PART – III

BIOLOGICAL CONTROL OF PEST MITES
INTRODUCTION

Of the various pest control strategies developed globally, chemical control involves only immediate and temporary decimation of the pest population and moreover, it leads to various health cum environmental problems resulting from the resurgence and resistance of pests, destruction of natural enemies, secondary pest out breaks, environmental pollution, residual problems in agricultural crops and fields and so on. As a safer and best alternative tool, biological control through the intentional usage of beneficial living organisms has gained much momentum in the present scenario, for suppression of pest population, below the economic injury levels, without disrupting the natural environment. Strategies of natural suppression of pests utilizing the biological enemies and application of plant based products are considered to be less harmful and moreover constitutes an ecofriendly approach to reduce yield loss and to attain better crop production.

Natural enemies, being the key component among the various biological control measures need special mention and their collection, rearing and appropriate and timely release in to the field determines the success of any biological control programme. Natural enemies like the predators, parasitoids, pathogens etc. exert effective control over pest population so as to maintain it always below the economic injury level. Among the various groups of natural enemies, arthropods, especially the insects and mites
constitute an important group comprising the predators and parasitoids. The populations of phytophagous mites are known to be suppressed by various groups of insect and mite predators. Of these, predatory mites constitute an excellent beneficial group of natural enemies which have the potential to suppress the pest mite populations. Varied families of predatory mites like Phytoseiidae, Cunaxidae, Bdellidae, Laelapidae, Stigmaeidae, Tydeidae, Cheyletidae etc. are known to have the potential to keep down the populations of phytophagous mites to desirable levels. Of these, members of Phytoseiidae owing to their extremely superior searching capacity, high consumption rate and very short life cycle have qualified as a superior group among the predatory mites. Based on their feeding habits, phytoseiids are classified into four categories (McMurtry and Croft, 1997) viz. Type I as specialized predators, Type II as selective predators, Type III as generalist predators and Type IV as specialized pollen feeders/generalist predators. More than 50 per cent of the members of Phytoseiidae come under the category Type II predators. Based on their ability for selective predation and high consumption rate, various countries have successfully implemented integrated pest control programmes by importing phytoseiid predators. Various species of phytoseiid predators like Phytoseiulus persimilis, Amblyseius longispinosus, A. channabasavannai, A. largoensis, Eusieus ovalis, Cunaxa myabunderensis etc. are recognized as very common predators associated with the pest mites on their respective host plants. The life stages of these predatory mites do not
induce any damage to the host plants as they feed on pollen and nectar in the absence of prey population. For exploiting the predatory potential of the phytoseiid mites, in the present study attempts were made by rearing three species *viz.* *Amblyseius* (*Amblyseius*) *largoensis* (Muma), *A.* (*Euseius*) *ovalis* and *Cunaxa myabunderensis* (Gupta) under laboratory conditions to evaluate their feeding potential against the selected species of pest mites *viz.* *T. neocaledonicus*, *O. biharensis* and *B. phoenicis*.

Apart from predatory mites, varied groups of insects belonging to the families Coccinellidae, Staphylinidae, Thripidae, Cecidomyidae etc. also have been recognized as potential predators on the pest mites. The larval and nymphal stages of predatory insects *viz.* *Stethorus punctillum S. punctum*, *S. pauperculus*, *Oligota flaviceps*, *O. oviformes*, *Scolothrips asura*, *S. longicornis*, *S. sexumaculatus* etc. have been observed to live in association with the pest mites on their respective host plants. The prey handling time of insect predators is comparatively shorter and their rate of predation is comparatively greater than those of the predatory mites. In the present study, attempts were also made to evaluate the predatory potential of insect predators like *Feltiella acarinsula* (Vallot) and *Scolothrips asura* Ramakrishna and Margabhandu against the selected species of pest mites.

Another ecofriendly and safe approach to pest control in the natural way is the application of biopesticides. Biopesticides have gained much
importance nowadays as a better alternative to synthetic pesticides, based on the possession of an array of beneficial properties which could be categorized as repellent, antifeedant, growth regulator, toxic etc. against the pest organisms. Among the various kinds of biopesticides, the secondary metabolites derived from plants dominate the usage since they have limited impact on the beneficial organisms. Plants are rich sources of many volatile compounds or oils which help the pest population to keep a distance away from the economically important crops. The application of the essential oils of many plant extracts is found to be more effective than their crude extracts. Research on the active ingredients, preparation and application and environmental impact of botanical pesticides are prerequisites for sustainable agriculture. The plant derived compounds cause both direct and indirect effects on pest populations and they induce mortality on the life stages of the mites, reduce fecundity, affect general fitness, reduce feeding activity etc. The plant derived volatile compounds are found to degrade quickly when applied in the greenhouses or agricultural fields and hence have reduced residual effect on nontarget organisms. Some commonly used plants for botanical preparations against the pest populations are *Azadirhcta indica*, *Glyricidia sepium*, *Chromolaena odorata*, *Lantana camara*, *Ocimum americanum* etc. Considering the environmental safety of botanical pesticides and the minimized residual problems on natural enemy complex, in the present study, attempts were made to formulate different concentrations of plant extracts
from selected species of plants like *Glyricidia sepium* (Jacq.) and *Chromolaena odorata* (L.) the efficacy of these extracts were evaluated against the different life stages of selected species of pest mites like *T. neocaledonicus* and *O. biharensis*. 
REVIEW OF LITERATURE

The present review includes citations of earlier research works carried out on aspects of natural suppression of pest mites through the release of biological enemies like predatory mites and insects. Earlier findings on the suppression effect of plant derived biopesticides on insect and mite pests also have been incorporated in the present review.

1. Natural enemies

The possibilities of biological control of the spider mite pest, *T. telarius* infesting the greenhouse plants by releasing the predatory mite, *Phytoseiulus persimilis* were explored by Chant (1961) and he reported that the predator was highly efficient in controlling the pest population and thereby reducing the crop damage. Lewis (1973) observed the predatory habit of thrips on pest mites and recorded that all species of the genus *Scolothrips* possessed specialized predation on spider mite pests. Zaher et al. (1975) conducted studies on the feeding habits of the cunaxid predator *viz. Cunaxa capreolus* on the citrus brown mite, *Eutetranychus orientalis*. The consumption rate of the predator showed an increase with slight increase in temperature. Mallik and Channabasavanna (1976) identified *A. longispinosus* as a highly potential predator of spider mites and they suggested the possibility of utilising the species for controlling the spider mite pest, *T.*
Takafuji and Chant (1976) observed that the predator, *Iphiseius degenerans* did not consume the captured prey completely and this feeding habit was observed frequently as the prey density got increased. Gilstrap and Oatman (1976) reported *Scolothrips sexmaculatus* as a potential predator of spider mites and recorded a decrease in prey consumption when the temperature increased to more than 30°C. They found that immatures of *S. sexmaculatus* consumed an average of 11.7 eggs of *T. pacificus* per day at 26°C whereas the adult females of the species had a consumption rate of 39 to 47 eggs/day as the temperature increased from 18 to 30°C.

Tanigoshi and McMurtry (1977) reported the coccinellid predator, *Stethorus picipes* as an effective biocontrol agent against the pest mite, *O. punicae* and the larvae and adults of the predator preferrably fed on the eggs of spider mites. Ball (1980) evaluated the potential of *P. macropilis*, *Proprioseiopsis temperellus*, *Neoseiulus fallacis*, and *Galendromus longipilus* as predators of the two spotted spider mite, *T. urticae*. Harris (1982) reported that the Cecidomyid predator, *Lestodiplosis oomeni* could effectively feed on the carinate tea mite, *Calacarus carinatus* as well as on other mites infesting tea plants in Indonesia. Boyne and Hain (1983b) based on laboratory experiments showed that the phytoseiid predator, *N. fallacis* could be used as an effective control agent of the spruce spider mite infesting the fraser fir seedlings.
Havelka and Kindlemann (1984) showed that the predatory mite, *P. persimilis* could be used for the control of the spider mite pest, *T. urticae* infesting glasshouse cucumbers. Gerson (1985) reported that *P. persimilis* was well-adapted to live and move through the silken web spun by spider mites on their host plants and could consume large number of prey mites within a short period of time. Gupta (1985) enlisted the potential predatory mite species feeding on the pest mites inhabiting on various species of economically important plants in India. Helle and Sabelis (1985) reported the predatory habit of insect groups such as Coleoptera, Dermaptera, Diptera, Hemiptera, Neuroptera, and Thysanoptera on spider mites. Oatman *et al.* (1985) successfully detected *Feltiella occidentalis* as an effective predator of almost all life stages of spider mites infesting strawberry in California. Chazeau (1985) observed that the adults and larvae of *Stethorus* and *Parastethorus* spp. of Coccinellidae were able to feed very actively on the spider mites as well as false spider mites. The authors found that when spider mite density was high, insect predators suppressed their populations owing to their voracity and reproductive capacity.

While conducting surveys on predatory mites inhabiting 11 species of major crops in Willamette Valley, Hadam *et al.* (1986) collected a total of 1,209 phytoseiid mites and the authors also studied the pesticide resistance in the phytoseiid predatory mite, *T. pyri*. van Lenteren and Woets (1988) suggested that varied parameters possessed by phytoseiid mites like
phytoseiid mites fast movement, rapid developmental cycle, dependence on alternative food source, high climatic adaptation, lack of harmful effects on beneficial and easy culturing favoured the effective utility of these predatory mites in biological control programs. Gerson and Smiley (1990) prepared the relevant taxonomic keys and other important details of the members of major predatory mite families. Clements and Harmsen (1990) reported the prey capturing behavior and prey-stage preferences of the Stigmaeid and Phytoseiid mites and their potential compatibility in biological control of most severe mite pests. Aydemir and Toros (1990) found that some species of the genus *Scolothrips* were predators on the spider mite pest, *T. urticae* infesting bean plant in Erzincan. Gough (1991) studied the predatory potential of *P. persimilis* in controlling the population of *T. urticae* on rose hedges in southern Queensland. Selhorst *et al.* (1991) prepared a model to describe the predator-prey interaction between *S. longicornis* and *T. cinnabarinus*.

