BIOLOGICAL STUDIES ON PHYTOSEIID PREDATORS (ACARI: MESOSTIGMATA)

Thesis Submitted to the University of Calicut
for the Award of the Degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

SHEEJA. U.M

DIVISION OF ACAROLOGY
DEPARTMENT OF ZOOLOGY
UNIVERSITY OF CALICUT
KERALA, INDIA
2010

CERTIFICATE

This is to certify that the thesis entitled **"BIOLOGICAL STUDIES ON PHYTOSEIID PREDATORS (ACARI: MESOSTIGMATA)"** has been carried out by **Ms. SHEEJA. U.M**, a candidate for Doctor of Philosophy in Zoology under my supervision and guidance, in the Acarology division of this Department and that no part of this work has been presented before for any other degree.

Place: C.U. Campus **Dr. N. RAMANI**

Date : .2010

DECLARATION

I do hereby declare that this thesis entitled **"BIOLOGICAL STUDIES ON PHYTOSEIID PREDATORS (ACARI: MESOSTIGMATA)"** is an authentic record of the work carried out by me under the supervision and guidance of **Dr. N. RAMANI**, Professor, Division of Acarology, Department of Zoology, University of Calicut and that no part of this has been published previously or submitted for the award of any other Degree or Diploma.

C. U. Campus, **SHEEJA. U.M**

Date: .2010

CONTENTS

Acknowledgement

It is with immense gratitude and love, that I remember all persons, whom I am indebted from the beginning of this venture, and with out all those timely help I could not have complete my research work successfully. My utmost thanks are due to my supervising teacher **Dr. N. Ramani**, Professor and Head of the Department, Division of Acarology, Department of Zoology, University of Calicut, who very generously supervised the work and improved the embryonic manuscript through her expert guidance, timely suggestions, pertinent criticism and immense patience which formed the basis for successful completion of my work.

I am also grateful to **Dr. V.S. Krishnan Nair** (Rtd.), **Dr. K.P. Janardhanan** (Rtd.) and **Dr. M. Gokuldas**, Professors and Former Heads of the Department of Zoology for creating conducive environment and facilities in the Department, that helped me a lot in the successful completion of the work.

I acknowledge with gratitude, **Dr. Mohanasundaram**, Professor and Head (Rtd.), Department of Agricultural Entomology, TNAU, Coimbatore and **Dr. S.K. Gupta**, Principal Investigator, USERS Project, Department of Science and Technology (Formerly Emeritus Scientist ZSI and Ex-National Co-ordinator, ICAR, Acarology Project) for their help in identification and confirmation of species of Tetranychid and Phytoseiid mites. Thanks are due to **Dr. A.K. Pradeep**, Herbarium Curator, Department of Botany, University of Calicut for his assistance in identification of host plants involved in the study.

I extend my sincere thanks to **Dr. K.V. Lazzar**, **Dr. M. Nasser**, **Dr. Y. Shibuvardhanan,** Department of Zoology, University of Calicut and **Dr. Mary Anitha Latha Sadhanandan,** Reader**,** Department of Zoology, Malabar Christian College, Kozhikode, for their constant encouragement and suggestions.

I am particularly indebted to each of my friends, Dr. K. Sudheer, Lecturer, Zamorins Guruvayurappan College and Dr. Sheeba, Mr. Santhosh S. Nair, Mr. P.P. Santhosh, Mr. K.V. Santhosh Kumar (Librarian, Department of Zoology), Miss. K. Bindhu (Lecturer, Victoria College Palakkad), Ms. P. Sheena (Lecturer, Government Arts and Science College, Calicut), Miss. P. Sajitha, Miss T. Leya, Mr. K. Mashhoor, Mr. V.P. Akhilesh, Mr. R. Brinesh, R.B. Smitha, Dr. Manju C. Nair and Mr. T. Rajesh Kumar for their constant encouragement, timely help and support, which I enjoyed throughout this course.

I shall be failing in my duty if I do not thank my research colleagues, Ms. M.T. Shiji, Ms. E. Julie, Dr. Sangeetha G. Kaimal and Ms. P. Prabheena for their wholehearted support, co-operation and encouragement.

My special thanks are also to Mr. Ramprakash (Infratec), Mr. Jabir (Department of Mass Communication and Journalism, University of Calicut) and Mr. Rajesh (Bina Photostat) for the technical assistance rendered for the printing of the thesis work.

This entire piece of work would not have been materialised, without the matchless love, warm impetus and mental courage received from my parents. Their unconditional love and affection always inspired me to strive for the best in life. My gratitude also goes to my brother, U.M. Prabheesh Kumar, my sister Ms. U.M. Pushpa and other family members for the needful help throughout the work.

I gratefully acknowledge, the **University of Calicut** for the financial assistance extended in the form of fellowship during the tenure of my work.

Above all, I remember with gratitude the grace of God for the successful completion of this work.

SHEEJA. U.M.

LIST OF PLATES INCLUDED

LIST OF TABLES INCLUDED

INTRODUCTION

Predatory mites constitute an important group owing to their potential in controlling the insect and mite pest populations well below the economic injury level. The most important predatory mites explored in this regard include members of Phytoseiidae, Cheyletidae, Cunaxidae, Stigmaeidae, Bdellidae, Tydeidae, Ascidae, Anystidae, Erythraeidae and some Tarsonemidae. The objective of using biocontrol agents is to restore and or to enhance the relationship between pests and their natural enemies either by reintroduction and or by creating the same habitat conditions under which the relationship would be strengthened or would form naturally. As a control tactic, biocontrol is most suited to pest species with a relatively high economic injury level. This is because a minimum prey density will usually be required to support a permanent predatory population. Of the 54 commercially available predator species for pest control used on a global level, 13 are predatory mites of the family Phytoseiidae.

Phytoseiidae of the order Mesostigmata is a large family with world wide distribution, comprising 1600 species belonging to over 70 genera. This family consists of three subfamilies viz. Amblyseiinae, Phytoseiinae and Typhlodrominae. Effective biocontrol agents occur in all these three subfamilies. Phytoseiids enjoy a wide range of habitats, ranging from the arctic to the tropics. They could be found out from all types of plants

comprising herbs, shrubs, trees, grasses, fungi, mosses and from any part of the plant viz. inflorescence, leaves, flowers and under barks etc. They are also found in the nest of birds, under logs, soil and leaf litter. It would be very hard to find out a single plant with out a phytoseiid mite. The ability to prosper on non-animal food items like pollen, honey and nector is another factor behind their success as a biocontrol agent. Besides these, phytoseiid mites posses an array of supreme adaptive features which often raise them to the level of potential predators of pest mites and also insects to a certain extent. These include wide distribution, high abundance, short life cycle than that of their prey, equivalent reproductive potential, good searching capacity, good dispersal rate, ability to survive on a low prey density, and adaptability to different ecological niches. Nowadays, the role of phytoseiid mites as a component in the IPM programmes has gained recognition world wide. They have drawn attention of economic entomologists and acarologists all over the world and has encouraged intensive and extensive faunistic exploratory studies. As a result, many countries have started implementing biological control programmes also as a part of IPM through mass rearing, release and export of phytoseiid predators. But in India, their importance is not properly recognized and little work is known to be done on the biological aspects of the same.

Among the various groups of pests, mites of the families Tetranychidae, Eriophyidae, Tenupalpidae and Tarsonemidae constitute the

most known preys of phytoseiid mites. Tetranychid mites, the popularly called spider mites are obligate plant feeders and several species are reported to show secondary pest out break. There are dozens of species of spider mites belonging to genera *Tetranychus*, *Eutetranychus*, *Eotetranychus*, *Schizotetranychus*, *Oligonychus*, *Panonychus* and so on, which cause severe damage to plants. The present day knowledge on spider mites undoubtedly confirmed them as the major agricultural mite pests. They have been accepted as a constant source of threat to the economy of agriculture. Chemical control of these mites is quite expensive and quite often useless as in several instances these mites are seen to develop resistance to various kinds of acaricides as per recent reports. Hence, there is an increasing trend recently, to devise control measures against mite pests, utilizing biological enemies like predatory mites- especially phytoseiid mites- insects, fungi, bacteria etc.

Eriophyid mites constitute another important group of invasive acarid pests comes under the family Eriophyidae, superfamily Eriophyoidea of the order Prostigmata. Exposed mites are easily controlled chemically, but most pesticides do not kill the mites living within galls or other such concealed and well protected habitats like the under surface of tepals of coconut. In most instances, the pesticides would become more fatal to the beneficial insects and predatory mites rather than the eriophyid pests dwelling in the same habitat. Several species of phytoseiids have been evaluated as potential predators of eriophyid mites.

False spider mites of the family tenuipalpidae are also a well known group of phytophagous mites which show close resemblance to the spider mites and hence accommodated in the superfamily Tetranychoidea, under the order Prostigmata. Unlike tetranychid mites, tenuipalpids never spin any web. These mites are slow moving and are usually found on the lower surface of the leaves, near the midrib or veins. Some species feed on the bark also. Others live in flower buds, under leaf sheath or in galls. Mites feeding on the under surface produce a brownish, scurfy discoloration extending along either side of the midrib to the base of the leaves. Apart from their pest status, several species are known as vectors of phytopathogenic bacteria, fungi, viruses, etc. Populations of these mites are also reported to be effectively checked under field conditions by the natural enemies, comprised of the phytoseiids.

There are many reports on phytoseiid mites as potential predators of insect pests such as thrips, scales and aphids. Despite the proportionately high degree of success reported through implementation of various biocontrol programmes against scale insects as compared with other pest groups, numerous serious economic problems still exist in many countries. There is hardly any country in the world today where scale insects do not constitute problems. They are notorious as invaders of new territories and it is thus expected that additional problems will continue to arise and that the already large insecticidal load, both economic and contaminative will

continue to increase unless alternative solutions are devised. Scale insects are monophagous, oligophagous or polyphagous. Trees and shrubs are most frequently infested. Due to their great reproductive capacity, survival ability and the difficulty in chemical control, many species are highly destructive pests of fruit trees and ornamentals. Any above or ground parts of the host plant may be infested. Injury to infested plant may result from both direct effects of feeding and toxic effects of injected saliva. Severe attack can cause discoloration of the leaves due to loss of chlorophill, deformation, splitting, retardation of growth and general weakening of the plant. In severe cases, yield loss, extensive defoliation and eventual death of the plant may result. Scale insects are rather more amenable to control by natural enemies, especially the phytoseiid predators.

Thrips constitute another important insect pest group coming under the order Thysanoptera. Many species are important economic pests of plants, causing significant damage globally. With their piercing and sucking mouthparts they pierce the cell wall of tissues and this make direct injury to leaves, flowers, stems and fruits. While feeding some species may inject digestive enzymes also by inserting the maxillary stylets and hypopharynx into the tissue to drain off cellular fluids. This process leads to the development of a distinct silvery or bronze scarring on the surface of the stems or leaves where the thrips feed. Moreover, they are increasingly being found to vector plant diseases. These insects can easily be introduced in to

new areas on cut flowers (especially in the flower head), ornamentals, fruits, and vegetables. Increased resistance against insecticides is probably the main factor involved in the spread of thrips pests along man-made routes. Once intercepted or established, thrips are extremely difficult to be controlled with chemical pesticides. Due to their small size, cryptophilic behavior and high rate of reproduction, classical biological control of thrips has become difficult, as the predators must be small and slender enough to penetrate the crevices where the thrips hide in while feeding. In this context phytoseiids can probably play a prominent role in regulating the number of plantfeeding thrips under natural conditions.

Regardless of the development of various control measures such as cultural, chemical, biological and high tech pest control using recombinant DNA technology, food production and arthropod pest control are the two most important challenges facing humanity in the 21st century. Some estimates suggest that ~99% of all potential pests can be controlled by natural enemies. But modification in natural enemy efficiency, crop plant conditions, intensive use of broad spectrum insecticides and fungicides against key pests, resistance of pests to these chemicals, changes in cultural practices all lead to the destruction of the relationship between naturally occurring biocontrol agents and pests, that is often responsible for pest out breaks.

Several factors such as food type, prey density, temperature, humidity etc. are known to exert remarkable impact on the life cycle

parameters of predatory mites like their feeding potential, daily rate of egg production, range of pre-oviposition and post-oviposition periods and extent and range of feeding etc. Considering the above factors, the present work has been undertaken to study the influence of qualitative and quantitative variation in food items such as spider mites, scale insects, thrips, and pollen grains of *Ricinus communis* on the feeding and breeding biology of some selected, locally available, important and potential phytoseiid species viz. *Amblyseius largoensis* Muma, *Typhlodromips suknaensis* Gupta, *Paraphytoseius multidentatus* Swirski and Shechter, *A. guptai* sp. nov. and *Phytoseius rachelae* Swirski and Shechter at a constant temperature of 30±2°C and relative humidity of 70± 2%. Attempt has also made to observe the impact of the most potential predator, *T. suknaensis* on the selected pest mite, *T. neocaledonicus* population in the field condition also.

REVIEW OF LITERATURE

Mites of the family phytoseiidae have received considerable attention for the last few decades because of their potential as biological control agents of phytophagous mites, and more recently of thrips, aphids, coccids etc. affecting various crops. Most of the earlier studies and majority of the current ones even focus on the abilities of these predatory mites to rapidly increase and overcome population outbreaks of spider mites. In recent years, studies have been undertaken to examine some of the attributes of phytoseiid mites which contribute to persistence of population at low prey densities. The present review includes a concise version of the developmental strategies and predatory behaviour of phytoseiid mites.

The predatory efficacy of *Seius pomi*, upon the blister mite, *Eriophyes pyri* was first established by Parrot *et al.* (1906). The potential of phytoseiid mites in regulating the populations of plant mites, especially the spider mites was studied by Quale (1912), Ewing (1914), Gillial (1935) *etc*. Lee and Davis (1968) conducted studies on the life history and behaviour of the predatory mite, *Typhlodromus occidentalis* in Utah and recorded an average period of 6.3 days as the developmental time from egg to adult. Swirskii and Dorzia (1969) in Israel recorded high rates of oviposition and percentage survival of young instars in *T. occidentalis* when fed on spider mite species like *Tetranychus cinnabarinus* and *Eutetranychus orientalis*. Swirski *et al*.

(1970) reported that certain phytoseiid species could develop only on tetranychid mites, some on combinations of tetranychids and eriophyids, some on mites and pollen and few others on pollen alone. The predatory habit of *Amblyseius finlandicus* on the tetranychid species infesting citrus in Punjab was reported by Gupta *et al.* (1971). Petrova (1972) conducted experiments illustrating the effects of food and temperature on spermatogenesis and oogenesis in *Phytoseiulus persimilis* in Lativa.

Pruszynski and Cone (1973) determined the life span, fecundity and prey consumption of species like *Metaseiulus occidentalis*, a potential predator of the two spotted spider mite, *T. urticae* at varying temperatures like 18.5^0C, 25^0C and 30^0C on hops in Washington. Kropezynska (1973) made observation on the feeding biology of four species of phytoseiid mites like *Phytoseius macropilis, T. potentillae, T. pyri* and *A. finlandicus* on different species of prey mites as well as on apple mildew and honey dew in Poland. Nelson (1973) reported that pollen feeding by *A. hibisci* in Southern California could be beneficial by causing a potential increase in predator population density before the commencement of the seasonal increase in prey density. Prasad (1973) studied the role of *P. macropilis* in control of the spider mites in Hawaii, and found a decrease in the size of the pest population with an increase in the predator population. The effect of the type and abundance of prey species on the development of *P. persimilis* was studied by Shehata (1975) in Czechoslovakia.

McMurtry and Scriven (1975) described a technique for mass rearing the predator, *P. persimilis* in the insectaries in California. Blommers and Etten (1975) observed that predation and oviposition of *A. bibens*, an important predator of several species of *Tetranychus*, in parts of the Malagasy Republic, were dependent on the densities of the prey mites. They found that predation was limited at the lowest densities, which in turn resulted in a lower oviposition rate also. Rasmy and El-Banhawy (1975) reported that the predatory mites, *A. gossypii* and *P. plumifer* successfully completed three generations on a diet of castor pollen (*Ricinus communis*) and were able to return to their natural prey, *T. urticae*. Santos (1975) observed that the number of eggs deposited by *A. fallacis* depended on the density of the prey up to daily maximum of about 2 eggs/female and then the oviposition rate leveled off. El-Banhawy (1975) studied the biology and feeding behaviour of *A. brazilli* on a diet comprised of *T. desertorum* and *Aponychus spinosus* and found that the life cycle from egg to adult required about 7 days for both sexes. Regusa and Swirski (1975) conducted studies on the feeding habits, development and oviposition of *A. swirskii* in Israel, providing pollen of various weeds and concluded that the presence of weeds and their pollen in citrus groves might permit population build up of the predator, which in turn would help in exerting an effective check when the pest population increased. Simova (1976) provided information on the population dynamics of phytoseiid species like *A. aberrans* and *P. plumifer*,

found on plum in Bulgaria. Takafuji and Chant (1976) in Canada compared the responses of two predaceous phytoseiid mites, *P. persimilis* and *Iphiseius degenerans* to the density of their prey, *T. pacificus* and found that the potential rate of *P. persimilis* was greater than that of *I. degenerans.* Sciarappa and Swift (1977) in USA reported that the mean rates of oviposition in *Typhlodromips sessor* when fed upon *T. urticae, Aculus schlechtendali, Thrips tabaci, Haplothrips subtilissimus*, pollen of *Cisium vulgare* or a tarsonemid mite were 0.79, 0.70, 0.51. 0.23, 0.15 and 0.13 eggs/female/day respectively. While studying the feeding and breeding biology of *A. swirskii*, the dominant phytoseiid mite in citrus orchards of Israel, by offering some coccids and mealy bugs, Ragusa and Swirskii (1977) established that the provision of honey dew and *T. cinnabarinus* enhanced the rate of oviposition in the above predator.

Sciarappa *et al.* (1977) conducted studies on the distribution, abundance and interspecific association of *T. sessor* in New Jersey and reported a positive association between this phytoseiid and with three common phytophagous species such as tetranychid mites, eriophyid mites and *Thrips tabaci*. Studies on the response of *A. bibens,* an obligatory predator in Madagascar, to conditions of prey scarcity were carried out by Blommers *et al.* (1977), the results of which revealed that the feeding activity was greatest in well fed females and decreased with increasing hunger and eventually inanimate. While studying some aspects of the practical use of

P. persimilis in the biological control of tetranychid mites on cucumbers grown in glass houses in Poland, Pruszynski (1978) found that *P. persimilis* could survive at temperatures below 0^0C and could develop by feeding on over- wintering tetranychids. Dyer and Swift (1979) determined the sex ratio of 15 species of phytoseiid mites collected from 24 locations throughout new jersey during the summers of 1973 and 1974, and reported that the sex ratio was not related to species frequency, density or host vegetation species. Instead, it was related to temperature, humidity and wind spread. Puttaswamy and ChannaBasavanna (1979) recorded *T. tetranychivorus* as a potential control agent of *T. ludeni* in India with adequate preference to adult females. The authors also reported that the females of the above predator laid an average of 43.33 $\pm$ 7.16 eggs during an oviposition period of 28.89 $\pm$ 4.01 days. The average life span of the females and males could be recorded as 39.22 $\pm$ 3.36 and 35.38 $\pm$ 5.57 days respectively. Daftari (1979) conducted studies on the reproduction and development of *A. aberrans* by offering *Colomerus vitis* and pollen of *Datura stramonium* and observed that the life span and reproduction rate of adult females of the species were higher when fed on *C. vitis* than on the other food. While determining the duration of feeding by various predators on different stages of the citrus pest, *E. orientalis* in India, Dhooria (1980) recorded that nymphs and adults of *A. alstoniae* fed on all stages of *E. orientalis* but preferred larvae and protonymphs and the average rates of consumption by a single larva, protonymph, deutonymph and adult female were 3.67, 5.20, 4.62 and 10.6 respectively.

Eveleigh and Chant (1981a) reported that many aspects of the feeding and searching behaviour of *P. persimilis* and *A. degenerans* in India were dependent on the prey density to which they were exposed. The authors (1981b) also compared the numerical responses of *P. persimilis* and *A. degenerans* to their prey, *T. pacificus*. The results of their studies showed that the nutritional requirements of the predators, the time that they were exposed to prey in relation to their life span, age and differences in nutritional history etc. could have important effects on their predatory behaviour and functional response. Tanigoshi *et al.* (1981) studied the significance of temperature and food resources on the developmental biology of *A. hibisci* in U.S.A. and found that the population and reproductive rate attained the optimum at 35^0C. The predators, *A. cucumeris* and *A. mackenziei* were reared on *Acarus spp.* and *T. urticae* by Schliesske (1981) in German Federal Republic and he observed that predators fed with equal readiness on either prey species but were hindered by the abundant webbing produced by *T. urticae*.

Overmeer (1981) carried out rearing experiments with phytoseiid mites in order to study different aspects of their biology relative to the use for biological control of phytophagous mites in apple orchards at Amsterdam. Obnesorge (1981) carried out studies on the preference of *P. persimilis* to individual stages of *T. urticae* in the German Federal Republic. Based on prey consumption, the author concluded that the ratio of nutritional values of

newly laid eggs, larvae, deutonymphs and adult females was 1.07: 2:4.4. Krishnamoorthy (1982) carried out studies on the effect of temperature on the development, survival and fecundity of the predatory mite, *A. tetranychivorus* feeding on *T. urticae* in India. The results of these studies showed that although higher temperatures favoured faster development of the pre-adult stages, survival, oviposition and fecundity of females were adversely affected and it was found that the most favourable temperature was 30^0C. Interactions between the predaceous mites, *P. persimilis* and *A. degenerans* and their prey *T. pacificus* were reported by Eveleigh and Chant (1982) in Canada. While studying the effect of prey species on the biology of *A. gossypii* in Egypt. Yousef *et al.* (1982) observed that over 90% of the total number of prey taken by *A. gossypii* was consumed during the adult stage. Yousef *et al.* (1982) investigated the effect of prey species, *Tenuipalpus granati* and *T. urticae* on the biology of *A. gossypii* and *Agistemus exsertus* in Egypt. They reported that fecundity of both predators was greater when they were fed on eggs of *T. granati* than the immatures of this species or eggs or immatures of *T. urticae*. Neelu Nangia and ChannaBasavanna (1982) in India established that populations of *T. tetranychivorus* when fed on mites and castor pollen became denser than those feeding on mites alone, and predators released on plants with exposed inflorescence were more efficient in suppressing *T. ludeni* than when they were released on plants with bagged inflorescence.

While studying the biology of *E. concordis* in Brazil, Moraes and Lima (1983) recorded similar biological cycles for the species when fed on *Aculops lycopersici* as well as pollen of castor. The ecological studies made by Kolodochka (1983) in USSR on *A. longispinosus* revealed that the rate of increase of the species was higher when the mite was fed on eggs of *T. urticae* than on deutonymphs. Mallik and Channabasvanna (1983) traced out the life history of *A. longispinosus* and found that the development from egg to adult required 99 hours and 11 minutes in females and 99 hours and 30 minutes in males.

