1.83)	4.20 (2.28)	7.41 (2.90)	7.82 (2.97)
T_9 Neem oil emulsion 5 %	9.05 (3.17)	3.37 (2.09)	5.66 (2.58)	8.99 (3.16)	10.09 (3.33)
T_{10} Garlic emulsion 2 %	4.52 (2.35)	3.67 (2.16)	3.75 (2.18)	8.36 (3.06)	5.76 (2.60)
T_{11} *Fusarium pallidoroseum* @ 7 x 10^6 spores / ml	10.29 (3.36)	8.12 (3.02)	7.64 (2.94)	7.94 (2.99)	9.05 (3.17)
T_{12} (T_1 + T_3 + T_{11})	7.70 (2.95)	5.40 (2.53)	7.82 (2.97)	7.70 (2.95)	9.30 (3.21)
T_{13} (T_2 + T_4 + T_{11})	6.02 (2.65)	7.29 (2.88)	5.20 (2.49)	4.57 (2.36)	3.62 (2.15)
T_{14} Fish oil insecticidal soap 2.5 %	5.10 (2.47)	4.76 (2.40)	4.76 (2.40)	7.70 (2.95)	8.36 (3.06)
T_{15} Control	6.24 (2.69)	6.67 (2.77)	8.73 (3.12)	8.24 (3.04)	8.99 (3.16)
CD		0.359	0.485	0.571	

Pre-count	Days after application/release		
	1	5	10
6.18 (2.68)	5.50 (2.55)	2.46 (1.86)	3.58 (2.14)
6.08 (2.66)	5.15 (2.48)	3.62 (2.15)	5.15 (2.48)
5.76 (2.60)	7.12 (2.85)	3.71 (2.17)	3.54 (2.13)
7.41 (2.90)	4.11 (2.26)	4.11 (2.26)	3.24 (2.06)
5.76 (2.60)	5.40 (2.53)	5.00 (2.45)	3.93 (2.22)
6.90 (2.81)	5.76 (2.60)	4.02 (2.24)	3.83 (2.21)
9.96 (3.31)	0.42 (1.19)	0.85 (1.36)	1.92 (1.71)
7.94 (2.99)	2.39 (1.84)	4.38 (2.32)	4.11 (2.26)
9.63 (3.26)	1.96 (1.72)	3.67 (2.16)	6.08 (2.66)
6.34 (2.71)	5.05 (2.46)	6.13 (2.67)	6.02 (2.65)
8.30 (3.05)	7.24 (2.87)	5.66 (2.58)	7.07 (2.84)
9.11 (3.18)	6.62 (2.76)	5.92 (2.63)	7.12 (2.85)
3.75 (2.18)	7.29 (2.88)	4.57 (2.36)	4.06 (2.25)
8.86 (3.14)	4.66 (2.38)	6.62 (2.76)	8.42 (3.07)
9.18 (3.19)	9.24 (3.20)	10.09 (3.33)	11.46 (3.53)
	0.87	0.92	0.593

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

lower than in control and the mean population in these treatments were 3.37 and 3.67 respectively. The population of *T. ludeni* in all other treatments were in par with control (6.67) and the population counts ranged from 4.76 to 11.04.

The effect of the predator, *C. carnea* in controlling *T. ludeni* was evident in the data recorded on the fifth day after treatment. Lowest population of *T. ludeni* was recorded in plants treated with *C. carnea* @ 10 per plant (3.13) and this was followed by *C. carnea* @ 5 per plant (3.25). Garlic emulsion 2 per cent (3.75), *C. carnea* 5 per plant+ *A.longispinosus* 10 per plant + Neem garlic emulsion 2 per cent (4.20), Neem garlic emulsion 2 per cent alone (4.20), fish oil insecticidal soap 2.5 per cent (4.76), the combination treatment *C. carnea*@10 per plant + *A.longispinosus* sp 20 per cent with *F. pallidoroseum* @ 7 x 10^6 spores/ml(5.2) and neem oil emulsion (5.66) showed lower population of *T. ludeni* when compared to control (8.73). However the population of *T. ludeni* in plants treated with *A.longispinosus* @ 20 and 10 per plant, *F. pallidoroseum* @ 7 x 10^6 spores /ml and its combination with *C. carnea* @ 5 per plant and predatory mite 10 per plant were on par with control (8.73). The population in these plants ranged from 7.41 to 7.82.

The effect of the predator released at higher levels was spectacular in the observations on the tenth day after treatment. Though the population of *T. ludeni* was least in the combined application of *C. carnea* 5 per plant + *A. longispinosus* 10 per plant and neem garlic emulsion 2 per cent (3.62). The incidence of *T. ludeni* in plants released with *A. longispinosus* 20 per plant, *C. carnea* 10 per plant, and in combinations of these two predators at

the higher levels tested were significantly lower than in control. The mean population in these treatments ranged from 4.38 to 4.90. Observations taken on the fifteen day after treatment showed no significant difference between the treatments. The mean population ranged from 3.62 to 10.09.

The variations observed in the population of *T. ludeni* one and ten days after the second treatment were also significant. Here also the combination of *C. carnea* 5 per cent + *A.longispinosus* 10 per plant + Neem garlic emulsion 2 per cent maintained its superiority. The population was very low in this treatment and it was only 0.42 in the observations taken one day after treatment. Neem garlic emulsion 2 per cent and neem oil 5 per cent were equally good in checking the population of *T. ludeni* and the population in these treatments were 1.96 and 2.39 respectively. The predatory mite released at higher rate also showed substantial reduction in population of *T. ludeni* (4.11) and proved superior to other treatments.

Regarding the observations taken on the fifth day after the second treatments, there was no significant difference between treatment. With reference the data on the tenth day after treatment, all the treatment except fish oil insecticidal soap 2.5 per cent had significant role in bringing down the population of *T. ludeni*. The performance of these treatments were found better with repeated application. The mean population in the treatments varied from 1.92 to 7.12 while it was 11.46 in control.

4.5.1.2 Effect on the predatory mites

The population count of predatory mites, observed at different intervals after treatment is presented in Table 14.

Table 14 Mean number of predatory mites per leaf at different intervals after the release of bioagents / application of botanical pesticides

Treatments	Pre-treatment	Days after application/release			
		1	5	10	15
T_1 *C. carnea* @ 5/plant	1.16 (1.47)	0.59 (1.26)	0.39 (1.18)	0.64 (1.28)	1.40 (1.55)
T_2 *C. carnea* @ 10/plant	1.16 (1.47)	0.72 (1.31)	0.59 (1.26)	0.69 (1.30)	2.35 (1.83)
T_3 *A. longispinosus* @ 10/plant	0.00 (1.00)	0.30 (1.14)	1.50 (1.58)	1.56 (1.60)	1.92 (1.71)
T_4 *A. longispinosus* @ 20/plant	1.19 (1.48)	0.69 (1.30)	1.40 (1.55)	1.62 (1.62)	2.57 (1.89)
T_5 (T_1 + T_3)	0.61 (1.27)	0.85 (1.36)	0.96 (1.40)	0.88 (1.37)	2.13 (1.77)
T_6 (T_2 + T_3)	0.61 (1.27)	0.93 (1.39)	0.66 (1.29)	1.99 (1.73)	1.92 (1.71)
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	1.31 (1.52)	0.06 (1.03)	0.42 (1.19)	1.62 (1.62)	1.53 (1.59)
T_8 Neem garlic emulsion 2 %	0.93 (1.39)	1.37 (1.54)	0.90 (1.38)	2.24 (1.80)	0.64 (1.28)
T_9 Neem oil emulsion 5 %	1.72 (1.65)	0.54 (1.24)	1.82 (1.68)	0.74 (1.32)	3.80 (2.19)
T_{10} Garlic extract 2 %	1.07 (1.44)	1.10 (1.45)	0.96 (1.40)	1.25 (1.50)	2.03 (1.74)
T_{11} *Fusarium pallidoroseum* @ 7 x 10^6 spores / ml	0.80 (1.34)	0.69 (1.30)	1.53 (1.59)	0.54 (1.24)	1.79 (1.67)
T_{12} (T_1 + T_3 + T_{11})	0.96 (1.40)	2.03 (1.74)	2.65 (1.91)	0.72 (1.31)	0.88 (1.37)
T_{13} (T_2 + T_4 + T_{11})	1.66 (1.63)	1.50 (1.58)	0.35 (1.83)	0.64 (1.28)	0.54 (1.24)
T_{14} Fish oil insecticidal soap 2.5 %	0.74 (1.32)	0.88 (1.37)	0.06 (1.03)	0.77 (1.33)	0.93 (1.39)
T_{15} Control	0.28 (1.13)	1.10 (1.45)	1.25 (1.50)	1.34 (1.53)	1.86 (1.69)
CD (0.05)					

Pre-treatment	Days after application/release		
	1	5	10
1.40 (1.55)	0.85 (1.36)	1.13 (1.46)	1.25 (1.50)
2.35 (1.83)	1.16 (1.47)	1.19 (1.48)	1.66 (1.63)
1.92 (1.71)	1.96 (1.72)	3.37 (2.09)	3.49 (2.12)
2.57 (1.89)	2.96 (1.99)	0.93 (1.39)	3.45 (2.11)
2.13 (1.77)	0.90 (1.38)	1.53 (1.59)	2.31 (1.82)
1.92 (1.71)	1.72 (1.65)	2.35 (1.83)	2.61 (1.90)
1.53 (1.59)	1.99 (1.73)	2.42 (1.85)	2.35 (1.83)
0.64 (1.28)	2.06 (1.75)	1.43 (1.56)	0.88 (1.37)
3.80 (2.19)	2.24 (1.80)	2.20 (1.79)	1.16 (1.47)
2.03 (1.74)	1.56 (1.60)	0.66 (1.29)	1.22 (1.49)
1.79 (1.67)	0.35 (1.16)	1.07 (1.44)	2.10 (1.76)
0.88 (1.37)	0.85 (1.36)	1.10 (1.45)	1.34 (1.53)
0.54 (1.24)	1.92 (1.71)	0.88 (1.37)	0.51 (1.23)
0.93 (1.39)	2.13 (1.77)	2.92 (1.98)	1.99 (1.73)
1.86 (1.69)	1.62 (1.62)	3.49 (2.12)	3.84 (2.20)
			0.359

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

The population of predatory mites recorded at 1,5 and 10 days after both the treatments were not significant. In the observations recorded 10 days after the second treatment, a significant difference in the population count of the predatory mite in the various treatments was observed. Control plants were found to harbour the maximum population of the predatory mites this population was on par with the population in plants released with *A. longispinosus* @ 10 and 20 per plant. A gradual increase in the population of the predatory mites was observed with time lapse. Though the population of the predatory mite also increased in plants wherein both predators were released together, the population was lower than in plants wherein the predatory mite alone was released but there was no significant difference between them. However, on plants where in *C. carnea* was given alone and where in neem garlic emulsion 2 per cent and neem oil emulsion 5 per cent alone were given, the population of the predatory mite was significantly lower.

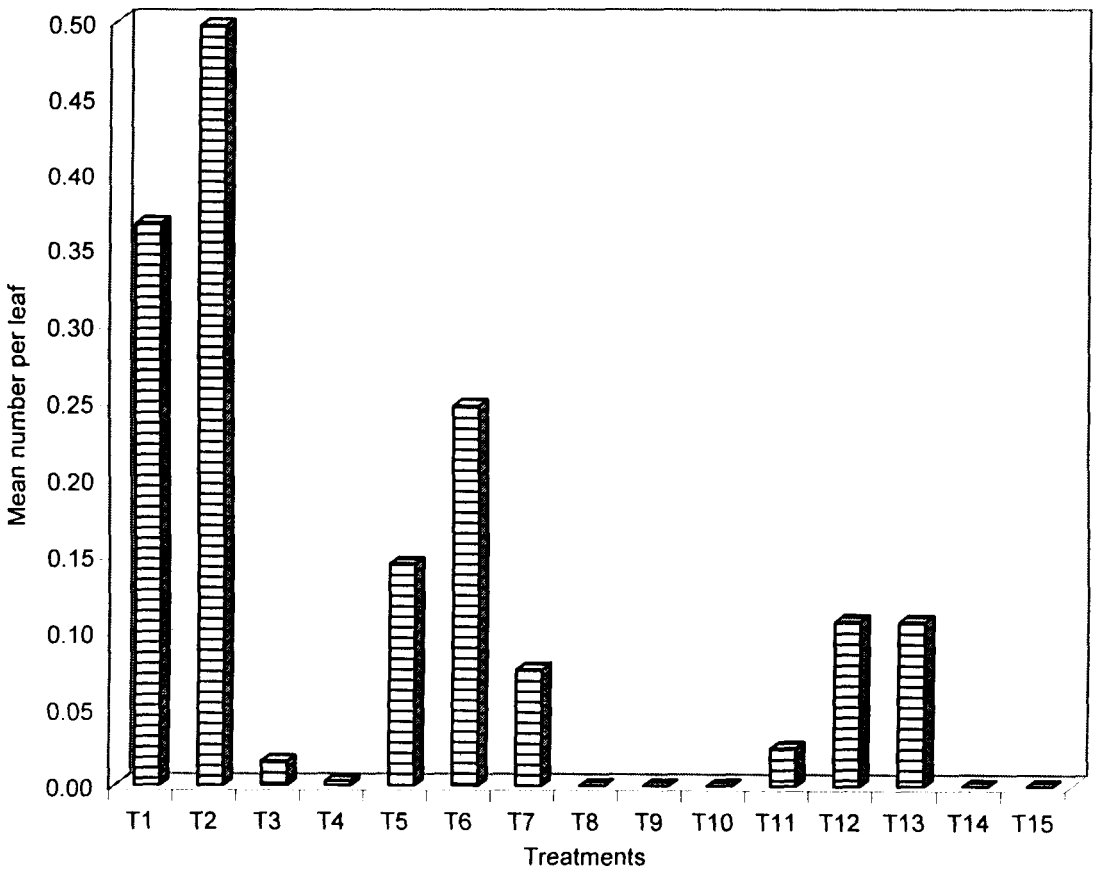
4.5.1.3 Effect on *C.carnea*

Only very low population of *C. carnea* was encountered in the field after the release of the bioagent. The mean population of the predator observed in the different treatments ranged from 0 to 0.5 predators per leaf (Fig.2).

4.5.1.4 Effect on yield

The data on yield of cowpea (in terms of the weight of pods) and the benefit cost ratio related to the different treatments is presented in Table 15. The mean weight of pods in the different treatments ranged from

Fig. 2 Mean number of *Chrysoperla carnea* per leaf after release of bioagents/ application of botanicals in Cowpea



T_1 *C. carnea* @ 5/plant at fortnightly intervals
T_2 *C. carnea* @ 10/plant at fortnightly intervals
T_3 *Amblyseius* @ 10/plant at fortnightly intervals
T_4 *Amblyseius* @ 20/plant at fortnightly intervals
T_5 (T1 + T3)
T_6 (T2 + T4)
T_7 (T1 + T3 + Neem garlic emulsion 2 % at fortnightly intervals)
T_8 Neem garlic emulsion 2 % at fortnightly intervals
T_9 Neem oil emulsion 5 % at fortnightly intervals
T_{10} Garlic emulsion 2 % at fortnightly intervals
T_{11} Fusarium pallidoroseum @ 7 x 106 spores / ml
T_{12} (T1 + T3 + T11)
T_{13} (T2 + T4 + T11)
T_{14} Fish oil insecticidal soap 2.5 %
T_{15} Control

134.67 g/plant (*F. pallidoroseum* 7 x 10^6 spores/ml) to 167.33 g/plant (neem oil emulsion 5 per cent).

The yield obtained from neem oil 5 per cent treated plants were on par with the yield from plants treated with neem garlic emulsion 2 per cent, combination treatment of *C. carnea* @ 5 per plant + *A. longispinosus* 10 per plant + Neem garlic emulsion 2 per cent, *C. carnea* @ 10 per plant + *A. longispinosus* @ 20 per plant. The mean yield in these treatments were 167.33, 164.33, 148.33 and 155 g respectively and were superior to control. The yield obtained from rest of the treatments were on par with control.

An analysis of the benefit cost ratio (Table 15) showed that the best treatment for management of *T. ludeni* in cowpea is application of neem oil 5 per cent with a cost benefit ratio of 1:1.21 and this was followed by neem garlic emulsion (1 : 1.20), fish oil insecticidal soap (1 : 1.04) and garlic emulsion (1 : 1.02). All the other treatments were not at all economical in the management of *T. ludeni*. The details pertaining to the calculations on the cost of production of the bioagents/botanicals is presented in 4.5.1.5.

4.5.1.5 Cost of production of bioagents/botanicals

4.5.1.5 Cost of production of bioagents / botanicals

1. *Chrysoperla carnea*

Cost of production of one egg = 13 paise (Fixed by State Biocontrol Laboratory, Mannuthy. Personal Communication)

Number of *C.carnea* required /ha. @ 5 per plant = 740740

Labour charge for release of *C.carnea* once = 160/-

Total amount required for production and release once in one hectare @ 5 per plant = Rs. 96456

Total amount required for production and release twice in one hectare @ 5 per plant = Rs.192912

Total amount required for production and release twice in one hectare @ 10per plant = Rs.385504

2. *Amblyseius longispinosus*, reared on excised cowpea leaves

Number of plants per ha.= 148148

Number of *A.longispinosus* required per hectare @ 10 per plant = 1481480

Number of *A.longispinosus* produced in a single unit (Trifoliate leaf) within 12 days = 40

Number of units handled by a person = 1000

Total labour required for production of *A.longispinosus* = 37

Wages per labour = Rs.160 per day

Labour required for release = 1/ha.

Total amount required for production and release of *A.longispinosus* once @ 10 per plant = Rs. 6080

Total amount required for production and release of *A.longispinosus* twice @ 10 per plant = Rs. 12160

Total amount required for production and release of *A.longispinosus* twice @ 20 per Plant = Rs. 24000

3. *F.pallidoroseum*

Cost of . *F.pallidoroseum* for 100g packet = Rs.4

Total amount required per ha. = 750 packets

Total amount required for production and application of *F.pallidoroseum* utilizing two labourers for application @ 7×10^6 spores per ml in one hectare once = Rs. 3320

4. Neem garlic emulsion

Cost of neem oil = Rs. 72 per kg

Quantity of neem oil required /ha. = 10 kg

Cost of garlic Rs. 26 per kg

Quantity of garlic required /ha = 10 kg

Cost of soap = Rs. 32/kg

Quantity of soap required /ha = 2.5 kg/ha.

Total cost for application of Neem garlic emulsion 2% in one hectare utilizing two labourers for application @ 500 l of spray fluid once = 1380/-

Total cost for application of Neem garlic emulsion in one hectare @ 500 l of spray fluid twice = Rs. 2760

5. Neem oil emulsion

Quantity of neem oil required /ha. = 25 kg

Cost of neem oil = Rs. 72 per kg

Cost of soap = Rs. 32/kg

Quantity of soap required /ha = 2.5 kg/ha.