A rapid decline in the two spotted spider mite population was observed by Spicciarelli *et al.* (1992) when the phytoseiid mites were released on to the mite infested leaves. Smiley (1992) reported that the cunaxid predatory mites were fast moving, adapted to live in a variety of habitats like plants, soil, moss, bark and food stores and could successfully thrive on prey items comprised of small arthropods like mites and nematodes. He also found that the members of the family Bdellidae shared some features of cunaxid mites. Shimoda *et al.* (1993) reported that a single larva of the staphylinid beetle,
*Oligota kashmirica benefica* could consume 300–400 eggs of *T. urticae* during its development period. Grout (1994) showed that *Euseius* spp. formed the most common species among the phytoseiid predators in citrus-growing regions in citrus plantations in Southern Africa. Daneshvar and Abaii (1994) provided information on the successful usage of the phytoseiid predator, *P. persimilis* against the spider mite population in soybean fields at a release rate of five predators per plant. Waite and Gerson (1994) made observations on the predatory habit of the larva of the cecidomyid predator, *Arthrocnodax* sp. on a serious eriophyid mite pest, *A. litchi* in Australia and China.

Castagnoli *et al.* (1995) reported *N. californicus* as one of the most effective phytoseiid predator which could be used successfully for the management of spider mite population on many agricultural crops and fruit orchards. Gilstrap (1995) stated that members of the thrips genus, *Scolothrips* were well known as efficient predators of plant mite pests. Gagné *et al.* (1995) provided information on the potential role of some species of the gall midge genus, *Feltiella* especially, *F. acarisuga* as effective predators on spider mites. Van Driesche and Bellows (1996) suggested that factors such as selection of control agents, quality control, mass-rearing techniques, release methods, and efficacy of target pest suppression were important for manipulating successful biological control strategies against the pest population. Wilson *et al.* (1996) observed that ‘phytophagous’ thrips were
facultative predators on the two spotted spider mites infesting cotton in Australia. McMurty and Croft (1997) made a review on the feeding habits of the members of Phytoseiidae and their application in biological control. The authors divided the family based on their feeding habits in to four different groups viz. Type I) specialized predators of *Tetranychus* like *Phytoseiulus*; Type II) selective predators like *Galendromus*, *Neoseiulus* and some *Typhlodromus* species; Type III) generalist predators including *Typhlodromus* and *Amblyseius* species and others; and Type IV) specialized pollen feeders/generalist predators like *Euseius*. Kirk (1997) noted that *S. longicornis* had the potential to suppress the spider mite population below the level of damage threshold depending up on the timing of their introduction. He reported that the predatory thrips killed or consumed the pest mites only partially when mite population was high. When the predators were distracted by the passing prey mites, they abandoned the captured preys and attacked the passing preys and this habit of the predators was found to enhance the mortality rate of prey mites.

Lacasa and Llorens (1998) pointed out the possibilities of controlling spider mite population using insect predators. Raworth (1998) recorded excellent control of the two spotted spider mite by releasing the lady bird beetle, *S. punctillum* on tomato, pepper and cucumber grown under greenhouse conditions in Canada. He noted that the per day consumption by the adult beetle ranged from 75-100 two spotted spider mites. Obrycki and
Kring (1998) observed that release of predaceous coccinellid beetles offered adequate control over mite population. Gillespie et al. (1998) detected *F. acarisuga* as one of the important biological control agent which could be used successfully for implementing integrated pest management programmes against the two spotted spider mite pest, *T. urticae* on greenhouse vegetable crops. The larval stage of *F. acarisuga* was recognized as a most efficient predator on *T. urticae*. It was found that weekly release of 1000 individuals per ha was extremely effective in controlling spider mites on tomato, pepper and cucumber. Ho and Chen (1998) conducted studies on the life history, food consumption and seasonal occurrence of *F. minuta* on the prey comprised of spider mites infesting eggplant. It was observed that the population of the predator got increased when the number of *T. kanzawai* was more on the host plant. The authors further performed a comparative study on the rate of food consumption by the two predators, *F. minuta* and *A. womersleyi*. Lester et al. (1999) reported the pyrethroid-resistant predatory mite, *Amblyseius fallaci* as a potential biological control agent against the most injurious species of tetranychid mites *viz.* *P. ulmi* and *T. urticae* in an Ontario peach orchard. Hoddle et al. (1999) successfully carried out observations on the biological control of *O. perseae* using six species of phytoseiid predatory mites *viz.* *G. annectens*, *G. helveolus*, *G. pilosus*, *G. occidentalis*, *N. californicus* and *T. rickeri* on avocado in California by releasing 2000 predatory mites per tree. Zhang et al. (1999) recorded instances of effective predation by *A.*
*longispinosus* on the prey species *viz. S. nanjingensis*, a spider mite injurious to bamboo in Fujian, China. Kerguelen and Hoddle (1999) conducted studies on the biological control of *O. persea* on avocado in California and evaluated the feeding efficacy of *Galendromus helveolus* and *Neoseiulus californicus*. The authors observed a reduction in the leaf area damage induced by *O. persea* when treated with *N. californicus* alone or in combination with *G. helveolus*. Shih (1999) observed that the eggs of the two spotted spider mite formed the primary food of the predator, *S. sexmaculatus*. Peterson *et al.* (2000) stated that *S. bifidus* could be effectively used to reduce the population of *T. lintearius* based on its functional response to the prey in laboratory arenas.

The possibilities of controlling the population of the two spotted spider mite, *T. urticae* on edible glasshouse crops were explored by Rott and Ponsonby (2000) using a specialist coccinellid, *S. punctillum*. Gillespie *et al.* (2000) studied the life table parameters of *F. acarisuga* on a prey comprised of the eggs of the carmine spider mite, *T. cinnabarinus* under laboratory conditions of 26.7 ± 2°C, 75 ± 5 per cent R.H. The authors observed that the first, second, and third instar larvae of *F. acarisuga* consumed an average of 35.5, 54.0 and 86.9 eggs respectively. Piatkowski (2000) recommended the use of the predatory fly, *Therodiplosis persicae* for suppression of mites injurious to plants in greenhouse conditions. Reis *et al.* (2000) showed that phytoseiid mites could be very effectively used to control the tenuipalpid mite
population which vectored the coffee ring spot virus. Ho and Chen (2001) evaluated the feeding and oviposition responses of the predator, *S. indicus* by offering a diet comprised of eggs of the Kanzawa spider mite. Nicetic *et al.* (2001) explored the possibilities of integrated pest management of the two-spotted mite on greenhouse roses using petroleum spray oil and also by releasing the predatory mite, *P. persimilis*. The relationship between temperature and rate of development of the predator, *S. punctillum* which fed up on the prey mite, *T. mcDanieli* was established by Roy *et al.* (2002).

Studies made by Osborne *et al.* (2002) showed that the adults of the insect predator, *F. acarisuga* possessed excellent ability in flying and tracking colonies of *T. urticae* on their host crops and their feeding potential was greater than that of the phytoseiid predator. The daily consumption rate of the larvae of *F. acarisuga* on the eggs, nymphs and adults of red spider mites was at least five times greater than that of *P. persimilus*. Reis *et al.* (2003) studied the functional response of the predatory mites, *E. alatus* and *I. zuluagai* on the tenuipalpid mite pest, *B. phoenicis* and recorded type II and type I functional responses respectively in the predators. Calvo *et al.* (2003) found that the gall midge, *F. acarisuga* was a potential natural predator of the two-spotted spider mite. Kishimoto (2003) assessed consumption rate of insect predators like *S. japonicus, O. kashmirica benefica* and *S. takahashii*, on some spider mite species and reported that the prey consumption rate of *S. japonicus* was 16 times higher than that of *S. takahashii*. Colfer *et al.* (2003,
reported that release of predatory mites would serve as an effective means for managing spider mite problems in many cropping systems. The authors recorded the effectiveness of releasing the western predatory mite, *G. occidentalis* in cotton fields to control spider mites. Opit et al. (2004) experimentally proved the predatory potential of the phytoseiid mite, *P. persimilis* on the two spotted spider mite, *T. urticae*. The biocontrol efficacy of *S. longicornis* on tetranychid mites under greenhouse situation was observed by Kiliç and Yoldas (2004). Studies on prey consumption and functional response of three acarophagous species *viz.* *S. japonicus*, *S. takahashii* and *A. californicus* to the eggs of the spider mite, *T. urticae* infesting lima bean leaf discs in the laboratory were made by Gotoh et al. (2004) at three constant temperatures (18–20, 25 and 30°C) and 16L:8D. The authors reported that the average daily consumption rates of adult females during the first 20 days after emergence at 25°C were 13.4 eggs for *A. californicus*, 23.0 eggs for *S. takahashii* and 294.4 eggs for *S. japonicas* and the adult females of the three predators showed a type II functional response to prey density, regardless of the temperatures tested. The daily egg consumption rate of immatures of *S. japonicus* was recorded as 9 to 14 times and 23 to 42 times more than those of *S. takahashii* and *A. californicus* respectively.