Badii and McMurtry (1984) carried out studies on the feeding behaviour of *T. rickeri, T. porresi, T. annectens* and *A. stipulatus* in California and found that the first three predators preferred larvae of *P. latus* to other stages where as *A. stipulatus* fed on all stages of the prey. However, the nymphal stages of the above predator showed a low level of preference to the larvae and females of the prey. Ezulike and Odebiyi (1984) demonstrated that the nymphs and adults of *A. fustis*, an important predator of *O. gossypii* on cassava in Nigeria, could feed on all stages of the tetranychid prey in the laboratory. But when the adults of the predator were fed separately on different developmental stages of the prey, mean consumption rates were 89.4 and 81.0 for mated male and female predators respectively and 69.4 and 59.4 for unmated ones. The authors (1985) further studied the life history of *A. fustis* and stated that the duration of life history of male and female was

about 8 days and the longevity was about 19.2 days. The effect of temperature on the biology of *A. longispinosus* was demonstrated by Nakawa (1985) who reported that besides temperature, the quality and quantity of food available also could influence the developmental period of the above predator. An increase in humidity caused a decrease in the duration of development of the species. The optimum temperature for the development of *A. finlandicus* was 25^0C as observed by Neelam and Sadana (1985) and the authors reported that at this temperature the total developmental period of the above species was quiet short with high fecundity and no mortality. Kolodochka (1985) observed that at 25^0C, a single female of *P. persimilis* could consume up to 7 eggs or larvae of *Bryobia lagodechiana* on cucumber leaves in a glass house in the Ukrainian SSR and lay 1-2 eggs/day. While studying the mode of predation as well as developmental biology of *E. hibisci* on the homopteran *Bemisia tabaci* on cotton in California, Meyerdirk and Coudriet (1985) observed that life span, fecundity and the oviposition period of *E. hibisci* feeding on *B. tabaci* were lower than those of pollen fed mites. Under laboratory conditions, Zhang and Kong (1985) recorded the respective durations of the different developmental stages of *P. persimilis* as 5.4, 0.5 and 2.4 days for the F_1 generation, larval and nymphal stages and the pre-oviposition and oviposition periods were 1.3 and 2.5 days respectively. While conducting a comparative study on the effectiveness of *P. persimilis* and predatory thrips, *Scolothrips longicornis* in controlling *T. urticae* in

German Federal Republic, Gerlach and Sengonca (1985) found that the immature stages of *P. persimilis* required 3.5 days for development from larva to adult during which they predated on an average of 30.8 eggs of *T. urticae* and the mean duration of the oviposition period was 18 days with a mean total progeny of 60/female. Zang and Kong (1986) observed that the development periods of the predator, *A. fallacis* lasted for 6.08, 6.68 and 6.54 days respectively in China when fed on *T.cinnabarinus* and *T.viennensis*. The predator was also found to complete its development on 18 of 22 kinds of pollen tested. Moraes and McMurtry (1986) evaluated the suitability of *T. evansi* as a source of food for *P. persimilis* in U.S.A. and found that the primary factor responsible for the low oviposition rate and survivorship of the predator was the low amount of food ingestion. Osakabe *et al.* (1986) investigated the feeding, reproduction and development of *A. sojaensis* on *P. citri* and *T. kanzawae* or on tea pollen and found that when the predator was fed on spider mites, the number of eggs laid was very low and individuals of the next generation did not develop. When tea pollen was provided as food, females laid many eggs and nymphs were frequently observed. Amano and Chant (1986) made observations on the ecology of the phytoseiids, *T. pomi*, *P. macropilis* and *A. finlandicus* collected from abandoned apple trees in Ontario, Canada and suggested *A. finlandicus* as a predacious species and the other two were more or less general feeders. While studying the life cycle and feeding habits of *N. anonymus*, a predator

of tetranychid mites infesting cassava in Colombia at different temperatures like 20^0C, 23^0C, 25^0C and 30^0C and 70% RH, Mesa and Bellotti (1986) found that at 20^0C and 30^0C the durations of development from egg to adult were 8.92 and 4.03 days respectively. Castagnoli and Liguori (1986) studied the development and feeding responses of *T. exhilaratus* associated with grape vines in Central Italy to *E.vitis, P. ulmi* and *E. carpini* and to the pollen of *Quercus ilex* and found that all the foods tested permitted adult emergence, oviposition and normal development times.

While comparing the influence of food and temperature on development and oviposition in *E. stipulatus* and *T. philatus,* Ferragut *et al.* (1987) observed that the maximum development was reached at 32^0C with rm values of 0.225 for *E. stipulatus* and 0.179 for *T. philatus* when fed on pollen of *Carpobrotus edulis* and *P. citri*. Sharma and Sadana (1987) studied the effect of predator- prey density on the prey consumption and daily rates of egg production in *A. finlandicus* when fed on *E. orientalis* at 27.6-30.5^{0}C in India. The authors found that the number of preys consumed and the daily fecundity increased with an increase in prey density but decreased at high predator densities. Hayes and McArdle (1987) studied the effect of temperature and food consumption on rate of development of the eggs and immature stages of *T. pyri,* an important enemy of *P. ulmi* in apple orchards of New Zealand and suggested the possibility of utilizing this species as an integrated control agent against *P. ulmi.* Biological studies of *E. scutalis* by

offering various life stages of *T. pacificus* were carried out by Bounfour and McMurtry (1987) and the authors reported that the durations of egg, larval and nymphal stages of the species were 2.2, 0.8 and 4.3 days respectively. Hariyappa and Kulkarni (1988) conducted studies on the biology of *A. longispinosus*, a predator of *Polyphagotarsonemus latus* in India at 23-27^{0}C and 65-70% RH and recorded that the mean durations of the egg, larval, protnymphal and deutonymphal stages were 45.67, 14.27, 23.18, 24.41 hours respectively in females and the respective durations in males were 46.45, 14.10, 2.78 and 22.71 hours. Congdon and McMurtry (1988) recorded differences in responsiveness to potential prey and pollen by *E. tularensis*, a facultative predator in U.S.A. and reported that the response to pollen was uniformly high regardless of earlier consumption of prey mites. Dicke *et al*. (1989) analyzed the prey selection behaviour of *T. pyri* and reported that it preferred *P.ulmi* to *A. schlechtendali*. Congdon and McMurtry (1988), tested the differences in responsiveness to *S. citri*, *P. citri* and *T. pacificus* in *E. tularensis* and the authors suggested that *E. tularensis* was a more effective biological control agent of *S. citri* than of *P. citri.* Abou-setta and Childers (1989) conducted studies on the feeding behaviour and oviposition of *E. mesembrinus* at 26^{0}C and 75%RH on food sources like ice plant pollen (*Malephora croceus*), *E. banski*, *E. sexmaculatus* and *P. citri* and found that survivorship of immatures of the predator was significantly higher on ice plant pollen than on other food types provided. Zhang and Li (1989a) developed an improved method for rearing *A. fallacis*, an important

biological control agent of apple spider mites in China, with apple pollen plus 30% honey solution or 30% royal jelly and for feeding the predator alternatively with apple pollen and its natural prey *T. cinnabarinus*. The results showed that these new methods could increase the female ratio in the progeny and eliminate cannibalism. The authors (1989b) investigated the effectiveness of pollen of 10 plant species for rearing *A. fallacis.* Bonde (1989) demonstrated that *A. barkeri* fed on *B. tabaci* at 25^0C showed an average duration of 2.2, 0.8 and 3.2 days for the egg, larval and nymphal stages respectively with respective mortalities of 1.0, 1.0 and 3.1%. In the absence of thrips, *A. barkeri* was able to consume eggs and adults of *T. urticae*, adults of *P. latus* and pollen of various plants. Neelu Nangia and Channa Basavanna (1989) studied the feeding potential of *A. tetranychivorus* on selected tetranychid and tenuipalpid mites and observed that the male larvae of the predator often starved but moulted successfully and completed life cycle. The life cycle of predator was short and fecundity was high on tetranychids. Sharma and Sadana (1989) traced the development of *A. finlandicus* on its prey, *E. orientatlis* and found that it required a minimum period of 7.8 days for its development when fed on females and maximum of 9.6 days when fed on prey larvae. The oviposition period of the predator was maximum when a combination of all the life stages of prey was given as food and minimum when fed on larvae only. Jose *et al*. (1989) reported that a single individual of *A. alstoniae* could consume a total of 191.30 eggs, 76 larvae, 2.60 nymphs and 46.24 adults of *T. macfarlanei* during its life time. The efficiency of

Gnorimus chaudhiri as a control agent of *T. fuzouensis* was reported by Zhang and Li (1989c). Rasmy *et al.* (1990) evaluated the effects of attack by phytoseiid predators *viz. P. persimilis*, *P. finitimus* and *A. gossypii* on the development, reproduction and mortality of *T. urticae* in Cairo, Egypt. Saito (1990) studied the life history and feeding habit of *T. bambusae* in Japan at 25 ± 1^0C and 60-80% RH and found that egg to egg period of development of *T. bambusae* when fed on the eggs of *Schizotelranychus celarius* was longer than those of *A. eharai*, *A. longispinosus* and *A. paraki* which fed on *T. urticae*. James (1990) reported *A. victoriensis* as an efficient predator of *T. urticae* occurring in peach orchards in two farms at Leeton, New South Wales and suggested the possibility of utilizing this species for managing *T. urticae.* Bruce and Hoy (1990) conducted experiments on the effect of prey stage on life table attributes of a genetically manipulated carbaryl- organophosphate sulfur resistant strain of *M. occidentalis* at 24-28^{0}C and 47-56%RH and found that females of this species lived longer (25.3 days Vs 19.7 days) with a higher total fecundity (43.8 Vs 33.6 egg/female) and a higher daily fecundity rate (2.4 egg/female/day Vs. 2.0 eggs /female /day) and exhibited a higher intrinsic rate of increase (0.243 individuals/ female/ day Vs. 0.182 individuals/ female/day) and shorter generation time (13.9 days Vs 17.0 days) on a diet of 0-48 hour old eggs rather than a diet of mixed active stages of *T. pacificus* .

Caceres and Childers ((1991) traced the biology of *Galendromus helveolus* on a diet of *E. sexmaculatus* and observed that the total developmental

periods were 12.36, 9.66, 5.63, 4.61 and 4.84 days respectively at 18^0C, 20^0C, 25^0C, 30^0C and 32^0C and an RH of 76%. Hardman and Rogers (1991) studied the effects of temperature and prey density on the survival, development and feeding rates of immatures of *T. pyri* and noticed the importance of alternative sources of food to the predator when spider mites were scarce. El-Laithy and Fouly (1992) conducted studies on the life history of *A. scutalis* and *A. swirskii* at 26 ± 1^0C, and 70 ± 3% RH and recorded that the developmental duration of the females of both *A. scutalis* and *A. swirskii* fed on nymphs of *T uriticae* were 7.81 and 5.50 days respectively. While studying the biology, feeding characteristics and life tables of *A. bibens* on two different host plants, Zamen and Sekeroglu (1992) reported that the net reproductive rate, intrinsic rate of increase and generation time of *A. bibens* on *T. cinnabarinus* were 28.88, 0.290 and 11.6 hours respectively on strawberry and 25.12, 0.259 and 12.45 hours on cucumber. Pena (1992) conducted studies on the predatory behaviour and feeding habits of *T. peregrinus* on *P. latus, Phyllocoptruta oleivora* and pollen from *Schinus terebinthifolius, Parthenium hysterophorus* and *Bidens bipinnata*.

Schausberger (1992) carried out a comparative study on the effect of different food items on the development and reproduction of *A. aberrans* and *A. finlandicus* in Australia, the results of which indicated the high value of pollen as a food source for *A. aberrans* and *A. finlandicus*. Kreiter (1992) highlighted the characteristics of phytoseiidae as predators in France.

Ferragut *et al.* (1992) made observations on the feeding behaviour of *E. stipulatus* and *T. phialatus*, the two main predatory phytoseiid mite species in Spanish citrus orchards, on the prey, *P. citri*. Considering the killing rate and the number of eggs laid by the predators in the same period, it was concluded that *E. stipulatus* consumed only 30% of the content of the prey killed, where as *T. phialatus* consumed 40-100% of prey individuals. Cloutier and Johnson (1993) reported the importance of alternative feeding strategies in determining the life style of the polyphagous spider mite predator, *A. cucumeris* and reported the key role of the species in the control of thrips also. While studying the developmental and reproductive characteristics of *T. pyri* on *T. urticae* and *Cecidophyopsis ribis*, Zemek (1993) observed that the average fecundity of females feeding on *C. ribis* was lower (13.79 eggs) compared to that of females fed on *T. urticae* (29 eggs). Momen and Saway (1993) reported that *A. swirskii* completed its life cycle on *T. urticae*, *E. dioscoridis* or on pollen grains of *R. communis*. The total developmental period was shorter when fed on eriophyid (5.71±0.12 days) and tetranychid (6.36±0.1 days) mites compared to that on pollen (7.73±0.16 days). Badii and Hernandez (1993) conducted studies on the life cycle, moulting and feeding behaviour of *E. mesembrinus* in Mexico on different food sources. Rijin and Sabelis (1993) reported that the pollen availability enhanced the development and reproduction of both the prey (*Frankliniella occidentalis)* and the predator (*A. cucumeris*), but the predation rate was

decreased by pollen feeding. Shih *et al.* (1993) evaluated the responses of *A. ovalis* to *O. mangiferus*, *O. taiwanicus*, *E. boemeriae*, E. *orientalis*, *P. elongatus*, *T. kanzawai* and Maize pollen. Engel and Ohnesorge (1994) tested the nutritional value of different food sources in relation to development and reproduction of *T. pyri* occurring on grape vines in Germany and found that the majority of the pollen species offered had some nutritional value. Toko *et al*. (1994) reported the effect of cassava exudates and prey densities on the survival and reproduction of *T. limonicus*, a predator of the cassava green mite, *Mononychellus tanajoa*. Gillespie and Quiring (1994) conducted experiments on the reproduction and longevity of the predatory mite, *P. persimilis* and its prey, *T. urticae* on different host plants in Canada. Jagadish *et al*. (1994) reported that the durations of the egg, larva, protonymph and deutonymph of *E. concordis* fed on *T. neocaledonicus* were 50.04$\pm$0.91, 17.68$\pm$1.90, 24.49$\pm$2.51 and 29.80$\pm$2.10 respectively and the males generally developed faster when compared to the females.

Momen (1995) reported that *A. barkeri* completed its life cycle when fed on *T. urticae* and *E. dioscoridis* at 25^{0}C and 70-75%RH and was not able to complete its development when fed on pollen grains of *R. communis* and *Phoenix dactylifera* as alternative food substances. The author found that the number of eggs increased when fed on tetranychids (1.9 eggs/female/day). Camporese and Duso (1995) traced the life history of *T. talbii* on different kinds of food. While studying the biology of *A. manihoti* on four cassava

varieties using *M. tanajoa* as prey, Noronha *et al*. (1995) observed that the duration of immature stages (5.2 days from egg to adult) and the average daily oviposition rate (2.6 and 2.4 eggs/female/day in F_1 and F_2 generations respectively) of *A. manihoti* were similar on all four varieties. Reuvery *et al*. (1996) studied the biology of *T. athiasae* on a diet comprised of pollen of *Carpobrotus edulis* and *T. urticae*. While studying the effect of prey density on reproduction, prey consumption and sex ratio of *A. barkeri*, Momen (1996) reported that the oviposition and prey consumption rates of the species depended on the number of prey available and increased with increasing prey density. Mochizaki (1996) compared development, fecundity, diapause attributes and reproductive compatibility of *A. womersleyi*, a pesticide resistant strain with several other strains and little difference was observed in the developmental periods at 25^0C between four strains. Abou-Setta *et al.* (1997) studied the biology of *Proprioseiopsis rotendes* on *T. urticae* and pollen of ice plant, *Malephora crocea*, *Quercus virginiana*, *Typha latifolia* and recorded the developmental times as 6.58 $\pm$ 0.36, 8.17 $\pm$ 0.92, 7.29 $\pm$ 0.51 and 7.41 $\pm$ 0.89 for females, and 6.12 $\pm$ 0.49, 7.96 $\pm$ 0.94, 6.68 $\pm$ 0.72 and 6.75 + 0.60d for males respectively. Momen and Borolossy (1997) tested the suitability of the citrus brown mite, *E. orientalis* as prey for 9 species of phytoseiid mites and observed that *T. athiasae* and *A. barkeri* had the highest oviposition rates. Wei and Walde (1997) conducted studies on the effect of the pollen of *T. latifolia* on the functional response of *T. pyri*

to its prey *P. ulmi* and found that pollen significantly reduced the predation rate but the magnitude of the effect was not large. Moneti and Croft (1997) reported that *N. californicus* might be a less specialized predator of spider mites in USA than *A. fallacis*. Wittmann and Leather (1997) compared the compatibility of *Orius laevigatus* with *N. cucumeris* and *I. degenerans* in the biocontrol of western flower thrips, *F. occidentalis* and hypothesized that *O. laevigatus* and *I. degenerans* could be used simultaneously in the biocontrol of *F. occidentalis* with minimal interference between them. Zacharda and Hluchy (1997) assessed the potential of *T. pyri* for the biological control of *T. urticae* on strawberry in a field plantation and a glass house without temperature control, and found that *T. pyri* had the potential to bring down the population of *T. urticae* in field and glass house condition. During the survey studies on the specific diversity, geographic distribution and the abundance of predaceous mites on citrus in South Africa, Banhway (1997) reported *A. pafuriensis, T. crassus* and *T. rasilis* as excellent biocontrol agents on citrus.

Abou *et al.* (1998) observed faster development and higher reproduction rate in *A. olivi* when fed on the eriophyid fig mite and pollen grains of *R. communis*. At oviposition stage, the predator female consumed daily 98, 16 and 5 individuals of *E. ficus*, *E. orientalis* and *B. tabaci* respectively. Kazak *et al.* (1998) compared the population growth and compatibility of *P. persimilis* and *A. bibens* in Turkey, when fed on

T. cinnabarinus at 20±1^{0}C and 90±5% RH and found that the competition pressure resulted in lower population densities of both predators with neither of the predator outcompeting each other. While conducting studies on the biology and life table parameters of *N. californicus* on prey mites, *E. dioscoridis* and *T. urticae* in Egypt, Laithy and Sawi (1998) reported that adult females had shorter life cycles when fed on *E. dioscoridis* (7.35 days) than on *T. urticae* eggs (9.76) or its nymphs (8.05). Adult female longevity was 39.2 days on *E. dioscoridis* but 31.58 and 35.7 on *T. urticae* eggs and nymphs respectively. Toyoshima and Amano (1998) conducted experiment on the influence of prey density on sex ratio of *P. persimilis* and *A. womersleyi* in Japan and observed that under the ample prey condition, the sex ratio was biased for females in both species, while under the poor prey conditions, the proportion of females and the total egg production was reduced and the sex ratio was shifted to the unbiased sex ratios of 1:1.

Castagnoli and Simoni (1999) studied the functional and numerical responses of *N. californicus* to eggs and protonymphs of *T. urticae* under laboratory conditions in Italy. Kerguelen and Hoddle (1999) reported *G. helvedus* and *N. californicus* as effective biological control agents of *O. persea* infesting avocados in California. Ho and Chen (1999) evaluated feeding and ovipositional responses of 3 phytoseiid species *viz*. *A. womersleyi, A. fallacis* and *P. persimilis* to amounts of Kanzawa spider mite eggs in Taiwan. Zhang *et al*. (1999) recorded *A. longispinosus* as a

biological control agent against *S. nanjingensis*, a mite pest injurious to the giant bamboo in Fujian. Momen and Hussein (1999) investigated the relationships between food substances, developmental successes and the reproduction in *T. transvaalensis* and recorded a higher degree of dependence of the predator on eriophyid mites than tetranychid mites, they also recommended a lower reproductive rate on pollen grains of *R. communis*. Rijin Van and Tanigoshi (1999) compared the dietary range and life history of two predatory mites, *I. degenerans* and *N. cuccumeris* which were used as biological control agents against thrips. The authors tested ≈ 25 species of pollen as a food source for these mites and found that compared to *N.cucumeris, I.degenerans* was able to utilize a larger proportion of ≈ 25pollen species tested.

While studying the development and reproduction of *A. cydnodactylon* on different stages of *T. urticae, A. ficus* and *E. dioscoridis* and 2nd nymphal stage of *B. tabaci*, Banhaway (2000) recorded the minimum developmental durations and maximum rates of reproduction in the predator when it was fed on the prey nymphs. Longest developmental durations coupled with zero rates of reproduction were observed when the predator was fed on the prey egg. Broufas and Koveos (2000) conducted studies on the effect of different pollens on development, survivorship and reproduction of *E. finlandicus* and recorded a very low fecundity on apple pollen. They also observed that, the nutritional value of cherry, peach, apricot, walnut and poppy pollens for

E. finlandicus was higher than that of apple and pear. Zang *et al* (2000), evaluated the potential of *A. cucumeris* as a biocontrol agent against *S. nanjingensis* in China, and found that the life cycle of *A. cuccumeris* (7.7 days and 7.8 days for the 1^{st} and 2^{nd} generations) was comparable with that on its normal diet in the laboratory, *Tyrophagus putrescentiae* (7.8 days) at 27-28^{0}C. Sarwar *et al.* (2000) studied the biological aspects of *N. cucumeris* on different food items such as stored mite, *T. putrescentiae*, *T. urticae* and *F. occidentalis* in Beijing and reported significant differences in the different biological parameters with respect to difference in food items.

Chittenden and Saito (2001) investigated the larval feeding traits and oviposition behaviour of 10 phytoseiid mites and suggested that the non-feeding larval behaviour was an adaptation to avoid cannibalism, which occurred when eggs were laid closer together. Manjunatha *et al*. (2001) tested the feeding preference of *A. ovalis* in India on different stages of the prey mite, *P. latus*.

Momen (2001) studied the effects of *T.urticae, E. dioscoridis*, date palm pollen and sweet corn pollen on the development, survival and reproduction of *E. yousefi* and reported that a diet of *T. urticae* supported the shortest generation time coupled with highest female longevity and intrinsic rate of natural increase. While studying the life history and reproductive parameters of *E. finlandicus* on varying food items like *Aceria* sp., *Tulipa gesnerana*

pollen and *T. urticae,* Abdallah *et al*. (2001) observed that the mean generation time was shortest on pollen (19.90) followed by the eriophyid mite (20.02) and then spider mite (20). Chittenden and Saito (2001) analyzed the feeding and nonfeeding behaviour of phytoseiid larvae in Japan and suggested that nonfeeding larval behaviour may be an adaptation to avoid sib-cannibalism, which occurred when eggs were laid closer together. Tsunoda and Amano (2001) conducted studies on the female mate-receptivity behaviour in multiple matings of predaceous mite, *A. womersleyi* in Japan and observed that females that copulated twice produced significantly more eggs than those that had mated only once. Abdallah *et al.* (2001) in New Zealand compared the life history and feeding habits of *E. finlandicus* on an eriophyid mite, *Aceria* sp., pollen of *T. gesnerana* and *T. urticae* and recorded shortest total development time for the immature stages on eriphyid mite, followed by pollen and then spider mite. They also observed highest fecundity on pollen (43.69 eggs), then eriophyid mites (39.73 eggs) and lowest on spider mites (18.16 eggs). Cuellar *et al.* (2001) estimated the effectiveness of 6 phytoseiid mites viz. *E. ho*, *T.aripo*, *T.tenuiscutus*, *N.californicus*, *N.idaeus* and *G.annectens* as a biological control agent of *M. tanajoa* by measuring rates of prey consumption and oviposition in relation to density under optimal laboratory conditions. The authors found a maximum daily consumption of 40, 35, and 18 eggs for *N.californicus*, *N.idaeus* and *G. annectens* respectively and a higher

maximum daily oviposition of 3.9, 3.6, 2.9 and 2.8 eggs for *T. tenuiscutus, N. californicus, N. idaeus* and *G. annectens* respectively.