Total cost for application of Neem oil emulsion in one hectare utilizing two labourers for application @ 500 l of spray fluid once = 2200/-

Total cost for application of Neem oil emulsion in one hectare for application @ 500 l of spray fluid twice = Rs. 4400

6. Garlic Emulsion

Cost of garlic Rs. 26 /kg

Quantity of garlic required /ha = 10 kg

Cost of soap = Rs. 32/kg

Quantity of soap required /ha = 2.5 kg/ha.

Total cost for application of garlic emulsion 2% in one hectare utilizing two labourers for application @ 500 l of spray fluid once = 660/-

Total cost for application of garlic emulsion in one hectare for application @ 500 l of spray fluid twice= Rs. 1320

7. Fish oil insecticidal soap

Cost of Fish oil insecticidal soap = Rs 54/ kg

Quantity of fish oil insecticidal soap required = 12.5 kg/ha.

Table 15. Economics of management of *Tetranychus ludeni* in cowpea

Treatment	Yield per plant (g)	Yield per ha (kg)	Net price (Rs. 10 per kg)	Cost of input (Rs.)	Net income (Rs.)	BC ratio
T_1 *C. carnea* @ 5/plant	139	20592.57	205925.7	192912	13013.7	0.06
T_2 *C. carnea* @ 10/plant	149	22074.05	220740.5	385504	-164763.5	-0.82
T_3 *A. longispinosus* @ 10/plant	140.66	20839.49	208394.9	12160	196234.9	0.98
T_4 *A. longispinosus* @ 20/plant	145.33	21530.84	215308.4	24000	191308.4	0.95
T_5 (T_1 + T_3)	148.33	21975.29	219752.9	205072	14680.9	0.07
T_6 (T_2 + T_4)	155	22962.94	229629.4	409504	-179874.6	-0.89
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	157.67	23358	233580	207832	25748.0	0.13
T_8 Neem garlic emulsion 2 %	164.33	24345.65	243456.5	2760	240696.5	1.20
T_9 Neem oil emulsion 5 %	167.33	24790.1	247901	4400	243501.0	1.21
T_{10} Garlic emulsion 2 %	138.33	20493.81	204938.1	1320	203618.1	1.01
T_{11} *Fusarium pallidoroseum* @ 7 x 10^6 spores / ml	134.67	19950.6	199506	3320	196186.0	0.98
T_{12} (T_1 + T_3 + T_{11})	140.33	20790.1	207901	208392	-491.0	0.00
T_{13} (T_2 + T_4 + T_{11})	141.67	20987.63	209876.3	412824	-202947.7	-1.01
T_{14} Fish oil insecticidal soap 2.5 %	142	21037.02	210370.2	1990	208380.2	1.04
T_{15} Control	135.67	20098.75	200987.5	0	200987.5	

Cost of fish oil insecticidal soap required in one hectare utilizing two labourers for application @ 500 l of spray fluid once =995/-

in one hectare utilizing two labourers for application @ 500 l of spray fluid twice = Rs. 1990.

4.5.2 Effect of bioagents and botanical pesticides on chilli mite *P. latus*, predators and on yield

4.5.2.1 Effect of treatments on *P. latus*

The data relating to the population count of *P. latus* observed in different treatments in the field experiment is presented in Table 16.

It was observed that one day after treatment, lowest incidence of *P. latus* was in plants where in combined application of *C. carnea* @ 5 per plant+ *Amblyseius* sp.10 per plant + neem garlic emulsion 2 per cent was given. The mean infestation of *P. latus* in these plants was 0.17 and it was on par with neem garlic emulsion 2 per cent (1.56). Significant reduction in population of *P. latus* was observed in neem oil emulsion 2 per cent also (1.89). All the other treatments did not exert significant role in reducing the mite population and were on par with control (5.81).

Five days after the first treatment also, the combination treatment of *C. carnea*, 5 per plant + *Amblyseius* sp. 10 per plant + neem garlic emulsion 2 per cent proved superior (1.99) to other treatments and this treatment continued to show its effectiveness in the subsequent observations taken on the tenth day after treatment also. However, in the observations recorded on the tenth day after treatment, lowest incidence of *P. latus* was in plants released with *Amblyseius* sp.10 per plant (2.96). The performance of the

Table 16. Mean number of *Polyphagotarsonemus latus* per leaf at different intervals after the release of bioagents / application of botanical pesticides

Treatments	Pre-count	Days after application /release			
		1	5	10	15
T_1 *C. carnea* @ 5/plant	7.47 (2.91)	10.70 (3.42)	10.09 (3.33)	9.24 (3.20)	9.30 (3.21)
T_2 *C. carnea* @ 10/plant	11.04 (3.47)	10.70 (3.42)	9.96 (3.31)	10.70 (3.42)	7.47 (2.91)
T_3 *Amblyseius* @ 10/plant	4.24 (2.29)	4.15 (2.27)	4.24 (2.29)	2.96 (1.99)	2.96 (1.99)
T_4 *Amblyseius* @ 20/plant	5.35 (2.52)	3.97 (2.23)	7.07 (2.84)	3.80 (2.19)	2.96 (1.99)
T_5 (T_1 + T_3)	7.18 (2.86)	6.62 (2.76)	6.67 (2.77)	4.24 (2.29)	4.71 (2.39)
T_6 (T_2 + T_4)	11.11 (3.48)	12.10 (3.62)	10.16 (3.34)	6.18 (2.68)	5.76 (2.60)
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	9.89 (3.3)	0.17 (1.08)	1.99 (1.73)	5.25 (2.50)	8.49 (3.08)
T_8 Neem garlic emulsion 2 %	12.40 (3.66)	1.56 (1.60)	3.16 (2.04)	8.55 (3.09)	9.97 (3.31)
T_9 Neem oil emulsion 5 %	8.73 (3.12)	1.89 (1.70)	3.71 (2.17)	7.01 (2.83)	8.06 (3.01)
T_{10} Garlic emulsion 2 %	11.82 (3.58)	4.20 (2.28)	4.06 (2.25)	6.34 (2.71)	9.56 (3.25)
T_{11} Fish oil insecticidal soap 2.5 %	6.18 (2.68)	3.20 (2.05)	5.92 (2.63)	7.41 (2.90)	8.42 (3.07)
T_{12} Control	6.78 (2.79)	5.81 (2.61)	7.24 (2.87)	10.09 (3.33)	13.82 (3.85)
CD (0.05)		0.61	0.83	0.56	0.43

Pre-count	Days after application/release		
	1	5	10
9.30 (3.21)	9.69 (3.27)	9.82 (3.29)	10.56 (3.40)
7.35 (2.89)	7.47 (2.91)	7.47 (2.91)	8.06 (3.01)
3.12 (2.03)	3.80 (2.19)	3.84 (2.20)	1.59 (1.61)
3.08 (2.02)	2.06 (1.75)	3.93 (2.22)	1.37 (1.54)
4.76 (2.40)	4.71 (2.39)	3.45 (2.11)	2.50 (1.87)
5.66 (2.58)	5.40 (2.53)	3.33 (2.08)	2.76 (1.94)
8.42 (3.07)	0.85 (1.36)	2.50 (1.87)	1.82 (1.68)
9.69 (3.27)	3.33 (2.08)	2.96 (1.99)	3.08 (2.02)
8.06 (3.01)	2.88 (1.97)	3.37 (2.09)	3.08 (2.02)
9.56 (3.25)	2.42 (1.85)	6.02 (2.65)	5.81 (2.61)
8.42 (3.07)	7.18 (2.86)	7.76 (2.96)	8.36 (3.29)
13.82 (3.85)	11.11 (3.48)	14.92 (3.98)	15.08 (4.01)
	0.49	0.35	0.49

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

predatory mite, *Amblyseius* sp. was found better as time elapsed which was evident from the data on the tenth day and fifteenth day after treatment. The lowest incidence of *P. latus* was observed in plants released with *Amblyseius* sp.@10 and 20 mites per plant (2.96) on the fifteenth day after treatment. These treatments were on par with the combination treatment of *C. carnea* @ 5 per plant + *Amblyseius* sp.10 per plant and were significantly superior to control (13.82).

The effect of neem oil emulsion was found to persist for about five days after treatment. Thereafter the population increased and came on par with the population in control on the fifteenth day after treatment.

The results of the observations taken one day after the second spraying also indicated the superiority of the combination treatment, *C. carnea* @ 5 per plant + *Amblyseius* sp. @ 10 per plant + neem garlic emulsion 2 per cent in checking the population of *P. latus*. The mean population of *P. latus* in these treatment was only 0.85 compared to 11.11 in control. The predatory mite *Amblyseius* sp. released @ 10 per plant was equally good in controlling *P. latus* and the mean incidence in these plants was 2.06. All the treatments except *C. carnea* @ 5 per plant proved significantly superior to control. In the subsequent observations at five days and ten days also the effect of the combination treatment and predatory mites was reflected. The mean population of *P. latus* in these plants were 2.5 and 3.84 on the fifth day after the second treatment and 1.82 and 1.59 ten days after the second treatment respectively as against a population of 14. 92 and 15.08 in control.

In the observations taken on fifth day, garlic emulsion 2 per cent and fish oil insecticidal soap 2.5 per cent were inferior to all other treatments but

was better than control (14.92) Observation taken on the tenth day after second spraying also showed a similar trend indicating their effect with repeated application, in bringing down the population of *P. latus*.

4.5.2.2 Effect on predatory mites

The population of predatory mites, was highest in plants (Table 17) released with predatory mites alone @ 20 mites and 10 mites per plant, in the observations taken one day after treatment. The mean population in these treatments was 2.35 and 1.43 mites per leaf. Both these treatments were significantly superior to control (0.087). The mean population of the predatory mite in the other treatments ranged from 0.0 to 1.07 and the populations were on par with control, showing no adverse effect of these treatments upon the predatory mite. Subsequent observations on fifth, tenth and fifteenth day after treatments showed no signification variations in the population of predatory mites in the different treatments.

Following the second spraying, significant impact of the treatments on the predatory mite population was evident in the observation taken on the fifth day. As noted in the observations after the first spraying maximum number of predatory mite was in plants released with 20 mites per plant (3.45) and it was followed by plants released with 10 mites per plant. But these treatments were on par with control and also with the combination treatments, Neem garlic emulsion 2 per cent + *C. carnea*@ 5 per plant + *Amblyseius* sp. 10 per plant; *C. carnea* 10 per plant + *Amblyseius* sp. 20 per plant.

Table 17 Mean number of predatory mites per leaf at different intervals after the release of bioagents / application of botanical pesticides

Treatments	Pre-count	Days after application /release			
		1	5	10	15
T_1 *C. carnea* @ 5/plant	0.00 (1.00)	0.25 (1.12)	0.46 (1.21)	0.54 (1.24)	0.85 (1.36)
T_2 *C. carnea* @ 10/plant	0.00 (1.00)	1.10 (1.45)	0.12 (0.94)	1.01 (1.42)	0.85 (1.36)
T_3 *Amblyseius* @ 10/plant	0.66 (1.29)	1.43 (1.56)	1.46 (1.57)	2.20 (1.79)	2.13 (1.77)
T_4 *Amblyseius* @ 20/plant	0.66 (1.29)	2.35 (1.83)	1.31 (1.52)	0.90 (1.38)	1.59 (1.61)
T_5 (T_1 + T_3)	1.19 (1.48)	0.85 (1.36)	0.49 (1.22)	1.01 (1.42)	0.98 (1.41)
T_6 (T_2 + T_4)	1.01 (1.42)	1.13 (1.46)	0.73 (1.31)	1.16 (1.47)	1.04 (1.43)
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	0.00 (1.00)	0.087 (0.96)	0.10 (1.05)	1.04 (1.43)	1.07 (1.44)
T_8 Neem garlic emulsion 2 %	0.44 (1.20)	0.69 (1.30)	1.16 (1.47)	0.56 (1.25)	1.01 (1.42)
T_9 Neem oil emulsion 5 %	0.72 (1.31)	0.06 (1.03)	0.41 (1.19)	0.27 (1.13)	0.46 (1.21)
T_{10} Garlic emulsion 2 %	0.00 (1.00)	0.66 (1.29)	0.48 (1.22)	0.98 (1.41)	1.04 (1.43)
T_{11} Fish oil insecticidal soap 2.5 %	0.54 (1.24)	1.07 (1.44)	0.71 (1.31)	0.16 (1.08)	0.69 (1.30)
T_{12} Control	0.00 (1.00)	0.087 (0.95)	0.90 (1.38)	1.43 (1.56)	2.17 (1.78)
CD (0.05)		0.41	-	-	-

Pre-count	Days after application/release		
	1	5	10
0.75 (1.32)	1.16 (1.47)	0.02 (1.01)	0.37 (1.17)
0.74 (1.32)	2.02 (1.74)	0.82 (1.35)	1.10 (1.45)
2.20 (1.79)	2.53 (1.88)	3.24 (2.06)	2.13 (1.77)
1.68 (1.64)	1.49 (1.58)	3.45 (2.11)	2.92 (1.98)
1.22 (1.49)	1.85 (1.69)	0.93 (1.39)	2.20 (1.79)
1.25 (1.50)	1.34 (1.53)	1.75 (1.66)	1.46 (1.57)
0.96 (1.40)	1.59 (1.61)	1.85 (1.69)	2.88 (1.97)
1.04 (1.43)	1.10 (1.45)	0.93 (1.39)	1.46 (1.57)
0.54 (1.24)	0.87 (1.37)	0.96 (1.40)	2.20 (1.79)
1.04 (1.43)	0.66 (1.29)	1.72 (1.65)	2.42 (1.85)
0.69 (1.30)	0.41 (1.19)	0.46 (1.21)	1.78 (1.67)
2.16 (1.78)	1.56 (1.60)	2.80 (1.95)	1.75 (1.66)
-	-	0.52	-

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

All the other treatments harboured significantly lower population of the predatory mites than in control indicating their negative impact on the population build up of predatory mite with repeated application.

4.5.2.3 Effect on *C.carnea*

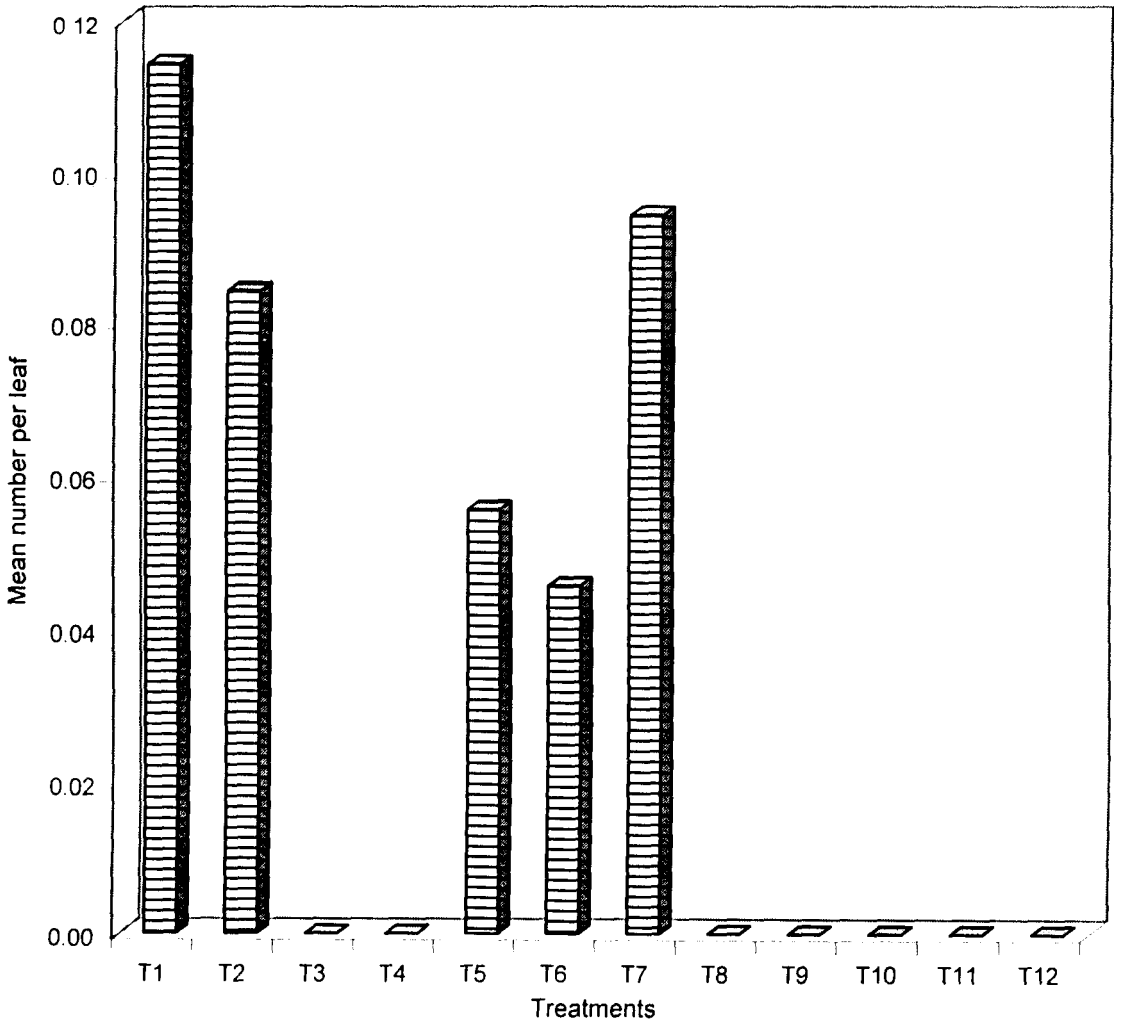
As in 4.5.1.3, the population of *C.carnea* was low in the different treatments after release. The population ranged from 0 to 0.11 (Fig. 3).

4.5.2.4 Effect on yield

The data on the yield of chilli (by weight) is presented in Table 18. The mean yield per plant varied from 116 to 179.6 g per plant in the various treatments but there was no significant difference between the treatments. However, an analysis of the cost benefit ratio presented in Table 18 showed that the application of garlic emulsion 2 percent ,neem garlic emulsioin 2 per cent, neem oil emulsion 5 percent and release of *Amblyseius* sp. @ 10 and 20 per plant are better than control and rest of the treatments.

The benefit cost ratios of these treatments were 1:1.24, 1:1.21, 1:1.18 and 1:1.01. For the predatory mite *Amblyseius* sp. reared using the technique of trifoliate leaf (4.1.1) a benefit cost ratio of 1 : 1.12 and 1 : 1.08 was obtained when 10 and 20 predators were released per plant. The predatory mite *M. merdarius*. was also found to be an efficient predator of *P. latus* (Table 18). The predatory potential of this mite was found almost equal to that of *Amblyseius* sp. If *M. merdarius* is mass produced and utilized in release programs a benefit cost ratio 1:1.18 and 1:1.20 is expected. The details pertaining to the calculations on the cost of production of the bioagents/botanicals is presented in 4.5.2.5.