Escudero and Ferragut (2005) reported that the predator, *P. macropilis* was well adapted to warm climates and was more effective in controlling the
population of the two spotted spider mites in the Mediterranean area. Lahiri et al. (2005) carried out a survey on the predatory mites which feed on pest mites infesting the medicinal plants of Kolkata and recorded that members of the family phytoseiidae formed the maximum number (16 spp.) of which four species were found to be highly efficient in feeding on the pest mites. The species of the family Bdellidae, Cunaxidae and Stigmaeidae were comparatively lesser in number. De Boer and Dicke (2005) reported that the predatory mite, *P. persimilis* could be used as a specialized natural controlling agent on herbivorous spider mites. Thakur and Dinabandhu (2005) observed that *N. longispinosus* could feed on *Tetranychus* species infesting on apple and fig trees. Kongchuensin et al. (2005) found that the phytoseiid member, *N. longispinosus* could successfully feed on *T. urticae* on 33 species of economically important plants in Thailand. Naher et al. (2005) assessed the predatory potential of three species of acarophagous mites viz. *P. persimilis*, *S. punctillum* and *S. sexmaculatus* against *T. urticae* and recorded that the daily consumption rate of *S. punctillum* was higher when compared to that of the other two predators. The larva of *S. punctillum* consumed an average of 114.33 eggs of *T. urticae* per day whereas the adult consumed 119.67 eggs, 73.67 immatures and 54.33 adults per day. Tsoukanas et al. (2006) studied the effect of temperature on the development of the immature stages of *I. degenerans* when fed up on the pest mite, *T. urticae*. Rhodes et al. (2006) was able to prove the biocontrol efficacy of *P. persimilis* and *N. californicus* on
the two spotted spider mites infesting strawberries. The predatory potential of *Galendromous helveolus* on a major citrus pest, *B. californicus* was assessed by Chen *et al.* (2006) in Texas. The authors recorded that a single immature of *G. helveolus* consumed an average of 30.7 eggs, 53.6 larvae, 22.7 nymphs of *B. californicus* during its period of development to adult while an adult female of the species consumed an average of 164.8 eggs, 369.6 larvae, 80.9 nymphs of the pest.

associated predatory mite families viz. Phytoseiidae and Stigmaeidae on coffee in Brazil. Oliveira et al. (2009) evaluated the feeding potential of the predatory mite, *P. macropilis* on the two-spotted spider mite on strawberry plants under greenhouse conditions. *P. macropilis* required about 20 days to reduce the pest mite population on strawberry plants which were initially infested with the two spotted spider mites @100 females /plant. Pakyari et al. (2009) reported that species of the thysanopteran genus *Scolothrips* were well known as predators of spider mite species like *T. urticae* and the authors analysed the most suitable conditions which favoured the predatory efficacy of *S. longicornis* on populations of the pest mite, *T. urticae*. Biddingger et al. (2009) reviewed the research works carried out on the role of members of the genus *Stethorius* as predators of most injurious pest mites. Perumalsamy et al. (2009) conducted studies on the predatory efficiency of *S. gilvifrons*, an important predator of the red spider mite, *O. coffeae*, infesting tea in Tamil Nadu, India. The predatory efficiency of *S. gilvifrons* was found increased during the growth of larval instars. An adult female consumed 205.0 eggs, 92.2 larvae, 81.8 nymphs and 52.4 adult mites per day.

Park et al. (2010) conducted studies on the predatory potential of *A. swirskii* against the tomato russet mite, *Aculops lycopersici*, a serious pest of greenhouse tomatoes. Haque et al. (2010) reported that spider mites problem would increase when natural enemies were destroyed by nonspecific application of insecticides. Negloh et al. (2010) studied the impact of season
and fruit age on the population dynamics of the eriophyid mote pest *A. guerreronis* and its associated predatory mite, *N. paspalivorus* on coconut in Benin. Zhu *et al.* (2010) assessed the feeding efficacy of *A. cucumeris* in controlling the population of *B. obovatus*. Mound *et al.* (2010) recorded a new species of predatory thrips *viz.* *Scolothrips ochoa* feeding on species of *Raoiella* on the leaves of *Lophostemon suaveolens* at The Gap, a western suburb of Brisbane in Australia. The authors reported that *S. ochoa* sp. n. was apparently host-specific and it lacked ocellar setae pairs I and II. It differed from other *Scolothrips* species in lacking an elongate pronotal midlateral setae, and by having antennal segments III-IV and V-VI broadly joined.

Darbemamieh *et al.* (2011) carried out observations on the population abundance and seasonal activity of the stigmaeid predator, *Zettellia pourmirzai* and its prey mites, *C. irani* and *B. rubrioculus* in sprayed apple orchards of Kermanshah, Iran. The smallest optimum sample sizes, calculated with a Taylors’ coefficient, were 20.806, 192.912 and 128.117 for *C. irani*, *B. rubrioculus* and *Z. pourmirzai*, respectively. Chauhan *et al.* (2011) managed to suppress the population of the two spotted spider mite on carnation by releasing the predatory mite, *N. longispinosus* and by applying biopesticide. It was found that the predatory mite was highly efficient in controlling the two spotted spider mite on carnation under greenhouse conditions in Himachal Pradesh, India. Reddy *et al* (2011) reported several new pests and predatory mite species associated with economic plants from Guam and the results of
their studies disclosed the presence of *T. marianaee* and the predatory mite, *P. horridus* on eggplant, *B. californicus*, *Eupodes* sp. and the predator, *Cunaxa* sp. on guava, *B. californicus*, *Lepidoglyphus destructor* and *A. obtusus* on cycad (*Cycas micronesica*). Sarwar et al. (2011) reported four species of predatory mites associated with sucking pests on protected cucumber (*Cucumis sativus*). Pakyari (2011) conducted studies on the rate of development of *S. longicornis* on the prey mite, *T. urticae* at different temperatures viz. 15, 20, 25, 30, 35 and 37°C. The total time of development from egg to adult emergence for females was estimated to be 48.1, 22.8, 13.6, 10.6, 8.3 and 9.6 days respectively. The development time showed a decrease with increasing temperature from 15 to 35°C and no development was observed at 40°C. Gonzáles-Zamora et al. (2011) recorded *S. longicornis* as a potential predator of the oriental species of spider mite, *E. orientalis* and found that it exhibited voracious feeding on various life stages of the pest mite, thereby reducing the pest population.

Xiao et al. (2011) suggested that the predatory gall midge, *F. acarisuga* could be used successfully for suppressing the populations of the two spotted spider mite, *T. urticae* infesting vegetables cultivated in greenhouses. The authors further provided experimental evidences based on laboratory cum greenhouse evaluation for the use of corn (*Zea mays*) as a banker plant for the predatory gall midge, *F. acarisuga* to potentially control *T. urticae*. Choice and no choice experiments were carried out to determine
the host plant preference of an alternative prey, *O. pratensis* to corn and green bean, *P. vulgaris*. The rate of predation by *F. acarisuga* on *T. urticae* and *O. pratensis* ranged from 43.7 to 67.9 per cent and 59.2 to 90.3 per cent, respectively, under laboratory conditions where as in a non-cage study, 81.2 per cent of *T. urticae* population was suppressed by *F. acarisuga* in reference to the control (cage treatment). Results of surveys conducted by Gupta and Karmakar (2011) enabled to record 56 species of predatory mites under 24 genera and 10 principal predatory mite families on the medicinal and aromatic plants in India. The predatory mite families recovered were Phytoseiidae, Tydeidae, Stigmaeidae, Cunaxidae, Anystidae, Ascidae, Bdellidae, Cheyletidae, Erythraeidae and Eupodidae and a total of 33 phytoseiid species were identified as potential predators. Chaaban *et al.* (2011) conducted studies on the seasonal distribution pattern of *O. afrasiaticus* and its phytoseiid predators on date palm, *Phoenix dactylfera* (Deglet Noor cultivar) in Tunisian oases for a period of two years and found that the incidence of infestation by *O. afrasiaticus* on the host initiated from the first to the third week of July. Indigenous predators were not observed on the host between mid-July till the end of August. The most common and abundant predator observed was *T. athenas*.

Pakyari and Enkegaard (2012) traced the impact of different temperatures (15 to 37°C, 60 ± 10 % RH, 16:8 L:D) on the rate of consumption of the predatory thrips, *S. longicornis* on the eggs of the two
spotted spider mite, *T. urticae* under laboratory conditions and the results of their studies revealed a significant effect of temperature on prey consumption by the predator. The number of prey eggs consumed daily by the first and second instar larvae showed a linear increase with the increasing temperature from 15 to 37°C and the daily consumption of eggs by ovipositing females followed a nonlinear pattern, with maximum daily predation at 32.8°C. Sarwar *et al.* (2012) proved the effective use of the phytoseiid predator, *N. pseudolongispinosus* for outdoor biological control programmes against spider mites. Carrillo and Pena (2012) reported the association of the predatory mite, *A. largoensis* with the red palm mite, *R. indica* in Florida. The authors evaluated the predator preferences among developmental stages of *R. indica* and estimated the functional and numerical responses of the predator to varying densities of its most preferred prey-stage. The life stages of *A. largoensis* showed more preference to the egg stage of the prey mite and its mean consumption rate was 45 eggs per day. Zheng *et al.* (2012) explored the possibilities of managing populations of *B. obovatus* using predatory mites and through artificial rainfall in South China. The results of the survey made by the authors in the tea gardens of Guangzhou enabled to record 13 species of predatory mites feeding on *B. obovatus*, of which the most abundant predator was *A. hainanensis* and it predatory potential was recorded as 68.6 per cent. Rahman *et al.* (2012) made observations on the predatory efficacy, prey stage preference and optimum predator-prey ratio of the phytoseiid mite,
on the red spider mite, *O. coffeae* on tea under laboratory and green house conditions. The results their studies disclosed a marked reduction in the number of adult stages of *O. coffeae* and an increase in the number of *N. longispinosus* in both conditions.