Osakabe (2002) compared the efficiency of *P. persimilis* in controlling *E. asiaticus* with the efficiency of *A. californicus* and *A. womersleyi* and suggested that the latter species had greater potential as a biological control agent in crops in W. Japan, where both species occurred. Abhilash and Sudharma (2002) studied the biology and predatory potential of *A. longispinosus* on *T. ludeni* in India and reported that the mean durations of egg, larva, protonymph and deutonymph were 3±0.35, 0.88±0.13, 1.43±0.18 and 1.55±0.14 days respectively.

Zhang *et al*. (2003) carried out studies on the life history of *A. cucumeris* on the prey mite, *A. corpuzae* under four constant temperatures and found that the females required 20±0.5 days to complete development from egg to adult at 15±1^{0}C, but took only 7.7±0.3 days at 30±1^{0}C. Sengonca *et al*. (2003) studied the prey consumption rates during development as well as longevity and reproduction of *T. pyri* at higher temperatures. Steiner (2003) reported that at 25^{0}C,*T. montdorensis* completed its life cycle in approximately 7 days on cumbungi pollen. Reis *et al*. (2003) compared the effect of prey density on the functional and numerical responses of 2 species of phytoseiid predators. Shrewsbury and Hardin (2003) released *N. fallacis* and *G. occidentalis* in order to evaluate the augmentative biological control approach for reducing population densities

of the pest mite, *O. ununguis* in Washington and reported that sequential releases of predator species individually or with combination in high pest population in initial stage would suppress spider mite population, but this method was found to be 2.5-7 times more expensive than chemical controls. Shipp and Wang (2003) compared the effectiveness of *A. cucumeris* and *O. insidiosus* as biocontrol agents of *F. occidentalis* on green house tomatoes in Canada and found that the percentage of the damaged fruit in the *A. cucumeris* release in green house offered control at acceptable levels where as the introductions of *O. insidiosus* failed to reduce thrips population at the economic level. To find out an appropriate domestic phytoseiid predator for controlling *P. ulmi* in Japan, the predatory characteristics of *A. tsugawai* and *T. vulgaris* were investigated in the laboratory at 20 ± 0.5^{0}C with a 15L:9D photoperiod and 90±5% RH by Toyoshira (2003). The author reported that *T. vulgaris* showed a favourable developmental ratio of 75% with female ratio of 67% when reared on *P. ulmi* and the author suggested *T. vulgaris* as an effective predator for suppressing the *P. ulmi* population in apple orchards under reduced spray programs.

Rodriguez and Ramos (2004) determined the average durations of life stages of *A. largoensis* such as egg (2.62±0.70 days), larva (1.06±0.51), protonymph (1.23±0.47 days) and deutonymph (1.43±0.47 days) and recorded that the mean duration of development from egg to adulthood was 6.33±1.49 days when fed on the prey mite, *P. latus.* Zaher *et al*. (2004)

studied the impact of diet on the development, reproduction and sex ratio of *A. denmarki.* Opit *et al.* in USA (2004) investigated the predatory efficacy of *P. persimilis* on *T. urticae* by releasing the predator in 1:6, 1:2, & 1:4 predator: prey ratio and reported that at lowest ratios of predator: prey (1:4 & 1:2) significantly reduced *T. urticae* population 1 week after release and kept them at low levels thereafter. Rasmy *et al.* (2004) observed interspecific predation and cannibalism on females of *A. swirskii*, in Egypt and reported that the high survival rates of females of *A. swirskii*, when fed on nymphs of its own and other phytoseiid or stigmaeid mites would be an indication of this predators' capability to overcome conditions where their natural prey was scarce. Kondo (2004) carried out experiments to compare the colonizing characteristics of *P. persimilis* and *N. womersleyi* in green house grape vine and effects of their release on *T. kanzawai* in Japan. The results showed that even though both the predators could suppress the pest populations, *N. womersleyi* could colonize grape vine more successfully and suppress the population density of *T. kanzawai* more efficiently than *P. persimilis* and hence the author recommended *N. womersleyi* as a control agent for *T. kanzawai* to introduce into grape vine green houses in Japan. Badii *et al.* (2004) carried out studies on the preference of *E. hibisci* to individual stages of *T. urticae* in Mexico under laboratory conditions of 25 ± 2^0C and $60 \pm 5\%$ RH and 12L photo phase. The authors observed that the predator consumed significantly more eggs than other prey stages and also the consumption of

deutonymphs and adults of the prey was so low that they were excluded from the non-choice functional response experiments. Vantornhout *et al.* (2005) compared the reproduction, longevity and life table parameters of *I. degenerans* on *R.communis*, *T.urticae*, *F.occidentalis* larvae and *Ephestia kuehniella* and observed that *I.degenerans* accepted all diets and reported female longevity in a range of 29.5 to 42.4 days, while the highest value was recorded on a diet at *Ephestia* eggs. While studying the prey-predator interaction of *N. californicus* and *T. urticae* in Argentina, Greco *et al.* (2005) observed the effect of the initial densities of the prey and predator on the system dynamics. The authors reported a population of pest below ETL at a 5/1-pest predator ratio. While studying the cannibalism and interspecific predation among the 3 phytoseiid mite species, *E. fustis, I. degenerans* and *T. aripo* in the absence of food and in the presence of limited or abundant quantities of two food types *M. tanjoa* and maize pollen, Zannou *et al.* (2005) in West Africa observed that cannibalism by females of all three predatory mites on hetero-specific larvae and protonymphs was negligible in the presence of limited or abundant quantity of food. Moreover an increased rate of oviposition was also observed in the same condition. Ebssa *et al.* (2006) conducted experiments on the effects of entomopathogenic nematodes (*Heterorhabditis bacteriophora* or *H. indica*) and *A. cucumeris* alone or in combination for the control of the western flower thrips *F. occidentalis* in Kenya and reported that combined applications of the mites and the

nematodes could control foliage-feeding and soil dwelling life stages of thrips. Rhodes *et al.* (2006) conducted field experiments to determine the effectiveness of combined releases of *P. persimilis*, *N. californicus* and a reduced – risk miticide Acramite for control of *T. urticae* in USA and found that combination treatments of *P. persimilis/N.californicus, Acramite/ N. californicus* and *Acramite/ P.persimilis* as promising options for *T. urticae* control in strawberries in northern Florida and other strawberry producing areas of the world.

Gotoh *et al*. (2006) while investigating the influence of 5 spider mite species viz. *T. urticae, T. kanzawai, Amphitetranychus viennesis, P. citri* and *P. ulmi* on the developmental performance, reproduction and prey consumption of *N. californicus* in Japan, reported that the developmental periods of immature *N. californicus* females and males were significantly affected by the prey species fed on, but pre-oviposition period, oviposition period and the number of eggs laid per female were not significantly affected by either the plants or the type of prey eggs. Messelink *et al.* (2006) evaluated the potential of 10 species of phytoseiid predators for control of *F. occidentalis* in Netherlands and confirmed *T. limonicus* as the best predator of *F. occidentalis* on green house cucumber.

Furtudo *et al.* (2007) traced the life history of *P. longipes* on *T. evansi*, *T. urticae* and pollen of *R. communis* in Brazil. The analysis showed the well

performance of the predator on *T. evansi* and *T. urticae* with higher reproductive parameters on *T. evansi* but the predator could not oviposit on pollen of *R. communis*. Frauto and Liburd (2007) in Florida conducted green house and field experiments to determine the effectiveness of *N. californicus* for control of *T. urticae* in strawberries and the results showed that *N. californicus* was able to sustained control of *T. urticae* at high prey density if the predator: prey ratio could be maintained at 1:10 and 1:5 or 1:10 in green house and field conditions respectively. Meszares *et al.* (2007) investigated cannibalism and intraguild predation in *T. exhilaratus* and *T. phialatus* under laboratory conditions in France. Gotoh and Tsuchiya (2008) conducted studies on the effect of multiple mating on reproduction and longevity of the phytoseiid mite, *N. californicus* in Japan and observed a positive correlation between the egg production and the copulation time. Momen and Abdel-Khalek (2008) in Egypt studied the biology of *T. swirskii*, *T. athiasae* and *Paraseiulus talbii* using *A. lycopersici* and reported that survival of imatures of *P. talbii* was low on *A. lycopersci* and all failed to develop to adulthood. The authors recorded mean generation time of 13.97 and 17.85 days for *T. swirskii* and *T. athiasae* respectively.

Gotoh and Tsuchiya (2009) conducted experiments on the effect of food scarcity on the female longevity of *N. californicus* in Japan. The authors reported that the total adult longevity was drastically reduced when the mite experienced deprivation. Arthurs *et al.* (2009) in USA evaluated the

efficiency of *N. cuccumeris* and *A. swirskii* as predators of *S. dorsalis* and reported that *A. swirskii* was more effective than *N. cucumeris*. The authors also recorded a mean consumption rate of 2.7 larvae/day and 1.1 – 1.7 larvae/day for *A. swirskii* and *N. cucumeris* respectively.

Ahn *et al.* (2010) explored the functional responses of *N. californicus* to *T. urticae* on strawberry leaves in Korea and observed that as the temperature increased the predator took less time to consume the prey eggs and nymphs and the consumption rate also was found to increase with an increase in the temperature. Domingos *et al.* (2010) in Brazil evaluated the diet-dependent life history, feeding preference and thermal requirements of *N. baraki* on *A. guerreronis*, *Steneotarsonemus concavuscutum* and *T. putrescentiae* and reported a highest fecundity on *T. putrescentiae* (39.4 eggs) followed by *A. guerreronis*.

MATERIALS AND METHODS

In the present work, feeding potential and developmental strategies of 5 species of phytoseiid mites viz. *A. largoensis, P.multidentatus, T. suknaensis, A. guptai* sp. nov. and *P. rachelae* were studied, following various methods discussed below:

I. SURVEY OF PESTS/PREDATORY MITES

I. A. SAMPLING LOCALITIES

Populations of phytoseiid mites and associated major pests, especially pest mites of the family Tetranychidae, Tenuipalpidae and eriophyidae as well as insect pests like thrips, scale insects etc. were located through field surveys made during the period of 2006 - 2007 at different sites distributed over two districts of Kerala viz. Kozhikode and Malappuram. Agricultural crops, medicinal plants, ornamental plants, horticultural plants and plantation crops grown in the Botanical garden of the Calicut University Campus, Chelari, Kondotty, Villoonniyal, Kottakkal and Thalappara, of Malappuram district were scrutinized for the incidence of phytoseiid mites and associated pest species. In the Kozhikode district, the Malabar botanical garden at Pokkunnu, the coconut nursery at Thikkodi, the experimental garden of Indian Institute of Spices Research (IISR), Marikkunnu and various agricultural fields located at Kunnamangalam, Olavanna, Pantheerankavu,

Edavannappara, Vazhakkad, Ramanatukkara, Azhinjilam, Kadalundi and Kotakadavu were the areas considered for collection of host plants .

I .B. PLANTS SURVEYED

Table I illustrates the details of the various species of plants surveyed with respect to mite pest infestation. A total of 77 species of plants comprising 24 species of vegetable plants, 27 species of medicinal plants, 7 species of ornamental plants, 5 species of spices, 2 species of oil yielding plants, 3 species of soft woods and 9 species of weeds were scrutinized for the recovery of both pest and phytoseiid mites. The medicinal plants grown both in green house conditions and open air conditions were surveyed during the present work. *Rosa indica*, *Jasminum grandiflorum*, *Hibiscus* spp. *Anthurium andraeanum*, and *Gomphrena globosa*, were the ornamental plants examined during the survey period. Among the spice crops, *Piper nigrum*, *Zingium officinale*, *Curcuma longa*, *Syzygium aromaticum* and punica granatum were surveyed during the present work. *Cocos nucifera*, and *Ricinus communis* were the two oil yielding plants included in the study. In order to explore the host range of polyphagous pest mites, especially the spider mites, weeds and wild plants such as *Centrosema pubescens, Zizyphus oenoplia, Quisqualis indica*, *Urina lobata*, several species of grass, *Glyricidia sepium*, *Chromolaena odorata*, *Ageratum conyzoides*, *Lantana camera, Calycopteris floribunda*, were also surveyed, as these plants would serve as the alternative hosts to the above pests during unfavourable conditions, especially in the monsoon season.

I.C. METHODS OF COLLECTION OF PEST MITES/PREDATORY MITES

Samples of infested leaves of various economically important plants like the medicinal plants, vegetables, plantation crops, ornamental plants and weeds were plucked and put in self-sealing plastic bags for subsequent screening of predatory mites / pests harboured by them in the laboratory. Within the laboratory, individual leaf was thoroughly examined under a stereozoom microscope for the recovery of predatory as well as pest mites included in the study. A fraction of the sampled phytoseiid mites, pest mites and insects was preserved in 70% ethyl alcohol for taxonomic studies.

I.D. CLEARING AND MOUNTING OF SPECIMENS

The specimens of phytoseiid mites and pest mites which were preserved in 70% alcohol were then upgraded through 80%, 90% and absolute alcohol series and mounted in Hoyer's medium for identification.

I.D. 1. Preparation of mounting medium

Hoyer's Medium

Hoyer's medium was prepared by careful and proper mixing of the following ingredients. The mixture was then filtered through two folds of thin cloth or glass wool and stored in a coloured bottle.

Distilled water - 50 ml

Gum-Arabic crystals - 30gms.

Chloral hydrate -200 gms.

Glycerine -20 ml.

I.E. PREPARATION OF PERMANENT SLIDES

The dehydrated specimens of phytoseiid mites and pest mites were slide mounted in the Hoyer's medium as given below. Usually 2-5 specimens representing both male and female mites of the same species were mounted on a single slide. The specimens were pressed to the bottom of the slide to spread out the legs in lateral position. Specimens were mounted both in the ventral and dorsal view. The mites were also mounted in the lateral position also to ensure the better view of their genital structures which were very important for generic and specific determination. After mounting, the slides were kept in an oven at 30-40°C for at least 24 hours in order to speed up the clearing process and subsequent drying of the slide. The slides were then labelled and numbered serially for identification. Data on host, locality, collector's name, date of collection and slide number were given on the label along with the scientific name of the specimen. To avoid damage of the specimen due to excessive moisture/drying, the edges of the cover glass were sealed with nail polish.

I. F. IDENTIFICATION OF MITES

Identification of slide mounted specimens was made under a Carl Zeiss Research microscope. For the identification of phyoseiid mites, shape, number and nature of setae on the dorsal and ventral shields, chelicera, spermatheca in females, spermatophoral processes in males, peritreme,

ventrianal shield, leg chaetotaxy, etc. were examined under the microscope. While in the case of spider mites, the morphological features like the number and nature of setae on the dorsal and ventral shields, leg chaetotaxy and male genital organ were carefully studied. Drawings were made with the help of a Camera Lucida attached to the Meopta Research microscope. Measurements in μm of the different structures of systematic importance were made with an ocular micrometer mounted in the objectives of Meopta microscope which were calibrated following stage micrometry. Photographs of the various species/life stages of the same species were also taken using a Canon digital camera attached to Zeiss Stemi 2000C stereozoom research microscope. Systematic position of the individual species of phytoseiid mites was assessed following Gupta (1985, 1986), Smiley (1992), Zhi-Qiang Zhang (2007) and other recent literature. The setal nomenclature suggested by Rowel *et al*. (1978) and Yoshida-Shaul (1989, 1991 &1992) as well as the chaetotaxy given by Evans (1963) were followed during the study in the case of predatory mites. Tetranychid mite identification was made following Gupta (1985, 1986), Smiley (1992) and Zhi-Qiang Zhang (2007) and recent literature. The identification of the phytoseiids and pest mites was confirmed by Dr. S. K. Gupta, Principal Investigator, USERS Project, Department of Science and Technology (Formerly Emeritus Scientist ZSI and Ex-National Co-ordinator, ICAR, Acarology Project) and Dr. M. Mohanasundaram, Professor and Head (Rtd.), TNAU, Coimbatore respectively.

II. BIOLOGICAL STUDIES OF PHYTOSEIID MITES

II. A. FEEDING BIOLOGY OF PHYTOSEIID MITES

II.A.1. Predatory Mites Selected

During the survey of predatory mites, attention was focused only on the predatory mites of the family phytoseiidae. More over, among the physeiid predators, only the most abundant and potent species in the field conditions were considered for the collection, identification and for further detailed studies. Table II. Illustrates the details of collected phytoseiid mites during the survey period. A total of 18 species were collected, of which 5 species viz. *A. largoensis, P. multidentatus, T. suknaensis, A. guptai* sp. nov. and *P. rachelae* were recognized as the most prominent ones. *A. largoensis,* a very common phytoseiid predator was found in association with *T. neocaledonicus, T. cinnabarinus, E. orientalis, T. ludeni, T. fijiensis, B. phoenicis* and scale insects on various host plants such as *Adathoda vasica, Rosa indica, Moringa oleifera, Momordica charantia, Vigna unguiculata, Pisum sativum, Ocimum sanctum, O. gratisimum, Amaranthus tricolor, Citrus limon and Gliricidia sepium.* This species had been recorded from more than 75 species of plants by several scientists, from most of the states in India and also from more than 14 foreign countries like Japan, U.S.A., S. Africa, Brazil etc. Several reports were available from many regions of India on the potential of this predator for the control of several spider mites, eriophyid mites and tenuipalpid mites.

T. suknaensis, an active phytoseiid species was usually found in the field in association with pest mites like *T. neocaledonicus, T. cinnabarinus* and *Acalitus adoratus* on *Chromolaena odorata*, *P. sativum*, *M. oleifera*, *G. sepium*, *Calycopteris floribunda*, *A. tricolor*, *A. viridis* and grasses collected from Olavanna, a local place in Kozhikode district. Originally this species was described from West Bengal on *Colocasia* sp. then the species could be recorded from more than 20 species of host plants, distributed over more than 11 states of India, including Kerala.

P. multidentatus was found in association with any one of the following pests viz. *Anthocoptex vitexae*, *Dendrothrips minutus*, *E. orientalis* and *B. phoenicis* on many host plants such as *Vitex negundo*, *C. odorata*, *Lucas aspera*, *Centrosema pubescens*, *Q. indica* and *Clitoria ternatea*. This species was first described from Hong Kong on *Bambusa* sp. and *Jasminum* sp., there after it was recorded in the world from more than 37 plants comprising both vegetable and medicinal plants. In India, this species was reported from around 15 states. It was also reported from Thailand, Philippines, Nigeria, Madagascar, Malaysia and China.

A new species of the genus *Amblyseius* currently named as *A. guptai* sp. nov. could be collected from the leaves of *Cocos nucifera*, in association with *Aspidiotus destructor, Raoiella indica, T. fijiensis* and *T. neocaledonicus*. It was found actively feeding on all these pests. *A. guptai* sp. nov. showed close resemblance to *A. largoensis* in several of its morphological characters.

The species was also found on plants viz. *A. viridis*, *A. tricolor*, *P. amarus* and *Boerhavia diffusa* grown in the near by areas of the Calicut University Campus.

P. rachelae was a highly abundant phytoseiid predator found in association with *A. adoratus* on *C. odorata* distributed over Kozhikode and Malappuram districts of Kerala. It was also found to feed on *D. minutus*, *A. destructor* and some other scale insects also. The first description of *P. rachelae* was from Hong Kong. In India, it was reported firstly from West Bengal and later from Kerala.

Compared to other phytoseiid mites collected above 5 predators selected were highly accessible and sustainable in the laboratory conditions. Wide host range and diverse food habits of *A. largoensis*, *A. guptai* sp. nov., *T. suknaensis, P. multidentatus* and *P. rachelae* enabled to confirm them as potential phytoseiid predators and hence selected for further detailed biological studies on some selected food items described below.

II. A.2. Test Food Items Offered

II. A.2. a. Pollen

Pollen grains of castor (*Ricinus communis*) were provided in order to trace the preference of selected species of predatory mites to this food item. This food item was selected to know whether it could be exploited as an alternative food source for the sake of mass rearing in the laboratory.

II. A.2. b. Honey

Commercial honey obtained from the hives of, *Apis cerana indica* was provided to the predatory mites to find out its fitness as an artificial diet.

II.A.2.c. Yeast

During the present work, yeast (*Saccharomyces cerevisiae*) was also tested as an artificial diet for the predators.

II.A.2.d.Mite pests selected as prey

II.A.2.d.i. Spidermites (Tetranychidae) (Plate I, Figs. B, E & F)

Tetranychid species like *Tetranychus neocaledonicus, T.cinnabarinus* and *T.fijiensis* were the most threatening species recognized during the study period. The above species were recovered from most of the plants surveyed for the recovery of predatory mites. *T.neocaledonicus*, the commonly called vegetable mite was already recognized as a serious pest of more than 110 species of plants from various parts of the world. The present survey enabled to record its presence on 23 species of plants viz. *M. oliefera*, *P. sativum*, *Manihot esculenta, V. unguiculata, A. tricolor, C. limon, A. vasica, Phyllanthus amarus, Sida alnifolia, R. indica, Azadirachta indica, Abelmoschus esculentus, Solanum melongena, Q. indica, Carica papaya, A.viridis, C. pubescens, C. ternatea, U. lobata, Euodialuna ankenda* and *Zizyphus oenoplia. T. cinnabarinus,* another tetranychid pest was found to infest on plants like *C. pubescens, C. ternatea, U. lobata, Q. indica* and *Z. oenoplia, A. tricolor, C. limon, A. vasica, P. amarus, S. alnifolia,*

Desmodium gangeticum, *Desmodium motorium*, *Acalypha fruticosa*, *Scoparia dulcis* and *C. nucifera*.

T.fijiensis formed one of the major spider mite pest on *C. nucifera,* several species of grasses, *G. sepium*, *P. amarus*, *S. alnifolia*, *A.tricolor*, *A.viridis, Q. indica and C. limon.*

II. A.2. d. ii. False spidermites (Tenuipalpidae) (Plate I, Fig. D)

The red palm mite, (*R. indica* Hirst) is a notorious pest of several important ornamental and fruit-producing palm species. This mite is easily distributed by wind currents and infestation to new plants take place through nursery stock and cut branches of plants. Adults and nymphs of *R. indica* are oval and reddish in colour. The red palm mite has been reported as a serious pest of several ornamental and fruit-producing palm species such as coconut and areca palms, and has been found attacking bananas and plantains. Palms are important components of our tropical landscapes, both indoors and outdoors, and in many countries coconut palms, *C. nucifera*, and date palms, *Phoenix dactylifera,* are important food crops. The red palm mite is expected to cause economic damage to tropical and subtropical agriculture and to urban and indoor environments. Palm nurseries, landscape palms, and horticultural gardens will be affected by this new pest, as well.

II.A.2.e.Insect pests as prey

II.A.2.e.i. Scale insects (Hemiptera: Diaspididae) (Plate I, Fig. A)

Aspidiotus destructor is one of the most destructive pest species on coconut, this species is highly polyphagous and therefore can easily be re-

introduced, even if it is successfully controlled on the primary host crop species. Its hosts are typically perennial plants and include many fruit tree species, such as avocado, bread fruit, mango, guava and papaya. This pest is usually found in densely massed colonies on the lower surfaces of leaves, except in extremely heavy infestations where it may be present on both sides. It may also be found on petioles, peduncles and fruits. Mature scales are found on the older leaves. Infestations are typically associated with yellowing of the leaves in areas where the scales are present.