Fig. 3 Mean number of *Chrysoperla carnea* per leaf after release of bioagents/ application of botanicals in Chilli



T_1 *C. carnea* @ 5/plant at fortnightly intervals
T_2 *C. carnea* @ 10/plant at fortnightly intervals
T_3 *Amblyseius* @ 10/plant at fortnightly intervals
T_4 *Amblyseius* @ 20/plant at fortnightly intervals
T_5 (T1 + T3)
T_6 (T2 + T4)
T_7 (T1 + T3 + Neem garlic emulsion 2 % at fortnightly intervals)
T_8 Neem garlic emulsion 2 % at fortnightly intervals
T_9 Neem oil emulsion 5 % at fortnightly intervals
T_{10} Garlic emulsion 2 % at fortnightly intervals
T_{11} Fish oil insecticidal soap 2.5 %
T_{12} Control

4.5.2.5 Cost of production of bioagents/ botanicals

1. *Chrysoperla carnea*

Cost of production of one egg = 13 paise (Fixed by State Biocontrol Laboratory . Mannuthy. Personal Communication)

Number of *C.carnea* required /ha. @ 5 per plant = 246915

Labour charge for release of *C.carnea* once = 160/-

Total amount required for production and release once in one hectare @ 5 per plant = Rs. 32158

Total amount required for production and release twice in one hectare @ 5 per plant = Rs. 64517

Total amount required for production and release twice in one hectare @ 10 per plant = Rs.128712

2a. *Amblyseius* sp, reared on excised cowpea leaves

Number of plants per ha.= 49383

Number of *Amblyseius* sp required per hectare @ 10 per plant = 493830

Number of *Amblyseius* sp produced in a single unit (Trifoliate leaf) within 12 days = 40

Number of units handled by a person = 1000

Total labour required for production of *Amblyseius* sp for application in one hectare= 13

Wages per labour = Rs.160 per day

Labour required for release = one/ha.

Total amount required for production and release of *Amblyseius* sp. once @ 10 per plant = 2240/-

Total amount required for production and release of *Amblyseius* sp twice @ 10 per plant = Rs.4480

Total amount required for production and release of *Amblyseius* sp twice @ 20 per Plant = Rs.8640

2b. *Macrochelus merdarius* , reared in rice bran

Number of *M.merdarius* required per hectare @ 10 per plant = 493830

Number of *M.merdarius* produced from 10 gram rice bran in a month = 400

Quantity of bran required for producing 493830 mites for application in one ha.= 12.34 kg

Cost of one gram rice bran=Rs 6

No of labourers required for production=1

Total amount required for production and release of *M.merdarius* once @ 10 per plant = 394/-

Total amount required for production and release of *M.merdarius* twice @ 10 per plant = Rs.788

Total amount required for production and release of *M.merdarius* twice @ 20 per plant = Rs.936

The cost of production of bioagents /botanicals for the management of *P. latus* utilizing botanicals viz., neem garlic emulsion (2 percent),neem oil emulsion (5percent), garlic emulsion (2 percent) and fish oil insecticidal soap(2.5 percent) is the same as mentioned in 4.5.1.5

Table 18 Economics of management of *Polyphagotarsonemus latus* in chilli

Treatment	Yield per plant (g)	Yield per ha (kg)	Net price (Rs. 12 per kg)	Cost of input (Rs.)	Net income (Rs.)	BC ratio
T_1 *C. carnea* @ 5/plant	133.33	6584.4	79012.8	64517	14495.8	0.21
T_2 *C. carnea* @ 10/plant	143	7061.77	84741.23	128712	-43970.8	-0.64
T_3 Predatory mites @ 10/plant	138	6814.85	81778.25	4480 788*	77298.25 80990*	1.12 1.18*
T_4 Predatory mites @ 20/plant	140.67	6946.54	83358.5	8640 936*	74718.5 82422*	1.08 1.20*
T_5 (T_1 + T_3)	149	7358.07	88296.8	68997 65305*	19299.8 22991*	0.28 0.33*
T_6 (T_2 + T_4)	152.33	7522.68	90272.12	137352 129648*	-47079.9 -39376*	-0.68 -0.57*
T_7 (T_1 + T_3 + Neem garlic emulsion 2 %)	179.67	8872.48	106469.7	71757 67831*	34712.7 38638*	0.50 0.57*
T_8 Neem garlic emulsion 2 %	145	7160.54	85926.42	2760	83166.42	1.21
T_9 Neem oil emulsion 5 %	144	7111.15	85333.82	4400	80933.82	1.18
T_{10} Garlic emulsion 2 %	146	7209.92	86519.02	1320	85199.02	1.24
T_{11} Fish oil insecticidal soap 2.5 %	120.67	5958.88	71506.58	1990	69516.58	1.01
T_{12} Control	116	5728.43	68741.14	0	68741.14	1.00

* Economics of predatory mite *Macrochelus merdarius*

DISCUSSION

5. DISCUSSION

Spectacular gains in crop production could be attained during the past decades due to the use of pesticides, but the over-reliance on chemical pesticides without regard to Agricultural ecosystems led to serious backlashes including secondary pest out break. The rise of once innocuous forms of mites as major pests today is evidently indicative of the side effects of insecticide misuse.

Natural enemies and naturally derived pesticides have key roles in ecologically sustainable pest management programme. Among natural enemies of phytophagous mites, acarine predators are the most dominant. Importance of phytoseiid mites as regulative agents of plant feeding mites is well recognized (Gupta and Gupta, 1992).Larvae of the green lacewing *Chrysoperla carnea* Stephens is a voracious feeder of soft bodied insects and is widely used in pest management programs. This predator is also reported to feed on phytopagous mites (Gupta 1985). Hence in the present investigation focus is given on mass production techniques of predatory mites and the green lacewing *C.carnea* . Further their, prey preference, toxicity to pesticides and their role in management of the red spider mite *Tetranychus ludeni* infesting vegetable cowpea and *Polyphagotarsonemus latus* infesting chilli were studied.

5.1 Mass multiplication of predators

5.1.1 Mass multiplication of *Amblyseius* spp

Mass production of phytoseiid mites has been attempted by scientists all over the world, since the first recorded mass rearing of *Phytoseiulus*

persimilis Athias-Henriot in 1960s. Different techniques of rearing like rearing on leaf arenas, cage rearing and rearing on plants were adopted (Gilstrap, 1977; Hendrickson, 1980; Fournier *et al.*, 1985; Abou-setta and Childers, 1987).

Species of *Amblyseius* viz., *A. longispinosus* and *Amblyseius* sp. belonging to phytoseiidae were observed as the dominant predators of *T. ludeni* and *P. latus* in the present studies (Plate 3&4). Hence attempts were made to mass multiply these two predators in the. in the laboratory. The polyphagous *Amblyseius* is known to thrive on pollen, alternate prey or even on artificial *diets* (Overmeer,1985 ; Karg, *et al.*,1987; Rasmy *et al.*,1987). In the present study their natural hosts viz., *T. ludeni and P. latus* were used for mass rearing. In addition to this artificial diets and alternate diets were also evaluated.

5.1.1.1 Mass multiplication of *Amblyseius longispinosus*

The results presented in 4.1.1 showed that *A. longispinosus* is amenable for mass rearing on its natural host viz., *T. ludeni* which was in turn reared on excised cowpea leaves. Excised leaves of cowpea when placed in water (Plate 1) was found to maintain turgidity for two weeks. This prolonged life of the excised leaves may be due to the rooting that occurred at the petiole base (Plate 5).

The technique of rearing on excised leaflet ensured adequate and continuous supply of the host mite as well as the predator. Within a period of seven days two fold increase in the predator population was observed. When

10 predatory mites were released into a colony of 20 numbers of *T. ludeni* 24 eggs and 19.4 immature stages and adults could be obtained. It was also seen that when the population of the host mite supplied was low (10 mites per leaf) it was necessary to supply the prey mite after four days. Removal of the predatory mite was also found essential since the predator showed tendency for dispersal at higher population levels even if prey was available.

Today techniques are available for rearing tetranychid prey on potted host plants and this is basically expanded versions of a method first out lined by Ristich (1956). Bean plants have been used for rearing spider mites (Naegele and Mc Enroe 1963; Hendrickson, 1980). The rearing systems were based on moving clean bean plants to spider mite rearing rooms and then using this plant to inoculate, the phytoseiids rearing plants with spider mites. When well infested, these plants were moved to phytoseiid rearing sections and for inoculation with *P. persimilis*. Using this system each pot of bean plants produced 1500 -4000 predators weekly

5.1.1.2 Mass multiplication of *Amblyseius* sp

P. latus is a polyphagous mite with wide host range (Jeppson *et al.*, 1975.,Gerson,1992.,Sudharma,1996) Since *P. latus* was found to infest vegetable cowpea, trifoliate leaves of cowpea were used for mass rearing of *P. latus* also. This mite being much smaller than *T. ludeni*, 200 numbers of this prey was introduced into a trifoliate leaf before releasing 10 numbers of the predatory mite. The predator survived on *P. latus* and the population doubled in a week. Even though 200 numbers of prey mite was

given initially, by about twelfth day the prey mite was completely fed and the predator population increased to 31.2 eggs and 25.4 young ones and adults per trifoliate leaf.

For mass rearing, adequate facilities by way of specially designed rearing rooms and equipment like mite brushing machines are necessary. Once the basic requirements are met, using the simple techniques like rearing on excised leaf, developed in the present studies will definitely help to increase the production of predators and production could be increased many fold than that produced in the present studies. Thus the present technique off rearing predatory mites and prey mites in excised trifoliate leaves offer scope for mass production of the two important predators, viz., *A. longispinosus* and *Amblyseius* sp and their further utilization in the biological control of the phytophagous mites *T. ludeni* and *P. latus* respectively.

5.1.1.3 Mass multiplication of *Macrochelus merdarius* on rice bran mite

Amblyseius sp. was identified as the important predator of *P. latus* in the field. However, the polyphagous predator *M. merdarius*. was found as a predator of *P. latus* in the laboratory. Since. *M. merdarius* was observed to feed on the storage mite, *Tyrophagus* sp. also,attempts were made to multiply this predator on this bran mite. The results presented in 4.1.1.3 and Fig. 1 revealed that rearing of *M. merdarius* can be easily done on *Tyrophagus* sp. From 10 g rice bran containing *Tyrophagus* sp. 410 predatory mites could be produced within a month.

The use of tyroglyphid mites has been a breakthrough for mass production of two species of phytoseiid mites, *Amblyseius cucumeris* and *Amblyseius barkeri* (Hughes). These are now mass produced on *Acarus* spp and *Tyrophagus sp.* for application against thrips in green house crops. (Ramakers, 1984). According to Rasmy *et al.* (1987) another predator, *Amblyseius gossypi* Elbadry, can also be reared on tyroglyphid mite, *Tyrophagus* casei Oudemans mixed with pollen. In the present studies, besides *Tyrophagus* sp.,*Suidasia* sp.and *Caloglyphus* sp. were also occasionally encountered in the culture used for rearing *M. merdarius*. Different species of tyroglyphiids have been used for mass rearing *Acarus farris*(Ramakers 1984). *A. siro* Linnaeus by Jakobsen (1989) and *Tyrophagus putrescentiae* (Schr) were used by commercial producers in Canada and England. Often the cultures were mixture of different storage mites (Gilkeson, 1992). The present studies indicate that the predatory mite of *M. merdarius*. can be also utilised for management of *P. latus* in chilli, as the rearing involves less labour, resource and space.

5.1.1.4 Mass multiplication of predatory mite on alternate diet

It is presumed that rearing of mites can be made cheaper and more predictable by resorting to artificial diets than rearing on natural prey. The food spectrum of predatory mites were reported to include pollen (Karg *et al.*, 1987; Rasmy *et al.*, 1987). Hence in the present studies attempts were made to multiply predators on artificial diets and pollen also.

A scrutiny of the results presented in Table 2 and 4.1.1.4 showed that predatory mite when fed on pollen diets viz., pollen of *Acacia auriculiformis* and *Hibiscus rosa-sinensis*, could survive on the diet. A maximum longevity of twelve days was recorded when fed on pollen of *H. rosa-sinensis*. It was also encouraging to note that the adult laid eggs and the larvae that emerged from the eggs could complete development on pollen. The development was completed in a period of 9 and 9.3 days in *Hibiscus* pollen and *Acacia* pollen respectively. Castor pollen was earlier reported as an alternate diet for rearing the predatory mites viz., *Euseius concordis* and *A. tetranychivorus* (Jagdish *et al.*, 1995; Krishnamoorthy, 1982b). Cent per cent survival in this diet was also recorded. In 1989, Krishnamoorthy and Mani used this technique for mass rearing *P. persimilis* and used it further for the control of two spotted spider mites on french bean.

In all the artificial diets tested in the present study the gravid females could survive. Egg laying was also noticed but the fecundity was less than that of pollen fed adults (0.35 to 0.63/ day). Further, the first generation did not reach adulthood in the artificial diets . Although there has been a great deal of interest in developing artificial diets for the mass production of phytoseiid predators, so far few species have been maintained for long period on diets lacking prey (Gilkeson, 1992). Mc Murtry and Scriven (1966) found that a 20 % yeast and 20 % sucrose mixture provided enough nutrients to sustain oviposition of the predatory mite, *Amblyseius limonicus* Garman and Mc gregor. Kennet and Hamai (1980) were also able to rear seven species of phytoseiids on an artificial diet of honey, sugar, yeast

hydrolysate, casein hydrolysate, egg yolk and water. Ochieng *et al.* (1987) also developed artificial liquid diet containing milk powder, honey, egg yolk, Wesson's salt and water for *Amblyseius teke* Pritchard and Baker and the mites were reared for 25 generations on this diet, but with slower development than in their natural spider mite prey.

It was also noted that the gravid females survived for a mean duration of eight days and laid eggs when fed with water alone. According to Ashihara *et al.*, (1978) also, the provision of water source alone improved survival of the predatory mite, *P. persimilis.*

5.1.1.5 Biology of the predatory mites

5.1.1.5.1 Biology of *Amblyseius longispinosus*

The predatory mite *A. longispinosus* took 6.85 ± 0.46 days to complete its development on *T. ludeni.* The mean duration of egg, larva, protonymph and deutonymph were 3, 0.88, 1.43 and 1.55 respectively. Mallik (1974) reported a shorter developmental period for the mite. The mean egg, larvae, protonymph and deutonymph were 44.42 h, 12.25 h, 20.53 h and 20.51 h respectively taking a total of 99 h. According to Burell and Mc Cormick (1964) related species of *Amblyseius* viz., *A. cucumeris* and *A. fallacis* had comparatively shorter life cycle of 4 and 4.5 days respectively. Chandrasekharappa *et al.*, (1995) observed a mean fecundity of 53 eggs per female for *A. longispinosus* during a life time of 33.1 days. In the present study fecundity observed was 25.2 ± 3.83 during a life span of 13.2 days. The lower fecundity observed in the present study can be attributed to shorter longevity of the adult predator.

5.1.1.5.2 Biology of *Amblyseius* sp.

The predatory mite *Amblyseius* sp.completed its development in 5.79 ± 0.44 days when reared on *P. latus*. The mean duration of egg, larva, protonymph and deutonymph were 2.71, 0.78, 1.17 and 1.13 days respectively. Average fecundity of 29.2 eggs per female and adult longevity of 14.2 days was observed.

5.1.2 Mass culturing of *C. carnea*

With a view of identifying suitable hosts for mass rearing of *C. carnea*, the predator was reared on different hosts viz. *A. craccivora*, *T. ludeni* and *Corcyra* eggs. Individual rearing of the predator was adopted. It was seen from the data presented in Table5 that *C. carnea* was able to complete its life cycle on all the three hosts tested. However, the developmental period was shorter when reared on *Corcyra* eggs. (8.3 ± 0.67) This was followed by *A. craccivora* (9.4 ± 0.54) and *T. ludeni* (10.6 ± 1.14). Balasubramani and Swamiappan (1994) observed prolonged larval period (11.10 days) when fed with neonate larvae of *H. armigera*. With reference to the fecundity also rearing on *Corcyra* eggs proved better than rearing on *A. craccivora* and *T. ludeni*. While the mean egg production per female was 219.4 on *Corcyra* eggs it was only 117 and 41.53 on *A. craccivora* and *T. ludeni* respectively.

In the present studies it was found that individual rearing of *C.carnea* is a very cumbersome process. Nijima and Matsuka (1990) have stated that predaceous insects are difficult to be reared together also because of

cannibalism. They also found that when ten or more larvae were reared together in petridishes only two or three larvae attained adult hood.

5.2 Assessment of predatory potential of predators

5.2.1 Assessment of predatory potential of *Amblyseius* spp.

5.2.1.1 Assessment of predatory potential of *A. longispinosus*

With reference to the results presented in 4.2.1.1 it is clear that *A. longispinosus* is an effective predator of *T. ludeni* which fed on all stages of the mite. The larvae was found to feed on all stages of the prey except adult. The most preferred stage of the prey consumed was observed as eggs. Among the different stages of the predator, adults were the most voracious stage, consuming 118.8 ± 11.8 eggs. The feeding pattern of the predatory mite, *A. alstoniae*, earlier reported by Jose *et al.*, 1989 revealed that the predatory mite belonging to the genus *Amblyseius* were capable of feeding all stages of the spider mite. They reported that adults consumed a total of 368.72 different stages of the spider mite. The finding of Biasi *et al.*, 1988 was that *A. fallacis*, another predator of *T. ludeni* consumed eggs of the prey and that the egg consumption was directly proportional to the quantity offered. An increase in temperature was also reported to increase the feeding potential.

5.2.1.2 Assessment of predatory potential of *Amblyseius* sp.

The results shown in 4.2.1.2 showed that all stages of the predator excepting the larvae killed the adult prey mite, *P. latus*. The predatory larvae was found to feed only on prey larvae. The larval period was very short and during this period each larvae consumed 1.16 ± 0.75 mites. Each adult

predator consumed 9.66 ± 1.91 larva, 8.66 ± 0.76 nymphs and 16.36 ± 2.62 adults of the prey mite in a period of three days. Karuppuchamy *et al.*(1994) reported *A. ovalis* as an efficient predator of *P. latus*. Investigations conducted by them showed that the adult predator was the most efficient in attacking *P. latus* consuming 5.76, 4.64, 3.20, 3.12 and 2.12 egg first instar, second instar nymphs, pupae and adults respectively. He further reported that the efficiency was gradually reduced in the deutonymphal and protonymphal stages of the predator and that the larvae was the least effective stage with respect to the predatory potential.