Onzo *et al.* (2012) observed the potential of *A. swirskii* to suppress the population of the broad mite, *P. latus* on the gboma eggplant, *S. macrocarpon* in Benin. Elmoghazy *et al.* (2012) practiced integrated approaches for the control of the two spotted spider mite, *T. urticae* on faba bean plant *Vicia faba* by releasing two species of predatory mites *viz.* *N. californicus* and *T. swirskii* in an open field at Behaira Governate, Egypt. The authors observed that *N. californicus* had a higher potential in controlling the pest mite, *T. urticae.*

Pappas *et al.* (2013) observed the predatory potential of *P. finitimus* on *T. urticae* along with two other species of insect pests in greenhouse condition. The adult female of *P. finitimus* was found to feed on a large number of eggs and larvae of *T. urticae.* Sajna and Anithalatha (2013) surveyed the fauna of predatory mites associated with 32 species of economically important plants belonging to 27 genera and 21 families in North Kerala. The results of their survey revealed 15 species of predatory mites belonging to 6 genera *viz.* *Amblyseius,* *Typhlodromips,* *Euseius,* *Neoseiulus,* *Phytoseius* and *Paraphytoseius* included under Mesostigmata. The first record on the predaceous thysanopteran species, *S. longicornis* was made by Masarovič *et al.* (2013) from soil and a tree photoeclector samples from Bábsky les wood, a
natural oak-hornbeam forest in Slovakia. Five specimens were captured in soil photoeclectors and two in tree photoeclectors during 2012 vegetation period. Studies on different biological characters and predation capacity of *F. acarisuga* on a diet comprised of eggs of the two spotted spider mite, *T. urticae* at 25 ± 2°C and 60-75 per cent were made by Refaei and Mohamed (2013). The mean duration of developmental stages of *F. acarisuga* was found averaged to 13.5 ± 2.6 and the pre-oviposition, oviposition and post-oviposition periods were on an average of 2.9 ± 3.9, 6.2 ± 5.2 & 6.9 ± 4.3 respectively. The total number of eggs of *T. urticae* consumed by the larval stages (1st, 2nd, and 3rd) of *F. acarisuga* were 21.9 ± 1.5, 47.1 ± 2.8 and 55.5 ± 2.9 respectively and the female longevity was recorded as 15.2 ± 4.0 days and it increased to 34.9 ± 6.1 at the experimental conditions when the daily rate reached 3.7 ± 1.9. A study on the functional responses and prey-stage preferences of the predatory gall midge *F. acarisuga* and two predatory mites *viz.* *N. californicus* and *A. swirskii* on pest mite, *T. urticae* was carried out by Xiao *et al.* (2013). The authors revealed that *F. acarisuga* was highly effective in feeding on the eggs of *T. urticae* when compared to those of the predatory mites. Among the three predators, *F. acarisuga* showed the highest predation on *T. urticae*. The maximum rate of predation by the larva of *F. acarisuga* was recorded as 50 eggs/day, followed by the female of *N. californicus* (25.6 eggs/day) and the female of *A. swirskii* (15.1 eggs/day).
Liyaudheen et al. (2014) evaluated the feeding efficacy of *E. ovalis* on *T. macfarlanei*, a major spider mite pest with wide host range, inducing considerable damage and yield loss to the vegetable crop, okra, *A. esculentus* in Kerala. The studies on feeding potential of *E. ovalis* were carried out in the laboratory at 30 ± 2°C and 64 ± 2 per cent RH by adopting leaf flotation technique and the results of the study indicated the maximum feeding preference of the predator to the eggs of the pest mite, followed by the larva and protonymph. Prey consumption rates by the adult female, deutonymph, protonymph and the adult male of the predator were 63 per cent, 52 per cent, 50 per cent and 33 per cent respectively. Shimoda et al. (2015) mentioned insects as natural enemies for controlling spider mites by testing the efficiency of four insect predator groups (*S. takahashii; F. acarisisuga; Oligota* spp., and *Stethorus* spp.,) by releasing them on potted komatsuna plants (*Brassica rapa*) infested with the two-spotted spider mite.

2. Biopesticides

Information on the traditional control of insect pests using some medicinal plants was provided by Abubakar and Abdurahman (1998) and they conducted surveys in Kaduna State of Nigeria to identify plant species and understand the methodologies used by the local people to eradicate the insect pests. The plants commonly used for the insect control were *Adansonia digitata, Annona senegalense, Cyperus rotundus, Prakia calppertonia,*
Newbouldia laevis, Striga senegalense, Swartzia madagascariensis and Hydropogon contortus and which possessed insecticidal, antifeedant and repellant properties also. The acaricidal activity of the compounds obtained from the plant, D. stramonium against the flat mite, B. phoenicis and the eriophyid mite A. guerreronis was studied by Guirado et al. (2001) and they found that the extracted compounds were toxic to all the life stages of these pest mites. Park et al. (2002) evaluated the acaricidal and insecticidal activities of some domestic plant extracts against five major arthropod pests and reported that the extracts of eight species of plants were more effective, inducing over 80 per cent mortality of the two spotted spider mite, T. urticae. Kim et al. (2005) screened methanol extracts from 22 species of plants for evaluating their acaricidal and insecticidal activities against T. urticae, P. citri, Myzus persicae, Trialeurodes vaporariorum, and Aphis gossypii. The extracts from the twig of Albizia coreana and leaf of Pyracantha angustifolia exhibited potent acaricidal activity against the two spotted spider mite, T. urticae. The extracts prepared from Camellia japonica seeds, Ranunculus japonicus leaves and roots, A. coreana leaves and Houttuynia cordata leaves exhibited acaricidal activity against P. citri in a field test. Martinez-Villar et al. (2005) studied the effect of the ‘azadirachtin’, one of the key active constituents of neem oil obtained from the plant, A. indica against the two spotted spider mite population. The authors observed that the compound ‘azadirachtin’ had the potential to suppress the mite population by acting as
feeding deterrent and thereby reducing the growth of the mite. Calmasur et al. (2006) reported the acaricidal activity of different concentrations of essential oils extracted from three species of plants belonging to Lamiaceae viz. Nepeta racemosa, Micromeria fruticosa and Origanum vulgare against the nymphs and adults of the two spotted spider mite, *T. urticae*. The highest mortality was recorded in 2µl/l air doses at 120 hours of exposure. According to Gencsoyulu (2007), botanical pesticides would provide mite control at a low cost, and with a low risk to man and environment and thus were recommended for the control of tetranychid mites. The author studied the effect of the pesticide derived from *Asphedolus aestivus* to control the pest, against the mite pest, *T. cinnabarinus*.

Nazli et al. (2008) studied the pesticidal activity of different concentrations of ethanolic extracts of the leaves of the plant, *Glyricidia sepium* on insects, nematodes and bacteria, in Pakistan. The authors found that extract caused 60 per cent mortality of the root knot nematode, *Meloidogyne incognita* and a maximum repellency of 78 per cent was observed against *Aedes aegypti*. The antibacterial activity was more effective against *Escherichia coli* than *S. aureus, S. typhi, Pseudomonas* spp., and *Klebsiella* spp. Sarmah et al. (2009) successfully evaluated the effect of aqueous plant extracts of *Acorus calamus, Polygonum hydropiper, C. infortunatum* and *Xanthium strumarium* on the tea red spider mite, *O. coffeae* under both laboratory and field conditions. Different concentrations of extract
viz. 2.5, 5.0 and 10.0 per cent (w/v) were applied on *O. coffeae* to assess the effect on ovicidal and acaricidal activities. Strong ovicidal activity was observed with *X. strumarium* (87.09 %) and *A. calamus* (70.62 %) whereas lowest activity was reported for *P. hydropiper* (30.86 %) and *C. infortunatum* (20.58 %). Extracts of 5 and 10 per cent concentrations showed more than 50 per cent mortality of mites in the laboratory condition, whereas in the field condition 46.9 – 81.8 per cent and 64.7 – 100.0 per cent mite reduction was recorded at 5 per cent and 10 per cent respectively. Sertkaya *et al.* (2010) screened the acaricidal activities of the essential oils obtained from several medicinal plants *viz.* oregano (*Origanum onites*), lavender (*Lavandula stoechas*), thyme (*Thymbra spicata*) and mint (*Mentha spicata*) against the adults of the pest mite, *T. cinnabarinus* under laboratory conditions. The principal compound, carvacrol was present in the essential oils of thyme and oregano (70.93 % and 68.23 %, respectively). Thujone (65.78 %) and carvone (59.35 %) were the two major compounds obtained from the essential oils of lavender and mint respectively. Results of laboratory bioassay showed that all these essential oils were effective in causing mortality in the adult pest mites and the better results were obtained by the oils from thyme and oregano. The mean lethal concentrations (*LC*$_{50}$) of the essential oils of thyme, oregano, mint and lavender were 0.53, 0.69, 1.83 and 2.92µg ml$^{-1}$ air, respectively.