II.A.2.e.ii.Thrips (Thysanoptera: Thripidae) (Plate I, Fig. C)

D. minutus is a small sized, phytophagous insect infesting medicinal plants. The larvae of this pest are transparent and are the most active feeding stage which later assume the colour of the leaf on which they feeds. The highly active larvae were found mainly associated with young leaves.

II.A.3. Raising of Stock Cultures of Pest Mites

The infested parts of the host plants, like the leaves, twigs etc. were cut with a scissors and put in self-sealing plastic bags and were transported to the laboratory. Successful rearing and maintenance of sufficient stock cultures of the prey mites in the laboratory were carried out following leaf flotation technique. For this, leaf discs (2cm x 2cm) were cut out from respective host plants and kept in petri dishes lined with water saturated cotton pads. Adult mated females of respective spidermites were transferred carefully to the leaf discs with the help of moistened camel hair brush. The

leaf discs were renewed in every 2-3 days for supplementing constant source of preferred food for the pest mites.

II.A.4. Raising of Stock Cultures of Predatory Mites

The predatory mites were collected along with the prey mites from the leaves of their respective host plants. In the laboratory, the leaves of the above host plants were carefully examined under a Wild M7 microscope for the recovery of different stages of the predatory mite. All stages of predatory mites were carefully transferred with a clean, fine camel brush to leaf discs cut from respective host plants of the prey mites and successfully reared following leaf flotation technique. Prey mites were provided to the predator during rearing period. Renewal of leaf discs was carried out at an interval of 2-3 days and a regular supply of prey mites was ensured for successful rearing of the predatory mites. On scarcity of prey population in the field, pollen of *R. communis* was also offered as an alternative food source, to which the predator showed great affinity.

Simultaneously, stock cultures of both prey and predatory mite populations were also raised on respective host plants planted in earthen pots outside the laboratory, after artificially infesting the plant with the prey/predator mites. This provided a ready and adequate supply of both prey and predator mites irrespective of seasonal variation, which other wise would interfere the constant availability of pest mites from the field.

II.A.5. Comparative Studies on the Feeding Potential of Phytoseiid Mites

Several culture sets were maintained in the laboratory as described above at a temperature of 30 $\pm$ 2^0C and a relative humidity of 70 $\pm$ 2% to study the feeding preference of individual stages of phytoseiid predators to the different stages of the pest species mentioned above. The experiment was initiated by setting five culture sets containing leaf discs with different stages of the prey. The culture sets was arranged in such a way that each leaf disc harboured 100 individuals of respective prey mites. In the case of insect pests, the total number of prey was 50/ leaf disc. Different stages of predator viz. male, female, larva, protonymph and deutonymph were released to each culture set containing different stages of prey mites/insects. Observation on feeding activity as well as feeding preference of immature and adult stages of each predator species was made daily. Data obtained on the above parameters were tabulated and presented through appropriate figures/graphs. Necessary photographs were also taken using a Canon digital camera attached to a Zeiss Stemi 2000C Stereozoom research microscope. Data obtained on feeding potential were also subjected to statistical analysis using ANOVA followed by Scheffe test.

II.B. STUDIES ON THE BREEDING BIOLOGY OF PHYTOSEIID MITES

A comparative study on the postembryonic development of phytoseiid mites on 4 distinct diets comprising *T.neocaledonicus, R.indica, A.destructor*, and pollen grains of *R.communis* was carried out in the laboratory at a

temperature of 30 ± 2^0C and 70 ± 2% humidity by adopting leaf flotation technique. The experiment was initiated by raising cultures of individual stages of the predator by offering prey mites collected from respective host plants. Developmental studies were carried out separately on each of the above food item. For each species of prey mite, five sets of cultures were maintained and regular observation was made per hour in order to collect data on various aspects like mating, oviposition, incubation, hatching, active stages, moulting etc. Females which got successfully matured and paired with males were reared until they died, to determine the oviposition and longevity. The experiments were repeated several times for confirmation of the data obtained. Results gathered on durations of individual instars of the predator, longevity of adults, pre-oviposition, oviposition and post-oviposition periods and fecundity were recorded, tabulated and presented. Necessary photographs of the developmental stages were also taken with the help of a digital camera attached to a Zeiss Stemi 2000c Stereozoom research microscope.

III. MORPHOLOGICAL STUDIES OF DEVELOPMENTAL STAGES

Morphological characters of the different life stages of individual species of predator were also studied during the present investigation. Specimens representing the different instars of each predator were preserved in 70% alcohol and upgraded through 80%, 90% and absolute alcohol series. The dehydrated specimens were cleared in a mixture of lactic acid and

absolute alcohol (1:1 ratio) and slide mounted in Hoyer's medium and dried in an oven at 30-40^{0}C. Drawings of individual stages were made with the help of a Camera Lucida attached to a Meopta Research microscope. Measurements of the various life stages of the predator were made using an ocular micrometer.

IV. EVALUATION OF BIOCONTROL POTENTIAL

IV.A. MASS REARING OF PREDATORY MITES

Four types of alternative food items other than the prey species, viz. pollen grains of *R.communis*, honey, yeast, honey +yeast, were tested during the study. Each food item was offered to at least 5 mated females along with two males. Based on the results of the observations, pollen grain of *R. communis* was chosen to be tested for its effect on the survival, oviposition and development of selected phytoseiid predators. Females which got successfully matured and paired with males were reared till death in order to determine the oviposition and longevity.

Selected species of predatory mite was reared under laboratory conditions on the pollen grains of *R. communis* following the technique of Zemika and Prenerova, 1997. Rearing was carried out in glass petri dishes of 15cm diameter kept in an inverted position of Ø 18 cm. The large petri dish was half filled with water. Black cloth cut in equal diameter to that of the smaller petri dish was lined on base of the inverted petri dish. The small petri dish was kept inverted in the water contained in the larger petri dish in such a

way that the cloth lined base of which faced upwards. Pollen grains of castor were placed on this black cloth cover and the females and males (5:2) of *A. suknaensis* were released on to the inverted petri dish, where the pollen grains were kept. The whole arrangement was covered with a lid formed of another larger petri dish of Ø 18 cm. This arrangement allowed the predator to feed exclusively on castor pollen. Renewal of food was made twice in a week.

IV. B. FIELD EVALUATION OF BIOCONTROL POTENTIAL OF *T. SUKNAENSIS* ON THE PEST MITE *T. NEOCALEDONICUS*

IV. B.i. Experiment Design

Plots for cultivation of *Vigna ungiculata* were prepared at Panambra, a nearby place of Calicut University Campus. The plots were arranged in a randomized complete block design. A total of 4 plots – 2 experimental and 2 control plots – were arranged for the present study. Each plot consisted of 4 rows having a length of 2.5 m. The distance between each row was around 0.5m. At least 3 m was left between experimental and control plots to prevent migration of released predator from experimental plot to control plot. Seeds of *V. unguiculata*, were sown in each row so that each row consisted of 5 plants. Thus each plot consisted of a total of 20 plants. Each of the plot was completely covered with nylon net of mesh size 0.6mm, in order to avoid the entry of both insect and mite pests and their natural enemies. Periodical spraying of Tobacco decoction was also practiced as a precaution, to ensure

that plots were free from any kind of pests and predators, before the start of the experiment.

IV. B.ii. Artificial infestation of *V. unguiculata* with *T. neocaledonicus*

When the seedlings reached the age of approximately 3 weeks, every 3/5th plant in each plot (both control and experiment) was artificially infested with 10 adult gravid females along with males (5:2,♀:♂) of *T. neocaledonicus*. Populations of *T. neocaledonicus* were allowed to grow for 3 weeks to ensure adequate population density of the pest mite to support the build up of predatory mite population, which was released subsequently.

IV. B.iii. Field Release of *T. suknaensis*

When the pest population attained 3 weeks of growth in the field, selected species of the phytoseiid predator, *T. suknaensis* which was mass reared in the laboratory was released in to the plot. A total of 150 individuals of *T. suknaensis* comprising the mated and gravid females along with males in 3:1 ratio were released into the experimental plot. The release of the predator was made on a random basis, but usually care was taken to include 3/5th of the plants in each plot, for releasing the predator. The control plot was kept devoid of any predatory mites, but with the pest population alone.

Frequent monitoring was made weekly. After a period of 3 weeks, leaves were collected in equal numbers (10 leaves per plots) from the plants grown in both the control and experimental plots. Leaf samples were

randomly collected from each plot and put in self sealing polythene bags separately for further transport into the laboratory. Such plucked leaves were thoroughly examined under a stereozoom microscope for the recovery of both the pest and phytoseiid mites. This process was repeated at every 3rd week of the month till the end of the experiment. Data were collected on the relative abundance of the introduced pest and predator in the experimental plot. Simultaneously, the population of pest mites in the control plot was also recorded. The above data were subjected to statistical analysis following ANOVA and regression correlation in order to know whether predator-prey interaction was significant or not.

IV. B. iv. Preparation of Tobacco Decoction

Tobacco decoction was prepared by steeping 500 gm of tobacco leaves in 4.5 liters of water for 24 hours.120gm of bar soap was dissolved separately in another vessel. The soap solution was then added to tobacco decoction under violent agitation. The stock solution was diluted 6-7 times before spraying.

OBSERVATION

I. SURVEY RESULTS

The results of the general survey could clearly establish the fact that among the natural invertebrate predators, phytoseiid mites were the most common group on plants. There was hardly any plant surveyed which showed a total exclusion of phytoseiid mites. These mites were the most active predators of the spider mites, tenuipalpids and eriophyids and were found distributed on all plants surveyed irrespective of the species difference in pest incidence. Moreover, they could be collected in all seasons, but with variation depending on the species composition and abundance of the pests. During monsoon season, the number of phytoseiid mites showed a decline in par with that of the pest species. It was observed that at the end of monsoon, when the pest mite population got re-established on respective host plants, the number of the local phytoseiid mites also showed an increasing trend in the field. Of the different genera of phytoseiids recovered during the present study, the genus *Amblyseius* showed the maximum representation (Table II).

Of the 24 vegetable plants surveyed, *A. viridis, A. tricolor, C. papaya, M. esculenta, M. deeringiana, M. oleifera, I. batatus, V. unguicultata* and *D. lablab* showed high incidence of any one or two species of tetranychid mites viz. *T. neocaledonicus, T. cinnabarinus, T. ludeni* and *E. orientalis.* Mild attack by the tenuipalpid member, *B. phoenicis* was also observed on

these plants. In the case of *M. charantia* and *H. longifolius*, the most dominant pests recognized were the chrysomelids and aphids. *V. unguiculata* was an exceptional case, where both the mite pests and aphids could be observed even though they did not coexist.

Medicinal plants also disclosed high incidence of tetranychid pests. The results of the survey helped to record high incidence of any one or more tetranychid species, *T. neocaledonicus*, *T. cinnabarinus* and *E. orientalis* on *A. vasica, A. indica, S. alnifolia, Premna latifolia, Emilia sonchifolia, S. indicum, Boerhavia diffusa, Catharathus roseus, L. aspera, P. amaranthus, C. ternatea, O. sanctum, O.gratissimum, Acalypha fruticosa, Aerva lanata, Eclipta alba, Vernonia cinerea, B. reinwardtii* and *Hygrophila auriculata*. Infestation by *O. bihariensis* was also observed on *A. vasica*. Besides these spider mites, *A. vasica* was also found infested by scale insects and the tenuipalpid mite, *B. phoenicis*. But *B. phoenicis* infestation was more intense on *O. sanctum, O. gratissimum* and *S. indicum. A. vitexae* and *D. minutus* were the two major pests encountered on the leaves of *V. negundo,* though some individuals of spider mites were present.

Of the various species of ornamental plants surveyed, *R. indica, Gomphrena globosa* and *G. serrata* showed a high infestation of *T. neocaledonicus, T. cinnabarinus, O. bihariensis* and *E. orientalis.* Compared to the genus *Tetranychus*, the severity of infestation by members of genera like *Oligonychus* and *Eutetranychus*, viz. *O. bihariensis* and *E. orientalis* was low. The other ornamental plants examined were *Jasminum grandiflorum*,

Hibiscus spp., and *Anthurium andraeanum*. The intensity of pest-infestation was low on these plants when compared to that of *R. indica*. On spice crops viz. *P.nigrum, C.longa, Z.officinalis* and *P.granatum,* the thrips were recognized as the common pests, while minor infestation by *T. neocaledonicus* and *T. cinnabarinus* could be observed in the case of *Z. officinale* and *C. longa. C. nucifera* and *R. communis* were the two oil yielding plants surveyed during the study period, both of which were found infested by *T. neocaledonicus*. In addition, coconut seedlings were found infested by mite pests such as *T. fijiensis, T. cinnabarinus, T. neocaledonicus* and *R. indica* and insect pest, *A. destructor*. Of these, *T. fijiensis, R. indica* and *A. destructor* were the most dominant pest species.

During monsoon season, the crops were found totally free from the attack of mite pests, especially that of the spider mites. However, these mites could be recovered from ground vegetation constituted mainly by weeds and grasses, during this period, on careful observation. The important weeds explored in this regard included *C.pubescens, Z.oenoplia, Q.indica, U.lobata, C. odorata, G. sepium* and many species of grasses.

Table III illustrates the most common and efficient phytoseiid predators selected for biological studies during the current investigation viz. *A. largoensis, P. multidentatus, T. suknaensis, A. guptai* sp. nov. and *P. rachelae* with respect to their host plants and associated pest species under field conditions. As shown in the table, *A. largoensis* was the most common species with a wide host range, distributed on 17 species of host

plants, in association with pest species like, *T. neocaledonicus, T. cinnabarinus, T. ludeni, T. fijiensis, E. orientalis, B. phoenicis,* some scale insects, chrysomelids, aphids and thrips.

T. suknaensis, was another important phytoseiid predator found distributed in the field on 11 species of host plants, in association with *T. neocaledonicus, T. cinnabarinus, A. adoratus*, aphids and scale insects. This species was found to feed very actively on all the pest species provided, with more preference to *T. neocaledonicus* in laboratory conditions.

The new species included in the present study viz. *A. guptai* sp. nov. was found distributed on coconut seedlings along with the pest species, *T. fijiensis, T. neocaledonicus, R. indica* and the scale insect *A. destructor*. Their host plants included species like, *A. tricolor, A. viridis, P. amaras,* and *B. diffusa* grown in the adjacent areas of the Calicut University Campus.

P. multidentatus recovered from the medicinal plant, *V. negundo* was found in association with the eriophyid mite, *A. vitexae,* the thrips species, *D. minutus* and the false spider mite *B. phoenicis*. This species of predator was also found distributed on other plants like *C. odorata, L. aspera, C. pubescens, Q. indica*, *C. ternatea* and *Z. oenoplia*. The species showed preference to *D. minutus* and *A. vitexae* but also devoured *B. phoenicis, T. neocaledonicus* and *E. orientalis*, under field conditions. Highest population of *A. multidentatus* was observed in the field when the population of *D. minutus* got established successfully on *V. negundo*.

P. rachelae was observed as a common phytoseiid species distributed along with populations of the eriophyid mite, *A. adoratus*, which produced erineal patches on the leaves of the terrestrial weed, *C. odorata*. High populations of *P. rachelae* were found colonizing on the undersurface of the leaves of *C. odorata*, feeding on all stages of *A. adoratus* under field conditions. In laboratory conditions also, *P. rachelae* exhibited the same feeding preference where the erineal patches were concentrated.

Among the phytoseiid mites collected during the survey period, *Amblyseius* was the most common genus followed by *Phytoseius*. Of the various species of phytoseiid mites recovered during the survey, 5 species viz. *A. largoensis*, *P. multidentatus*, *T. suknaensis*, *A. guptai* sp. nov. and *P. rachelae* showed high population density, wide distribution trend and voracious feeding habits. These species were always found in constant association with one or more of the major pest species, which prompted to undertake further biological studies.

II. BIOLOGICAL STUDIES OF PHYTOSEIID MITES

II. A. FEEDING ACTIVITY OF PHYTOSEIID PREDATORS ON PEST MITES/INSECTS

The 5 species of phytoseiid predators viz. *A. largoensis*, *T. suknaensis*, *A. guptai* sp.nov., *P. multidentatus* and *P. rachelae* selected for the present study, proved their efficiency as predators of various pests including insect

pests. Even though they showed quantitative variation depending on the pest species, they showed a unique feeding technique on both mites and insect pests. The feeding process of the predators was initiated by touching the prey with their legs, especially tarsi I, then grasping it with the II pair of legs (Plate II, Fig.1 A-B). The first pair of legs held over the prey and then retrieved from the prey and was found extended anteriorly. Meanwhile, the palps were directed ventrad and slightly laterad, touching the prey with the dorsal setae on palp tarsus and tibial setae. The predator then bent its gnathosoma ventrad until its longitudinal axis was perpendicular to the prey's cuticle. In this position, the angle between the predator's body axis and gnathosoma was approximately 90^0. The chelicerae were alternately protracted beyond the apex of the corniculi, for a distance at least equal to the length of the movable digit. While the fixed digit remained outside the cuticle, the movable digit cut the cuticle. As soon as the body cuticle of the prey got penetrated, expansion and contraction of the pharyngeal muscles of the predator were observed, accompanied by the movement of fluids from the body of the prey into the predator's gut. The body colour of the predator was found changing and the coloured body fluid of the prey could be clearly seen through the transparent body of the predator. The feeding process of the various life stages of predators was more or less similar and all the instars were found very actively wandering on the leaf bits in search of the prey. However, the time taken by the different stages of the predator to devour the

life stages of the prey mite showed variation. Accordingly, 5-10 minutes could be recorded for consumption of adult/nymphs of pest mites and 3-5 minutes for their eggs. The mean time to consume the life stages of insect pests by different life stages of the predators was found to vary between 15-20 minutes. The mode of consumption of egg by the predator was more or less similar to that followed in the case of nymphs and adults. However, the palps were found laid over the egg and chelicerae were found extended towards the eggs. Several punctures were produced on the egg surface with the help of the extended chelicerae, through which the contents were withdrawn, leaving behind the collapsed egg shell.

II.B. FEEDING POTENTIAL OF SELECTED PHYTOSEIID MITES

II.B.i. Feeding Potential of Life Stages of *Amblyseius largoensis*

In the field, *A. largoensis* was found in association with *T. cinnabarinus, T. neocaledonicus, B. phoenicis* and *T. fijiensis* on various plants such as *A. vasica, R. indica* and *O. sanctum*.

A. largoensis was recognized as an active phytoseiid predator under laboratory conditions. The total percentage consumption of individual stages of *A. largoensis* viz. the adult female, male, deutonymph, protonymph and larva on *T. neocaledonicus* could be recorded as 51%, 21%, 46%, 23% and 9% respectively. While on *T. cinnabarinus* the respective rates were 53%, 27%, 46%, 27% and 12%. On *T. fijiensis*, the same could be recorded as 48%,

24%, 37%, 24% and 8% respectively. Table IV presents the percentage consumption of *A. largoensis* on different life stages of *T. neocaledonicus.* The feeding potential of *A. largoensis* decreased in the order: Adult female> Deutonymph> Protonymph> Adult male> Larva (Plate III, Fig.1). The percentage consumption of the larva of the predator was very low when compared to the other stages of the predator, the observed percentage consumption on the prey *T. neocaledonicus* being 20% eggs, 6% larvae, 4% protonymphs 1% deutonymphs and 0.4% adults. The consumption rates of protonymph and deutonymph of *A. largoensis* were 37%, & 59% eggs, 35% & 51% larvae, 21% & 44% protonymphs, 4% & 23% deutonymphs and 2% & 15% adults of the pest, *T. neocaledonicus.* The most voracious stage of *A. largoensis* was the adult female which consumed 64% eggs, 57% larvae, 50% protonymphs, 29% deutonymphs and 18% adults of *T. neocaledonicus.* The respective percentage of different life stages of *T. neocaledonicus* consumed by the adult male of *A. largoensis* were 29%, 23%, 22%, 15% and 12% respectively.

The average consumption rates of adult male and protonymph of *A. largoensis* on *T. cinnabarinus* were observed to be the same (27%) (Plate III, Fig.2) and the feeding rates of individual stages of the predator on *T. cinnabarinus* were higher than that on *T. neocaledonicus* (Plate IV, Fig. 3) and which were 53% in adult female, 27% in adult male and protonymph, 46% in deutonymph and 12% in larva. (Table V). It was observed that the

mean consumption of larva of *A. largoensis* was 28% eggs, 9% larva, 4% protonymphs, 1% each of deutonymphs and adults of *T. cinnabarinus*. The protonymph of *A. largoensis* consumed 38% eggs, 31% larvae, 25% protonymphs, 6% deutonymphs and 2% adults of *T. cinnabarinus* while the adult male consumed 36% eggs, 27% larva, 22% protonymph, 19% deutonymph and 13% adults in a period of 24 hours. The predator female, the most voracious stage of *A. largoensis* consumed 69% eggs, 58% larvae, 52% protonymphs, 31% deutonymphs and 19% adults of *T. cinnabarinus*. The predator deutonymph consumed 61% eggs, 52% larvae, 40% protonymphs, 23% deutonymphs and 14% adults.

The rates of feeding by *A. largoensis* on *T. fijiensis* appeared comparatively low (Plate IV, Fig. 3). The predator female devoured 60% eggs, 46% larvae and protonymphs each, 43% deutonymphs and 26% adults of the pest mite, *T. fijiensis* (Table VI). While the consumption rates of the deutonymph on the eggs, larvae, protonymphs, deutonymphs and adults of *T. fijiensis* were 51%, 38%, 30%, 28% and 18% respectively. The adult male and protonymph of the predator consumed more or less same number of preys in 24 hours, consisting of 34% and 35% eggs, 24% and 30% larvae, 19% and 29% protonymphs, 16% and 19% deutonymphs, 11% and 12% adults respectively constituting a total of 24% each. While the larva devoured 22% eggs, 19% each of pest larvae and protonymphs, 1% deutonymphs and 1% adults (Table VI; Plate III, Fig.3).

Different life stages of *A. largoensis* showed comparatively higher feeding potential on *R. indica* (Table VII; Plate III, Fig.4; Plate IV, Fig.3). The adult female consumed a total of 56% individuals of *R. indica* consisting of 68% eggs, 58% larvae, 50% protonymphs, 46% deutonymphs and 32% adults. The predator deutonymph consumed 64% eggs, 53% larvae, 40% protonymphs, 39% deutonymphs and 23% adults, constituting a total of 49% individuals of *R.indica*. The adult male and protonymphs of *A. largoensis* devoured a total of 27% each of individuals of *R.indica* respectively. The percentage consumption on different stages of *R. indica* by the adult male predator could be recorded as 40% eggs, 27% larvae, 21% protonymphs, 18% deutonymphs, and 14% adults while that of the protonymph was 42% eggs, 30% larva, 25% protonymphs, 5% of deutonymph and 1% adults. The total percentage consumption by the predator larva was 9%, which consisted of 18% eggs, 8% larva, 4% protonymphs, 2% deutonymphs and 1% adults of *R. indica*.

A. largoensis showed it's potential as a predator when it was provided with different life stages of the scale insect, *A. destructor* also in the laboratory conditions. The total consumption rates of the different life stages viz. larva, protonymph, deutonymph, adult male and adult female of *A. largoensis* on *A. destructor* were found to be 1%, 4% 12% 1% and 20% respectively (Table VIII). Adult female predator devoured 49% egg mass, a total of 17% crawlers and females, 1 % adult males of the insect pest, *A. destructor*. While the consumption rates of the predator deutonymph on

the egg mass, crawlers + females, adult males of *A. destructor* were 26%, 11%, 0.1% and 12% respectively. The adult male and protonymph of the predator consumed 3% and 11% egg mass, 0.2% and 4% crawlers +females, 0.1% each of the males of *A. destructor* respectively. Meanwhile the predator larva, devoured 3% egg mass, 0.3% crawlers + females and showed a total exclusion of males of *A. destructor* (Table VIII; Plate IV, Fig.1).