Besides *Amblyseius* sp., the Macrochelytid mite, *M. merdarius* was also observed as an efficient predator of *P.latus*. In the present studies, the predatory potential of the adult predator was found to be 43.35 ± 1.82

5.2.2 Assessment of the predatory potential of *C. carnea*

The results presented in 4.2.2.1 showed that *C. carnea* consumed both nymphs and adults of *A. craccivora*. The total number of aphids consumed by the predatory larvae during its developmental period was 419 ± 9.14. The quantity of prey consumed was reported to vary under different situations. According to Balasubramani (1991), *C. carnea* consumed 374.38 to 419.18 aphids of different species in its larval period. Climatic conditions was also reported to influence predatory potential. Temperature was reported to play a role in prey consumption of *C. carnea* (Sundby, 1966; Scopes, 1969 and Zaki, 1987). In the present studies the mean daily consumption was observed to be highest for the third instar larva. Each third instar larvae fed 579 ± 426 aphids

daily. Similar observations were also made by Obrycki *et al.* (1989), Sharma and Verma (1991) and Balasubramani and Swamiappan (1994).

An assessment of the predatory potential of *C. carnea* on *T. ludeni* showed that each *C. carnea* consumed 1064.6 ± 135.7 adults of *T. ludeni* during its developmental period. The feeding potential was found to increase correspondingly with the growth of the larva. As observed earlier in the case of *A. craccivora*, the mean daily consumption was also highest for the third instar. A mean daily consumption of 136. 82 ± 5.71 was observed for the third instar while the values were 54.72 ± 3.59 and 87.58 ± 2.40 for first and second instar respectively.

5.3 Prey preference of predators

5.3.1 Prey preference of *A.longispinosus*

A.longispinosus is a very efficient predator of *T. ludeni* and *P.latus* (Mallik,1974;Hariyappa and Kulkarni,1988). In the present studies besides *A.longispinosus* ,the broad mite *P.latus* was also found preyed by the predator in both the multiple choice and the single choice tests. However, total avoidance was shown towards the bran mite, *Tyrophagus* sp. Eventhough *A.cucumeris* and *A.barkeri* were reported to be inexpensively mass produced on *Tyrophagus* (Ramakers,1984;Rasmy *et al.*,1987), present studies indicate that *Tyrophagus sp* cannot be utilized for the mass production of *A. longispinosus.*

5.3.2 Prey preference of *C. carnea*

C. carnea is a voracious feeder having wide host range. The larvae of *C. carnea* was reported to feed on *Aphis pomi* (De geer) (Amin Masoodi and Trali, 1988),*A. craccivora* (Mehta *et al.*, 1989), *A. gossypii* (Balasubramanian and Swamiappan, 1994), *Bemisia tabaci* (Pathummal beevi *et al.*, 1988), *T. urticae* (Pavlova and Aripova, 1991) and *Amrasca biguttula* (Singh *et al.*, 1993) Hence it is worth while considering the prey preference of *C. carnea* before utilizing it for management of pests in a particular crop The results of the study (Table 12 and 4.3.2) conducted to assess the prey preference of the predator by adopting single choice as well as multiple choice tests revealed that the preference for the prey differed significantly. In multiple choice tests, among the five prey tested, the most preferred one was *A. craccivora*. All the aphids (40 numbers) provided were consumed by the predator within 48 hours of exposure. The red spider mite, *T. ludeni* was the next preferred host (66.22 percent). Spiralling white fly was the least preferred one. Senior and McEwen (1998) found that *C. carnea* fed on all stages of whitefly, *Trialeurodes vaporarium* but none of the *C. carnea* survived to pupation. In single choice tests also the predator consumed 86.6 percent out of 40 numbers of *A. craccivora* within 24 hours of exposure to the second instar larvae of *C. carnea*. It can be concluded that from the present results that *C. carnea* is a suitable predator for the management of *A. cracccivora* and *T . ludeni* infesting cowpea.

5.4 Effect of pesticides on predators

The escalation in the status of the tetranychid mites and tarsonemid mites as pests in vegetables in the recent past is mainly due to the decimation of the predatory fauna by extensive pesticide application. Hence probing studies on the effect of pesticides on the predatory fauna is absolutely necessary. In the present studies ,commonly used pesticides at the recommended concentrations were evaluated against the predatory mite *A. longispinosus* preying *T. ludeni* and the polyphagous predatory insect *C.carnea.*

5.4.1 Effect of pesticides on *Amblyseius longispinosus*

The results presented in 4.4.1 on the relative toxicity of pesticides to *A. longispinosus* assessed by dry film method indicated that triazophos 0.05 percent was the most toxic chemical against *A. longispinosus*. None of the predatory mites survived after six hours of treatment. The acaricide, dicofol at 0.05 per cent concentration also indicated mortality significantly higher than in other insecticides .Nevertheless the residual toxicity of other insecticides tested also proved much harmful to the predatory mite as none of them survived after a period of one day. While studying the effect on the predatory mite, *A.tetranychivorous*, Jagdish and ChannnaBasavanna (1989) also found that dicofol, quinalphos, carbaryl and malathion caused 93.89 to 100 percent mortality of predator twelve hours after treatment at the recommended doses.

Though botanical pesticides were found significantly better than chemical pesticides in protecting the predatory mite, mortality to the tune of 10.63 to 42.30 and 37.71 to 47.63 were observed when predatory mites were exposed for 6 hours and 48 hours respectively.

There is also a general contention that botanical pesticides are safe to natural enemies. The present studies have shown that botanicals are safe when compared to chemical pesticides. However, the results also indicated that the negative impact of botanicals on natural enemy cannot be overlooked. As predatory mites exert a major role in the population regulation of the phytophagous mites, the application of botanical pesticides also needs reservation. Eventhough in Fish oil insecticidal soap 2.5 percent, mortality was on par with *F. pallidoroseum* @ 7 x 10^6 spores/ml six hours after treatment, subsequent observations at 24 and 48 hours showed higher mortality of the predator. Earlier reports by Faizal (1992) also indicated that the fungal pathogen *F. pallidoroseum* is safe to natural enemies as it is a specific pathogen of pea aphid.

5.4.2 Effect of pesticides to *C. carnea*

C. carnea is employed as a biocontrol agent in several integrated pest management programmes (Canard *et al.*,1984;Adashkevich, 1987; Bindu, 1997) In view of the fact that pesticides cannot be totally dispensed with in IPM is essential to elucidate the impact of pesticides upon this bioagent. Considering this, studies were undertaken to assess the effect of currently used chemical pesticides as well as botanical pesticides.

The results presented in 4.4.2 showed that organophosphorous insecticides tested were harmful to the larvae of *C. carnea*. Among the insecticides tested, triazophos 0.05 percent proved to be the most toxic one. Within six hours of exposure 87.67 percent mortality was observed. None of the larvae tested survived after 24 hours in this treatment. Quinalphos 0.03 percent and malathion 0.05 percent proved equally toxic to the predator and there was no significant difference in the mortality between these treatments. The acaricide, dicofol tested had not much effect on the larvae. Earlier reports of Krishnamoorthy(1985) on the effect of pesticides to the larvae of another species of *Chrysopa* viz. *Chrysopa scelestes* Banks also indicated that dicofol was safe to the predator. He further found that quinalphos 0.05 per cent and malathion 0.05, percent were highly toxic to the larvae and adults of *C. scelestes*. At the same time other organophosphorous compounds viz. monocrotophos, phosphamidon and dimethoate were innocuous to the predator. Studies conducted by Bartlett (1964) showed that larvae and adults of *C. carnea* were killed by residues of most organophosphorous and chlorinated hydrocarbons, out of the sixty chemicals tested but a few showed a toxicity to the larvae. Plapp and Bull (1978) also reported that organochlorines viz., endosulfan and dicofol had little effect on *C. carnea*.

The mortality of the larvae of *C. carnea* when exposed to botanical pesticides was low compared to chemical pesticides but these were not totally safe to the predator. The percentage mortality observed was 15.84,17.80,18.50 and 20.88 when exposed to neem oil emulsion 5 per cent, 10 per cent extract of *A. paniculata*, 10 per cent extract of *H. suaveolens* and neem garlic

emulsion 2.5 per cent respectively. The Fungal pathogen *F. pallidoroseum* @ $7x10^6$ spores/ml, fish oil insecticidal soap 2.5 percent and garlic emulsion 2 percent had no adverse effect on the predator.

It is clear from the studies that in integrated pest management, selective use of pesticides is essential even while using *C. carnea* which is reported tolerant to pesticides (Pree *et al.*, 1989).Even though botanical pesticides had shown low toxicity to *C. carnea* compared to chemical pesticides, proper timing of the application of the botanical pesticides would be essential to exploit the best performance of *C. carnea*.

5.5 Field trial to assess the effect of bioagents and botanical pesticides for the management of mites

The red spider mite, *T. ludeni* in vegetable cowpea and the broad mite, *P. latus* in chilli were earlier identified as important mite pests in Kerala (Saradamma and Nair, 1976; Sudharma,1996).Only few works related to management of mites in vegetables have been reported in Kerala (Santhoshkumar, 1999). Synthetic pesticides have been the main tool for controlling mites in vegetables (Brown and Jones, 1983; Gerson,1992) Sulphur used for controlling chilli mites was reported harmful to predaceous mites (Childers and Enns, 1975; Debach and Rosen,1991). The acaricides, dicofol which was reported effective against *P. latus* (Karuppuchamy and Mohanasundaram, 1987; Jayarajan *et al.*, 1995) were also found harmful to predaceous mites (Herne and Chant,1965; Krishnamoorthy,1982a) Hence in

the present studies, field trials were undertaken to assess the role of bioagents and botanical pesticides in the management of *T. ludeni* and *P. latus* in chilli.

5.5.1 Effect of bioagents and botanical pesticides on cowpea mite *T. ludeni*, predators and on yield of cowpea

The results of the study presented in 4.5.1.1 showed that the lowest incidence of spider mite, *T. ludeni* was in the treatment where in combination of bioagents and botanical pesticides (*C. carnea* @ 5/plant + *A.longispinosus* 10/plant+neem garlic emulsion 2%) was given, in the observation taken one day after the first as well as second sprayings (1.37 and 0.42). This was followed by neem garlic emulsion 2 percent and neem oil 5 percent with mean population of 2.35,2.39 and 3.37,1.96 respectively. The importance of botanical pesticides in the management of mites pests was highlighted by earlier workers also. Ramaraju *et al.* (1995) found neem oil 3 percent effective against another species of spider mite, *T. urticae*. Acaricidal values of plant extracts against *Oligonychus indicus* studied by Manjunatha *et al.*,1995 indicated that leaf extracts of neem was effective against the mite. In the present studies, the population of *T. ludeni* was found to decrease immediately after application but after five days the population increased. It was also observed that with repeated application population build up of the mite was checked upto ten days after treatment.

The effect of release of the biocontrol agent *C. carnea* was observed on the fifth day following the release of *C. carnea* @ 5 and 10 per plant, there after the population increased gradually. The last instar larvae of *C. carnea*

was reported to consume more than 1500 mites daily (Gupta,1985) but in the present studies, *C. carnea* with such voracious feeding habit could not bring about spectacular reduction in population of *T. ludeni* under field situations. This may be due to the polyphagous nature of this predator.

With regard to the effect of the release of predatory mite, immediate effect in the population reduction of *T. ludeni* was not noticed but a slow decline in the population of the prey mite was observed with advent of time(Fig 4). One interesting observation was that the population of the predatory mite increased steadily and within a month the population of the predator and prey became almost equal (Fig. 4c & 4d) Krishnamoorthy and Mani (1989) obtained similar results with release of *P. persimilis* against *T. urticae* in French beans and found a release rate of predators 10 per plant was ideal for suppressing *T. urticae* . According to Coppel and Mertins (1977) in general, introduced entomophages require at least three generation of reproductive increase before their effect on target pest population becomes noticeable.

A steady decline in the population of *T. ludeni* and a progressive increase *in* the number of predatory mites were also observed when the bioagents, *C. carnea* and predatory mite *A. longispinosus* were released together (Fig.4e& 4f).

Application of *F. pallidoroseum* @ 7 x 10^6 spores/ml had practically no effect in checking the population of *T. ludeni*. The results supports the

Fig. 4 Effect of bioagents/botanical pesticides on *Tetranychus ludeni* and predatory mites on cowpea

Fig. 4a *C. camea* 5 per plant (T_1)

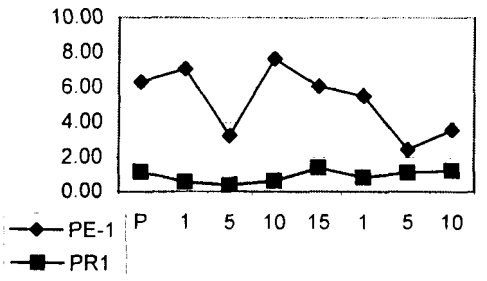


Fig. 4b C. carnea 10 per plant (T_2)

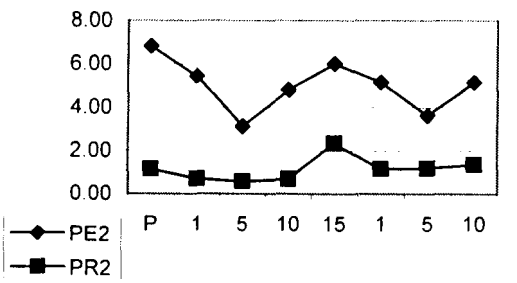


Fig. 4c *A. longispinosus* 10 per plant (T_3)

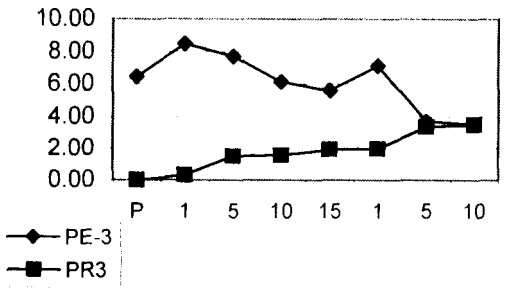


Fig. 4d *A. longispinosus* 20 per plant (T_4)

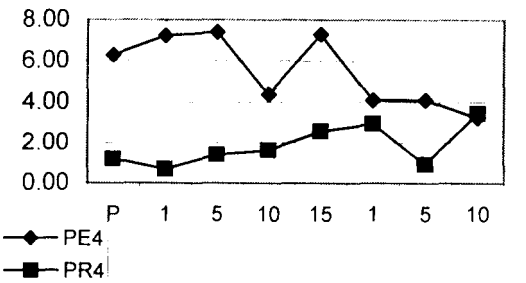
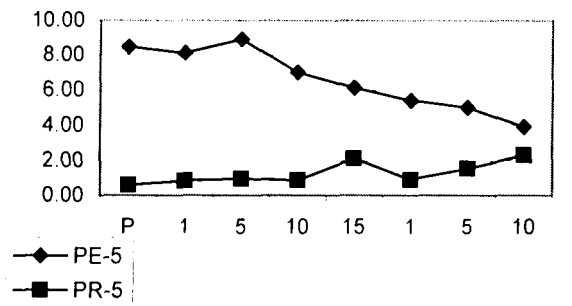


Fig. 4e $T_1 + T_3$ (T_5)



X axis - Days after first and second application/release
Y axis - Mean number of mites per leaf
PE - Pest (*T. ludeni*)
PR - Predatory mite
P - Pre-count

Fig. 4f $T_2 + T_4$ **(T_6)**

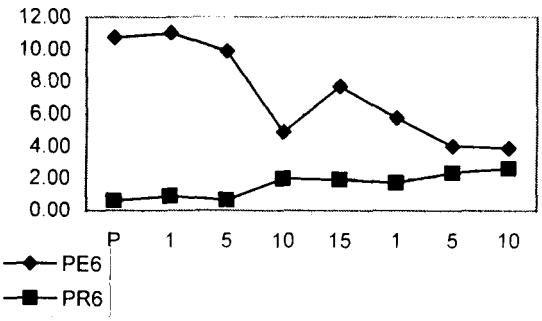


Fig. 4g $T_1 + T_3$ + Neem garlic emulsion 2% **(T_7)**

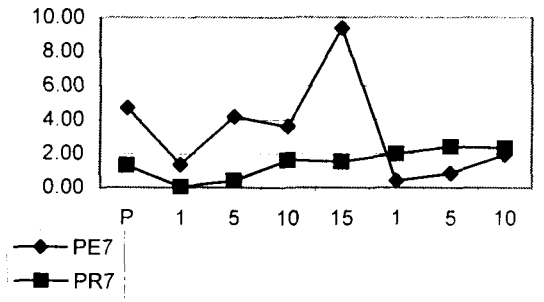


Fig. 4h Neem garlic emulsion 2 % **(T_8)**

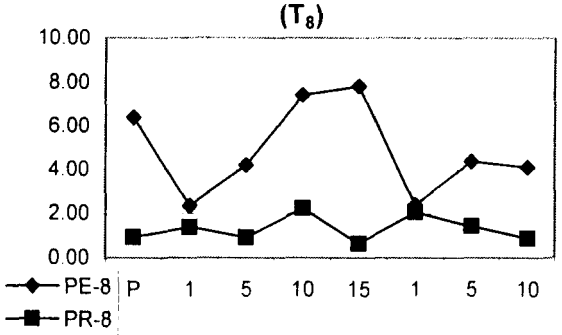


Fig. 4i Neem oil emulsion 5 % **(T_9)**

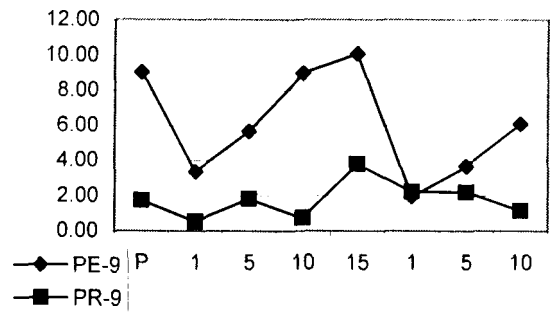
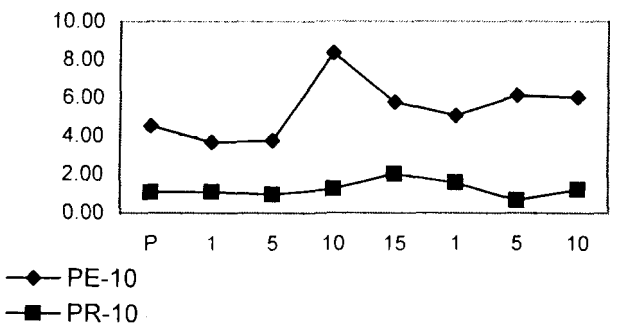


Fig. 4j Garlic emulsion 2% **(T_{10})**



X axis - Days after first and second application/release
Y axis - Mean number of mites per leaf
PE - Pest (*T. ludeni*)
PR - Predatory mite
P - Pre-count