Araujo *et al.* (2010) studied the acaricidal effect of the plant-derived molecules extracted from three species of citrus cultivated in north east Brazil
against the pest mite, *T. urticae*. Attia *et al.* (2011) evaluated the biopesticide efficacy of different concentrations of garlic distillate (*Allium sativum*) to suppress the population of the serious mite pest, *T. urticae* and the results of their study showed that the garlic extracts in concentrations of 7.49 and 13.5 mg/l showed LD$_{50}$ and LD$_{90}$ values respectively. Sivira *et al.* (2011) conducted studies on the toxicity of the ethanol extract of the plants of wild oregano, *Lippia origanoides* and *G. sepium* on the population of the spider mite pest, *T. cinnabarinus* in Yaracuy State, Venezuela. Different concentrations of the ethanol extract *viz*. 5, 10, 15, and 20 per cent were applied following the leaf disk immersion technique and the authors recorded a reduction of 43.7 to 57 per cent in the rate of oviposition in *T. cinnabarinus* when treated with 5 per cent oregano or *Glyricidia* extracts respectively. When 10 per cent concentration of the extracts of *L. origanoides* and *G. sepium* were applied, the rate of mortality could be recorded as 42.2 or 72.5 per cent respectively in *T. cinnabarinus*. Jie *et al.* (2011) evaluated the acaricidal activity of acetone, water, ethanol and ethyl acetate extracts of the leaves of *Aloe vera* against the adult females of *T. cinnabarinus* by slide-dip bioassay. Of the four different extracts tested, acetone extract showed the strongest acaricidal activity, with LC$_{50}$ value of 90 ppm at 72 hours whereas LC$_{50}$ values of ethanol, water and ethyl acetate extracts were recorded as 391, 340 and 113 ppm respectively.
Patnaik et al. (2011) observed that essential oils and herbal extracts of different formulations extracted from different aromatic and medicinal plants were able to suppress the population build up of the eriophyid mite pest of coconut, *A. guerreronis*, in both laboratory and field conditions. Krishnappa et al. (2012) studied the mosquitocidal (larvicidal, ovicidal and pupicidal) activity of the extract of *G. sepium* against the malarial vector, *Anopheles stephensi*. The maximum larval mortality of *A. stephensi* (96.0 ± 2.4 %) was induced by the ethanol extract of *G. sepium* at a concentration of 250 ppm. The LC$_{50}$ and LC$_{90}$ values were recorded as 121.79 and 231.98 ppm respectively and higher concentrations of the solvent extract showed 100 per cent ovicidal activity. The pupae when exposed to different concentrations of ethanol extract were found dead with 58.10 per cent adult emergence when it was treated with 25 ppm concentration. Nong et al. (2012) analysed the acaricidal activity of the extract of *Eupatorium adenophorum* prepared by water decocting, ethanol thermal circumfluence, and steam distillation. The acaricidal effect of each extract was tested against *Psoroptes cuniculi* and *Sarcoptes scabiei* in vitro. Ethanol thermal circumfluence extract showed strong acaricidal activity and it killed all *S. scabiei* at 0.5 and 1.0 g/ml (w/v) concentration. A concentration of 1 g/ml extract was found to kill all *P. cuniculi* within 4-hours period. Zaman et al. (2012) studied the acaricidal activity of aqueous herbal extracts of *A. indica* leaves, *Calotropis procera* flowers, *Nicotiana tabacum* leaves and *Trachyspermum ammi* seeds following
adult immersion test, larval packet test and ear bag method both in vitro and in vivo conditions. The extract exhibited lethal effects on egg laying (index of egg laying = 0.371404 ± 0.00435), hatching (22.35 %) and total larval mortality at 50 mg ml$^{-1}$ and reduced tick intensity on the infested calves (18 detached out of 35 at 45 per cent (w/w) suspension, topically applied).

Felicien et al. (2012) conducted studies on the chemical composition and biological activities of the essential oil extracted from the fresh leaves of *Chromolaena odorata* growing in Benin. Twenty three compounds were identified viz. $\alpha$-pinene (20.7 %), pregeijerene (14.6 %), geijerene (12.0 %), $\beta$-pinene (10.3 per cent), germacrene-D (9.7 %). The antibacterial activity of the oil was found to be high when compared to the antifungal and antiradical activities.

The various major biological approaches adopted to control the worldwide pest, *T. urticae* with special reference to natural pesticides were reviewed by Attia et al. (2013). Kumral et al. (2013) evaluated the sub-lethal and lethal effects of the ethanol extracts of the thorn apple leaves, *D. stramonium* against the European red mite, *P. ulmi* and its lady bird predator, *S. gilvifrons* in the laboratory by adopting petri leaf disc-spray tower method. The authors observed that treatments with increasing concentration of leaf extract increased the mortality rate of the adults of both *P. ulmi* and *S. gilvifrons* leading to respective LC$_{50}$ values of 7097.5 and 1853.9 mg/l at 24 hours residual activity and the mortality of both the pest and its predator
increased further at 48 hours. However, the LC$_{90}$ values of the extract were lower for the predator than the pest mite at both 24 and 48 hours. Roh et al. (2013) studied the acaricidal and repellent effects of essential oils extracted from nineteen plants of the family Myrtaceae against T. urticae in Australia. The assay was carried out in the laboratory following dipping method and choice- and no-choice tests and the results of which showed that the essential oils obtained from Eucalyptus sideroxylon, Callistemon viminalis, E. bicostata, E. approximans and E. maidenii significantly increased the mortality rate of adult female mites and decreased the fecundity. Results of gas chromatograph/mass spectroscopy analyses revealed that the major components viz. 1, 8-cineole, limonene, and α-pinene were present in E. sideroxylon and E. bicostata. The 1, 8-cineole and limonene showed significant repellent effects on the mites and reduced fecundity in the choice test.

Reddy et al. (2014) studied the repellent activity of the methanolic leaf and bark extracts of three species of Cinnamomum viz., C. camphora, C. tamala and C. zeylanicum on the pest mite, T. urticae infesting tomato. The leaf extracts were evaluated at 4 per cent and 8 per cent concentration and the bark extracts were tested at 3 per cent and 6 per cent and high repellency of the pest mites was noted with the leaf extracts of all the three species of Cinnamomum at 8 per cent concentration up to 24 hours. Highest repellency of 59 per cent and more mortality were noted with C. camphora. Radhakrishnan and Prabhakaran (2014) studied the biocidal activity of
extracts of *Allamanda cathartica*, *Ageratum houstonianum*, *Casuarina equisetifolia*, *L. camara*, *Tithonia diversifoila*, *Bidens pilosa*, *Conyza bonariensis*, *Crassocephalum crepidioides*, *G. sepium* and *O. basilicum* against the red spider mite, *O. coffeae* infesting tea. The extracts were evaluated for adulticidal and ovicidal activity at two different concentrations viz. 2.5 and 5.0 per cent. Aqueous extracts of *A. cathartica* and *C. bonariensis* showed 100.0 and 80.0 per cent adult mortality respectively at 5 per cent concentration after 96 hours. Neethu *et al.* (2014) reported that a new *Bacillus thuringiensis* strain isolated from the gut of Malabari goat was effective against *T. macfarlanei*. A novel strain (designated as BPU5) of *B. thuringiensis* (Bt) isolated from the rumen of Malabari goat, capable of producing polymorphic d-endotoxin crystals concomitantly with sporulation in Luria– Bertani medium (LB), and the d-endotoxin was efficient to combat *T. macfarlanei*, a severe pest on some agricultural crops. Lawal *et al.* (2015) conducted a study on the phytochemical and insecticidal activity of the leaf extracts of *C. odorata* prepared in different solvents like hexane, chloroform, ethyl acetate and methanol against the stored product pest, *Sitophilus zeamis*. Udebuani *et al.* (2015) studied the insecticidal properties of *C. odorata* against *Periplanata americana* at room temperature and recorded the maximum mortality after exposure of the test species to the highest concentration of the leaf extract. The survival and mortality rates were highly significant at 0.001 per cent level of confidence.
MATERIALS AND METHODS

During the present study, attempts were made to formulate measures for the biological suppression of the selected species of pest mites which were recognized as most injurious to the medicinal plants of local importance. Possibilities for the biological control of pest mites were explored during the present study by adopting two kinds of regulatory measures i.e. (1) by locating and releasing natural enemies like the predatory mites and insects which exhibited potential to suppress pest population and (2) by formulating and applying different concentrations of plant extracts which possessed insecticidal/acaricidal properties.

1. Detection, collection and identification of natural enemies of selected species of pest mites

During the present study, natural enemies representing the predatory mites and insects were identified as potential agents, in suppressing the population of selected species of pest mites. During field surveys carried out for collection of mite fauna infesting medicinal plants, association of life stages of several groups of predatory insects and mites also could be identified on various species of medicinal plants. The various life stages of the natural enemies viz. larvae, nymphs and adults present on the mite infested leaves were collected and preserved in 70-75 per cent alcohol for subsequent identification. Live specimens of predatory insects and mites were also
collected along with phytophagous mites from medicinal plants cultivated in various localities of Kerala. Identification of the natural enemies was carried out following relevant taxonomic keys and also seeking help from the expert taxonomists.