The feeding potential of *A. largoensis* on the thysanopteran pest, *D. minutus* was found to be very low when compared to the other phytoseiid mites (Plate IV, Fig.3) (Female-24%, Male-10%, Deutonymph-22%, Protonymph 12%, larvae 6%) (Table IX). But the feeding potential and feeding preference of different stages of *A. largoensis* was similar to that of other phytoseiid mites (Plate IV, Fig.2). The rates of consumption on N_1 (1^{st} nymph), N_2 (2nd nymph), prepupa + pupa and adult stages of *D. minutus* consumed by female of *A. largoensis* were 32%, 32%, 15%, and 8% respectively. While the adult male consumed 12% N_1, 14% N_2, 9% prepupa + pupa, and 2% adults of *D. minutus*. The deutonymph, protonymph and larva of *A. largoensis* consumed 30%, 13%, 5 % N1; 28%, 20%, 10% N_2; 16%, 14%, 2% prepupa+pupa and 5%, 1%, and 0.3% adult of *D. minutus* in a duration of 24 hours (Table IX).

II.B.ii. Feeding potential of life stages of *Typhlodromips suknaensis*

Results of the comparative studies on the feeding preference of *T.suknaensis* on prey mites like *T. neocaledonicus, T. cinnabarinus, T. fijiensis,*

R. indica, *D. minutus* and *A. destructor* showed that all stages of the predator could feed on either all stages or any one or two life stages of the pests (Plate VII, Fig.3). It was also observed that the feeding potential of individual stages of the predator showed considerable variation not only with respect to the different species of the prey but also with the different stages of the same prey. The percentage consumption of the various life stages of the predator on different life stages of the pests in 24 hours was recorded and tabulated. The percentage consumption by a single larva of *T. suknaensis* in 24 hours was found to be 9% on *T. neocaledonicus*, 14% on *T. cinnabarinus*, 8% on *T. fijiensis*, 14% on *R. indica*, 9% on *D. minutus* and 1% on *A. destructor* (Table X-XV). The mean rate of consumption on the life stages of *T. neocaledonicus* by the larva of *T. suknaensis* in 24 hours could be recorded as 19% eggs, 8% larvae, 7% protonymph, 1% deutonymph and 0.3% adult respectively. While that of the protonymph was 45%, 42%, 41%, 10%, 5% respectively. Mean while the predator deutonymph consumed 76% eggs, 68% larvae, 64% protonymphs, 24% deutonymphs and 21% adults of *T. neocaledonicus*. The consumption rates of male predator on the egg, larva, protonymph, deutonymph and adult stages of *T. neocaledonicus* in 24 hrs were 57%, 42%, 41%, 23% and 13% while a single female predator devoured 86% eggs, 74% larvae, 71% protonymphs, 32% deutonymph and 22% adults of *T. neocaledonicus* provided (Table X; Plate V, Fig.1).

The consumption rates of *T. suknaensis* on different life stages of *T. cinnabarinus* are presented in Table XI (Plate V, Fig.2). The larva of

T. suknaensis devoured 22% eggs, 17% larvae, 13% protonymphs, 2% deutonymphs and 0.4% adults. The rate of consumption on eggs, larvae, protonymph, deutonymph and adults of *T. cinnabarinus* by the predator protonymph/day was found to be 43%, 38%, 36%, 4%, and 2% respectively. Deutonymphs, males and females of *T. suknaensis* were proved active predators of *T. cinnabarinus*. The consumption rates of the deutonymph being 69% eggs, 65% larvae, 61% protonymphs, 23% deutonymphs, and 17% adults of *T. cinnabarinus*. The predator female fed 77% eggs, 64% larvae, 63% protonymphs, 27% deutonymphs and 21 % adults. While the male predator consumed 49% eggs, 46% larvae, 42% protonymphs, 17% deutonymphs and adults of *T. cinnabarinus* each. The female and male individuals of *T. suknaensis* consumed a total number of 60% and 40% individuals of *T. cinnabarinus*/day respectively.

The feeding potential of *T. suknaensis* on *T. fijiensis* was higher than that on *T. cinnabarinus* (Plate VI, Fig.3). The percentage consumption of the female predator on different stages of *T. fijiensis* was 78% eggs, 71% each of larvae and protonymphs, 26% deutonymphs and 25% adults. The deutonymph, the second active feeding stage, was found devouring 74% eggs, 68% larvae, 64% protonymphs, 23% deutonymphs and 22% adults of *T. fijiensis*. The consumption rates of protonymph and larva of the predator on different life stages of *T. fijiensis* were 44% and 15% eggs; 38% and 10% larvae; 20% and 7% protonymphs; 2% and 1% deutonymphs and 1 % and 0.3% adults respectively (Table XII; Plate V, Fig.3). While the male

consumed 51% of eggs, 49% larvae, 41% protonymphs, 24% deutonymphs and 2% adults of *T. fijiensis*.

The different life stages viz. larva, protonymph, deutonymph, and adult male and adult female of *T. suknaensis* were found to feed on all stages of *R.indica.* Different life stages of the predator preferred the eggs and larvae of the prey mite when compared to the other stages. The larva of the predator fed 19% eggs, 18% larvae, 8% protonymphs, 2% deutonymphs and 1% adult comprising a total of 14% individuals of *R.indica* in a period of 24 hours. The respective consumption rates on different stages of prey viz. egg, larva, protonymph, deutonymph and adult consumed by the predator protonymph were 46%, 42%, 37%, 9% and 3% comprising a total consumption of 35%. The deutonymph of *T. suknaensis* which appeared as the most voracious nymphal stage consumed a total of 61% of *R.indica* consisting 78% eggs, 71% larvae, 66% protonymphs, 21% deutonymphs and 15% adults of the prey in a period of 24 hours. The adult female of the predator devoured the highest number of the prey (66%), consisting of 84% eggs, 71% larvae, 69% protonymphs, 40% deutonymphs and 21% adults of *R.indica.* The adult male predator consumed 63% eggs, 50% larvae, 49% protonymphs, 16% deutonymphs and 15% adults comprising a total of 47% of *R. indica* population. (Table XIII; Plate V, Fig. 4).

All stages of *T. suknaensis* were found to feed on both *D. minutus* and *A. destructor*, the two insect pests provided during the present study (Plate

VI, Fig.1&2). Table XIV illustrates the percentage consumption of life stages of *T.suknaensis* on the different life stages of *A. destructor* in 24 hours. The adults and the nymphs viz. deutonymph and protonymph of the predator were found to feed on all life stages of the scale insect *A. destructor* provided but the larval stage of the predator was found devouring comparatively less egg mass (4%), crawlers and females (0.3%) of the scale insect (Plate VI, Fig.1). The larva, protonymph, deutonymph, female and male of the predator were found to consume a total of 1%, 6%, 14%, 2% and 22% individuals of *A. destructor* per day. It was observed that a single female predator devoured 58% egg mass, 18% crawlers+ adult females and 1% adult males of the scale insect. The respective percentage of egg mass, crawlers+adult females and adult males of the scale insect consumed by the male predator were 6%, 0.3% and 0.3% respectively. The deutonymph of the predator consumed 37% egg mass, 11% crawlers+ adult females and 0.1% males of the scale insect. Percentage consumption of egg mass, crawlers+adult females and males of the scale insect consumed by protonymph of the predator was 16%, 4%, and 0.1% respectively.

The rate of consumption on different life stages of *D. minutus* viz. the first and second nymphs (N_1 and N_2), prepupa and pupa by larva of *T. suknaensis* were recorded as 13%, 13%, 6% and 2% respectively. While the protonymph fed 31% N_1, 25% N2, 11% prepupa + pupa and 9% adults of *D. minutus*. The female predator i.e., the most potential stage fed 76% N_1,

74% N_2, 62% prepupa + pupa and 23% adults of *D. minutus*. The daily consumption rate of the deutonymph was 67% N_1, 66% N_2, 51% prepupa + pupa, 15% adults while that of the male predator was 63%, 62%, 49%, 14% respectively (Table XV). The total daily consumption rates of the larva, protonymph, deutonymph, adult male and female of *T. suknaensis* on *D.minutus* were 9%, 21%, 54%, 50% and 62% respectively.

II.B.iii. Feeding potential of life stages of *Amblyseius guptai* sp.nov.

A. guptai sp.nov. was found to be an active predator found in association with *T. neocaledonicus, T. fijiensis, R. indica* and *A. destructor* on different host plants, especially on coconut palms, where the above mentioned pests were very common. Voracious feeding trend could be attributed during the present work to the above predator species. All stages of *A. guptai* sp.nov. were very active and fed on all stages of the prey mites/insects given, irrespective of the species variation (Plate VIII, Fig.3).

The percentage consumption of different stages of *T. neocaledonicus* consumed by different stages of *A. guptai* sp.nov.is shown in Table XVI. The total consumption of the various instars of *A. guptai* sp.nov. viz. larva, protonymph, deutonymph, adult male and adult female on the pest mite, *T.neocaledonicus* was 8%, 34%, 52%, 40% and 62% respectively. Different life stages of the predator showed a preference to the eggs and larvae of the prey than the other stages and the adult female and deutonymph showed a higher feeding rate than the other nymphal stages viz. larvae and

protonymphs and adult males (Plate VII, Fig.1). The predator deutonymph devoured 70% eggs, 55% larvae, 53% protonymphs, 21% deutonymphs and 19% adults of the prey mite while an adult female predator fed 76% eggs, 71% larvae, 61% protonymphs, 32% deutonymphs and 20% adults of the prey. The male and protonymph of the predator showed a more or less similar feeding potential consuming 54% and 45% eggs; 45% and 40% larvae; 38% and 39% protonymphs; 17% and 9% deutonymphs; 15% and 3% adults respectively (Plate VII, Fig. 1). The larva showed the lowest feeding rate and consumed 15% eggs, 9% larvae, 4% protonymphs, 3% deutonymphs and 1% adults of *T. neocaledonicus* (Table XVI).

The feeding rate and feeding preference of *A. guptai* sp.nov. on *T. cinnabarinus* resembled that on *T. neocaledonicus* (Plate VIII, Fig.3). The total number of eggs consumed by different life stages viz. larva, protonymph, deutonymph, adult male and adult female of *A. guptai* sp.nov. in a period of 24 hours appeared to be 16%, 46%, 70%, 57% and 77% respectively. At the same time, 65%, 48%, 56%, 44% and 14% larvae were found devoured by adult female, adult male, deutonymph, protonymph and larva respectively. The respective rates of feeding on the protonymphs by the female, male, deutonymph, protonymph and larva of the predator were, 62%, 39%, 54%, 41% and 13%. The deutonymphs and adults of the prey were the least preferred stages and the larva of the predator consumed only 1% deutonymphs and adults of the prey. The predator protonymph consumed 9%

deutonymphs and 4% adults. The consumption rate of deutonymph was higher than that of the larva and protonymph of the predator (Plate VII, Fig.2) and it was observed to be 25% deutonymphs and 22% adults respectively. The adult male devoured 16% deutonymphs and adults of the prey mite each. The respective rates of consumption by the female predator was 42% deutonymphs and 29% adults of the prey *T. cinnabarinus*. (Table XVII)

Even though *A. guptai* sp.nov. showed a comparatively higher feeding preference to *T. fijiensis* than to the other two tetranychid mites viz. *T. neocaledonicus* and *T. cinnabarinus* (Plate VIII, Fig.3), their preference to the different life stages of the prey, *T. fijiensis* was observed to be the same (Table XVIII). The feeding efficacy of different life stages of *A. guptai* sp.nov. increased in the sequence of larva <protonymph <adult male < deutonymph<adult female (Plate VIII, Fig.3) in the case of pest mites and thrips, *D.minutus*. The adult female, the most active feeding stage consumed an average of 79% eggs, 69% larva, 65% protonymphs, 44% deutonymphs and 30% adults of the prey, *T.fijiensis*. At the same time the adult male consumed 61% eggs, 49% larvae, 44% protonymphs, 17% deutonymphs and 16% adults. Among the nymphal stages of *A. guptai* sp.nov., the deutonymph consumed a total of 57% individuals of *T. fijiensis* comprising 73% eggs, 60% larvae, 57% protonymphs, 38% deutonymphs and 22% adults. The total number of individuals of the prey fed by the predator protonymph/day was 38%, comprising 51% eggs, 45% larvae, 36% protonymphs, 19% deutonymphs

and 7% adults. The larva of *A. guptai* sp.nov. consumed an average of 17% eggs, 15% larvae, 3% protonymphs, 1% deutonymphs and 1% adults constituting a total of 11% individuals of *T. fijiensis* in a duration of 24 hours (Table XVIII; Plate VII, Fig.3).

During the present work, the adult females of *A. guptai* sp. nov. showed a higher feeding potential on *R. indica* by consuming 85% of its eggs, 75% of larvae, 67% of protonymphs, 42% of deutonymphs and 26% of adults. But the other life stages of *A. guptai* sp.nov. exhibited a more or less similar feeding response as shown towards the other pest mites offered (Plate VIII, Fig.3). The total number of individuals of *R. indica* consumed by different life stages of *A. guptai* sp.nov. viz. larva, protonymph, deutonymph, adult male and adult female was found to be 8%, 34%, 58%, 45% and 68% respectively (Table XIX; Plate VII, Fig.4). The average number of different stages of *R. indica* viz. egg, larva, protonymph, deutonymph and adult fed by the predator deutonymph was 71%, 65%, 63%, 29% and 23% respectively, while an adult male predator consumed 56% eggs, 49% larva, 48% protonymphs, 22% deutonymphs and 14% adults of the prey. The percentage of different life stages of *R. indica* consumed by the protonymph and larva of *A. guptai* sp.nov. were, 50% & 14% eggs, 46% & 11% larvae, 21% & 7% protonymphs, 11% & 1% deutonymphs and 2% & 1% adults respectively.

A. destructor was one of the abundant pest found associated with A. *guptai* sp.nov. The predator was found actively feeding on all stages of the

scale insect except on the adult male of the pest which was winged and performed active movements on the host plant. All stages of the predator were found to feed on any two or more life stages of the scale insect pest (Table XX; Plate VIII, Fig.1). The total percentage consumption of different life stages of *A. guptai* sp.nov. viz. adult female, adult male, deutonymph, protonymph and larva was recorded as 33%, 2%, 22%, 8% and 2% respectively (Table XX). The egg mass of the scale insect constituted the most preferred stage and the individual life stages of the predator viz. adult female, adult male, deutonymph, protonymph and larva consumed 63%, 9%, 39%, 23% and 8% of egg mass within 24 hours. The crawlers and the adult females of the scale insect were the second stage of the pest preferred by the predator. It was observed that the female predator consumed 34% crawlers+females and 1% adult males/day. While the deutonymph of the predator was found to feed 24% crawlers + females and 0.4% males of the scale insect /day. The protonymph and the larva of the predator showed the least preference to scale insect (Plate VIII, Fig.1). The number of crawlers and females devoured by the predator protonymph were 6% and that of the males was 0.1%. The larva did not show any attempt to feed on the adult males of the pest while it fed 1% crawlers+females in of 24 hours.

The feeding behaviour of *A. guptai* sp.nov. on the insect pest *D. minutus* confirmed its efficacy as a predator of insect pests also. The feeding efficiency of different stages of *A. guptai* sp.nov. on different life

stages of *D. minutus* and its preference towards the same followed a similar pattern as that on other pests (mite pests) (Plate VIII, Fig.3). The individual stages of *A. guptai* sp.nov. viz. larva, protonymph, deutonymph, adult male and adult female consumed a total of 6%, 24%, 43%, 26% and 48% individuals of the prey in 24 hours respectively (Table XXI; Plate VIII, Fig.2). The female predator, the most active stage, consumed 62% N_1, 56% N_2, 43% prepupa + pupa and 18% adults of *D. minutus* while an adult male fed 35% N_1, 26% N_2, 18% prepupa + pupa and 14% adults of *D. minutus*. The percentage of different life stages of *D. minutus* viz. N_1 and N_2, Prepupa + Pupa and adult devoured by the deutonymph of *A.guptai* sp.nov. was 61%, 55%, 25% and 12% respectively. The protonymph and larva of the predator consumed a relatively low number of *D. minutus* and the larva consumed 12% N_1, 8% N_2 and 1% prepupa + pupa while the protonymph was found to devour 36% N_1, 31% N_2, 16% prepupa + pupa and 3% adult respectively (Table XXI).

II.B.iv. Feeding potential of life stages of *Paraphytoseius multidentatus*

Among the five species of phytoseiid mites selected for detailed studies on feeding potential, *P. multidentatus* showed low preference to mite pests when compared to the insect pests offered in the laboratory (Plate X, Fig.3). Of the various species of pest mites offered, *R. indica* was the most preferred food to the various life stages of the predator (Plate X, Fig.3). The feeding preference of the predator, *P. multidentatus* towards the different

species of the pest mites decreased in the sequence: *R. indica*> *T. neocaledonicus*> *T. cinnabarinus*> *T. fijiensis* (Plate X, Fig. 3). The total percentage consumption of the various life stages of *P. multidentatus* viz. larva, protonymph, deutonymph, adult male and female on *R. indica* were 4%, 13%, 28%, 18% and 35% respectively (Table XXV; Plate IX, Fig. 4). The female predator consumed 49% eggs, 36% larvae, 34% protonymphs, 13% deutonymphs and 12% adults of the pest mite, *R. indica* while a deutonymph consumed 42% eggs, 30% larvae, 20% protonymphs, 16% deutonymphs and 12% adults of *R. indica*. The respective percentage consumption of eggs, larvae, protonymphs, deutonymphs and adults of *R. indica* by the protonymph of *P. multidentatus* were 23%, 13, 6%, 1%, 0.1% and that of adult male were, 26%, 17%, 17%, 11% and 8% respectively. The feeding potential of the predator larva was comparatively low, the total consumption rate being 4% and when compared to the other life stages, the larva occasionally fed on the eggs, larvae, protonymphs and deutonymphs of *R. indica.* The mean rates of consumption by the predator larva on *R. indica* life stages (egg, larva, proto and deutonymph) were 8%, 5%, 2%, and 0.3% while the adult stages of the prey mite were not at all consumed by the predator larva.

Table XXII (Plate IX, Fig.1) illustrates the mean rates of consumption of *P. multidentatus* on the prey mite, *T. neocaledonicus.* The adult female of *P. multidentatus* consumed a total of 24% individuals of *T. neocaledonicus* comprising 36% egg, 21% larvae, 20% protonymphs, 19% deutonymphs and

16% adults. The deutonymph, the second actively feeding life stage of the predator consumed 34% eggs, 18 % larvae, 10% each of protonymphs and deutonymphs and 9% adults of *T. neocaledonicus* thereby constituting a total of 19% individuals. The consumption rates of male and protonymphal stage of the predator were more or less same (Plate IX, Fig.1). The predator male consumed 13% eggs, 8% larvae, 4% protonymphs, 2% deutonymphs and 1% adults of *T. neocaledonicus*, where as the protonymph devoured 14% eggs, 8% larvae 5% protonymphs, 2% deutonymphs and 0.4% adults of *T. neocaledonicus*. The percentage of prey mites of the species *T. neocaledonicus* consumed by the predator male and protonymph were 7% & 8% respectively (Table XXII). The larva of *P. multidentatus* was less active, but found to feed on various life stages of prey mites except the adult stages. The total rate of consumption of the predator larva was 3% comprising 6% eggs, 4% larvae, 2% protonymphs, and 0.4% deutonymphs of *T.neocaledonicus*.

It was also observed that the feeding potential of individual stages of *P. multidentatus* not showed considerable variation between the prey mites *T. cinnabarinus* and *T. neocaledonicus* (Plate X, Fig.3). The percentage consumption of the predator larva/day was found to be 3% on both *T. cinnabarinus* and *T. fijiensis*. Similarly, the rate of egg consumption was 5% in both cases and the rate of consumption of larvae was found to be 4% in both cases. The average consumption rates of the protonymph on the egg,

larva, protonymph, deutonymph and adult stages of *T. cinnabarinus* could be observed as 13%, 8%, 4%, 1% and 0.3% there by reaching a total of 7% individuals/day (Table XXIII). However, on *T. fijiensis* the consumption rates were 11%, 7%, 4%, 0.4%, and 0.3% respectively and a total of 6% individuals were consumed/day. The adult female and deutonymphal stages of the predator were comparatively more voracious (Plate IX, Figs.2&3) and the total number of individuals consumed by the adult female and deutonymph/ day were 22% & 16% on *T. cinnabarinus* respectively and 20% & 15% on *T. fijiensis.* The respective consumption rates of the deutonymph of *P. multidentatus* on the egg, larva, protonymph, deutonymph and adult stages of *T. cinnabarinus* were 30%, 14%, 9%, 10% and 5% while that on *T. fijiensis* were 27%, 14%, 12%, 7%, and 5% respectively. The adult female of *P. multidentatus* consumed 31% eggs, 21% larvae, 19% protonymphs, 18% deutonymphs and 14% adults of *T. cinnabarinus* and 28% eggs, 20% larvae, 18% protonymphs, 15% deutonymphs and 13% adults of *T. fijiensis* in a period of 24 hours (Tables XXIII-XXIV).

P. multidentatus exhibited a high percentage of consumption on insect pests, viz. *D. minutus* and *A. destructor* under laboratory conditions (Plate X, Fig.3). All the stages of the predator were found to feed on all stages of the insect pests provided (Plate X, Fig.1&2). The egg mass of the scale insect *A. destructor* was the most preferred food to all the feeding stages of the predator, *P. multidentatus*. The different life stages of the predator viz. larva,

protonymph, deutonymph, adult male and adult female consumed a total of 4%, 26%, 58%, 3% and 60% egg mass of the scale insect with in 24 hours (Table XXVI). The consumption rate of the predator stages on the other life stages of *A. destructor* was found to be decreased in the sequence of crawlers + females >males. The mean rate of consumption on the crawlers + females and males consumed by the predator female was found to be 37% and 1% respectively. While the respective rate of the adult male was found to be very low and it was 1% and 0.3%. The deutonymph and protonymph of the predator, *P. multidentatus* consumed more number of crawlers+females and males of the scale insect than the predator male (Plate X, Fig.1). The respective consumption rates of deutonymph on the crawlers + females and males were 25% and 0.3% and that of protonymph were 14% and 0.1%. Even though the larva of *P. multidentatus* showed high feeding potential than the male predator, it was not found to feed on the adult male stage of the pest, *A. destructor*. The larva consumed 1% of crawlers + females of the scale insect.

The rates of consumption of larva, protonymph, deutonymph, male and female of *P. multidentatus* on *D. minutus* were 15%, 34%, 58%, 38% and 64% respectively (Table XXVII). The highest feeding potential on *D. minutus* was shown by the adult female of *P. multidentatus* (Plate X, Fig.2). The adult female often consumed 64% individuals of *D. minutus*, comprising 78% N_1, 77% N_2, 61% prepupa + pupa and 36% adults of *D. minutus*. The respective

consumption rates of the predator deutonymph on N_1, N_2, prepupa + pupa and adult of *D. minutus* were found to be 74%, 71%, 58%, 14% and those of the adult male were 62%, 39%, 39% and 10% respectively. The larva and protonymph of the predator consumed 54% & 17% N_1, 40% & 26% N_2, 36% & 15% prepupa + pupa and 4% &1% adults of *D. minutus*/day (Table XXVII).