Fig. 4k *Fusarium pallidoroseum* **(T_{11})**

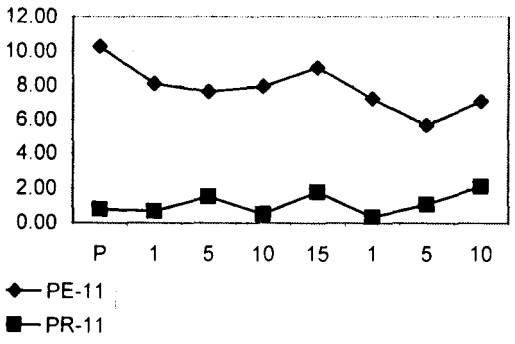


Fig. 4l $T_1 + T_3 + T_{11}$ **(T_{12})**

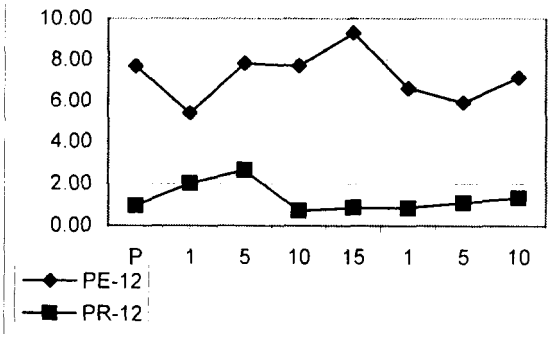


Fig. 4m $T_2 + T_4 + T_{11}$ **(T_{13})**

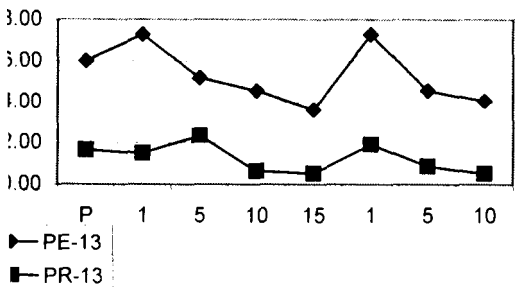


Fig. 4n Fish oil insecticidal soap 2.5 % **(T_{14})**

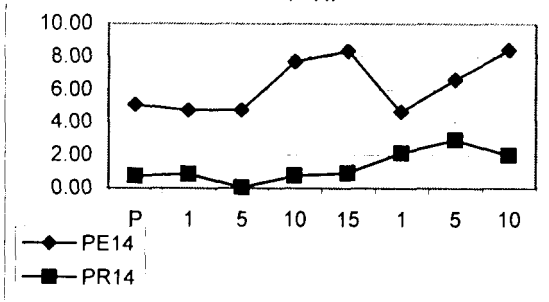
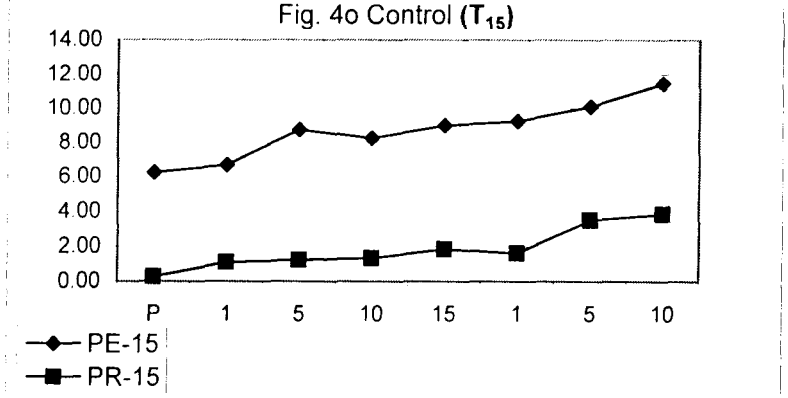


Fig. 4o Control **(T_{15})**



X axis - Days after first and second application/release
Y axis - Mean number of mites per leaf
PE - Pest (*T. ludeni*)
PR - Predatory mite
P - Pre-count

research works of Hareendranath (1989) and Faizal (1992) that *F.pallidoroseum* is a specific pathogen of pea aphid.

In control plots the population of *T. ludeni* showed a steady increase as time elapsed. Though predatory mites were not released in control plants, predatory mites were seen associated with *T. ludeni*. The close association of phytophagous mites and acarine predators were earlier reported (Mallik,1974, Sudharma,1996) Moreover it was seen that the population of these mites increased with increase in population of its prey mite, *T. ludeni* (Fig.4o). The intimate association with predators and their prey means that population density changes in one group may well effect complementary changes in another group (Coppel and Mertins, 1977). These observations further stress the role of acarine predators in the management of mites.

5.5.1.1 Effect on yield

The results given in 4.5.1.4 showed that there was significant difference in the yield of cowpea in the various treatments. Highest yield was recorded from plants treated with neem oil emulsion 5percent (167.6gm). This was on par with the yield obtained from treatments, neem garlic emulsion 2%, combination treatment of *C. carnea* @5/plant + *A. longispiosus* 10/plant + neem garlic emulsion 2%,*C.carnea* @ 10/plant and *C. carnea* 10/plant + *A.longispiosus* 20/plant. Studies conducted by Sudharma (1996) on the yield loss caused by *T. ludeni* in bhindi showed that the stage of the crop infested by the mite is an important factor which affects the yield. When *T. ludeni* were released @ 30mites/plants 15days after sowing, the plants succumbed to

death but when 40 mites were released 45 days after sowing there was no significant reduction in yield.

Considering the benefit cost ratio application of neem oil 5 per cent was found to be the best treatment for management of mites (1 : 1.21). This was followed by application of neem garlic emulsion (1 : 1.20), fish oil insecticidal soap 2.5 per cent (1 : 1.04) and garlic emulsion 2 per cent (1 : 1.01). All the other treatments were uneconomical even though these treatments showed significant reduction in mite population. The present studies point out that mass production and release of predatory mites is economically not viable for managing the mites. However this technique can be made economical provided production system is expanded, skilled men and mechanized rearing systems are used.

Release of the green lacewing *C. carnea* though found effective in reducing the mite population was not economical. According to Nordlund and Morrison (1992) development of a cost effective system for mass production of C. carnea would result in an effective system of biological control technology with applications especially for high value fruit and vegetable crops.

5.5.2 Effect of bioagents and botanical pesticides on chilli mite *P. latus*, predators and on yield

The result presented in 4.5.2.1 showed that the most effective treatment in checking the population of *P. latus* was the combined use of *C. carnea* @ 5/plant+ *Amblyseius* sp. @ 10/plant+neem garlic emulsion 2%. The incidence of *P. latus* recorded 1 and 5 days after treatments were only 0.17 and 1.99.

Significant reduction in population of *P. latus* was observed in plants treated with neem garlic emulsion 2 per cent (1.56) and neem oil emulsion 5 per cent (1.89). However, the effect of neem oil emulsion 5 per cent was found to persist for about five days only after the first application thereafter the population increased to 8.55 and 7.01 and came on par with control (10.09) but with the repeated application the effect was observed up to 10days after treatment. Earlier Santhoshkumar (1999) also reported the effect of neem oil 10 percent in the management of *P. latus in* chilli.

The release of the predator *C. carnea* was not effective @ 5 per plant. At the higher level tested also no reduction in population of *P. latus* was obtained following the initial release. Under lab conditions, *C. carnea* was never found to feed on *P. latus*. Hence it may be concluded that release of *C. carnea* is not a suitable approach for managing chilli mite *P. latus*.

The impact of the predatory mite, *Amblyseius* sp. was pronounced from the tenth day onwards at both the levels tested (10 and20 mites per plant). Fan and Petitt (1994) found that four releases of the predatory mite, *Neoseiulus barkeri* effectively reduced the broad mite population from more than 100 mites per leaf to zero in a week and that three weekly release of five predatory mites *Neoseiulus barkeri* per main stem provided adequate protection from infestation of *P. latus* for seven weeks.. In the combined application of *C. carnea* and predatory mite also, the treatment was found effective from the tenth day onwards which may be due to the activity of the predatory mite alone.

Fish oil insecticidal soap 2.5 per cent was ineffective against *P. latus*. Garlic emulsion gave substantial reduction immediately following application, subsequently the population was found to increase but significant reduction in population was noticed following a second spray (Fig. 5j).

An analysis of population of predatory mites in the different treatments (Fig 5) showed that invariably in all the treatments natural population of predatory mite *Amblyseius* sp existed under field situations. In plants released with predatory mites, a gradual decline in the population of the prey mite *P. latus* along with a gradual increase in population of predatory mites were observed (Fig.5c&5d). Pena and Osborne (1996) in his studies also observed that field release of *Neoseiulus californicus* together with a complex of indigenous predaceous mites kept *P. latus* density below economic damage levels on lime fruits. In control plants a prey density dependent increase of existing predatory mites was observed (Fig.5l).

5.5.2.1 Effect on yield

The effect of treatments on yield given in 4.5.2.3 showed that there was no significant difference between the treatments. The mean yield per plant varied from 116 to 179.67 g.

However, the benefit cost ratio (Table 18) showed that the application of garlic emulsion 2 per cent, neem garlic emulsion 2 per cent, neem oil emulsion 5 per cent and release of predatory mites, *Amblyseius* sp. @ 10 and 20 per plant were better than control and rest of the treatments. The benefit cost ratios of these treatments, 1 : 1.24, 1 : 1.21, 1 : 1.18 ,1 :1.12 and 1:1.08 respectively. Hence it may be concluded that application of neem oil 5 per

Fig. 5 Effect of bioagents/botanical pesticides on *Polyphagotarsonemus latus* and predatory mite on chilli

Fig. 5a *C. camea* 5 per plant (T_1)

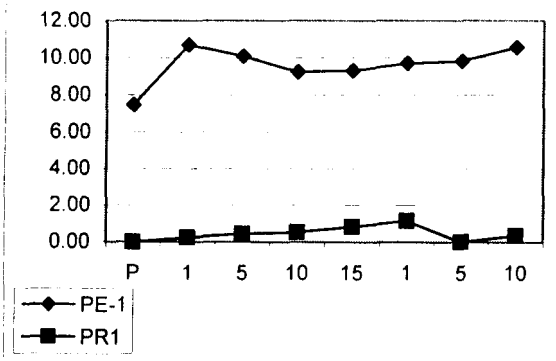


Fig. 5b *C. camea* 10 per plant (T_2)

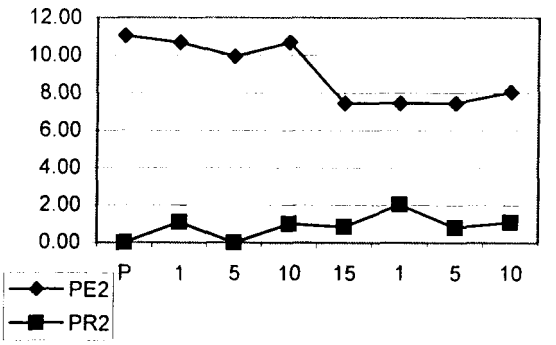


Fig. 5c *Amblyseius* sp. 10 per plant (T_3)

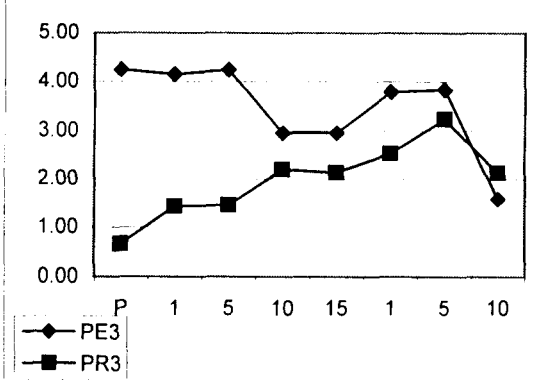


Fig. 5d. *Amblyseius* sp. 20 per plant (T_4)

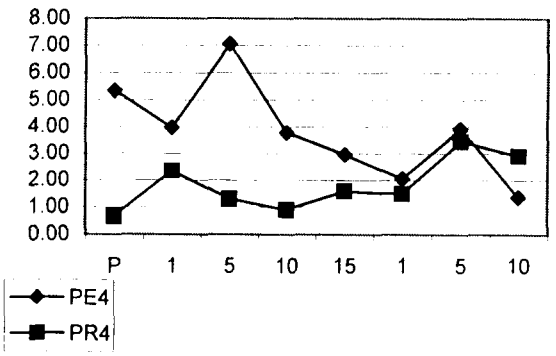


Fig. 5e $T_1 + T_3$ (T_5)

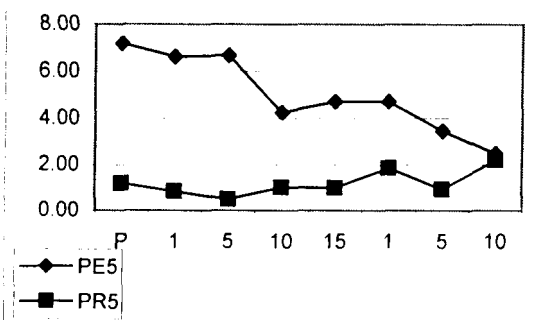
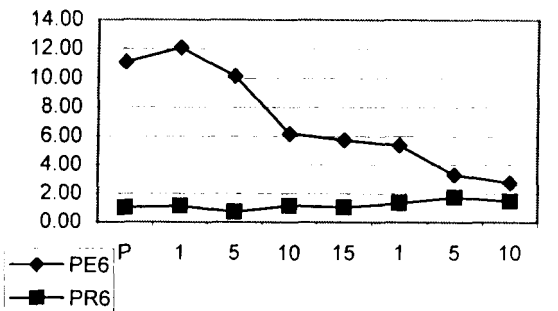


Fig. 5f $T_2 + T_4$ (T_6)



X axis - Days after first and second application/release
Y axis - Mean number of mites per leaf
PE - Pest (*P. latus*)
PR - Predatory mite
P - Pre-count

Fig. 5g $T_1 + T_3$ + Neem garlic emulsion 2% (T_7)

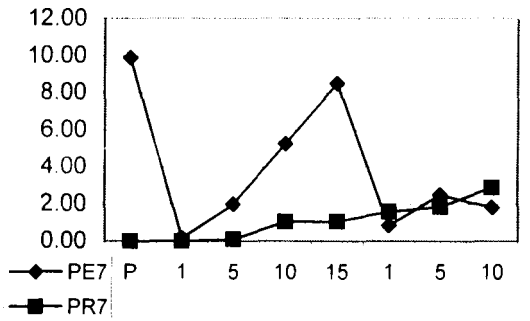


Fig. 5h Neem garlic emulsion 2 % (T_8)

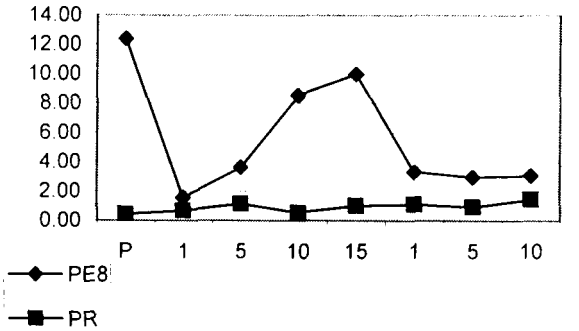


Fig. 5i Neem oil emulsion 5 % (T_9)

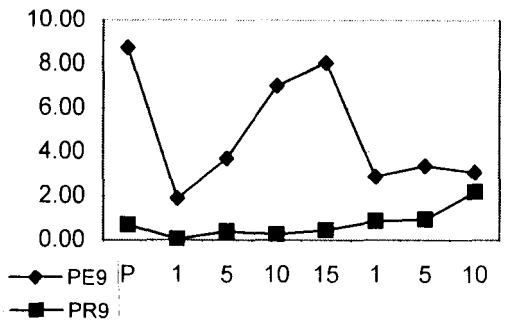


Fig. 5j Garlic emulsion 2% (T_{10})

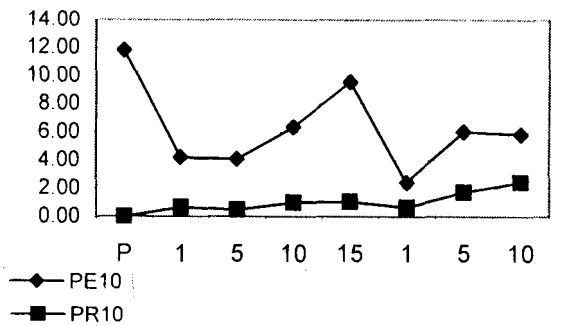


Fig. 5k Fish oil insecticidal soap 2.5 % (T_{11})

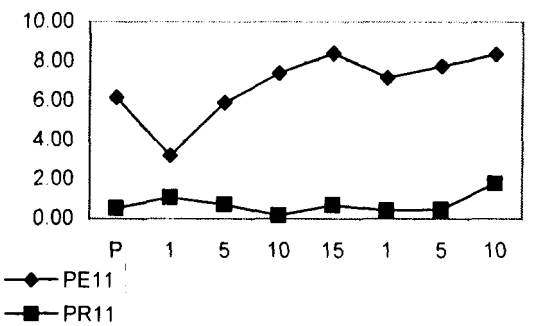
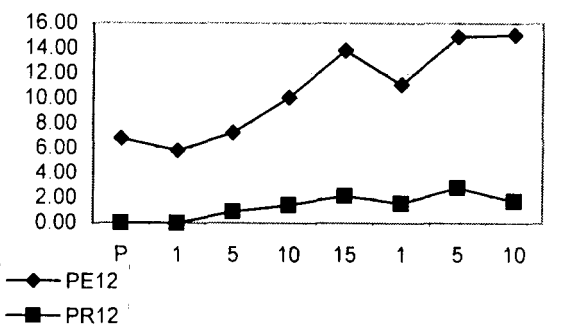


Fig.5l Control (T_{12})



X axis - Days after first and second application/release
Y axis - Mean number of mites per leaf
PE - Pest (*P. latus*)
PR - Predatory mite
P - Pre-count

cent, neem garlic emulsion 2 per cent, garlic emulsion 2 per cent, fish oil insecticidal soap 2.5 per cent and release of *Amblyseius* are economically viable for management of *P. latus* in chilli. Benefit cost ratio of another predatory mite *Macrochelus merdarius* which was found to be an efficient predator of *P. latus* would be 1 : 1.18 and 1 : 1.20 @ 10 and 20 mites per plant if mass produced using rice bran mites, *Tyrophagus* sp. Since the mass production techniques of this mite in rice bran mite is simple compared to rearing of predatory mite, *Amblyseius* spp. in their natural host this technique offer scope for management of *P. latus*.