2. Studies on feeding potential of natural enemies on selected species of pest mites

A total of five species of natural enemies representing the predatory mites, *Amblyseius largoensis* (Muma), *Euseius ovalis* and *Cunaxa myabunderensis* (Gupta), and insects such as the predatory gall midge, *Feltiella acarisuga* (Vallot) and predatory thrips (*Scolothrips asura* Ramakrishna and Margabhandu) were selected for studying the feeding potential on selected species of pest mites (*T. neocaledonicus*, *O. biharensis* and *B. phoenicis*). The various life stages viz. larva, nymph and adult of the natural enemies, which were recognized as potential predators of pest mites on their respective host medicinal plants under natural condition were selected for assessing the predatory potential. For conducting studies on the predatory potential of the selected species of natural enemies, laboratory stock cultures were raised and maintained through rearing under constant temperature-humidity conditions in petri dishes following the leaf disc method. Rearing/maintenance of the predatory mites and insects was carried out in an incubator, in which the temperature and relative humidity were maintained at
25 ± 2°C and 60 ± 5 per cent by keeping saturated solution of NaBr.2H₂O. Culture of prey/predatory mites /insects was done following leaf disc method. Five each leaf discs (2 cm x 2 cm) were made from the fresh leaves collected from the respective host plants for the rearing purpose.

2.1 Rearing/ Laboratory maintenance of natural enemies

a) Rearing of predatory mites

Known numbers (n = 10) of active adult females of the selected species of the predatory mites viz. *A. largoensis*, *Euseius ovalis* and *Cunaxa myabunderensis* were collected from the leaves of respective host plants like *C. halicacabum*, *J. adhatoda* and *V. negundo* from the Calicut university campus.

Adult females (2 nos. each) were released onto each leaf disc kept in the Petri dish. The Petri dish along with the mites was kept in the incubator. After 24 hours the adult females were removed from the leaf discs and the eggs were retained on the leaf disc for subsequent observation. Regular observations were made on the eggs laid on each leaf disc at 6 hours intervals under a Stereo zoom microscope to record hatching and emergence of larva. The culture sets were maintained in Petri dishes, on host leaves kept on moistened cotton pads in the incubator until the development was completed. Various life stages of the prey/mites were offered as food for the developing stages of the predatory mite.
b) Rearing/ Laboratory maintenance of predatory thrips

Ten adult female thrips were collected from the mite infested leaves of respective host plant for subsequent rearing and raising of stock cultures. Two adult females each was released on each leaf disc and kept undisturbed for 24 hours in an incubator. The adult females were found to insert eggs into the surface of the leaf disc. After 24 hours, the females were removed from the leaf discs and the eggs were kept in the incubator for subsequent development. Regular observation was made to detect hatching and emergence of the predatory larva. When the larva of the thrips got emerged, life stages of the prey mites were offered as food and the culture sets were maintained in the incubator until the completion of development.

c) Laboratory maintenance of predatory gall midge larva

The larval stages of the predatory gall midge, were directly collected from mite infested leaves under natural field conditions. The collected larvae were maintained/reared in the laboratory by offering life stages of the prey mite. Studies on the predatory potential of the gall midge larva on the prey mite were made by offering the different life stages of the prey mite and recording the rate of consumption. The adult stages of the gall midge were not considered for studies on predatory habit owing to difficulties in their maintenance under laboratory conditions.
2.2. **Experimental set up for studies on predatory potential of the natural enemies**

Studies on feeding potential of both the insect and mite predators of different pest mites were carried out at 25 ± 2°C and 60 ± 5 per cent relative humidity following the leaf disc method. Rate of prey consumption by the natural enemies was tested on three species of pest mites *viz.* *T. neocaledonicus, O. biharensis* and *B. phoenicis* on the leaves/leaf discs (3 cm x 3 cm) of their respective host plants. The various life stages of pest mites like the eggs and the most injurious life stages like nymphs and adults were offered as food during the study. The life stages of the pest mite were transferred from the stock cultures to the fresh leaf/leaf discs in a Petri dish with the help of a fine moistened hair brush. In order to get the sufficient number of egg of the pest mites, 12-15 reproductively active females of each species of pest mites were released on fresh leaf/leaf disc in separate Petri dishes and allowed to lay a sufficient number of eggs. The adult females and excess eggs were removed from the leaf disc before releasing the natural enemy onto the leaf disc.

Observation was made on feeding activity, nature of predation and the consumption rate of the natural enemies on the life stages of the pest mites offered. After 24 hours, the number of live and dead life stages of the pest mites was recorded. The experiment was repeated ten times in order to
confirm the results obtained. Data obtained on feeding potential were subjected to statistical analysis for testing significance with IBM SPSS Statistics (Version 19).

**a) Predatory potential of the natural enemies on *T. neocaledonicus***

Predatory potential of two natural enemies *viz.* the predatory mite, *A. largoensis* and the predatory gall midge, *F. acarisuga* was assessed on various life stages *viz.* eggs, nymphs and adults (female) of the pest mite, *T. neocaledonicus* was studied on the leaf disc of the host plant, *C. halicacabum*. The adult female of *A. largoensis* and the larval stage (second instar) of the *F. acarisuga* were selected for studying the predatory habit on the pest mite. For conducting feeding experiments, 50 Nos. each of the life stages of *T. neocaledonicus* *viz.* egg, nymph and adult were introduced on to the leaf discs of the host plant, *C. halicacabum* and to each leaf disc one female of *A. largoensis*/one second instar larva of *F. acarisuga* was introduced in separate petridishes. The predator-prey ratio considered during the study was 1:50. The feeding response of the individual predator towards the different stages of the prey mite was studied through frequent observation under a stereozoom microscope. Data on the rate of consumption by the individual predator on the individual life stage of the prey mite were recorded for an interval of 24 hours and presented.
b) Predatory potential of the natural enemies on *O. biharensis*

The predatory potential of two natural enemies *viz.*, the predatory mite, *E. ovalis*, and the predatory thrips, *S. asura* on the life stages *viz.* egg, nymph and adult (female) of the pest mite, *O. biharensis* was assessed on the leaf disc of the host plant, *J. adhatoda*. The adult females of *E. ovalis* and the larval stage (second instar) of *S. asura* were used for the present study. The various life stages *viz.* egg, nymph and adult of *O. biharensis* (50 Nos. each) were provided separately as prey for the adult female of *E. ovalis* and the larval stage of *S. asura* in separate Petri dishes. Data on rate of predation were recorded at an interval of 24 hours on each of the life stages of the natural enemies.

c) Predatory potential of the natural enemies on *B. phoenicis*

The rate of predation by the adult female and nymph of the predatory mite, *C. myabunderensis* and adult female of *A. largoensis* was assessed on the different life stages *viz.* egg, nymph and adult of the pest mite, *B. phoenicis* on the host, *M. rotundifolia*. Each life stages of *B. phoenicis* (30 Nos. each) were provided separately for both the nymph and adult female of the predatory mite in separate Petri dishes. After an interval of 24 hours, the number of life stages of the pest mite consumed by the adult and nymph of *C. myabunderensis* and adult of *A. largoensis* was recorded.
3. Evaluation of the acaricidal activity/bio control efficacy of plant extracts on selected species of pest mites.

In the present study attempts were made to evaluate the efficacy of different concentrations of extracts prepared from two species of plants, as given below:

3.1. Plant species selected:

Two species of plants were selected during the present study for testing the acaricidal activity. The selection of plants was made duly considering their wide distribution pattern and ease of availability from local habitats.

a) *Glyricidia sepium* (Jacq.) (Plate: 18; Fig. A & B)

*G. sepium* (Fabaceae) is a fast growing exotic and medium sized leguminous tree. The plant has the common name as quick stick, madrecacao (mother of cocoa), spotted *Glyricidia* etc. and local name as *seema konna*. It is widely used as a poison for rodents and in fact the Latin name *Glyricidia* means “rat poison”.

The plant has one of the multipurpose activity as a hedge plant, flowers as food in certain parts of the World, as fuel wood, animal feed, green manure, shade, as supportive plants for many agricultural crops etc. The different solvent extracts of the various parts of the tree have antibacterial, antifungal, nematicidal and insecticidal properties. The plant has medicinal
properties also like antidiarrheal, antidysenteric, antimutagenic, antioxidant, hepatoprotective etc.

b) *Chromolaena odorata* (L.) (Plate: 18; Fig. C & D)

The shrub, *C. odorata* (Asteraceae) is one of the world’s tropical weed having the common names like siam weed, chrismas bush, bitter bush and local name as *communist-pacha*. The shrub has many medicinal properties *viz.* antibacterial, antifungal, antihypertensive, anti-inflammatory, astringent, diuretic and hepatoprotective. The essential oil of the plant possesses insecticidal, insect repellent and nematicidal properties. Phytochemical screening of leaf extracts of *C. odorata* has shown the presence of tannins, steroids, flavanoids, alkaloids and cardiac glycosides. *C. odorata* is distributed throughout Kerala and the flowering and fruiting season of the plant is in the period of November to May.

3. 2. Preparation of crude plant extract:

Fresh and healthy leaves of *C. odorata* and *G. sepium* were collected from the plants growing in Calicut University campus and the adjacent locality. The collected leaves were put in polythene bags and brought to the laboratory for preparation of leaf extracts. In the laboratory, the leaves were washed thoroughly with clean tap water and shade dried for two weeks. The dried leaves were crushed or ground with an electric grinder to get a fine powder and stored in an airtight plastic container. Known weight (100 g) of
the powdered dry plant material was taken into a 1 liter capacity conical flask and 500 ml of distilled water was added to it and shaken for 8 hours in a mechanical shaker and then kept for 24 hours. The extract was separated using the muslin cloth and then filtered. The filtrate was collected in a 1 liter conical flask and the volume was made up to 1 liter and the prepared solution was stored as the stock. Different concentrations viz. 2.5, 5.0 and 10 per cent were prepared as the test concentrations, from the stock solution.