II.B.v. Feeding potential of life stages of *Phytoseius rachelae*

Results of field studies on the feeding potential of the various life stages of *P. rachelae***,** on the mite and insect pests revealed its preference to insect pests and eriophyid mites rather than the spider mite pests. It was observed that the different life stages of the predator preferred the eggs and larval stages of the spider mite pests as that of other phytoseiid mites under study. The different life stages of the predator viz. the adult female, adult male, deutonymph, protonymph and larva consumed 31%, 9%, 29%, 9%, and 5% eggs of the mite pest, *T.neocaledonicus*. While the respective rates of consumption on the larva of the pest were 16%, 5%, 14%, 5% and 2%. But the total consumption rates of the different life stages of the predator viz. the adult female, adult male, deutonymph, protonymph and larva on *T. neocaledonicus* were found to be less, being 19%, 5%, 16%, 5% and 2% respectively (Table XXVIII). The preference to the proto- and deutonymphal stages and adults of the pest mites by the different life stages of the predator was comparatively very low and the larva did not feed on the adult stage of

the pest mite (Plate XI, Fig.1). The percentage consumption of the adult female of the predator on the proto and deutonymphal stages and adults of *T.neocaledonicus* were 16%, 12% and 11% respectively. While male predator fed 3% protonymphs, 1% deutonymphs and 1% adults of *T.neocaledonicus.* The predator larva was found to consume 1% protonymphs and 0.1% deutonymphs of the pest mite in a period of 24 hours and protonymph of the predator consumed 3% protonymphs, 1% deutonymphs and 0.1% adults of *T. neocaledonicus*. The percentage consumption of the predator deutonymph was 9% protonymphs, 7% deutonymphs and 7% adults.

The percentage consumption of different life stages of *P. rachelae* on different life stages of the pest mite, *T. cinnabarinus* are presented in Table XXIX. The larva of *P. rachelae* was found to consume 4% eggs, 3% larvae, 1% protonymphs of *T. cinnabarinus* while the protonymph of *P. rachelae* devoured a total of 5% individuals of *T. cinnabarinus* comprising 8% eggs, 5% larvae, 2% protonymphs, 0.3% deutonymphs and 0.1% adults/day. While the male predator of *P. rachelae* consumed a more or less similar number (4%) of *T. cinnabarinus*/ day with 7% eggs, 5% larvae, 4% protonymphs, 2% deutonymphs and 0.3% adults. The adult female and deutonymph showed little more feeding rate (Plate XI, Fig.2). The respective rates of consumption of eggs, larvae, protonymphs, deutonymphs and adult of *T. cinnabarinus* consumed by the adult female predator were 25%, 16%, 15%, 12%, 10%,

and by a deutonymph of *P. rachelae* were 24%, 12%, 8%, 7% and 5% respectively.

The predatory potential of *P. rachelae* on the two species of tetranychid pests viz. *T. fijiensis* and *T. cinnabarinus* was more or less equal as observed during the study (Plate XII, Fig.3). The total consumption rates of individuals of *T. fijiensis* consumed by the adult female, male, deutonymph, protonymph and larva of *P. rachelae* were found to be 16%, 5%, 13%, 5%, 2% respectively. The different stages of the predator viz. female, male, deutonymph, protonymph and larva consumed 22%, 9%, 22%, 8%, 4% eggs and 14%, 4%, 12%, 5% and 3% larvae of the pest respectively. The adult stages of the predator i.e., the adult female and adult male consumed 17% & 2% deutonymphs; 14% & 1% adults of *T. fijiensis* respectively. The life stages of the prey, viz. the protonymph, deutonymph and adults devoured by the predator deutonymph was 10%, 7% and 4% respectively. The protonymph consumed 3% protonymphs, 0.3% deutonymphs and o.1% adults of the pest mite. The predator larva exhibited a total rejection of the adult stages of the prey mite but it consumed 1% protonymphs and 0.1% deutonymphs of *T.fijiensis*/day (Table XXX; Plate XI, Fig.3).

The total consumption rate of *P. rachelae* was comparatively greater on the tenuipalpid mite, *R. indica* than that of the spider mites (Plate XII, Fig. 3). However, the feeding preference and feeding potential of individual stages of the predator on the different life stages of *R. indica* were comparable to that

of other pests offered (Plate XII, Fig.3). The percentage consumption of different stages of *P. rachelae* on *R. indica* is presented in Table XXXI (Plate XI, Fig.4). The total percentage consumption of different life stages of the predator, *P. rachelae* viz. larva, protonymph, deutonymph, adult male and adult female of on the pest *R.indica* were 2%, 7%, 14%, 6%, and 35% respectively. All life stages of the predator preferred the eggs and larvae of the prey mite when compared to the other stages. The rates of consumption of larva, protonymph, deutonymph, and adult male and female of the predator *P. rachelae* on the eggs of *R.indica* were 4%, 12%, 23%, 11% and 42% respectively. The larva of *P. rachelae* totally rejected the deutonymph and adult stages of the pest. It consumed 3% larvae and 2% protonymphs of *R. indica* with in a period of 24 hours. The protonymph of *P. rachelae* also consumed the egg, larva, protonymph and deutonymph of *R. indica*. It consumed 7% larvae, 4% protonymphs and 2% deutonymphs of *R. indica*. The deutonymph, adult male and adult female of *P. rachelae* devoured 9%, 4% & 28% protonymphs; 7%, 4% & 13% deutonymphs and 4%, 1% & 11% adults of *R. indica* respectively.

Table XXXII describes the consumption rates of individual life stages of *P. rachelae* on different life stages of *A. destructor*. Feeding preference of the predator, *P. rachelae* towards the different life stages of the scale insect, *A. destructor* followed a similar pattern of the other phytoseiid mites under study. Similarly the feeding rates of individual life stages of the predator also

resembled that of other phytoseiids. The adult female of *P. rachelae* consumed 56% egg mass, 35% crawlers + females and 1% males constituting a total of 32% individuals of the scale insect pest. The percentage consumption of deutonymph of *P. rachelae* was less than that of the adult female but it devoured a total of 18% individuals of the pest comprising 38% eggmass, 17% crawlers+ female and 4% males (Plate XII, Fig.1). While the adult male of *P. rachelae* consumed 7% egg mass, 0.1% crawlers+ female and 0.1 % males of *A. destructor* which was found more or less similar to the feeding rate of larva of *P. rachelae* (5% egg mass, 0.3% crawlers+ female and 0% males). The feeding potential of the protonymph of *P. rachelae* was found as higher than that of the adult male of the predator (Plate XII, Fig. 3). The percentage consumption on the egg mass, crawlers+ female and males by the protonymph was 21%, 5% and 0.1% respectively.

The feeding efficiency of different life stages of *P. rachelae* on different life stages of *D. minutus* and its preference towards the same followed a similar pattern as that on other pests (mite pests) (Plate XII, Fig.3). The larva, protonymph, deutonymph, adult male and adult female stages of the predator consumed a total of 9%, 25%, 47%, 33% and 60% individuals of *D. minutus* in 24 hours (Table XXXIII; Plate XII, Fig.2). The female predator was detected as the most active stage and it consumed 72% N_1, 69% N_2, 54% prepupa + pupa and 33% adults of *D. minutus*, while an adult male predator devoured 49% N_1, 39% N_2, 33% prepupa+pupa and 9% adults of the thysanopteran pest *D. minutus*. The average consumption rates

of different life stages of *D. minutus* viz. N_1, N_2, prepupa + pupa and adults by the predator deutonymph recorded during the study were 65%, 57%, 41% and 8% respectively. The protonymph and larva of the predator consumed a relatively low number of *D. minutus*. The larva consumed 15% N_1, 14% N_2, 0.3% prepupa + pupa only and it was proved inefficient to feed on the adults of the prey, while the protonymph was found to devour 37% N_1, 33% N_2, 26% prepupa + pupa, 1% adults of *D. minutus* respectively.

II. C. STUDIES ON THE BREEDING BIOLOGY OF PHYTOSEIID MITES

Breeding biology of all the 5 species of predatory mites viz. *A. largoensis, A. guptai* sp.nov., *P.multidentatus, T. suknaensis* and *P.rachelae* followed a similar pattern, though species specific variations could be observed in the durations of individual instars as well as the total duration of F_1 generations. Hence the various processes which were found common to all species involved in the breeding biology like mating, oviposition, hatching, quiescence, moulting etc. have been presented together here while the durations of the various stages of individual species have been dealt with separately.

II.C.i. Developmental Pattern

All the 5 species of phytoseiid mites considered for breeding studies were proved pseduo-arrhenotokous in which the males though haploid, developed from fertilized eggs. The population sex ratio could be recorded as

female biased, with the number of females being 3-4 times greater than that of the males. The initiation of breeding biology was marked by the occurrence of mating, which appeared as a pre-requisite, leading to the production of eggs and subsequent oviposition by females. The life cycle of all the species comprised of the eggs, larva, protonymph, deutonymph and adult stages with intervening inactive (quiescent) phases between the larva and protonymph, protonymph and deutonymph and deutonymph and adult respectively. Each of the active stage was emerged through moulting of the quiescent phase of the preceding stage.

II.C.ii. Mating

The process of mating included more or less similar patterns of behaivour in all the 5 species of predatory mites studied. Mating could be observed immediately after the emergence of the adult female. The mating behaviour in all species was found to be comprised of searching for the female, orientation towards the mate, copulatory behaviour, and post-copulatory behaviour. The males exhibited high searching behaviour for females and they established contact with the females with their first pair of legs. This was followed by the orientation phase, in which the males were succeeded to climb over the dorsum of the females. The females were found moving about carrying the males on their dorsum. At the same time the males displayed several modes of behavior until they could establish a venter-to-venter position (Plate II, Fig. 2A) with the females. Meanwhile the males

also made a firm grip over the females with their legs and in that posture the posterior hysterosomal margin of the males could be seen beyond that of the female. Such paired mites were found moving very fast on the leaf surface. In paired conditions the female predators were found feeding on the eggs and larvae of the prey mites. Then the male of each species was found lifting up the hysterosoma of the respective female, which appeared to move up and down. Soon after copulation, the male moved away from the female. A single male was found to mate with more than one female during its life span and the multiple mating in females could be observed only in the genus *Amblyseius*. The duration of mating process was found to vary in different species. The entire process was found to complete within 30-45 minutes in *A. largoensias*, *T. suknanensis* and *P. multidentatus* while it was more prolonged 2.40 – 3.00 hours in *A. guptai* sp. nov. and 3-4 hours in *P. rachelae*.

II.B.iii. Pre-oviposition, Oviposition and Post-oviposition Periods

The life span of each mated female was found to comprise of three periods viz. pre-oviposition, oviposition and post-oviposition periods. Pre-oviposition period was the time taken by an adult mated female to initiate the process of egg deposition. The duration of pre-oviposition period of the 5 species of predatory mites selected for the current study showed variation with respect to the difference in the nature of food items consumed. The period of egg deposition was recognized as the oviposition period. Adult females of all species were found laying eggs on the lower surface of the

leaves of the host plants on which the prey mites were found distributed. Eggs were laid singly or in pairs in horizontal position generally, closely apposed to the mid rib or leaf hair tip or on the silken thread of the web spun by the prey mites or any where on the leaf surface. The eggs were found glued to the leaf surface by a sticky substance secreted by the female. The period of oviposition, the number of eggs laid/day and total number of eggs laid by a single female etc. also showed variation with respect to the species and food item consumed. The oviposition period of the adult females of all the 5 species were succeeded by the post-oviposition period. This period was recognized by a reduced rate of food consumption in all the species, followed by an inactive phase, leading to death.

II.C. iv. Hatching and Emergence of Larva

Freshly laid eggs of all the 5 phytoseiid species appeared oval, transparent, shining and larger than the prey eggs. During progressive days of incubation, eggs gradually became translucent and then opaque. Just before hatching, the eggs became somewhat dirty white in colour. Initiation of the process of hatching was marked by the appearance of a few wrinkles on lateral sides of the egg. These wrinkles then were found to run downwards to a point. Then a slit was formed at this point. The larval hysterosoma was found protruded out through this slit. Through the wriggling movements of the larva, the slit got widened and the larva protruded its 2^{nd} and 3^{rd} pairs of legs through the slit. Later, the larva was found trying to escape out of the

egg shell by the vigorous tilting of the legs and wriggling movements of the body which resulted in the complete extrusion of its body from the egg case by a backward emergence. Finally the egg case got removed by the wriggling movement of the 2nd pair of legs of larva. Such egg cases were found attached to the mouthparts and first pair of legs of larva, in several instances. The process of hatching was completed within 30-60 minutes in all cases.

II.C.v. Quiescent Periods (Plate II, Fig. 2B)

All active developmental stages of the 5 predators selected for the current study were found to be followed by an inactive or quiescent phase. The initiation of quiescence was marked by the cessation of feeding activity and the immature stage became sluggish in nature. Such sluggish life stages remained stationary on the leaf bits and on disturbance, displayed highly restricted movements. At the onset of the quiescent phase, the body of all instars became more or less swollen in appearance and opaque in nature. As the quiescent period proceeded, they assumed a characteristic posture by stretching the mouth parts and 1st pair of legs in a forward direction and the posterior legs were found spread in a backward direction. The posterior end of the body was found raised slightly. The mean duration of quiescence in the different life stages of all the 5 species of phytoseiids showed considerable variation with respect to the difference in species and also with the type of food they consumed.

II.C.vi. Moulting (Plate II, Fig.2C)

The emergence of each of the active life stage of the predator from the respective quiescent phase was resulted through the process of moulting. Moulting process was found more or less similar in all species of the phytoseiids studied. The process was initiated with the appearance of a longitudinal slit at the posterior end of the hysterosoma. The slit further proceeded anteriorad and the 4^{th} and 3^{rd} pairs of the legs of the moulting instars were found extruded through the split skin. Through the gradual and constant movements of the legs and the wriggling movements of the body of the moulting individual, the complete separation of the exuvium was resulted, leading to the emergence of the succeeding instar. The left out exuviae were very delicate and appeared as wrinkled.

II.D. DURATION OF DEVELOPMENTAL STAGES

II.D.i. Duration of Developmental Stages of *Amblyseius largoensis*- Oviposition, Pre-oviposition and Post-oviposition periods

The mean durations of the pre-oviposition period of *A. largoensis* on different diets showed only slight variations (Table XXXIV). When the prey offered was *T. neocaledonicus*, the mean duration was 2.1 days, while it was found slightly extended when the diet constituted individuals of the prey mite, *R.indica* (2.4days), the scale insect *A.destructor* (2.5 days) and pollen grains of *R.communis* (2.6 days). On the other hand the oviposition period of *A. largoensis* showed considerable variation depending on the diet difference.

The mean durations of oviposition period was 14.8 days, 13.5 days and 13.3 days on animal diets like *T. neocaledonicus*, *R. indica* and *A. destructor* respectively while it got decreased to 9.7 days when fed on plant diet comprising pollen grains of *R. communis*. The number of eggs laid by a single female of *A. largoensis* per day also showed considerable variation with respect to the variations in the food item provided (Plate XIV, Fig.2). The minimum number of eggs was found deposited on the 1st and 2nd days of oviposition under laboratory conditions. The maximum number of eggs laid per day also was great on animal diet and it was found to be 3 eggs each on a diet of *T. neocaledonicus* and *R. indica* and 4 eggs on *A. destructor*. On a diet comprised of pollen grains of *R. communis*, the maximum number of eggs produced per day was 2. Qualitative variation in food drastically influenced the fecundity also, as the females of *A. largoensis* deposited an average number of 24.7 eggs, 24.1 eggs, 23.3 eggs and 7.2 eggs when fed on *T. neocaledonicus*, *R. indica*, *A. destructor* and *R. communis* respectively. The fecundity was lowest when the rearing was carried out on a diet of pollen grains of *R. communis* (Table XXXIV). Depending on the variations in the food item consumed, the post-oviposition period also showed slight variation in *A. largoensis*. The post-oviposition periods could be recorded as 4 days, when fed on *T. neocaledonicus* and *R. indica*, 4.2 days on *A. destructor* and 5.7 days on pollen grains of *R. communis* under the same temperature and humidity conditions (Table XXXIV).

Incubation Period

The incubation period also showed considerable variation with respect to the food items provided. The mean duration of incubation period was minimum (28.7 hrs) when the insect pest, *A. destructor* was offered as the diet. The duration of incubation period was found to be the maximum (36 hrs) when fed on the prey mite, *T. neocaledonicus*, while it was slightly lowered on *R. indica* (32 hrs). When fed on castor pollen, the incubation period could be recorded as 29 hrs, on an average (Table XXXV).

Larval period (Plate XIII, Fig. B)

The duration of active larval period of *A. largoensis* was the minimum on the plant diet, comprised of pollen grains of castor (19 hrs). As shown in table XXXV, slight variations could be recorded in the durations of the larval stage on the animal diets, the respective durations were 21.3 hrs, 19.7 hrs and 20.2 hrs on *T.neocaledonicus*, *R.indica* and *A. destructor* respectively. Following the active period of development, the larva passed through an inactive period called the 1^{st} quiescent phase. The respective durations of the 1^{st} quiescent phase also varied in accordance with the diet difference as 8.4 hrs, 7.6 hrs, 7.7 hrs and 6.7 hrs on diets of *T. neocaledonicus*, *R. indica*, *A. destructor* and pollen grains of *R. communis* respectively at a temperature of 30 ± 2^0C and 70 $\pm$ 2% RH (Table XXXV).

Protonymphal period (Plate XIII, Fig.C)

The first quiescent period was culminated with the process of moulting, leading to the emergence of the protonymph. Compared to the

larva, the protonymph was larger and was characterized by the presence of 4 pairs of legs. Protonymph was a more voracious feeder than the larva and the average duration of active protonymphal period of *A. largoensis* was the maximum when fed on the pest mite, *R. indica* (51.6 hrs). The protonymphal period appeared to be of the minimum duration when fed on the pest mite, *T. neocaledonicus* (39.4 hrs). The protonymphal period could be recognized as 49 hrs on the insect pest, *A. destructor*. While the protonymphal period on pollen of *R.communis* was observed as 44.4 hrs with the same experimental conditions. Following the active period, the protonymph became inactive and entered in to the 2nd quiescent phase. The duration of the 2nd quiescent phase of *A. largoensis* though was found varying with respect to diet difference, only slight difference could be observed (Table. XXXV).

Deutonymphal period (Plate XIII; Fig. D)

The 2nd quiescent phase got moulted into the deutonymph which could be distinguished from the adult predator by its small size and narrow abdomen. The female deutonymph was the second active feeding stage of the predator. The active deutonymphal period lasted for 69.8 hrs when fed on *T. neocaledonicus*, 70.6 hrs on a diet of *R. indica*, 68.5hrs on *A. destructor* and 59.5 hrs on pollen grains of *R. communis* (Table XXXV). Subsequently, the deutonymph entered into the 3rd quiescent phase, the duration of which also was subjected to difference in the diet. The mean durations of the 3rd quiescent phase were 5.6 hrs, 5 hrs, 4.8 hrs and 5.2 hrs, when fed on *T. neocaledonicus*, *R. indica*, *A. destructor* and pollen grains of *R. communis* respectively.

Longevity, Sex Ratio and Mortality

In *A. largoensis*, the sex ratio also was found influenced by the type of food consumed. The sex ratio was more or less same when rearing was carried out on *T. neocaledonicus* and *A. destructor* (7:3). The sex ratio could be recorded as 4:1 when development was completed on *R. indica* and pollen grains of *R. communis*. Similarly, the longevity of the male and female individuals of the predator also showed variation with respect to the food types. The most active feeding stages of *A. largoensis*, the adult females survived for 20 days when fed on *T. neocaledonicus* and *A. destructor* while a slight decrease in longevity could be observed on *R. indica* and pollen of *R. communis* (19.9 and 18 days respectively) (Table XXXIV). Diet difference was found exerting an influence on the mortality rate of individual life stages of the predator. It was observed that *A. largoensis* showed a highest mortality rate when fed on pollen of *R. communis* (75%). More survival was noted when reared on *T. neocaledonicus* where the mortality was the minimum (40%).

II.D.ii. Duration of developmental stages of *Typhlodromips suknaensis*

Pre-oviposition, Oviposition and Post-oviposition periods

Experimental studies on the feeding potential of *T. suknaensis* proved its efficacy as a potential predator of the mite pests, *T. neocaledonicus, T. fijiensis* and *R. indica* and the insect pests, *A. destructor* and *D. minutus*, in laboratory conditions of 30 ± 2^0C and 70 ± 2% RH. The species also completed its

development successfully on selected food items such as *T. neocaledonicus, R. indica* and *A. destructor*.

Table XXXVI illustrates the mean duration of the pre-oviposition period of *T. suknaensis* when reared on the mite pests, *T. neocaledonicus, R. indica, A. destructor* and the pollen of *R. communis*. The duration of pre-oviposition period was observed to decrease on the above diets in the sequence: *R. communis*> *R. indica*> *A. destructor*> *T. neocaledonicus* (Plate XV, Fig.1). The respective durations could be recorded as 3 days, 2.5 days, 2.5 days and 1.5 days on diets comprising *R. communis*, *R. indica, A. destructor* and *T. neocaledonicus* under the same experimental conditions. The oviposition period had the maximum duration when the predator was reared on *T. neocaledonicus*. The respective durations of oviposition period ranged from 13-15 days on *T. neocaledonicus*, 12-15 days on *R. indica* and *A. destructor* while it was 7-11 days on a diet of pollen of *R. communis* (Plate XV, V. Fig. 2). A considerable variation was observed in the number of eggs laid also by the predator mite according to the diet difference. The minimum number of eggs was found laid by the predator on the 1st and 2nd days of oviposition irrespective of the diet difference. It was observed that the daily egg production in *T. suknaensis* reached the peak level on the 5th and 6th days of oviposition, with the mean number being 3.4 and 3.7 eggs respectively, when fed on *T. neocaledonicus* (Plate XV, Fig.2). On a diet of *R. indica*, it was lowered, the mean number being 3.1 eggs. The rate of egg production

again got reduced when fed on the insect pest like *A. destructor* (2.9 and 2.5 eggs on 5th and 6th days respectively) (Plate XIV, Fig.2). A further reduction was occurred when the food was the pollen grain of *R. communis*, the average number of eggs laid were 1.8 eggs on the 4th day and 1.6 eggs on the 5th and 6th days of oviposition under the same experimental conditions (Plate XIV, Fig.2). The fecundity of *T. suknaensis* also was found influenced by the quality of the food. A higher fecundity was observed when the predator fed on the prey mite, *T. neocaledonicus* as the females deposited an average of 28.1 eggs, while the average fecundity on other food items could be found as 22.4 eggs, 18 eggs and 10.1 eggs on diets of *R. indica*, *A. destructor* and pollen of *R. communis* respectively (Table XXXVI). The post-oviposition period in *T. suknaensis* also showed variation with respect to the difference in food items consumed. The duration of post-oviposition period was more or less similar on diets of *R. indica* (3.2 days) and *A. destructor* (3.4 days) while it was found more extended on pollen grains of *R. communis* (3.7 days) and got slightly lowered when fed on *T. neocaledonicus* (2.5 days). Reduced food consumption could be observed during the post-oviposition period and the females appeared more sluggish (Table XXXVI; Plate XV, Fig. 1).