SUMMARY

6. SUMMARY

In the current scenario of pest management, focus is on biocontrol since it is regulatory and gives the advantage of permanency. Before adopting biocontrol in a crop, informations on the control exerted by the bioagent on the pest, compatibility of bioagents with other management tools and economics of management are required. Further, the bioagent should be available for mass production at competitive prices for augmentative releases. Considering these aspects, in the present investigation attempts were made to mass multiply predatory phytoseiid mites and an insect predator, *C. carnea*. The biology, predatory potential and prey preference of these bioagents and the effect of pesticides upon them were assessed. Further, the role of the bioagents in the management of phytophagous mites, *T. ludeni* and *P. latus* were also assessed.

Predatory mites belonging to the genus *Amblyseius* of the family phytoseiidae were observed as the dominant predators of *T. ludeni* in cowpea and *P. latus* in chilli under field situations. However the species preying *T. ludeni* and *P. latus* were different. *A. longispinosus* was identified as the predator of *T. ludeni*. Another species (unidentified) of the genus *Amblyseius* was the major predator of *P. latus* in the field. In the lab, a macrocheyletid mite, *Macrochelus merdarius* found in rice bran was also observed as an efficient predator of *P. latus*.

Techniques were developed to mass multiply both the species of *Amblyseius*, preying *T. ludeni* and *P. latus* on excised leaves of cowpea. Excised leaves of cowpea when placed in water remained fresh for two weeks.

The technique of rearing on excised leaflet ensured adequate and continuous supply of the host mite as well as the predator. Within a period of seven days two fold increase in the predator population was observed.

Since the chilli mite *P. latus* was found to infest vegetable cowpea also excised leaves of cowpea were used for mass rearing. *P. latus* and its predator.When the predator was released into a colony containing 200 numbers of prey mite, population of predator doubled in a week.

The Macrocheylitid, mite, *M. merdarius* preying on *P. latus* in the laboratory could be easily multiplied on storage mite *Tyrophagus* sp. From 10 g rice bran containing *Tyrophagus* sp. 410 *M. merdarius* could be produced in a month. Since the mass production technique of this mite is simple compared to rearing of *Amblyseius* on its natural hosts, there is scope for utilization of this predator in the management of *P. latus*.

The predatory mite, *A. longispinosus* when fed on diet pollen viz., pollen of *A. auriculiformis* and *H. rosa-sinensis*, it could survive on these diets. It was also encouraging to note that the adult fed on pollen laid eggs and the larvae that emerged from these eggs could complete development on pollen.

In all the artificial diets tested in the present study the gravid females could survive. Egg laying was also noticed but the fecundity was less than that of pollen fed adults. Further the first generation did not reach adulthood in the artificial diets.

The biology of the predatory mite *A. longispinosus* studied in the laboratory revealed that the predator completed its development in 6.85 ±

0.46 days on *T. ludeni* whereas the predatory mite *Amblyseius* sp completed its development in 5.79± 0.44 days when reared on *P. latus*.

With a view to identifying suitable hosts for mass rearing of *C. carnea* the predator was reared on different hosts viz., *A. craccivora, T. ludeni* and *Corcyra* eggs. It was seen that *C. carnea* was able to complete its life cycle on all the three hosts. The developmental period was shortest on *Corcyra* eggs. With reference to the fecundity also rearing on *Corcyra* eggs proved better than rearing on *A. craccivora* and *T. ludeni*.

An assessment of predatory potential of *A. longispinosus* revealed that the predator fed on all stages of *T. ludeni*. The larva was found to feed on all stages except adult. Among the different stages of the predator, adult was the most voracious one and the most preferred stage of the prey consumed was eggs.

In the case of the predatory mite *Amblyseius* sp. preying *P. latus* also the larva of predator consumed all stages of prey mite except the adult.

Besides the above mentioned predators, *M. merdarius* was also observed as an efficient predator of *P. latus*. In the present studies, the predatory potential of the adult predator was found to be higher than *Amblyseius* sp.

Studies on the assessment of the predatory potential of *C. carnea* revealed that this is a voracious feeder of cowpea aphids and *T. ludeni*. The mean daily consumption was highest for the third instar larva in both the cases.

The prey preference of the predators was assessed through multiple choice and single choice tests. Among the prey tested viz., *T. ludeni*, *P. latus* and *Tyrophagus* sp., maximum preference was shown towards *T. ludeni*. The broad mite, *P. latus* was also found to be preyed upon by the predator in both multiple and single choice tests. But total avoidance was shown towards bran mite *Tyrophagus* sp.

The prey preference of the general predator *C. carnea* was also assessed also through multiple choice and single choice tests. In multiple choice test, among the five prey tested, highest preference was shown towards *A. craccivora*. All the forty aphids provided were consumed by the predatory larva within 48 h of exposure. The red spider mite *T. ludeni* was the next preferred host and spiralling whitefly was the least preferred one. In the single choice tests also the predator consumed 86.6 per cent and 96.6 per cent out of forty *A. craccivora* and *T. ludeni* provided within 24h of exposure to the second instar larvae of *C. carnea*.

The effect of pesticides on the predator was assessed by exposing the predator to dry films of the pesticide and observing mortality at different intervals after exposure. It was found that triazophos 0.05 per cent was the most toxic chemical against *A. longispinosus*, in which none of predatory mites survived 6 h after exposure. The acaricide, dicofol 0.05 per cent also indicated significantly higher mortality at 6 h of exposure. Observations recorded at 24 h revealed cent per cent morality in all the chemical pesticides tested.

Though botanical pesticides were found significantly safer than chemical pesticides with respect to toxicity to the predatory mite, mortality to

the tune of 10.63 to 42.3 and 37.71 to 47.63 were observed when predatory mites were exposed for 6 h and 48 h respectively indicating that the negative impact of botanical pesticides on natural enemy cannot be overlooked.

Evaluation of the effect of pesticides on *C. carnea* also showed that Triazophos 0.05 per cent was the most toxic chemical. None of the larvae tested survived after 24 h in this treatment. Quinalphos 0.03 per cent and Malathion 0.05 per cent proved equally toxic to the predator and there was no significant difference in the morality between these treatments. The acaricide, dicofol did not have much effect on the larvae. The mortality of the larvae of *C. carnea* when exposed to botanical pesticides viz., 10 per cent emulsified extract of *A. paniculata* and *H. suaveolens* and Neem garlic emulsion (2.5 per cent) was lower compared to chemical pesticides.

Field experiments were conducted in vegetable cowpea and chilli to study the effect of bioagents and botanical pesticides on phytophagous mites viz., *T. ludeni* and *P. latus*, their predators and on yield. The highlights are given below.

Lowest incidence of the spider mite *T. ludeni* was in the treatment where in combination of bioagents and botanical pesticides (*C. carnea* @ 5 / plant + *A. longispinosus* 10 / plant + Neem garlic emulsion 2 per cent) was given in the observations taken at both one day and five days after first and second applications. This was followed by neem garlic emulsion 2 per cent and neem oil 5 per cent.

The population of *T. ludeni* was found to decrease immediately after application of neem garlic emulsion 2 per cent, neem oil emulsion 5 per cent

and garlic emulsion 2 per cent but after five days the population increased. It was also observed that with repeated application, population build up of the mite was checked upto 10 days after treatment.

The effect of release of the biocontrol agent *C. carnea* on *T. ludeni* was observed till the fifth day following the release of *C. carnea* @ 5 and 10 per plant, thereafter the population of *T. ludeni* increased gradually. The voracious feeder *C. carnea* could not bring about spectacular reduction in population of *T. ludeni* under field situations. With regard to the effect of the release of predatory mite, immediate effect in the population reduction of *T. ludeni* was not noticed but a slow decline in the population of the prey mite was observed with advent of time. It was also observed that the population of the predatory mite increased steadily and within a month the population of the predator and prey became almost equal.

A steady decline in the population of *T. ludeni* and a progressive increase in the number of predatory mites were also observed when the bioagents, *C. carnea* and predatory mite *A. longispinosus* were released together.

Application of the entomopathogenic fungus *Fusarium pallidoroseum* @ 7 x 10^6 spores/ml had practically no effect in checking the population of *T. ludeni*.

In control plots, the population of *T. ludeni* showed a steady increase as time elapsed. Though predatory mites were not released in control plants, predatory mites were seen associated with *T. ludeni*. Moreover it was seen that the population of these mites increased with increase in population of its

prey mite, *T. ludeni*. These observations further stress the role of acarine predators in the management of mites.

Highest yield was recorded from plants treated with neem oil emulsion five per cent. This was on par with yield obtained from treatment, neem garlic emulsion 2 per cent, combination treatment of *C. carnea* @ 5 per plant + *A. longispinosus* 10 per plant + neem garlic emulsion 2 per cent, *C. carnea* @ 10 per plant and *C. carnea* 10 per plant + *A. longispinosus* 20 per plant. Considering the benefit cost ratio, application of neem oil 5 per cent was found to be the best treatment for management of mites. This was followed by application of neem garlic emulsion fish oil insecticidal soap 2.5 per cent and garlic emulsion two per cent. All the other treatments were uneconomical even though these treatments showed significant reduction in mite population.

In chilli the most effective treatment in checking the *P. latus* population was the combined use of *C. carnea* @ 5 per plant + *Amblyseius* sp. @ 10 per plant + neem garlic emulsion 2 per cent. Significant reduction in population of *P. latus* was observed in plants treated with neem garlic emulsion 2 per cent and neem oil emulsion 5 per cent.

The release of the predator *C. carnea* was not effective @ five per plant. At the higher level tested also no reduction in population of *P. latus* was obtained following initial release.

The effect of the predatory mite, *Amblyseius* sp. was pronounced from the tenth day onwards at both the levels tested (10 and 20 mites per plant). In the combined application of *C. carnea* and *Amblyseius* also, the treatment was found effective from the tenth day onwards.

Fish oil insecticidal soap 2.5 per cent was ineffective against *P. latus*. Garlic emulsion gave substantial reduction immediately following the first spray. Subsequently the population was found to increase but significant reduction in population was noticed following a second spray.

With respect to the yield, there was no significant difference between treatments however, based on the benefit cost ratio it is concluded that application of neem oil 5 per cent, neem garlic emulsion 2 per cent, garlic emulsion 2 per cent, fish oil insecticidal soap 2.5 per cent and release of *Amblyseius* @ 10 and 20 per plant are economically viable for management of *P. latus* in chilli.

REFERENCES

REFERENCES

*Abbot, W.S. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* **18**: 265-267

*Abou-Setta,M.M. and Childers,C.C. 1987 A modified leaf arena technique for rearing phytoseiid or tetranychid mites for biological studies. *Fla Entomol.* **70** : 245-248

Adashkevich,B.P.1987. The aphid lion:for and against *Zaschita Rastenii* Moskova **7** : 29-30

Almaguel, L., Perez, R. and Ramos, M. 1986. Life cycle and fecundity of mite *Polyphagotarsonemus latus* on pepper. *Cienc. Tecn. Agric. Prot. Plant.* 7(3): 94-114

Amin Masoodi, M. and Trali, A.R. 1988. Seasonal phenology of *Aphis pomi* De Geer (Homoptera: Aphididae) and its association with natural enemies in Kashmir. In: *Proceedings of the National symposium on Integrated Pest Control Progress and Perspectives*, 15-17. Oct., 1987, Thiruvananthapuram, India

Ansari, M.A. and Pawar, A.D. 1992. Biology of spider mite, *Tetranychus ludeni*, Zacher (Acari: Tetranychidae) recorded on water hyacinth. *Pl.prot. Bull.* **44** (3): 28-31

Ashihara, W., Hamamura T. and Shinkaji N. 1978. Feeding, reproduction and development of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) on various food substances. *Bull. Fruit Tree Res. Stn.*, Japan E2: 91-98

*Badawy, H. M.A., Elnarnouty, S.A. 1999. Direct and indirect effects of some insecticides on *Chrysoperla carnea* Stephens. (Neuroptera: Chrysopidae) *J. Neuropterology* 1999 **2** : 67-74

*Bakasova, N.F. 1978. Instructions provisories concemant les methods selvage conservation des fameless de *Phytoseiulus persimilis* A.H. Ed. VIZR Leningrad, p.2-8

Bakthavalsalam, N.,Singh,S.P.,Pushpalatha,N.A.,Bhumannavar,B.S.1994. Life tables of four species of chrysopids (Neuroptera : Chrysopidae). *J. Entomol. Res.* **18** (4):357-360

Balasubramani, V. 1991. Studies on the green Lace-wing, *Chrysoperla carnea* Stephens (Chrysopidae-Neuroptera) in Tamil Nadu. M Sc. (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore

Balasubramani, V. and Swamiappan, M. 1993. Screening of insecticides used in cotton ecosystem for their effect on the green lace wing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). *National Symposium on Advances in Biological control of insect pests* November 2-4, 1993

Balasubramani,V. and Swamiappan, M.1994. Development and feeding potential of the green lacewing,*Chrysoperla carnea* Steph. (Neur:chrysopidae) on different insect pests of cotton. *Anzeiger fur Schadlingskunde,Pflanzenschutz, Umweltshutz* **67** (8):165-167

Ballard,R.C.1954. The biology of the predaceous mite *Typhlodromus fallacis*(Garman)(Phytoseiidae) at 78°F .*Ohio J. Science.* **54** :175-179

Bartlett, B.R. 1964 Toxicity of some pesticides to eggs, larvae and adults of the green lacewing *Chrysopa carnea J. Econ. Entomol.* **57**: 366-369

Biasi, L.A., Santos, H. and Dos, H.R. 1988. Consumption of eggs of *Tetranychus ludeni* Zacher, 1913 (Acari: Tetranychidae) by *Amblyseius fallacis* Garman (Acari: Phytoseiidae) *Revista do setor de ciencias Agrarias.* 10 (1-2): 99-102

Bindu, S.S. 1997. Biocontrol of Pests of vegetable cowpea (*Vigna unguiculata* sub. sp. *Sesquipedalis* (L.) Verdcourt) M. Sc. (Ag.) Thesis Kerala Agricultural University

Bravenboer, L. 1975. Biological control in Protected Cultivation. *Semaine detude agriculture et hygiene des plantes*, 8-12 Sept. 1975, Gemblowo, pp. 289-296

*Bravenboer, L. and G. Dosse. 1962. *Phytoseiulus riegeli* Dosse als predator einiger Schildmilben aus der *Tetranychus urticae* Gruppe. *Entomol. Exp. Appl.* **5:** 291-304

*Brown, R.D., and Jones, V.P. 1983. The broad mite on lemon in southern California. *California. Agric.* **27**:21-22

Burell, R.W and Mc Cormick, W.J. 1964. *Typhlodromus* and *Amblyseius* (Acarina: Phytoseiidae) as predators on orchard mites. *Ann. Entomol. Soc. Am.* **57**: 483-487

Canard, M. 1973. Voltinism, diapause et sex ratio de *Chrysopa perla* (L.) (Neuroptera: Chrysopidae) dans le sub- quest. *Ann.. Zool. Ecol. Anim.* **5**: 29-37

Canard, M., Semeria Y. and. New, T.R. 1984. *Biology of Chrysopidae*, Dr. W. Junk publishers The Hague, p. 287

Chandrasekharappa, B.; Mallik, B. and Harishkumar, M. 1995. Effect of temperature and humidity on the biology of the predatory mite *Amblyseius longispinosus* (Acari: Phytoseiidae). *Abstr. V. National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 32

ChannaBasavanna,G.P. and Puttarudriah,M. 1959. *Hemitarsonemus latus* (Banks), a potential pest of cotton in Mysore .*Sci.cult.* **25**:322-323

Childers, C. C., and Enns, W.R. 1975. Field Evaluation of early season fungicide substitutions on Tetranychid mites and the predators *Neoseiulus fallacis* and *Agistemus fleschneri* in two Missouri apple orchards. *J. Econ. Entomol.* **68**: 719-724

Coppel, H.C and Mertins, J.W. 1977. *Biological insect pest suppression.* Advanced series in Agricultural sciences 4. Springerverlag, Berlin, Heidelberg, New York, p. 244

Croft, B.A and Mc Murtry, J.A. 1972. Minimum releases of *Typhlodromus occidentalis* to control, *Tetranychus mcdanieli on apple J. Econ. Entomol.* **65:** 188-191

Croft, B.A. and Nelson,E.E. 1972. Toxicity of apple orchard pesticides to Michigan populations of *Amblyseius fallacis. Environ. Entomol.* **1** : 576-579

De Bach, P., and Rosen, D. 1991. *"Biological control by natural enemies"* 2nd ed. Cambridge Univ. Press, New York

Dhooria, M.S. 1982. Natural enemy complex of Citrus mite, *Eutetranychus orientalis* in Delhi, India, *Acarology Newsletter.* **11**: 6

Dhooria, M.S. 1983. Effect of different levels of mite population on the growth of French bean *Phaeseolus vulgaris* . *Acarology News letter* 2:5

Dhooria, M.S and Bindra, O.S. 1977 *Polyphagotarsonemus latus* Banks, a mite pest of chilli and potato in Punjab. *Acarology Newsletter* **4**: 7-9

*Elkarmi, L.A., Harris M.K. and Morrison R.K.. 1987. Laboratory rearing of *Chrysoperla rufilabris* (Burmeister); a predator of insect pests of pecans. *South West Entomol.* **12**: 73-78

F.A.O. 1984. Recommended methods for the detection and measurement of resistance of Agricultural pest to pesticides –Method for phytoseiid predatory mites- F.A.O method ,*FAO Pl. Prot. Bull.* **32**: 25-27

Faizal, M.H. 1992 Studies on the entomogenous fungus *Fusarium pallidoroseum*(Cooke)Sacc. Associated with cowpea aphid *Aphis craccivora* Koch. M.Sc. (Ag.) Thesis Kerala Agricultural University Thrissur, p. 90

Fan, Y and Petitt, L.F. 1994. Biological control of Broadmite, Polyphagotarsonemus latus (Banks) by *Neoseiulus barkeri* Hughes on pepper. *Biological control* **4**: 390-295

Finney, G.L. 1948. Culturing *Chrysopa california* for obtaining eggs for field distribution. *J. Econ. Entomol.* **41** : 719-721

Finney, G.L. 1950. Mass culturing *Chrysopa californica* to obtain eggs for field distribution *J. Econ. Entomol.* **43** (1): 97-100

Fournier, D., Millot, P. and Pralavoria, M. 1985. Rearing and Mass production of the predatory mite, *Phytoseiulus persimilis* A. H. (Phytoseiidae) *Entomol. Exp Appl.* **38**: 98-100

Gautam, R.D. and Navarajan Paul, A.V., 1987. An artificial diet for the larvae of green lacewing *Chrysopa scelestes* Banks (Neuroptera: Chrysopidae) *J. Entomol. Res.* **11**(1): 69-72

Gautam, R.D. and Navarajan Paul, A.V. 1988. Influence of adult food supplements on *Chryropa scelestes* Banks. (Neuroptera: Chrysopidae) *J. Entomol. Res.* **12** (1): 25-27