3.3. Acaricidal / miticidal test on pest mites

The acaricidal test was carried out at 25 ± 2°C and 60 ± 5 per cent relative humidity by following leaf disc method (Ebeling and Pence, 1953; Siegler, 1947). The acaricidal assay was performed with three different concentrations of the plant extract viz. 2.5, 5.0 and 10 per cent on the newly emerged active adult females of two most injurious species of spider mites viz. *T. neocaledonicus* and *O. biharensis*. Observation was made at three different exposure period viz. 24, 48 and 72 hour.

For testing the acaricidal activity 40 adult females of each species of pest mites were transferred from the stock cultures onto new leaf discs in separate Petri dishes 2-3 h before the application of the plant extract. 500µl each from the various concentrations (2.5, 5.0 and 10 per cent) of the extract was sprayed on the leaf disc containing the mites with the help of a glass atomizer. The control set of mites was sprayed with 500µl of sterilized
distilled water. The rate of mortality of pest mites for each concentration of the plant extracts were assessed through observation under a stereo zoom microscope at 24 h, 48 h and 72 h after the treatment. The experiment was repeated for ten times in order to get consistent results. The percentage of mortality was calculated/corrected following Abbott’s formula (Abbott, 1925) given below.

Corrected percentage (per cent) of Mortality = \((1 – \frac{n \text{ in T after treatment}}{n \text{ in Co after treatment}}) \times 100\)

Where as

\(n\) = Mite population
\(T\) = Treated
\(Co\) = Control

Data obtained on the rate of mortality of each species of mite for each concentration of plant extract were subjected to statistical analysis for testing significance.
OBSERVATIONS

During the period of work, the collection and identification of some predatory mites and insects feeding on the pest mites infesting the medicinal plants was also made.

1. **Identification of the natural enemies of the pest mites attacking the common medicinal plants of Kerala**

A total of 20 species of predatory mites and 5 species of insect predators were identified (Table. 41 & 42). The major families of the predatory mites recovered during the survey were Phytoseiidae, Cunaxidae, Bdellidae, Stigmaeidae and Cheyletidae and the major families of insect predators recovered during the study were Cecidomyiidae, Thripidae and Coccinellidae. The important genera of the predatory mites recorded during study were *Amblyseius*, *Euseius*, *Cunaxa*, *Bdellodes*, *Agistemus* and *Cheyletus*. The important genera of the insect predators were *Feltiella*, *Scolothrips* and *Stethorus*.

The most common potential species of predatory mites recovered from various host medicinal plants during the study period were *Amblyseius largoensis* (Muma, 1955) (Plate. 19; Fig A & E; Plate. 20; Fig H), *A. channabasavannai* Gupta and Daniel, 1978 (Plate. 20; Fig A & B), *A. indirae* Gupta, 1985, *A. herbicolus* (Chant) (Plate. 19; Fig B), *Neoseiulus*
longispinosus (Evans, 1952), A. coccineae Gupta, 1975, A. paraaearialis Muma, 1967, Paraphytoseius multidentatus (Swirski and Shechter, 1961), P. orientalis (Narayanan, Kaur & Ghai) (Plate. 20; Fig E & F), A. aeralis (Muma, 1955), A. adhatodae Muma, 1967, Euseius sacchari Ghai and Menon, 1967, E. coccineae Gupta, 1975, E. ovalis (Evans) (Plate. 19; Fig C), E. alstoniae Gupta, 1975, E. rhododendronis Gupta, 1970 (Plate. 20; Fig C & D), E. finlandicus (Oudemans, 1915) (Plate. 21; Fig A-D), Cunaxa myabunderensis (Gupta & Ghosh, 1980 (Plate. 20; Fig G), Cheyletus malaccensis Oudemans, 1903 (Plate. 19; Fig H), Agistemus sp., (Plate. 19; Fig D), and Bdellodes sp. (Plate. 19; Fig F & G). The most efficient species of insect predators recorded during the study were Feltiella acarisuga (Vallot, 1872), Scolothrips asura Ramakrishna & Margabandhu, 1931, S. longicornis Priesner, 1926, Stethorus punctillum Wiese, 1981 and S. gilvifrons (Mulsant, 1850) (Table. 41).

The results of the study also enabled to add new distribution records for 15 species of predatory mites and 5 species of insect predators. Accordingly, new record of distribution was attributed to A. largoensis (L. lavendulifolia, A. indica, M. frondosa & I. racemosa); A. channabasavannai (B. reinwardtii & E. sonchifolia), A. indirae (A. paniculata, E. viride & B. reinwardtii); N. longispinosus (G. sepium, C. halicacabum & L. lavendulifolia); A. paraaearialis (Eucalyptus globules); P. multidentatus (I. tinctoria, H. aculeatus, & L. camara); A. adhatodae (L. lavendulifolia & T.
chebula); E. sacchari (P. emblica & C. infortunatum); E. coccineae (E. recurvatus & G. sylvestre); E. ovalis (P. amboinicus, S. dulcis, C. halicacabum, I. mauritiana, A. indica & L. lavendulifolia); E. alstoniae (E. viride & P. corymbosa); E. rhododendronis (I. balsamina); C. myabunderensis (V. negundo, O. sanctum & L. inermis); Agistemus sp. (A. zeylanicus); C. malaccensis (A. marmelos).

The new distribution record for the insect predators were F. acarisuga (C. halicacabum, S. dulcis, C. ternatea, A. indica, L. aspera & L. lavendulifolia); S. asura (B. accuminata, M. sylvestris, B. reinwardtii & J. adhatoda); S. longicornis (C. halicacabum, R. communis, E. sonchifolia & Thottea siliquosa); S. punctillum (E. sonchifolia, C. ternatea, A. indica, S. rhombifolia, & D. motorium); S. gilvifrons (H. rosa-sinensis). The species of predatory mites with the respective range of host plants (Table. 42) could be recorded as: A. largoensis (20 species of plants), A. channabasavannai (11 species of plants), N. longispinosus (14 species of plants) and E. ovalis (19 species of plants). Among the the insect predators recovered, wide distribution/host range could be evidenced in two species viz. F. acarisuga (12 plants) and S. punctillum (14 plants) when compared to other three species of insect predators.
2. Feeding potential of natural enemies on selected species of pest mites

The natural enemies of the pest mites selected during the present study were found to suppress the pest population through their predatory activity on various life stages of the pest mites. Table. 43, illustrates the results of the predatory potential of the various natural enemies selected during the present study on the three species of pest mites tested viz. *T. neocaledonicus*, *O. biharensis* and *B. phoenicis*. Among the natural enemies selected for detailed studies, the insect predators were proved more effective in suppressing the mite population, when compared to the mite predators tested.

a) Nature of predation and predatory potential of the natural enemies on *T. neocaledonicus*

The natural enemies selected during the present study to suppress the population of the pest mite, *T. neocaledonicus* were the predatory gall midge, *F. acarisuga* and the phytoseiid predatory mite, *A. largoensis*.

The size of the yellowish orange coloured larvae of the gall midge, *F. acarisuga* ranged from 0.5-2mm (Plate. 22; Fig. A & B), and the adult midge appeared pink-brown. The pupae of the midge were found inside the yellowish white cocoons along the veins of the leaves (Plate. 22; Fig. C). The midge exhibited slow movement on the leaf surface and preferred to confine in areas where the pest mites were aggregated and were found to initiate their
feeding activity. While feeding, the gall midge larva penetrated the posterior part of the hysterosoma of the pest mite with its oral hook, to suck out its body contents. As a result of feeding on the pest mite, the body color of larva of *F. acarisuga* got transformed into more bright orange or red (Plate. 22; Fig. A & B). Quite often, the midge larva slowed down or arrested the movement of the pest mite, by bending its body and pressing the body of the pest mite with its posterior end. It took 1-2 minutes to consume an egg and 2-3 minutes to kill the nymph/adult stages of the pest. It was found that when the midge larva got disturbed or came in contact with a nearby moving prey while it was already engaged in predation, the predator give up the partially fed prey and captured the new prey which came in contact with it. After sucking out the body fluid of the prey completely, the midge larva was found to actively wander in search of another prey. The nymphal and adult stages of *T. neocaledonicus* which were attacked/killed by the larva of *F. acarisuga* were found shrivelled and often assumed a brown or black color (Plate. 22; Fig. H). The larva of *F. acarisuga* showed more preference to the eggs of the pest mite and adult stages were the least preferred (Table. 44).

The adult female of the predatory mite, *A. largoensis* was also proved to be an efficient agent in suppressing the population density of the pest mite, *T. neocaledonicus* (Plate. 19; Fig. A). The predatory mite seized the prey mites more rapidly by grasping the prey with its first and second pairs of legs. Subsequently, the predatory mite pierced the hysterosoma of the pest mite
either at the anterior or at the posterior end with its chelicerae and the body contents were sucked out completely. The colored body fluid of the nymph/adult stages of the pest mite, *T. neocaledonicus* was clearly visible in the gut of the transparent body of the predatory mite. The duration of egg consumption by the predator was 2-3 minutes whereas 6-7 minutes were taken to kill the nymph/adult stages of the pest. No continuous predatory habit was detected in the mite predator and a small time gap was required by the predator after consuming a prey mite.