Incubation period

The incubation period was not found significantly affected by the diet difference in *T. suknaensis*. The mean duration of incubation could be recorded as 22.8 hrs on *T. neocaledonicus*, 23 hrs on *R. indica* and 21.9 hrs

on caster pollen. A slightly prolonged incubation period was noted (24 hrs) when *T. suknaensis* was reared on *A. destructor* (Table. XXXVII)

Larval period (Plate XVI, Fig. B)

The active period of the larva in *T. suknaensis* on different diets was recorded as 26.6 hrs on *T. neocaledonicus*, 28.3 hrs on *R. indica* and 24 hrs on *R. communis*. A further extended larval period could be observed when the insect prey, *A. destructor* was offered (32.2 hrs). Subsequent to larval period, the 1st quiescent phase was noted, which also showed slight variation. The respective duration of larval quiescence was observed to be 10.8 hrs on *T. neocaledonicus* while it was 11.4 hrs, 11.8 hrs and 10.4 hrs when reared on *R. indica*, *A. destructor* and pollen of *R. communis* respectively (Table XXXVII).

Protonymphal Period (Plate XVI, Fig. C)

The protonymph of *T. suknaensis* was comparatively a more voracious feeder than the preceding stage. The average duration of active protonymphal period was noted to be 44.6 hrs on *T. neocaledonicus*, 46 hrs on *R. indica* and 47.6 hrs on *A. destructor* but it was shorter (43.9 hrs) on pollen of *R. communis* (Table. XXXVII). Subsequently, the protonymph became inactive and entered into the 2nd quiescent phase, the duration of which was subjected to variation with respect to diet difference as 8.4 hrs, 8.5 hrs, 8.7 hrs and 7.9 hrs on diets comprising *T. neocaledonicus*, *R. indica*, *A. destructor* and *R. communis* respectively.

Deutonymphal Period (Plate XVI, Fig. D)

The 2nd quiescent phase was culminated by the process of moulting, leading to the emergence of the deutonymph. The active feeding period of deutonymph also varied with respect to the nutritional variation. More over, it also showed a longer active period than that of the larval and protonymphal stages. The duration of deutonymphal period was 70.9 hrs on *T. neocaledonicus*, 71 hrs on *R. indica* and 72.8 hrs on *A. destructor* while it was observed to be shorter when it was fed on *R. communis* (68.2 hrs). The respective quiescent period (3rd quiescence) of deutonymph was recorded to be 6 hrs on *T. neocaledonicus*, 8 hrs on *R. indica*, 8.3 hrs on *A. destructor* and 7.7 hrs on *R. communis* under the same experimental conditions of 30±2^{0}C and 70±2% RH (Table XXXVII).

Longevity, Sex ratio and Mortality

The sex ratio in *T. suknaensis* was found biased toward the females. The observed female-male ratio under laboratory conditions was 7:3 on *T. neocaledonicus* and *R. indica* and 4:1 on *A. destructor* and *R. communis*. Similarly, the longevity of the male and female individuals of the predator also showed variation with respect to type of food. But it was more or less same, when the predator was provided with *R. indica* (19.1 days) and *A. destructor* (19.3 days), while it was 18.2 days on *T. neocaledonicus* and 15.9 days on *R. communis* (Table XXXVI). *T. suknaensis* showed comparatively less mortality rate on the above food items. The observed

mortality rate was 25%, 30%, 30% and 35% on diets comprising *T. neocaledonicus, R. indica, A. destructor* and pollen of *R. communis* respectively under the same laboratory conditions of 30±2^{0}C and 70±2% RH.

II.D.iii. Duration of developmental stages of *Amblyseius guptai* sp.nov.

Pre-oviposition, Oviposition and Post-oviposition periods

Oviposition in *A. guptai* sp.nov. was initiated following a short period of pre-oviposition. Even though the pre-oviposition period of *A. guptai* sp.nov. was found more or less of equal duration on *T. neocaledonicus* (1.9 days), *R. indica* (1.7 days) and *A. destructor* (1.9 days), it showed much variation when it was reared on a diet of pollen of *R. communis* (2.8 days) (Table XXXVIII; Plate XVII, Fig.1). A similar result was obtained in the case of oviposition period also. The mean durations of oviposition period of *A. guptai* sp. nov. on varied diets like *T. neocaledonicus*, *R. indica, A. destructor* and pollen of *R. communis* were 11.7 days, 11.5 days, 13.2 days and 8.5 days respectively. (Table XXXVIII; Plate XVII, Fig. 1). The mean number of eggs laid by *A. guptai* sp. nov. appeared more or less the same on animal diets like *T. neocaledonicus* (20.4 eggs) *R. indica* (23.9 eggs) and *A. destructor* (28.5 eggs), but the fecundity was comparatively very low on a diet comprised of plant matter like pollen of *R. communis* (6.9 eggs). But the post-oviposition period of the predator was not found significantly affected by the diet difference. The mean post-oviposition period could be recorded as 3.6 days when fed on *T. neocaledonicus*, 3.2 days on *R. indica*, 3 days on

A. destructor and 3.8 days on pollen of *R. communis*, under the same laboratory conditions of 30± 2^0C and 70±2% RH (Table XXXVIII). However, the predator laid the maximum number of eggs on the 6th day of oviposition, being 2.9, 3.6 and 1 eggs when fed on *T. neocaledonicus, R. indicia* and *R. communis* respectively while it was on the 8th day of oviposition when fed on *A. destructor* (4 eggs) (Plate XVII, Fig.2).

Incubation period

The incubation period of *A. guptai* sp.nov.was found to be 29.8 hrs when fed on *T. neocaledonicus*, 27.4 hrs on *A. destructor* and 24.8 hrs on pollen of *R. communis* and it was still lower (22.08 hrs) when fed on *R. indica* (Table XXXIX).

Larval Period (Plate XVIII, Fig. B)

A. guptai sp.nov. showed considerable variation in the duration of its larval period with respect to the variation in the food item consumed. However, there was not much variation when it was fed on *T. neocaledonicus* and *R. indica* (18.3 hrs and 19.5 hrs respectively), while it was much prolonged, being 39.6 hrs when fed on *A. destructor* and 28.8 hrs on pollen grains of *R. communis* (Table XXXIX). The active feeding period of larva was followed by the 1st quiescent phase, which also was more or less same when the predator larva fed on all the food items provided. The respective duration of 1st quiescent phase could be noted as 12.3 hrs, 11.7 hrs, 12.4 hrs

and 11.8 hrs respectively on diets of *T. neocaledonicus*, *R. indica*, *A. destructor* and pollen of *R. communis* (Table. XXXIX).

Protonymphal Period (Plate XVIII, Fig. C)

Compared to the larval period, the duration of protonymphal period showed considerable variation with respect to the variation in the food. The active feeding period of protonymph of *A. guptai* sp.nov. was found to be in the order of *T. neocaledonicus* (33.2 hrs), *R. indica* (48.6 hrs), *R. communis* (52 hrs) and *A. destructor* (55.1 hrs). This active period of feeding was followed by the next inactive phase i.e., the 2nd quiescent phase, the duration of which was comparatively shorter as it was 6.8 hrs, 7.9 hrs, 6.9 hrs and 5.6 hrs when fed on *T. neocaledonicus, R. indica, A. destructor* and pollen grains of *R. communis* respectively (Table XXXIX).

Deutonymphal Period (Plate XVIII, Fig. C)

The 2nd quiescent phase was culminated by the process of moulting and subsequent emergence of the deutonymph. The active feeding period of the deutonymph also varied with respect to nutritional variations. The duration of deutonymphal period was 45.7 hrs when fed on *T. neocaledonicus*, while the same was 51.8 hrs, 65.3 hrs and 50.1 hrs when fed on *R. indica, A.destructor* and castor pollen respectively(Tables XXXIX). The deutonymphal quiescence (3rd quiescent phase) lasted for 5.4 hrs, 7.2 hrs, 6 hrs and 5 hrs respectively on diets of *T. neocaledonicus*, *R. indica*, *A. destructor* and pollen of *R. communis* (Table XXXIX).

Longevity, Sex ratio and Mortality

During the present work, it was observed that female population of the predator out numbered the male population both in laboratory and field conditions. The observed sex ratio in the laboratory conditions was the same (7:3) when fed on *A. destructor* and pollen of *R. communis*, while it showed some variation when fed on *T. neocaledonicus* (4:1) and *R. indica* (3:2). Similarly, the longevity of the male and female individuals of the predator also showed variation with respect to food types. The observed longevity under laboratory conditions was 17.2 days, 16.4 days and 18.1 days respectively when fed on *T. neocaledonicus, R. indica* and *A. destructor* respectively while it was found reduced on a diet of pollen of *R. communis* (15.1 days) (Table XXXVIII). *A. guptai* sp.nov. showed a lowest mortality rate of 20% on food items like *R. indica* and *A. destructor*, while it showed 50% mortality when fed on *T. neocaledonicus* and 63% mortality on pollen of *R. communis* under the same laboratory conditions of 30$\pm$ 2^0C and 70$\pm$ 2% RH.

II.D.iv. Duration developmental stages of *Paraphytoseius multidentatus*

Pre-oviposition, oviposition and post-oviposition periods

P. multidentatus, a potential predator of *D. minutus* in the field and laboratory conditions was found to complete its development, when provided with prey items like the pest mites, *T. neocaledonicus* and *R. indica* and the insect pest *A. destructor* in laboratory conditions of 30$\pm$ 2^0C and 70$\pm$ 2% RH.

But it could not complete its life cycle on artificial diets like, honey and pollen of *R. communis*. The process of oviposition was initiated by the mating process, which was followed by a short period, the so called pre-oviposition period. The mean duration of pre-oviposition period of *P. multidentatus* was found to be 2 days, and 2.5 days when fed on *T. neocaledonicus* and *R. indica* respectively while it was still shorter, 1.8 days when fed on *A. destructor* (Table XL; Plate XIX, Fig.1). The respective duration of oviposition period ranged from 6-9 days, 7-11 days and 6-10 days on diets comprised of *T. neocaledonicus*, *R. indica* and *A. destructor* respectively. (Plate XIX, Fig.2). The numbers of eggs laid by a single female of *P. multidentatus* also showed considerable variation with respect to diet difference. The minimum number of eggs was laid on the 1st and 2nd days of oviposition under experimental conditions. It was observed that *P. multidentatus* produced the maximum number of eggs on the 4th day, but it showed difference with respect to prey, being 1.5 when fed on *T. neocaledonicus* and 1.9 when fed on *R. indica*. But, when the prey was an insect-pest, maximum number of eggs could be laid on the 3rd day of oviposition, being 1.8 on an average (Plate XIX, Fig.2). The fecundity of *P. multidentatus* also was influenced by the food variation, as the females laid 7.5 eggs, 10.8 eggs and 8.3 eggs when fed on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively. (Table XL; Plate XIX, Fig.2). However, the post-oviposition period of *P. multidentatus* appeared to be more or less of the same duration when it consumed

T. neocaledonicus (4.1 days), *R. indica* (3.9 days) and *A. destructor* (3.1 days) under the same laboratory conditions (Table XL).

Incubation Period

The incubation period in *P. multidentatus* appeared some what of equal duration when it fed on *R. indica* (41.9 hrs) and *A. destructor* (41.06 hrs), while it was found reduced being 40.7 hrs when fed on *T. neocaledonicus* (Table XLI).

Larval Period (Plate XX, Fig. B)

The newly hatched larva appeared small, six legged, translucent, but with a comparatively sclerotized dorsum. The mean duration of active larval period was very less when offered with the prey, *T. neocaledonicus* (21.7 hrs). However, the duration of larval period got prolonged when offered with the prey mite, *R. indica* (44.8 hrs) and the insect pest, *A. destructor* (48.2 hrs) (Table XLI). Subsequently, the 1st quiescent phase which followed the larval period was of some what equal duration on diets of *R. indica* and *A. destructor* (5.5 and 5.2 hrs respectively) while it appeared shorter, being 3.6 hrs on a diet of *T. neocaledonicus*.

Protonymphal Period (Plate XX, Fig. C)

The 1st quiescent period was culminated with the process of moulting, leading to the emergence of the protonymph. The feeding potential of the protonymph was comparatively greater than the larval stage and the duration of active period was also found to be longer. The average duration of active

protonymphal stage was noted to be 40.3 hrs on *T. neocaledonicus* and 49.4 hrs on *R. indica* and 50.6 hrs on *A. destructor* (Table XLI). Subsequently, the protonymph became inactive and entered into the 2nd quiescent phase. A decrease in the duration of quiescent phase of *P. multidentatus* could be observed as the development proceeded. The respective mean durations of 2nd quiescent phase were 2.9 hrs, 5.3 hrs, 5.2 hrs on diets of *T. neocaledonicus, R. indica* and *A. destructor* respectively

Deutonymphal period (Plate XX, Fig. D)

The second quiescent phase on moulting led to the emergence of the deutonymph. The body of the deutonymph and adult of *P. multidentatus* appeared longer than broader, more or less hexagonal in shape with a rounded posterior end. The duration of deutonymphal period also showed variation with respect to diet difference. When fed on *T. neocaledonicus* the duration of deutonymph lasted for 65.5 hrs while the same was 70.2 hrs and 72.4 hrs on *R. indica* and *A. destructor* respectively. (Table XLI). After this long period of active feeding, the deutonymph became inactive and entered into the 3rd quiescent phase. The average duration of 3rd quiescent phase could be recorded as 2.7 hrs, 4.9 hrs and 3.9 hrs when it consumed *T. neocaledonicus*, *R. indica* and *A. destructor* respectively.

Longevity, Sex ratio and Mortality

The sex ratio of *P. multidentatus* followed the same pattern as that of the other phytoseiid mites studied. The observed sex ratio (Female: Male), on

different food items, like *T. neocaledonicus*, *R. indica* and *A. destructor* were 3:2, 4:1, 4:1 respectively. Similarly, the longevity of the male and female individuals of the predator also showed variation with respect to food type. The observed mean longevity on different food items were 13.8 days, 15.6 days, 12.6 days on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively (Table XL). A more or less equal mortality rate could be met with on *T. neocaledonicus* (45%) and on *R. indica* (43%) under laboratory condition of 30 ± 2^0C and 70±2% RH, while it was 30% when fed on *A. destructor* under the same laboratory conditions.

II.D.v. Duration of developmental stages of *Phytoseius rachelae*

Pre-oviposition, oviposition and post-oviposition periods

P. rachelae was a phytoseiid predator, the population of which was found flourishing well with that of the eriophyid mite, *A. adoratus* which produces erinea on the leaves of the terrestrial weed, *C. odorata*, under field conditions. Its population abundance in the field and ease of accessibility prompted to undertake studies on *P. rachelae* to disclose its developmental pattern and predatory potential on some selected mite and insect pests viz. *T. neocaledonicus*, *R. indica* and *A. destructor* in laboratory conditions of 30 ± 2^0C and 70± 2% RH. *P. rachelae* was found to complete its life cycle on *T. neocaledonicus*, *R. indica* and *A. destructor* and it showed variation in its developmental aspects with respect to difference in the food items provided. Table XLII; Plate XXII, Fig.1 illustrates the pre-oviposition, oviposition and post-oviposition periods of *P. rachelae* on different food items like

T. neocaledonicus, *R. indica* and *A. destructor*. As shown in the table, the mean pre-oviposition period of *P. rachelae* was found to be 2.8 days, 2 days and 1.3 days when fed on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively.

P. rachelae showed a similar range in oviposition period also (10-12 days) when fed on *T. neocaledonicus* and *A. destructor* while it was 9-12 days when fed on *R. indica* (Plate XXII, Fig. 2). The respective durations of post-oviposition period could be recorded as 3.4 days, 2.8 days and 2.7 days when fed on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively. The average fecundity of *P. rachelae* also showed considerable variation with respect to the variations in the food item consumed. The rate of fecundity of the predator also varied with respect to the quality of the food it consumed. An average number of 18.9 eggs, 16.6 eggs and 17.8 eggs were found produced by the predator when offered with diets comprising. *T. neocaledonicus*, *R.indica* and *A.destructor* respectively, under the experimental conditions of 30 ± 2^0C and 70±2% RH (Table XLII). The daily egg production of *P.rachelae* reached the maximum level on the 6^{th} day of oviposition when fed on *T. neocaledonicus* (3.4 eggs), *R. indica* (2.8 eggs) and *A. destructor* (3 eggs) respectively (Plate XXII, Fig. 2).

Incubation Period

Table XLIII illustrate the duration of development of different life stages of *P. rachelae* viz. egg, larva, protonymph, deutonymph and total

duration on varied food items like *T. neocaledonicus*, *R. indica* and *A. destructor* respectively. The average incubation period was observed to be more or less similar on diets, *T. neocaledonicus* (29.6 hrs) and *R. indica* (30.7 hrs) whereas it was lower being 26.6 hrs when fed on *A. destructor* (Table XLIII).

Larval Period (Plate XXI, Fig. B)

The mean duration of active larval period was 25.3 hrs, 23 hrs and 23 hrs when fed on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively. (Tables XLIII). The duration of 1st quiescent phase of *P. rachelae* was more or less similar on all diets viz. *T. neocaledonicus* (3.3 hrs), *R. indica* (3.2 hrs) and *A. destructor* (3 hrs) under the same experimental conditions.

Protonymphal period (Plate XXI, Fig. C)

The duration of active feeding period of the protonymph of *P. rachelae* was decreased when the predator was reared on *T. neocaledonicus*, *R. indica* and *A. destructor* and the durations recorded were 47.5hrs, 45.2hrs and 46.6 hrs respectively, under laboratory conditions of 30 $\pm$ 2^0C and 70 $\pm$ 2% RH (Table XLIII). The quiescent period of the protonymph lasted for 7 hrs, when fed on *T. neocaledonicus*, where as it was 6.4 hrs on *R. indica* and 5.5 hrs on *A. destructor* under the same experimental conditions (Tables XLIII).

Deutonymphal Period (Plate XXI, Fig. D(1))

The body of the deutonymph and adult of *P. rachelae* appeared longer than broader, and more or less hexagonal in shape. The deutonymph as in

other phystoseiid predators under study was the second active feeding life stage of *P. rachelae*. The duration of this period was found to be comparatively longer, but it was observed to decrease in the order 73.5 hrs, 71.5 hrs and 68 hrs when fed on *T. neocaledonicus*, *R. indica* and *A. destructor* respectively (Table XLIII). After this period of active feeding, the deutonymph became inactive and subsequently entered into the 3rd quiescent phase. The respective durations of 3rd quiescence were 8 hrs, 6.8 hrs and 6 hrs on diets comprising *T. neocaledonicus*, *R. indica* and *A. destructor* respectively.

Longevity, Sex ratio and Mortality

Under laboratory conditions, the number of females of *P. rachelae* was found out numbering that of the males. The observed female-male ratio on different diets like *T. neocaledonicus*, *R. indica* and *A. destructor* was 7:3, 7:3 and 4:1 respectively. Similarly, the longevity of the male and female individuals of the predator also showed variation with respect to the diet difference. The mean longevity on different food items could be recorded as 17.2 days on *T. neocaledonicus*, 14.8 days on *R. indica* and 15 days on *A. destructor* under the same laboratory conditions of 30 ± 2^0C and 70 $\pm$ 2% RH (Table. XLII). The mortality rate of individual stages of *P. rachelae* also showed considerable variation with respect to food variation. A high rate of mortality was observed on *R. indica* (52%), while it was 49% on *T. neocaledonicus*. A comparatively low rate of mortality (35.5%) could be accounted when *A. destructor* was offered as the food item under the same experimental conditions.

II E. COMPARATIVE STUDIES AND STATISTICAL ANALYSIS ON THE BREEDING AND FEEDING BIOLOGY OF PHYTOSEIID MITES

The results of the studies carried out on the development and feeding biology of 5 species of phytoseiid mites viz. *A. largoensis*, *T. suknaensis*, *A. guptai* sp. nov. *P. multidentatus* and *P. rachelae* were subjected to statistical analysis following, Analysis of Variance (ANOVA) in order to test whether the observed variations in developmental parameters were significant or not. Statistical analysis was also found essential to compare the significance of predatory potential of individual species of predator mite included in the study.

Results of laboratory studies on the development of *A. largoensis* enabled to record a shortest duration of incubation period when fed on insect pest *A. destructor* and pollen of *R. communis* (28.9/29.9 hours) but it was found more extended on the pest mites *T. neocaledonicus* and *R. indica* (36/32 hours). However, the duration of larval period did not show any significant difference with respect to food variation (Plate XXIII, Fig. 2). The observed duration of larval period ranged from 19.6 – 21.3 hours. The active durations of protonymphal and deutonymphal periods showed significant differences in accordance with the difference in food items consumed (Plate XXIII, Fig.2). The lowest deutonymphal period was observed on the food pollen grains of *R. communis* (59.5 hours) where as it was more or less same

on animal diets, which ranged from 68.5-70 hrs. But the inactive phases of *A. largoensis* not showed much variation with respect to variation in food item (Plate XXIII, Fig. 2). Total duration of development of *A. largoensis* also showed significant difference with respect to diet variation ($F = 10.75$, $P < 0.01$) (Plate XXIII. Fig.1). Lowest duration was recorded on pollen or *R. communis* (171.7 hrs) but on which the predator exhibited highest mortality/escape rate (75%), lowest fecundity (7.2 eggs) and also longevity (18 days) (plate). A more or less same or slightly higher developmental time, fecundity, longevity and survivorship could be recorded on animal diets, viz. *T. neocaledonicus, A. destructor* and *R. indica* (Table XXXIV; Plate XXIII, Figs. 1&2).

Compared to other phytoseiid mite under study, *T. suknaensis* showed the lowest mortality/escape rate in the laboratory conditions (25% - 35%) on different food items. The species showed highest fecundity on the pest mite, *T. neocaledonicus* by producing 28.1 eggs/mite in an average 14.2 days of oviposition (Table XXXIV), whereas on *R. indica* and *A. destructor*, the predator produced 22.4 eggs/mite and 18 eggs/ mite respectively in an average of 13.4 days of oviposition. Compared to the phytoseiid predators, studied *T. suknaensis* produced more number of eggs (10.1 eggs/mite) on the plant diet formed on the pollen of *R. communis* (Table XXXVI). Plate XXIV, Fig.2 illustrates the duration of development of life stages of *T. suknaensis* on different food items. As shown in the plate, animal diets did not induce any

significant differences in the incubation period in *T. suknaensis*. Similar observations were obtained in the case of larval period on all food items except that of *A. destructor*, where the period was more extended (32 hrs). The active period of protonymph was longer on a diet of *R. indica* and *A. destructor* (46/47.6 hrs) but was found to be shorter on *T. neocaledonicus* (44.6 hrs) and pollen grains of *R. communis* (43.9 hrs). Similar influence of diet was also observed on the durations of deutonymphal and quiescent phases also in *T. suknaensis* (Plate XXIV, Fig.2). Total duration of F_1 generation is showed significant difference with respect to difference in food items consumed ($F=57.63$, $P<0.01$) (Plate XXIV, Fig.1). Development was found comparatively fastest on the prey mite, *T. neocaledonicus* and the plant diet, *R. communis*, whereas prolongation of development was observed on animal diets, *R. indica* and *A. destructor* (Plate XXIV, Fig.1).