Geetha, B. 1994. Studies on developing adult diets, rearing methods and field manipulation to maximize the reproductive potential of green lacewing, *Chrysoperla carnea* Stephens (Chrysopidae: Neuroptera). M.Sc. (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore

Gerson, U. 1992 Biology and control of broad mite *Polyphagotarsonemus latus* (Banks) (Acari: tarsonemidae) *Exp. Appl. Acarol.* **13** : 163-178

Gikorashvili, G.S. 1983. Against the Red fruit mite. *Zashchita-Rastenii* **8** : 28

Gilkeson, L.A. 1992. Mass rearing of phytoseiid mites for testing and commercial application In: *Advances in insect Rearing for research and pest management.*). (Anderson, T.E and.Leppla, N.C eds.) Oxford and IBH publishing Co.Pvt. Ltd., New Delhi, pp. 489-506

*Gilstrap, F.E. 1977. Table-top production of Tetranychid mites (Acarina) and their phytoseiid natural enemies. *J. Kansas Entomol.* Soc. **50** (2): 229-233

Gupta, S.K.,1985 *Hand book, Plant Mites of India* Zoological survey of India, Calcutta, p.520

Gupta, S.K., Dhooria, M.S. and Sidhu, A.S. 1971. A note on predators of citrus mite in Punjab *Sci. cult.* **37**(10) : 484

Gupta, V.N. and Gupta, S.K. 1985. Mites associated with vegetable crops in West Bengal. *Indian J. Acarol.* 10 (2): 61-64

Gupta, S.K., and Gupta, A. 1992. Predatory plant mites of India and their importance in biological control. In: *Man mites and Environment* (Haq, M.A. and Ramani, N. eds.) Anjengo publications, Calicut, Kerala, p. 146-153

*Gurbanov, G.G. 1982. Effectiveness of the use of common lacewing (*Chrysopa carnea* Steph.) in control of sucking pests and cotton moth on cotton. *Izvestiya-Akademii-Namk-Azerbaidzham Kai*, SSR **2** : 92-96

Hagen, K.S. 1950. Fecundity of *Chrysopa californica* as affected by synthetic food. *J. Econ. Entomol* **43**: 101-104

Hagen, K.S. and Tassan, R.L. 1965. A method of providing artificial diets to *Chrysopa* larva *J. Econ. Entomol.* **58** : 99-100

Hagen, K.S. and Tassan, R.L. 1966. The influence of protein hydrolysates of yeast and chemically defined diet upon the fecundity of *Chrysopa carnea* Steph. *Vest. Csl. Spol. Zool.* **30**: 216-227

Hambleton, E.J., 1938. The occurrence of the tropical mite, *Tarsonemus latus*, the causes of tearing of leaves in the cotton fields of Sao Paulo. *Arg. Inst. Bull.* **9** : 201-209

Hareendranath,V.1989. Control of *Aphis craccivora* Koch. with fungal pathogens and their impact on natural enemies of the pest. M.Sc. (Ag.) thesis, Kerala Agricultural University,Thrissur

Hariyappa, A.S. and Kulkarni, K.A. 1988. Biology and feeding efficiency of the predatory mite *Amblyseius longispinosus* Evans on chilli mite *Polyphagotarsonemus latus* Banks. *J. Biol. Control.* **2**:131-132

Hassan, S.A. 1975. Ulber die Massenzucht von *Chrysopa carnea* Steph. (Neuroptera: Chrysopidae) *Z. ang. Entomol.* **79**: 310-315

Hassan, S.A. and Hagen, K.S. 1978. A new artificial diet for rearing *Chrysopa carnea* larvae. (Neuroptera: Chrysopidae). *Z. ang. Entomol.* **86** : 315-320

*Hendrickson, R.M., Jr. 1980. Continuous production of predacious mites in the green house, *N.Y. Entomol. Soc.* **88** (4): 252-256

Herne, D.C. and Chant, D.A. 1965. Relative toxicity of parathion and kelthane to the predacious mite *Phytoseiulus persimilis* Athias-Henriot and its prey *Tetranychus urticae* Koch. (Acarina: Phytoseiidae, Tetranychidae) in the laboratory. *Can. Entomologist*, **97**: 172-176

Jakobsen, J. 1989. Mass production of rovmiden *Amblyseius barkeri* till trips bekaempelse. (Mass rearing of the predatory mite *Amblyseius barkeri* for control of thrips),. *6th Danish Plant Protection Conference pests and Diseases*. pp. 77-82

Jagdish, P.S. and ChannaBasavanna, G.P. 1989. Toxicity of Pesticides on *Amblyseius tetranychivorus* (Acari: Phytoseiidae) an effective predator of *Tetranychus ludeni* (Acari: Tetranychidae) In: *Progress in Acarology* vol.2 (Channa Basavanna, G.P. and Viraktamath, C.A., eds.) Oxford and IBH publishing Co. Pvt. Ltd. New Delhi, Bombay, Calcutta, p. 449-452

Jagdish, P.S. Channabasavanna,G.P.,NeeluNangia and Nageshchandra, B.K.1995 Studies on the alternate food source other than prey mites for the predatory mite *Eusieus concordis*(Acari:Phytoseiidae) *Abstr. V. National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p.71

Jagdish, P.S. and Nageshchandra, B.K. 1982. Biology of *Typhlodromips tetranychivorus* (Acari: Phytoseiidae) on red palm mite. *Raoiella indica* (Acari: Tenuipalpidae) *Acarology Newletter*, 11: 9

Jayarajan,S., Natarajan, S. and Kandasamy, D. S. 1995. resurgence of yellow mite in semi dry chilli. *South Ind. Hort.* **43** : 3-4, 117-119

Jeppson,L.R.,Keifer,H.H.and Baker, E.W.1975.*Mites injurious to economic plants*. Universityof California press. California, p.614

Jose, V.T., Shah, A.H. and Patel, C.B. 1989. Feeding potentiality of some important predators of the spider mite, *Tetranychus maefarlanei*, In: *Progress in Acarology* vol.2 (ChannaBasavanna, G.P. and Viraktamath, C.A., eds.) Oxford and IBH publishing Co. Pvt. Ltd. New Delhi, Bombay, Calcutta, p. 345-355

Kabir, A.K.M.F., 1979. Bioecology and behaviour of yellow jute mite In: Rodriguez, J.G. (Ed.) *Recent Advances in Acarology*. Vol. I Academic press, New York, pp. 519-523

Kamburov, S.S. 1971. Feeding development and reproduction of *Amblyseius largoensis* on various food substances. *J. Econ. Entomol.* **64**: 643-648

Kandasamy, C., Mohanasundaram, M. and Karuppuchamy, P. 1987. Evaluation of insecticides for the control of yellow mite *Polyphagotarsonemus latus* Banks on chillies. *Madras Agric. J.* **74** (8): 351-355

Kareem, A., Thangavel, P. and Balasubramanian, M. 1977. A new mite *Hemitarsonemus latus* Banks (Tarsonemidae: Acarina) as a serious pest of chilli *Capsicum annuum*. L. *Pesticides* **11** (6): 42-43

*Karg, W., Mack S. and Baier, B. 1987. Advantages of Oligophagous predatory mites for biological control. *Bull.* SROP/WPRS **10** (2): 66-73

Karmakar, K. 1995. Comparitive symptomatology of chilli leaf curl disease and biology of tarsonemid mite *Polyphagotarsonemus latus* (Banks). *Ann. Entomol.* **13** : 65-70

Karmakar, K. 1997 Size, shape and behaviour of *Polyphagotarssonemus latus* (Banks). *Environ. Ecol.* **15**: 1, 219-220

Karpacheva, N.S. 1991. The common lacewing *Zashchita Rastenii* **11**: 36

Karuppuchamy, P. and Mohanasundaram, M. 1987 New species and records of tetranychid mites (Tetranychidae: Acarina) from India, *Entomon.* **12** (2): 89-94

Karuppuchamy, P., Balasubramanian, G., Sundarababu, P.C. and Gopalan, M. 1994. A potential predator of chilli mite, *Polyphagotarsonemus latus* (Banks) (Tarsonemidae: Acari) *Madras Agric. J.* **81** (10): 552-553

Karuppuchamy, P., Mohanasundram, M., Jayarajan, S. 1988. A new method of mass rearing predatory phytoseiid mites in the laboratory. *Current Science* **57** : 7, 379-380

Kennett, C.E. and Hamai J. 1980. Oviposition and development in predaceous mites fed with artificial and natural diets (Acari: phytoseiidae) *Entomol. Exp. Appl.* **28** : 116-122

Kerala Agricultural University.1996. *Package of Practices Recommendations*, Directorate of Extension,Thrissur, p. 267

Kharizamov, A. and Babrikova, T. 1978. Toxicity of insecticides to certain species of chrysopids. *Zaschita Rastenii* **26** (5): 12-15

*Knisley, C.B. and Swift, F.C., 1971 Biological studies of *Amblyseius umbraticus* (Acarina: Phytoseiids). *Ann. Ent. Soc. Ame.* **64**: 813-822

Krishnamoorthy, A. 1982a. Effect of some pesticides on the predatory mite, *Amblyseius tetranychivorus* (Gupta) (Acarina: Phytoseiidae) *Entomon* **8** (3): 229-234

Krishnamoorthy, A. 1982b. Mass rearing technique for an indigenous predatory mite. *Amblyseius (Typhlodropmips) tetranychivorus* (Gupta) (Acarina: Phytoseiidae), in the laboratory. *Entomon* 7(1): 47-49

Krishnamoorthy, A. 1983. A New record of phytoseiid mite from Karnataka. *Acarology Newsletter* **13** (2): 1

Krishnamoorthy, A. 1985. Effect of several pesticides on eggs, Larvae and adults of the green lacewing *Chrysopa scelestes* Banks. *Entomon* **10** (1) : 21-28

Krishnamoorthy, A. and Mani, M. 1989. Effect of releases of *Phytoseiulus persimilis* in the control of two spotted spider mite on french beans. *J. Biol. Control.* **3** (1): 33-36

Krishnamoorthy, A. and Nagarkatti, S. 1981. A mass rearing technique for *Chrysopa scelestes* Banks (Neuroptera: Chrysopidae) *J. Entomol. Res.* **5** (1): 93-97

*Kulkarni, G.S. 1922. Symptoms of damage caused by mite on chilli *Agric. J. India* **17** : 51-54

Kundu, S.K; Jeyakumar,P., Meenakshi and Gupta,G.P.1998 Conservation of Chrysoperla carnea Steph in Cotton Ecosystem for sustainable IPM Programme. *Ind. J. Entomol.* **60** (3) : 297-300

*Lavioperse, M.M.J., 1940 *Hemitarsonemus latus* (Banks), a mite of economic importance of South Africa. *J. Entomol. Soc. South Afr.* **3**: 116-123

Lingren, P.D. and. Ridgway R.L 1967. Toxicity of five insecticides to several insect predators. *J. Econ. Entomol.* **60** : 1639-1641

Malaviya, M.D. and Rai, A.B.1995a. Laboratory evaluation of conventional acaricides/pesticides against *Tetranychus ludeni Abstr V National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 80

Malaviya, M.D. and Rai, A.B.1995b Studies on biology of red spider mite *Tetranychus ludeni* on Indian bean *Abstr V National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 43

Mallik, B. 1974. Biology of *Amblyseius longispinosus* (Evans) (Acarina: Phytoseiidae and *Tetranychus ludeni* Zacher (Acarina: Tetranychidae) and interaction between them. M. Sc. (Ag) Thesis University of Agricultural Sciences, Bangalore, p. 72

Manjunatha, M., Puttasamy, Holihosur,S.N. and Lingappa, S.1995. Acaricidal value of Plant Extracts against Sorghum mite *Oligonychus indicus* (Acari:Tetranychidae). *Abstr V National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 84

McEwen, P.K., S. Clow, M.A. Jervis and N.A.C. Kidd, 1993 a. Alternation in searching behaviour of adult green lacewing *Chrysoperla carnea* (Neur: Chrysopidae) following contact with honey dew of black scale *Saissetia oleae* (Hom: Coccidae) and solutions containing acid- hydrolysed L- tryptophan, *Entomologica* **38** : 347-354

McEwen, P.K., M.A., Jervis and N.A.C. Kidd, 1993b. Influence of artificial honeydew on larval development and survival in *Chrysoperla carnea* (Neur: Chrysopidae), *Entomophaga* **38** (2) : 241-244

McMurtry, J.A. 1989. Utilizing natural enemies to control pest mites on citrus and avocado in California, U.S.A. In: *Progress in Acarology. Vol.2* (ChannaBasavanna, G.P. and Viraktamath, C.A. eds.) Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, Bombay Calcutta, p. 325-337

McMurtry, J.A. and G.T. Scriven. 1966 Effect of artificial foods on reproduction and development on four species of phytoseiid mites. *Ann. Entomol. Soc. Am.* **59** : 267-269

McMurtry, J.A., Badii, M.H. and Johnson, H.G. 1984. The broad mite, *Polyphagotarsonemus latus* as the potential prey for phytoseiid mites in California. *Entomophaga* **29**(1): 83-86

McMurtry, J.A., Huffaker, C.B. and Van de Vrie, M. 1970. Ecology of Tetranychid mites and their natural enemies, a review. I. tetranychid enemies; their biological characters and impact of spray practices. *Hilgardia* **40** : 331-390

Mehta, D.N., Singh, K.M. and Singh, R.N. 1989. Natural enemy complex in insect pest complex in chickpea. *Cicer arietinum* Linn. *Bull. Entomol.* **27** (1) : 1-12

*Mironova,M.K., Khorkhordin, E.G. and Kleeberg, H.1997. Effect of Neem-Azal-T/S on *Tetranychus urticae* Koch. In: *Practice oriented results on use and production of neem ingredients and pheromones* (Kleeberg, H. eds.). *Proceeding 5th Workshop* Wetzlar, Germany, 22-25 January, p.129-137

*Miszczak, M. and Niemczyk, E. 1978. Green lacewing *Chrysopa carnea* Steph. (Neuroptera, Chrysopidae) as a predator of the European mite *Panonychus ulmi* Koch on apple trees 2. The effectiveness of *Chrysopa carnea* larvae in biological control of *Panonychus ulmi* Koch. *Fruit Sci. Red.* **5** (2) : 21-31

*Momen,F.M.,Reda,A.S. and Amer,S.A.A. 1997. Effect of Neem-azal-F on *Tetranychus urticae* and three predaceous mites of the family Phytoseiidae. *Acta-Phytopathologia-et. Entomologia-Hungarica* **32** : 3,4,355-362

Morrison, R.K. and E.G. King, 1977. Mass production of natural enemies. In: *Biological control by augmentation of natural enemies.* (R.L. Ridgeway and S.B. Vinson eds.) plenum press: New York, pp. 183-217

Morrison, R.K., Honse, V.S. and Ridgeway, R.L. 1975. Improved rearing unit for larvae of a common green lacewing. *J. Econ. Entomol.* **68**: 821-822

Morros, C. ME and Aponte, L.O. 1994. Biology and life table of *Tetranychus ludeni* Zacher on black bean, *Phaeseolus vulgaris* L. *Agronomia. Tropical. Maracay*. **44** (4) : 667-677

Mote, U.N. 1976. Seasonal fluctuation in population and chemical control of chilli mite. *Polyphagotarsonemus latus* Banks. *Veg. Sci.* **3**(1): 54-60

Naegele ,J.A. and McEnroe,W.D.1963 Mass rearing of two spotted spider mite ,pp191-192.*In Recent Advances in Acarology,* (Naegele,J.A. eds.) vol1 Cornel Univ., Ithaca, New York

Nagaraja, S.D. 1988. Studies on chilli thrips *Scirtothips dorsalis* Hood and chilli mite *Polyphagotarsonemus latus* Banks with reference to chemical control and pesticide residue estimation. M. Sc. (Ag.) thesis. U.A.S. Bangalore, pp. 69-73

*Nakagawa, T. 1985. Effect of humidity on the development, reproduction and predatory activity of *Amblyseius longispinosus* Evans, a predator of *Tetranychus Kanzawai* Kishida. *Proc. Assoc. Pl. Prot.* Kyushu **31**: 220-222

Nandihalli, B.S., 1979, Efficacy of different insecticides in the control of chilli leaf curl and their residues. M.Sc. (Ag.) Thesis.Univ. Agric. Sci., Dharwad, p.119

Nangia, N. 1980 Studies on biological control of spider mite *Tetranychus ludeni* Zacher using *Typhlodromips tetranychivorus* Gupta (Acari: Phytoseiidae), M.Sc. (Ag.) Thesis. Univ. Agril. Sci., Bangalore, pp. 156

Nicole,G.,Galazzi,D.;Mosti,M. and Burgio,G.1991. Embryonic and larval development of C*hrysoperla carnea*(Steph) (Neuroptera : Chrysopidae) at different temperature regimes.*Bull.SROP* **14** (5): 43-49

*Niijima, K.and Matsuka, M. 1990. Artificial diets for mass production of chrysopids (Neuroptera) In: FFTC-NAKC *International Seminar on 'The use of parasitoids and predators to control agricultural pest. 1989' National Agricultural Research Centre.* 15 p.