A comparative assessment of the rate of predation by the insect predator, *F. acarisuga* and the mite predator, *A. largoensis* revealed that *F. acarisuga* consumed more number of life stages of *T. neocaledonicus* than that of *A. largoensis* (Table. 44.). As represented in the table, the per day consumption of *F. acarisuga* on the eggs, nymphs and adults of the pest mite, *T. neocaledonicus* were 43.07 ± 2.04, 35.19 ± 2.13 & 23.27 ± 2.17 respectively. Whereas *A. largoensis* was found to consume 27.48 ± 1.92, 18.79 ± 2.05 & 10.47 ± 1.08 eggs, larvae and adults respectively (Table. 44). The consumption rate of the larva of *F. acarisuga* was found relatively higher than that of the adult female of *A. largoensis* and its feeding potential up on statistical analysis was proved to be significant at *p* < 0.01 level.
b) **Nature of predation and predatory potential of the natural enemies on* O. biharensis*

During the present study, the feeding potential of two natural enemies *viz.*., the adult female of the phytoseiid predatory mite, *E. ovalis* (Plate. 19; Fig. C) and the larval stage of the predatory thrips, *S. asura* on the life stages *viz.* egg, nymph and adult (female) of *O. biharensis* was studied following the leaf disc method on the host plant, *J. adhatoda*.

Adults of *S. asura* were comparatively fast movers and larger in size than the other natural enemies of *O. biharensis* (Plate. 22; Fig. D-G). They were found wandering on the leaf surface in search of the prey and once they came in contact with the prey, they immediately attacked and punctured the body of the prey mite and sucked out the body fluids/contents. *S. asura* killed the various life stages of *O. biharensis* within 2-3 minutes. The newly emerged creamy white-yellow colored larvae of *S. asura* (Plate. 22; Fig. E), also were proved as potential predators on the life stages of *O. biharensis* and their predatory potential was significantly higher (*P < 0.01*) than that of the adult females of the predatory mite, *E. ovalis* (Plate. 19; Fig. A & B). After feeding on the life stages of *O. biharensis*, the colour of *S. asura* larvae assumed a more reddish or darker colour (Plate. 22; Fig. F & G) and the dead mite became blackish/brownish in colour (Plate. 22; Fig. H). The feeding activity of *E. ovalis* was more or less similar to that of the phytoseiid predator,
A. largoensis on the pest mite T. neocaledonicus described earlier. Both S. asura and E. ovalis showed more preference to the eggs of O. biharensis and least preference to the adult stages of the pest mite.

Both the insect and mite predators were proved to cause a marked reduction in the mite population. The rate of predation of S. asura on the egg, larva and adult stages of the pest mite, O. biharensis was 39.61 ± 1.32, 27.15 ± 1.16 & 21.27 ± 2.13 respectively and that of E. ovalis was 21.92 ± 1.09, 14.79 ± 2.05 & 8.47 ± 2.08 (Table. 44).

c) Nature of predation and predatory potential of the natural enemies on B. phoenicis

The predatory potential of two species of predatory mites of the families Cunaxidae and Phytoseiidae viz. C. myabunderensis (adult female and nymph) and A. largoensis (adult female) respectively was analysed during the present study on the various life stages viz. egg, nymph and adult of the tenuipalpid mite, B. phoenicis. Both the predators were found to be fast runners in laboratory cultures and exhibited promising roles in suppressing the population of the pest mite, B. phoenicis.

The adult females of C. myabunderensis were dark red in colour, with well visible snout like mouthparts (Plate. 23; Fig. A & B), and the nymphs were pale yellow in color prior to feeding on the pest mites. However, after feeding on the different life stages of B. phoenicis, the body color of the
larva/nymph of the predatory mite got changed to orange red (Plate. 23; Fig. D & E). The prey mite life stages were found seized by the adults as well as nymphs of the predator, *C. myabunderensis* with their pedipalps and the first and second pairs of legs and the body of the prey mite was found pierced with their long snout like mouthparts (Plate. 23; Fig. B & E). The body fluid of the prey mite was found completely sucked out by the predator leaving behind the dead body of the prey. The adult predatory mite was found to kill the prey mite within 1-2 minutes while the nymph took 3-4 minutes. On completion of predation of one prey mite, the predator was found to attack a new prey.

The rate of consumption by the adult female of *C. myabunderensis* on the egg, larva and adult stages of *B. phoenicis* was 26.03 ± 2.02, 23.61 ± 1.57 & 17.19 ± 2.17 and that of the nymph of *C. myabunderensis* was 19.14 ± 1.83, 14.61 ± 2.04 & 11.61 ± 2.13 (Table 44). The predatory habit of the phytoseiid mite, *A. largoensis* was similar to that on the pest mite, *T. neocaledonicus* described earlier. The per day consumption by the adult female of *A. largoensis* was 14.32 ± 2.07, 9.92 ± 1.09 & 6.73 ± 1.24 respectively on the egg, larva and adult stages of the pest mite, *B. phoenicis* (Table 44). In the present study, the adult females of *C. myabunderensis* were observed as the most potential predators on the life stages of the pest mite, *B. phoenicis*, exhibiting significantly high rate of predation (p < 0.01).
3. **Acaricidal activity of the plant extracts on pest mites**

The aqueous extracts of both species of plants selected during the study *viz.* *Glyricidia sepium* and *Chromolaena odorata* were found to possess acaricidal activity, leading to mortality of the adults of the two species of pest mites selected *viz.* *T. neocaledonicus* and *O. biharensis* (Table. 45 & 46). During the present study, the acaricidal activity of three different concentrations *viz.* 2.5, 5.0 and 10.0 per cent of the aqueous extracts of the above species of plants was evaluated at three different exposure periods *viz.* 24, 48 and 72 hours, against the pest mites. The rate of mortality was found relatively high for the aqueous extracts of *G. sepium* on both the species of pest mites when compared to extracts of *C. odorata*. The effect of plant extracts on *O. biharensis* is shown in Plate. 24 and Fig. A & B.

The results of the study revealed that the acaricidal effect of the plant extracts was concentration-dependent. The mortality rate of pest mites followed a linear trend with the concentration of the plant extract, i.e., an increase in the concentration of the extract resulted in an increase in the percentage of mite mortality. All the three concentrations (2.5, 5.0 and 10.0 per cent) of the aqueous extracts of both species of plants were found to induce comparatively high mortality of the adults of *T. neocaledonicus*, than that of *O. biharensis*. Treatments with the crude extracts of both species of
plants were found more effective at higher concentration (10 per cent) against both species of pest mites selected.

As shown in the Table 45 and 46, treatments with 10 per cent of plant extracts (G. sepium & C. odorata) at 72 hour exposure induced the maximum mortality of the pest mites. Treatment of T. neocaledonicus with 10 per cent aqueous extract of G. sepium induced the maximum percentage of mortality of 89.31 ± 2.15 at 72 hours of exposure (Fig. 24). Application of 10 per cent concentration of the same extract on O. biharensis caused 77.37 ± 1.98 per cent mortality for the same period of exposure (Fig. 24). Whereas exposure to 10 per cent of aqueous extract of C. odorata induced a relatively lower mortality rate of 77.29 ± 2.03 per cent in T. neocaledonicus and 65.03 ± 2.09 per cent in O. biharensis at an exposure time of 72 hours (Table. 46 & Fig. 25). In the present study, the acaricidal activity was found at the lowest level for the aqueous extract of 2.5 per cent concentration of C. odorata on both species of pest mites (Fig. 24 & 25). Treatments with 2.5 per cent aqueous extract of C. odorata for an exposure time of 24 hours induced 6.13 ± 1.20 and 9.15 ± 0.93 per cent of mortality in O. biharensis and T. neocaledonicus respectively (Table. 46).

A gradual increase in the percentage of mortality was observed when the exposure time was increased from 24 to 72 hours in both the species of pest mites, treated with the plant extracts. Treatments with different
concentrations of *G. sepium* extract showed a noticeable variation in the percentage of mortality with an increase in the time of exposure. As shown in Table. 45, treatment with 2.5 per cent of *G. sepium* extract was found to increase the percent mortality of *T. neocaledonicus* as $10.34 \pm 1.21$, $13.24 \pm 2.25$ & $15.47 \pm 2.10$ respectively at increased periods of exposure like 24, 48 & 72 hours. Treatments with the same concentrations of the plant extract on *O. biharensis* induced $7.25 \pm 1.17$, $10.41 \pm 2.19$ & $11.21 \pm 2.05$ per cent of mortality at 24, 48 & 72 hours of the exposure period respectively. Exposure of mites to 5 per cent of *G. sepium* extract to three successive periods of exposure showed a similar increase in the percentage of mite mortality. A high variation was observed in the mortality rate of mites at the three exposure periods when treated with 10 per cent extract of *G. sepium*. Treatment with 10 per cent extract of *G. sepium* on *T. neocaledonicus* induced a mortality rate of $81.83 \pm 1.16$, $85.83 \pm 2.03$ & $89.31 \pm 2.15$ per cent at 24, 48 & 72 hours of the exposure periods respectively (Fig. 26). Similarly, treatment with the above concentrations of extract of *G. sepium* on *O. biharensis* induced $72.52 \pm 1.24$, $73.98 \pm 2.24$ & $77.37 \pm 1.98$ per cent mortality respectively at 24, 48 and 72 hours of the exposure (Table. 45). The mites treated with 2.5, 5 and 10 per cent extracts of *C. odorata* did not cause much variation in the rate of mortality at the three successive exposure periods mentioned above. Results of the data on acaricidal activity of extracts of both species of plant on the pest mites under study up on statistical analysis
were proved highly significant (p < 0.01). The percentage of mite mortality showed variation with respect to the plant extract used/treated. *G. sepium* extract was found to possess more efficient acaricidal property than that of *C. odorata* extract on the pest mites studied and its impact was found significant at p < 0.02 level.