Ningappa, M.S. 1972. Studies on the role of *Scirtothips dorsalis* Hood. (Thysanoptera: Thripidae) and *Polyphagotarsonemus latus* Banks (Acari: Tarsonemidae) in causing leaf curl and their control. *Mysore J. Agric. Sci.* **6** (3): 378-379

Nordlund, D.A., 1993. Improvements in the production system for green lacewings (*Chysoperla carnea* and *C. rufilabris*) a hot melt glue system for preparation of larval rearing units *J. Entomol. Sci.* **28** (4): 338-342

Nordlund, D.A and Morrison R.K. 1992 Mass rearing of *Chrysoperla* species In: *Advances in insect Rearing for research and pest management.* (Anderson, T.E and.Leppla, N.C eds.) Oxford and IBH publishing Co.Pvt. Ltd., New Delhi, pp. 427-439

Obrycki, J.J., Hamid, M.N., Sajap, A.S. and Lewis, L.C. 1989. Suitability of corn insect pests for development and survival of *Chrysoperla carnea* and *C. oculata* (Neuroptera: Chrysopidae) *Environ.Entomol.* **18** (6): 1126-1130

Ochieng, R.S., G. W. Oloo and E.O. Amboga. 1987. An artificial diet for rearing the phytoseiid mite *Amblyseius teke.* Pritchard and Baker. *Exp. Appl. Acarol.* **3**: 169-173

*Okamato, H. 1919. Studies on the Japanese chrysopidae, *Rep. Hokkaido Natn. Agric. Exp. Stn.* **9**: 1-76

Overmeer, W.P.J. 1985. Alternative prey and other food resources. In (Helle W. and Sabelis M.W. eds.), *Spider mites: Their biology, natural enemies and control*, vol. IB Elsevier, Amsterdam, pp. 131-137

Patel, A.G., Yadav, D.N and R.C. Patel 1988. Improvement in mass rearing technique of green lacewing *Chrysopa scelestes* Banks Neuroptera – Chrysopidae) *G.A.U. Res. J.* **14** (1): 1-4

Patel, C.B., Patel, J.R., M.B. Patel, A.J. Patel and A.B. Rai. 1995. Evaluation of Pesticides including plant products against Red spider mite, *Tetranychus mcfarlanei* (Acarina: Tetranychidae) on okra *Abstr. V National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 81

Pathumal Beevi, S., Natarajan, S. and Balasubramanian, M. 1988. Natural enemies of whitefly *Bemisia tabacci* on Brinjal. *Proceedings of the National Symposium on integrated pest control progress and perspectives*, 15-17 Oct., 1987. Thiruvananthapuram, India

Pavlova, G.A. and. Aripova ,F.K.H. 1991. Predators of web mite on various cotton samples. *Zashchita Rastenii.* **8**: 41-42

Pena, J.E. and Osborne,L.1996. Biological control of *Polyphagotarsonemus latus* (Acarina: Tarsonemidae)in green houses and field trials using introduction of predaceous mites(Acarina: Phytoseiidae). *Entomophaga* **41** (2): 279-285

Plapp, F.W. and D.L. Bull. 1978. Toxicity and selectivity of some insecticides to *Chrysopa carnea* a predator of tobacco budworm. *Environ. Entomol.* 7: 431-434

*Pomonareva, I.A. 1971. Artificial diet for the larvae of *Chrysopa carnea* Steph., pp. 77-90. In (eds. A. I. Sikura *et al*), *Biological pest control on vegetable and fruit crops.* Biol. Method Zasc. Plodov. Iovosc. Kul'tur ot Vredit., Bolezn. I Sornj., Osnovy Integrirov. System (Yezisy Doki.) Okt. 1971. Minist. Sel sk. Chozj. SSSR. Kisinev. (in Russian)

Pree, D.J., Archibald, D.E. and Morrison, R.K. 1989 Resistance to insecticides in the common green lace wing *Chrysoperla carnea* (Neuroptera: Chrysopidae) in Southern Ontario. *J Econ Entomol.* **82**: 29-34

Pushpalatha, N.A., S.P. Singh, H. Baktavatsalam and B.S. Bhumannavar, 1994. A Semisynthetic larval diet for *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) *J. Biol. Control* **8**(1): 54-55

Puttaswamy, 1978. Studies on the ecology of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) and its interaction with the predator *Typhlodromips tetranychivorus* Gupta (Acari: Phytoseiidae). Ph.D. thesis. Univ. Agril. Sci., Bangalore, p. 204

Puttaswamy and ChannaBasavanna, G.P. 1979. Life History of *Tetranychus ludeni* (Acari; Tetranychidae) under field conditions. *Indian J. Acarol.* **4** (2): 41-48

Rai, A.B., Malaviya, M.D and C.B. Patel 1995. Toxicity of pesticides including neem products on *Amblyseius alstoniae* (Acari: Phytoseiidae) an important predator of *Tetranychus ludeni* (Acari: Tetranychidae) *Abstr V National Symposium on Acarology*, Sept 20-22, 1995, Bangalore, p. 89

Rajagopalan, K. 1974. First record of spidermites *Tetranychus ludeni* Zacher. transmitting Dolichos enation mosaic virus *Curr. Sci.* **43** (15): 488-489

Ramakers, P.J.M. 1980. Biological control of *Thrips tabaci* (Thysanoptera: Thripidae) with *Amblyseius* spp. (Acari: Phytoseiidae). IOBC/WPRS/ *Bull.* 11/3: 203-207

Ramakers, P.J.M. 1983. Mass production and introduction of *Amblyseius mckenziei* and *A. cucumeris* IOBC/ WPRS/ *Bull.* VI/ 3:203-206

Ramakers, P.J.M. 1984. Mass production and introduction of *Amblyseius mckenziei* and *Amblyseius cucumeris*. OILB SROP/WPRS *Bull.* **6** (3): 203-210

Ramaraju, K., Velusamy, R., M. Mohanasundaram 1995. Laboratory evaluation of various plant products against *Tetranychus ludeni* infesting egg plants in Tamil Nadu. *Abstr. V National Symposium on Acarology*, Sept. 20-22, 1995, Bangalore, p.81

Rasmy, A.H., Elbagoury M.E. and Reda A.S. 1987. A new diet for reproduction of two predacious mites *Amblyseius gossypii* and *Agistemus exsertus* (Acari: Phytoseiidae, Stigmaeidae) *Entomophaga* **32**: 277-280

Reghunath, P. and Gokulapalan, C. 1996. Management of American Serpentine leaf miner (*Liriomyza trifolii*), pea aphid (*Aphis craccivora)* and cowpea mosaic. *Proc. Acad. Environ. Biol.* **5** (2) : 207-208

Regupathy, A., Palanisamy,S., Chandramohan, N. and Gunathilagaraj, K. 1997 *A Guide On Crop Pests.* 3rd ed. Department of Agricultural Entomology, Centre for Plant Protection Studies, T.N.A.U. Sooriya Desktop Publishers, Coimbatore, India, p. 293

Ridgeway, R.L., Morrison ,R.K. and Badgley, M. 1970. Mass rearing green lacewing. *J. Econ. Entomol.* 63: 834-836

Ristich, S.S. 1956. Mass rearing and testing techniques of *Typhlodromus fallacis* (Gar.) *J. Econ. Entomol.* **49** (4): 476-479

*Roush, R.T., Peacock, W.L., Flaherty, D.L. and Hoy, M.A. 1980. Dimethoate Resistant spider mite predator survives field tests. *California Agric.* **34**: 12-13

*Rousset, A. 1980. Biometrical study of the ovarian growth in *Chrysoperla* under optimal diet and under malnutrition. *Ann. Soc. Entomol. Fr.* **16**(3): 453-464

Sandhu, G.S., Dhooria, M.S., Ajith singh, C. 1974. Chemical control of Tarsonemid mite *Hemitarsonemus latus* Banks (Acarina: Tarsonemidae) infesting Brinjal in Punjab. *Sci. Cult.* **40** (6): 258-260

Santhoshkumar, T. 1999. Eco friendly management of important sucking pests of chilli *Capsicum annuum* L. M. Sc. (Ag.) Thesis. Kerala Agricultural University Thrissur, p. 90

Saradamma, K and Nair, M.R.G.K. 1976. Phytophagous mites recorded in Kerala. *Acarol. Newsl.* **2** : 6

Saradamma, K.S., Pillai, K.S., Nair, M.R.G.K. and Das, N.M. 1979. Studies on the use of some pesticides for the control of yellow mite. *Polyphagotarsonemus latus* (Acari : Tarsonemidae). In : *Proceedings of I All India Symposium in Acarology.* 23-25 April, 1979, Bangalore

Sarode, S.V.and Sonalkar.1998 Effect of *Corcyra cephalonica* Staint on density on the development of *Chyrsoperla carnea* (Stephens). *J. Biol. Control.* **12** (2) : 153-156

Sathiamma, B. 1991. Investigations on *Oligonychus iseilemae* (Hirst) (Acarina) and other tetranychid mites on coconut foliage. Ph.D. thesis. University of Kerala, p. 206

*Schoonhoven, A., Piedarjita, J., Valderrama, R. and Galvez, G., 1978. Biology, injuriousness and control of the Tropical mite *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) on beans. *Turrialba* **28**(1): 77-80

Scopes, N.E.A. 1969. The potential of *Chrysopa camea* as a biological control agent of *Myzus persicae* on glass house chrysanthemums. *Ann. Appl. Biol.* **64**: 433-439

*Sengonca, L., Coepicus, S. 1985. Feeding Activity of *Chrysoperla carnea* compared to *Tetranychus urticae* Koch. *Z. ang. Zool.* **72**: 335-342

Senior, L.J. and McEwen, P.K. 1998 Laboratory study of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Predation on *Trialeurodes vaporariorum* (West wood) (Hom., Aleyrodidae). *J. Appl. Entomol.* **122** (2,3) 99-101

Senthamil selvan, B. 1989 studies on the scale of synthetic pyrethroids on the occurrence of sucking pests and diseases on cotton. M. SC (Ag.) thesis T.N.A.U Coimbatore, p. 111

Sharanabasava, H. and Manjunatha, M. 1998. Reproductive Biology and feeding potential of *Chyrosoperla carnea* Stephens (Neuroptera: Chrysopidae) on *Tetranychus neocaledonicus* Andre (Acari: Tetranychidae) *Ann. Pl.Protec.Sci.* **6** (1) :115-118

Sharma, P.K and Verma, A.K. 1991. Biology of *Chrysoperla carnea* (Stephens) Neuroptera: Chrysopidae) in Himachal Pradesh. *J. Biol. Control* **5** (2) : 81-84

*Shehata, K.K and Weismann, L. 1972 Rearing the predaceous mite *Phytoseiulus persimilis* A. H. on artificial diet. (Acarina: phytoseiidae). *Biologia Bratislava* **27** : 609-615

*Silva, C.A.D., Cordao sobrinho, D.A. and Silva, F.P.A.D. 1999. Biology and thermal requirements of red spider mite *Tetranychus ludeni* Zacher. (Acari: tetranychidae) on cotton . *Anais II Congresso 1999 Brasiliero de Algodao no sceulo XX,perspectives para o sceulo XXI,* Ribeirao Preto,Sp,Brazil, 5-10 septembro 1999, pp. 329-331

Singh, J. and Ray, R. 1977. *Stethorus* sp. (Coleoptera: Cocinellidae) a predator of *Tetranychus neocaledonicus* Andre on okra at Varanasi. *Acarol. Newsl.* **4** : 5-6

Singh, J., Soh, A.S., Dhaliwal, Z.S. and Mann, H.S. 1993. Comparative incidence of *Helicoverpa armigera* (Hub.) and other insect pests on okra and sunflower intercrops in cotton under Punjab conditions. *J. Insect Sci.* **6** (1): 137-138

Singh, P.P and Varma, G.C. 1986. Comparative toxicities of some insecticides to *Chrysoperla carnea* (Chrysopidae: Neuroptera) and *Trichogramma brasiliensis* (Trichogrammitidae: Hymenoptera), two arthropod natural enemies of cotton pests *Agric. Ecosystems Environ.* p. 23-30

Somchoudhury ,A.K and Sarkar ,P.K.1989 Observations on natural enemies found in association with coconut mite *Raoiella indica* Hirst. *Bull. Entomol.* **28** (2)104-107

Sudharma, K. 1996. Distribution and bioecology of phytophagous mites of vegetables, medicinal plants and ornamentals in Thiruvananthapuram district Ph. D thesis. Kerala Agricultural University, Thrissur, p.171

Sundby, R.A. 1966. A comparative study of the efficiency of three predatory insects, *Coccinella septempunctala* L. (Coleoptera: Coccinellidae) *Chrysopa carnea* Stephens (neuroptera: Chysopidae) and *Syrphus ribessi* L. (Diptera: Syrphidae) at two temperatures. *Entomophaga* **11**: 395-404

Tanigoshi, L.K., S.C. Hoyt, R.W. Browne and J.A. Logan. 1975. Influence of temperature on population increase of *Metaseiulus occidentalis* (Acarina: Phytoseiidae) *Ann. Entomol. Soc. Am.* **68** : 979-986

Theaker, T.L. and N.V. Tonks. 1977. A method for rearing the predaceous mite, *Phytoseiulus persimilis* (Acarina: Phytoseiidae). *J. Entomol. Soc.* B.C. **74**: 8-9

*Tulisalo, V. and Korpela, S. 1973. Mass rearing of the green lacewing *Chrysopa carnea* Steph. *Suom hyont Aikak* **39**: 143-144

Van de Vrie , M. and Boersma, A.1970 The influence of the predaceous mite *Typhlodromus(A.)potentillae*(Garman) on the development of *Panonychus ulmi*(Koch)on apple grown under various nitrogenous conditions *Entomophaga* **15**(3):291-304

Vanderzant, E.S. 1969. An artificial diet for larvae and adults of *Chrysopa carnea*, an insect predator of crop pests. *J. Econ. Entomol.* **66** : 336-338

Venkatesan, T., Singh, S.P. and Jalali, S.K. 2000. Semi synthetic diet rearing of Chrysoperla camea (Stephens) (Neuroptera : chrysopidae) and its predatory efficiency against cotton pests *Entomon.* **25** (2): 81-90

Watve, C. M and Lienk, S.E. 1976 Responses of two phytoseiid mites to pesticides used in New York apple orchards. *Environ. Entomol.* **4** : 797-800

Withycombe, C.L. 1923. Notes on the biology of some British Neuroptera. *Trans. R. ent. Soc.* Lond., 1922: 501-594

Yazloveskij, I.G., Abashkin, A.S. and Keiser, L.S. 1990. The mass rearing of *Chrysopa carnea, Zaschita Rastenii.*, 1 : 27-28

*Yolda, Z.,1994. Studies on biology of *Chrysoperla carnea* (Stephens) (Neuropetra:Chrysopidae) on two different prey. *Turkiye III Biyolojik Mucadele Kongresi Bilidrileeri* , 25-28 ocak, p.375-380

*Zaki, F.N. 1987. Larval duration and food consumption for the predator, *Chrysoperla carnea* Steph. Under different constant regimes. *Ann. Agric. Sci.* **32**(3): 1827-1836

Zhurba, G.T., Pamukchi, G.V., Popov, N.A., Khudyakova, O.A. 1986. An improved method of rearing and using *Phytoseiulus. Zaschita-Rastenii.* **10** : 26-27

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*Original not seen

BIOCONTROL OF MITES ON YARD LONG BEAN (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt) AND CHILLI (*Capsicum annuum* (L.))

BY

ABHILASH B.

ABSTRACT OF THE THESIS
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ABSTRACT

Mass production techniques, biology, predatory potential and prey preference of predatory mites and the chrysopid predator, *C. carnea* preying *T. ludeni* in cowpea and *P. latus* in chilli were studied. Further, the effect of pesticides on these bioagents and the role of these predators in the management of *T. ludeni* and *P. latus* were also assessed.

A.longiøspinosus was identified as the major predator of *T. ludeni*. Another species of *Amblyseius* (unidentified)was the major predator of *P .latus* in the field. In the laboratory a macrocheylitid mite, *M. merdarius* found in rice bran was also observed as an efficient predator of *P. latus*.

Techniques were developed to mass multiply both species of *Amblyseius* and their hosts, *T. ludeni* and *P. latus* in excised leaves of cowpea. Using this technique, within a week a two fold increase of the predator was seen. Techniques were developed to multiply another predatory mite of *P. latus*, *M. merdarius* in storage mite, *Tyrophagus* sp. From 10 g rice bran containing *Tyrophagus* sp., 410 *M.merdarius* were produced within a month.

A. longispinosus when fed with pollen of *A. auriculiformis* and *H. rosa-sinensis* , survived in the diet and laid eggs . The larvae that emerged from the eggs completed development on pollen diet where as in artificial diet , though the gravid females survived and laid eggs, the larvae that emerged from eggs did not reach adulthood. Studies on the biology of predatory mites *A.longispinosus* and *Amblyseius* sp preying on *T. ludeni* and

P. latus respectively revealed that the predators completed its development within a week.

In order to identify suitable hosts for mass rearing *C. carnea*, the predator was reared on different hosts and it was observed that developmental period was shortest when reared on *Corcyra* eggs. The fecundity and longevity was maximum when reared on *Corcyra* eggs.

An assessment of predatory potential of *A. longispinosus* revealed that the predator fed on all stages of *T. ludeni*. Among the different stages of the predator ,adult was the most voracious and the most preferred stage of the prey was eggs. In the case of *Amblyseius* sp. preying on *P. latus* the larvae of the predator consumed all stages of prey mite except adult. The predatory potential of *M. merdarius* on *P. latus* was higher than that of *Amblyseius* sp.

An assessment of predatory potential of *C.carnea* revealed that it was a voracious feeder of *A. craccivora* as well as *T. ludeni*, The mean daily consumption was highest for the third instar larvae in both the cases.

The prey preference of the predators was assessed through multiple choice and single choice tests. Among the prey tested viz. *T. ludeni* , *P. latus* and *Tyrophagus* sp, maximum preference was shown towards *T. ludeni*. The broad mite, *P.latus* was also found to be preyed upon by the predator in both multiple and single choice tests, but total avoidance was shown towards bran mite *Tyrophagus* sp.

The prey preference of *C. carnea* assessed through multiple choice and single choice tests revealed that *A. craccivora* was the most preferred prey and it was followed by *T. ludeni*. Spiralling white fly was the least preferred one.

Effect of pesticides on predators assessed by exposing them to dry films of pesticide showed that triazophos 0.05 per cent was the most toxic chemical against *A. longispinosus*. In all the chemical pesticides tested none of the predators survived after 24 hours. Though 10 percent emulsified extract of *A. paniculata*, *H.suaveolens* and neem garlic emulsion 2.5 per cent were found significantly safer than chemical pesticides, mortality of the predator was observed in these treatments also indicating that negative impact of botanical pesticides on natural enemy cannot be overlooked. Similar response was shown by *C. carnea* towards these pesticides, except in dicofol 0.05 percent which imparted lower mortality to the larvae.

Field experiments conducted in cowpea to study the effect of bioagents and botanicals on *T. ludeni*, predators and yield showed that, application of neem oil 5 percent was the best treatment for management of *T. ludeni*. This was followed by application of neem garlic emulsion 2 percent, Fish oil insecticidal soap 2.5 percent and garlic emulsion 2 percent taking into consideration the benefit cost ratio.

Comparatively high population of predatory mites was observed in plants released with *A. longispinosus*. The population of the predatory mite increased steadily and within a month the population of the predator and prey became almost equal. Though the predatory mite could check the population of *T.ludeni*, the treatment was uneconomical.

The general predator, *C. carnea* could not bring spectacular reduction in population of *T. ludeni* which may be due to the polyphagous nature of the predator.

Field experiments conducted on chilli showed pronounced effect of *Amblyseius* sp on *P. latus* from tenth day onwards at both the levels tested. The release of the predator *C. carnea* @5 and 10 per plant, and fish oil insecticidal soap 2.5 percent was not effective in checking *P. latus* . Garlic emulsion 2 percent gave substantial reduction immediately after first application. Subsequently, the population increased but with repeated application significant reduction in population was noticed.

There was no significant difference in the yield of chilli in the different treatments. However based on benefit cost ratio, it is concluded that application of neem oil 5 percent, neem garlic emulsion 2 percent, garlic emulsion 2 percent, fish oil insecticidal soap 2.5 percent and release of *Amblyseius* @ 10 and 20 per plant are economically viable for management of *P. latus* in chilli.