Comparative analysis on the developmental patterns in *A. guptai* sp. nov. on different food items significant differences enabled to record among the food items ($F= 110.5$ $P<0.01$). The longest duration could be on the scale insect *A. destructor* followed by pollen of *R. indica* and *T. neocaledonicus* (Plate XXV, Fig.1). When the predator showed high mortality/escape ratio on *T. neocaledonicus* and pollen of *R. communis*, comparatively higher survivalship was observed *R. indica* and *A. destructor* (80%). Similarly a highest fecundity was also observed on diets of *R. indica* (23.9 egg/mite) and *A. destructor* (28.5 eggs/mite) were as low egg production was noted at produced only (20.4 egg/mite) on *T. neocaledonicus* and *R. communis* (6.9

eggs/mite). A higher longevity was also observed on *A. destructor* (18.1 days) while it ranged from 15.1 – 17.2 days on *R. communis, R. indica* and *T. neocaledonicus* (Table XXXVIII). The incubation period of *A. guptai* ranged from 22-29 hrs on different diets, while the active periods of larva protonymph and deutonymph were found significantly influenced by the variations in food item (Plate IIf). The duration of inactive phases of *A. guptai* was more or less comparable on all food items even though slight variations could be observed in the same (Plate XXV, Fig.2).

Analysis of univariance (ANOVA) revealed significant influence of food/prey species on the total developmental time, developmental time of instars and different reproductive aspects of P. multidentatus ($P< 0.01$) (Plate XXVI, Fig.1). *P. multidentatus* successfully completed its development on all food items provided except pollen grains of *R. communis*. The total developmental time from egg to adult was found shorter when the predator was fed with the pest mite, *T. neocaledonicus* and a longer duration of development was recorded on a diet of *A. destructor*, the scale insect pest (Plate XXVI, Fig.1). Additionally, *P. multidentatus*, showed significant variation in the pre-oviposition, oviposition and post-oviposition periods with respect to variation in food items consumed ($F = 3.086$, $P<0.01$). Highest fecundity was observed on the diet, *R. indica* (Plate XXVIII, Fig.2), with a high rate of oviposition and longevity period (Table XL), followed by *T. neocaledonicus* and *A. destructor* with a more or less similar reproductive parameters. Development periods of all life stages of *P. multidentatus* were

found influenced by the food items consumed, except at the egg stage. The incubation period of *P. multidentatus* was more or less the same on all the food items consumed (Plate XXVI, Fig.2), But the quiescent phases/inactive period of the predator were found not much influenced by the diet difference (Plate XXVI, Fig. 2) being fallen in the same ranges.

P. rachelae on the other hand took longer time to complete its development from egg to adult, on a diet of *T. neocaledonicus* and shorter time on *R. indica* (Plate XXVII, Fig.1). But the variations in the duration of development of *P. rachelae* on different food items were also found to be significant at $P < 0.01$ level. The species showed higher fecundity and longevity on *T. neocaledonicus* when compared to the other food items (Table XLII). The duration of development of the different life stages of *P. rachelae* viz. egg, larva, protonymph and deutonymph also showed significant difference among food items (Plate XXVII, Fig.2). All stages of the predator except the protonymphal stage appeared to have shorter duration on the scale insect pest, *A. destructor* while the protonymph completed its development with the shortest time when it consumed *R. indica*. The 1st quiescent phase of the predator was found more ore less similar on all food items provided, while the 2nd and 3rd quiescent phases were found more extended on diets of *T. neocaledonicus* and *R. indica* (Plate XXVII, Fig.2).

Comparative analysis of the total developmental time of the five species of predators revealed that the total developmental time was not uniform with respect to the food items they consumed. But the feeding potential and feeding preference of different life stages of the predators

followed a general pattern irrespective of diet variation. The adult female was the most voracious life stage with maximum predatory potential in all the 5 species studied, while the larva constituted the weakest one. The feeding potential of the different life stages of the predators increased in the order of Larva< protonymph<male<deutonymph<adult male. Among the different life stages of the pests offered as the test food items, the eggs constituted the most preferred stage white the adults constituted the least preferred one.

A. largoensis, the most common phytoseiid predator encountered during the survey, showed its highest feeding potential on *R. indica* followed by *T. cinnabarinus* and *T. neocaledonicus*, while it stook shortest time to complete its life cycle from egg to adult on *A. destructor* to which the predator showed least preference. At the same time, the number of eggs laid/female mite was found not much influenced when the predator reared on animal food items. The new phytoseiid species included in the study viz. *A. guptai* sp. nov., which showed close morphological resemblance to *A. largoensis* was proved as an active predator of all the pest species offered, with a highest preference to *R. indica* and a more or less similar feeding potential (61%-67%) towards the spider mite pests. But it showed the highest fecundity on the insect pest, *A. destructor* (28.5 eggs/mite), on which it showed a total percentage consumption of 48%. The shortest period of development of the predator could be recorded on a diet of *T. neocaledonicus* with the fecundity of 20 eggs/mite, which was lower when compared to those on *A. destructor* and *R. indica* (Plate XXVIII, Fig. 1 & 2).

Among the five species of phytoseiid mites studied, *T. suknaensis* exhibited the highest feeding potential and fecundity on *T. neocaledonicus*. It also showed a more or less similar predatory behaviour on all other pest species provided. The feeding potential of *T. suknaensis* was found to decrease in the sequence of *T. neocaledonicus*> *R. indica*> *T. fijiensis*> *T. cinnabarinus*> *A. destructor*> *D. minutus. P. multidentatus* and *P. rachelae*, the other two phytoseiid mites studied showed least preference to pest mites compared to insect pests, with a more or less same rate of egg deposition (Plate XXVIII, Fig. 2). The influence of food on the developmental time of the phytoseiid predator and fecundity was not prominent in all cases, but a positive relation between the food consumption and fecundity was clearly observed, as higher fecundity was recorded on higher rates of food consumption. Comparative analysis made on the biological studies of *A. largoensis*, *A. guptai* sp. nov. and *T. suknaensis* enabled to record a shortest duration for *A. largoensis* followed by *A. guptai* sp. nov. and *T. suknaensis* (Plate XXVIII, Fig.1). But, *T. suknaensis* showed high survivalship and fecundity on pollen of *R. communis* than *A. largoensis* and *A. guptai* sp. nov.

III. MORPHOLOGICAL STUDIES OF PHYTOSEIID MITES

III. A. GENERAL MORPHOLOGY AND TERMINOLOGY

The body of any predatory mite is divided into two distinct parts, the Gnathosoma and Idiosoma. The gnathosoma bears the mouth parts, a pair of

chelicerae and a pair of pedipalp. The mouth is surrounded by the palpi and chelicerae. The gnathosoma is covered by a thin shield called tectum or epistome, which varies in shape.

III A. i. Mouthparts (Plate XXX, Fig. B & C)

(a) Chelicerae – The chelicerae of phytoseiid mites are of chelate type, terminated in a chela which is provided with two digits, a dorsal fixed digit and a ventral movable digit. The number of teeth varies with species. The fixed digit bears a process called *pilus dentilis*. In males, the movable digit of each chela bears a process called the spermatophoral process (Plate XXX, Fig. B).

(b) Pedipalpi – Coxae of palpi are fused together to form a basal shield known as basis capituli. The segments of each palpus are named as that of legs, viz. coxa, trochanter, femur, genu, tibia and tarsus.

III A.ii. Idiosoma (Plate XXIX, Fig. A)

Idiosoma is covered with a dorsal shield which may be entire or divided transversely. It is furnished with the following sets of setae.

a. **Vertical Setae (J_1):** One pair of setae, anterior in position on the dorsal shield.
b. **Clunal setae (J_5):** One pair, posterior in position on the dorsal shield.
c. **Dorsocentral Setae (j-J)**; Paired setae present on the central region of dorsal shield. Generally 3 pairs are present, 4^{th} and 5^{th} pairs may also be present.

d. **Mediolateral setae (z-Z)**: First pair of median setae is always present at level mid way between j_5 and j_6. Second pair of median setae if present, is situated on the proscutum of the shield. At the posterior region, one pair of setae is present medially.

e. **Dorsolateral setae (s-S)**: The number of dorsolateral setae varies with species. A maximum number of 12 may be present on each side.

f. **Sub lateral setae (r_3 and R_1)**: Two pairs of sub lateral setae (r_3 and R_1) are present on the membrane lateral to the dorsal shield. The presence or absence of r_3 and R_1 may be species specific.

III A. iii. Venter (Plate XXIX, Fig. B)

The ventral side of a phytoseiid mite possesses the following shields and structures.

a. **Sternal shield (ss):** The shape and size of sternal shield varies with species. Generally, the sternal shield bears 2 or 3 pairs of setae, namely sternal setae (ST). If only 2 pairs are present, they are situated on the shield proper, while the third pair is present on the membrane or may be at the shield proper. In males, the sternal and genital shields are fused together to form sternitigenital shield (Plate XXX, Fig.A) which bears 5 pairs of setae.

b. **Metasternal plates (Msp)**: One pair of small metasternal plates are present, with setae.

c. **Genital-Shield (GS)**: Genital shield is truncated posteriorly with a pair of setae (G.).

d. **Ventri-anal shield (VAS)**: The shape of the ventri-anal shield varies with respect to the species. It carries 1-4 pairs of setae known as pre-anal setae. A pair of anal and post-anal setae are also present. A pair of pores – pre-anal pores – may also present, in some phytoseiids. The ventrianal shield of male shows little variation when compared to females, so they are of little taxonomic importance. The ventrianal shields of all males are of the same shape and possess 4-5 pairs of setae, either entire or fragmented, sometimes fused lightly with sternitigenital shield but the line of fusion is clear.

e. **Metapodal plates (MP)**: Metapodal plates are seen on just behind the IV^{th} coxae, they may be 1 or 2 pairs. The metapodal plates may be round, oval or triangular in shape and serve as important characters for recognition of genera and species.

f. **Setae on membrane**: Posteriorly, a variable number of setae or pores are present on the membrane surrounding ventri-anal shield. One pair of caudal setae (JV5) is always present. In addition to seta JV5, 1-5 pairs of setae and a variable number of pairs of setae and a variable number of pores are present.

g. **Spermatheca (Sp.) (Plate XXX, Fig. D)**: A pair of spermatheca, which receives and stores the spermatophores is present in females of

phytoseiids. The structure of spermatheca is of great importance in phytoseiid taxonomy. Each spermatheca opens ventrally through an external orifice between coxae III and IV.

h. Peritreme (P): The stigmata and peritreme are on peritremal shield; length of peritreme has recently been looked upon as of great taxonomic importance. Often, the peritremal shield may be fused anteriorly with dorsal shield and posteriorly curves around coxae IV.

III. A. iv. Legs

There are 4 pairs of legs and chaetotaxy of legs is of great value for generic and specific determination. Evans (1963) in his pioneering work has showed that all phytoseiids have standard chaetotaxy of legs II and III. The leg chaetotaxy, especially of genu II and III and tibia II and III are represented by leg chaetotactic formula as:

genu, $2\frac{2}{0}\ \frac{2}{0}1$ or $2\text{al}\ \frac{2\text{ad}}{\text{Oav}}\ \frac{2\text{pd}}{\text{Opv}}1\text{pl}$

where, al- anterolateral, ad-anterodorsal, av – anteroventral, pd – posterodorsal, pv-posteroventral and pl-posterolateral.

Generally genu, tibia, and basitrsus of leg IV and in some cases the genu and tibia of legs II and III bear macrosetae, the relative length of which are of taxonomic value for separation of species, macrosetae may be simple, knobbed, spatulate or with some other shape.

III. B MORPHOLOGICAL DESCRIPTIONS OF THE LIFE STAGES OF *AMBLYSEIUS LARGOENSIS*

Egg (Plate XIII, Fig. A)

Measurements: Length: 80 -110μm

Width : 70-90 μm

Freshly laid eggs were transparent, glazing appearance with smooth surface

Larva (Plate XXXI, Fig. A & B)

Measurements: Length – 117 – 125 μm

Width – 85 - 90μm

Dorsal region bears 9 pairs of setae. Measurements of setae; j_1-13μm; j_4, j_6 - 5μm each; j_3 - 14 μm; z_2, z_4 - 3μm; s_4 - 19μm; S_2 - 6μm; Z_5-80μm; Z_4 - 11μm. z_2, z_5, z_1, J_2 j_5, J_5, S4, S5, r3 and R1 setae not developed. Sternal shield bears 3 pairs of setae ST_1, ST_2, ST_3 – 19μm each, genital shield and ventri-anal shield not developed. 3 pairs of pre-anal setae, & 1 pair of anal setae present, JV_5 also developed (11μm).

Protonymph (Plate XXXI, Fig. C & B)

Measurements : Length: 134 – 140 μm

Width : 100 – 120 μm

The dorsal region of protonymph bears 16 pairs of setae. Measurements of setae: j_1 – 20 μm; j_4, j_6, j_5, j_2 – 7 μm each; j_3 – 24 μm; z_2, z_4 – 3.5μm each; S_4 - 45μm; Z, -7μm; S_2, S_5, 7μm; 2_4-34μm; 25 - 95μm, 35-

7μm. Ventral region possesses 3 pairs of sternal setae (20μm), 3 pairs of pre-anal setae, 1 pair of anal setae and a single post-anal setae and one pair of ventro-caudal setae (JV_5 – 17.5 μm).

Deutonymph (Plate XXXII, Figs. A & B)

Measurements : Length: 180 – 220 μm

Width : 130 – 143 μm

Dorsal region possesses complete set of setae (17 pairs). Measurements of Setae**:** j_1-28μm; j_4, j_2, j_5 - 7 μm each; j_6 - 7 μm; j_3 -31.5μm, z_2, z_4 -7 μm each; 84 - 87.5 μm; Z_1 - 3.5 μm; S_2, S4, S_5, - 7 μm; Z_5 - 203 μm; z_5 - 3.5 μm and Z_4 - 70μm and R3 and R1 developed (3.5μm). Ventral region bears 3 pairs of sternal setae (26μm each), one pair of genital setae (G-17.5μm), one pair of meta sternal setae, 3 pairs of pre-anal setae, one pair of anal setae, one pair of ventro-caudal setae (JV_5 - 21μm) and a single post-anal seta.

Adult

Female (Plate XXXIII, Figs. A & B)

Measurements: Length: 275 - 353 μm

Width: 210 - 245 μm

Dorsal region bears 17 pairs of setae. Measurements of setae: j_1-35μm; j_4, j_5, j_6-J_2-5μm each; j_3-47μm; Z_4-105μm, Z_5 - 250μm, z_2, z_4 - 7μm each; s_4-99μm; r_3 and R_1 - 8.3 μm each.

Sternal shield with 90 μm long and 82 μm wide, bears 3 pairs of sternal setae (26μm), metasternal plates with setae (28μm) and genital shield (84μm wide) with a pair of setae (28μm). Ventrianal shield 104μm long, 73 μm wide with 3 pairs of pre-anal setae and a pair of semi lunar pores, 4 pairs of setae on the membrane around ventrianal shield, also observed. Smooth ventro caudal setae (56μm). Fixed digit of chelicera bears 4 teeth anterior to pilus dentilis and 3 teeth posterior to it, movable digit with 2 sharp teeth (Plate XXXIII, Fig. C). Spermatheca as figured (Plate. XXXIII, Fig. D).

Leg (Plate XXXIII, Fig. E):

Macrosetae on leg IV: genu 96μm, tibia 72μm, basitarsus 48μm.

Leg chaetotactic formula – genu II $2\frac{2}{0}\ \frac{2}{0}1$, tibia II $1\frac{1}{1}\ \frac{2}{1}1$,

genu III $1\frac{2}{1}\ \frac{2}{1}1$, tibia III $1\frac{1}{1}\ \frac{2}{1}1$

Male (Plate XIII, Fig. F; Plate XXXII, Fig. A & D)

Measurements : Length: 250-300 μm

Width: 224-263 μm

Dorsal chaetotaxy same to that of female. Spermatophoral process as figured (Plate XXXIII, Fig.F).

III. C. MORPHOLOGICAL DESCRIPTIONS OF LIFE STAGES OF *TYPHLODROMIPS SUKNAENSIS*

Egg (Plate XVI, Fig. A)

Measurements : Length: 100 – 120 μm

Width: 70 – 95 μm

Smooth and soft eggs of predator show a shiny appearance and have a light-white colour.

Larva (Plate XXXIV, Fig. A & B)

Measurement : Length: 110 – 126 μm

Width : 71 – 83 μm

Dorsal region bears 10 pairs of setae. Measurements of setae: j-10.5μm, j, j_6-3.8μm and 1.9μm each ; j_3 – 4.8 μm; z_4 – 2.9μm; s_4 – 7.6μm; s_2 - 2.9μm; s_5 - 4.8μm; Z_5-6.7μm, j_2, j_5, Z_2, Z_1, z_5 and Z_4 not developed, R_1 and r_3 also absent. Ventral region possesses, 3 pairs of sternal setae (3.8μm long) 1 pair of pre-anal setae, 1 pair of anal setae and a single post-anal seta. Genital shield and ventri-anal shield not developed.

Protonymph (Plate XXXIV, Fig. C&D)

Measurements : Length: 201 – 213 μm

Width : 100 – 122 μm

Dorsal region consists of 15 pairs of setae. Measurements of setae: j_1 – 15.5 μm; j_4, j_5, j_{16} - 6.1μm each; J_2 – 3.1 μm, j_3 – 8.81 μm, z_2 – 4.6μm; z_4 –

5.4 μm; s_4 –7.7μm; z_1 – 8.8μm, S_2, s_5 – 4.8μm; S_4 – 8.8μm; Z_4-29.4 μm; z_5 – 4.8μm and Z_5-30.9μm, r_3 and R_1 developed, measuring 4.6 μm each. Ventral region bears 3 pairs of sternal setae, measuring 10.8μm each, 3 pairs of pre-anal setae; 1 pair of anal setae and single post-anal seta. JV_5 developed (12.4 μm). Genital shield and ventri anal shield not fully developed.

Deutonymph (Plate XXXV, Fig. A & B)

Measurements : Length: 210 – 229 μm

Width: 125 – 142 μm

Dorsal region possesses 18 pairs of setae. Measurements of setae: j_1-20.9μm; j_4 - 7.7 μm; j_5 and j_6-6.1μm each; J_2 - 4.2μm; j_3 -15.5μm, z_2 - 6.1μm; z_4-10.8μm; s_4-15.8μm; z_1-4.6 μm; and S_2, S_5-7.7μm each; Z_5-44.8μm; z_5-4.8μm and Z_4 - 44.81μm; r_3 and R_1 measure 6.1μm each. Ventral region of deutonymph possesses, 3 pairs of sternal setae (18.5μm) of equal length. 1 pair of metasternal setae; 1 pair of genital setae (G-13.9μm); 3 pairs of pre-anal setae; 1 pair of anal setae and single post-anal seta and 1 pair of ventro-caudal setae (JV_5-21.6μm).

Adult

Female (Plate XXXVI, Fig. A & B)

Measurements : Length: 395 - 474μm

Width : 284 - 313 μm

Dorsal region bears 18 pairs of setae. Measurements of setae: j_1-31.6μm; j_4 - 7.9, j_6 - 9.5 μm; J_2-9.5 μm; j_5-11.05 μm; J_5 - 7.9 μm; j_3 - 25.3μm, z_2 - 11.4μm; z_4 - 15.8 μm, z_1 - 7.9μm; S_2 - 12.6μm; S_4 - 15.8 μm, S_5 - 12.6μm; Z_5 - 72.6μm; z-7.9μm and Z_4 - 72.6 μm, r_3 and R_1 measure 7.9 μm each.

Sternal shield 79μm long, 70μm wide with 3 pairs of setae (22μm). Genital shield 79μm wide with 1 pair of setae (22μm). Ventri anal shield 95μm long, 90μm wide, with 3 pairs of pre-anal setae. Ventro caudal setae also present (12.6 μm). Fixed digit of chelicera with 3-4 teeth anterior to pilus dentilis, 3 teeth posterior to it, movable digit with 2 teeth (Plate XXXVI, Fig. C). Spermatheca as figured (Plate XXXVI, Fig. D)

Legs (Plate XXXVI, Fig. E)

Macrosetae on leg IV; genu - 24, tibia - 20, basitarsus - 50; genu III - 2. Spermatheca as figured. Leg chaetotactic formula, genu II $2\ \frac{2}{0}\ \frac{2}{0}1$, tibia II $1\frac{1}{1}\frac{2}{1}1$, genu III $\frac{1}{1}\frac{2}{0}1$, tibia III $1\frac{1}{1}\frac{2}{1}1$.

Male (Plate XVI, Fig. F; Plate XXXV, Figs. C & D)

Measurements: Length: 350- 406 μm

Width : 205 - 228 μm

Dorsal chaetotaxy as in female. Spermatophoral process as figured (Plate XXXVI, Fig.F).

III. D. MORPHOLOGICAL DESCRIPTIONS OF LIFE STAGES OF *AMBLYSEIUS GUPTAI* SP. NOV.

Egg (Plate XVIII, Fig. A)

Measurements : Length: 83 – 110 μm

Width : 75 – 84 μm

Eggs are smooth, shiny and transparent.

Larva (Plate XXXVII, Fig. A & B)

Measurements : Length: 94-100 μm

Width : 53-70 μm

Dorsal region bears 9 pairs of setae. Measurements of setae; j_1-9.5μm; j_6 - 4.6μm; j_3- 12.4μm; z_4-3.8μm; s_4-4.6 μm; S_2, S_5-4.6μm; Z5 - 25.7μm; j_4, j_5, J_5, J_2, z_2, z_5, z_1 and Z_4 setae not developed. r_3 and R_1 also absent. Sternal shield bears 3 pairs of setae (ST_1, ST_2, ST_3 – 17.9 μm each), genital shield and ventrianal shield not developed. 2 pairs of pre-anal setae, & 1 pair of anal setae present. JV_5 not developed.

Protonymph (Plate XXXVII, Figs. C & D)

Measurements : Length: 132-140 μm

Width : 88 -110 μm

The dorsal region of protonymph bears 15 pairs of setae. Measurements of setae: j_1 - 26.6 μm; j_4, j_6 - 4.6μm each; j_3 - 34 μm; z_2, z_4 -

4.6 μm each; s_4-47.9 μm; S_5, 4.6 μm each; Z_4-49.5μm; Z_5-119μm; z_5-4.6μm. z_1, J_5, J_2-3.1μm. Ventral region possesses 3 pairs of sternal setae (30.9 μm), 3 pairs of pre-anal setae, one pair of anal seta and a single post-anal setae and one pair of ventro-caudal setae (JV_5 – 4.6 μm). Genital setae not developed.

Deutonymph (Plate XXXVIII, Figs. A & B)

Measurements : Length: 247-272 μm

Width: 169-183 μm

Dorsal region possesses complete set of setae (17 pairs). Measurements of setae: j_1-30.9μm; j_4, J_2, j_5, j_6 - 4.6 μm each; j_5, j_2-3.1μm each; j_3 - 44.8 μm, z_2, z_4-4.6μm each; s_4-69.54μm; z_1-4.6 μm; S_2, S_4, S_5-4.6 μm; Z_5-253μm; z_5-4.6μm and Z_4-126μm. Ventral region bears 3 pairs of sternal setae (27.8μm each), 1 pair of genital setae (G-10.8 μm), one pair of metasternal setae, 3 pairs of pre-anal setae, one pair of anal setae, one pair of ventro-caudal setae (JV_5 – 30.9 μm) and a single post-anal seta.

Adult (Detailed description will be published elsewhere)

Female (Plate. XXXIX, Figs. A & B)

Measurements : Length: 537-555 μm

Width: 290-300μm

A. guptai sp. nov. shows close resemblance to *A. largoensis* with respect to the number of dorsal setae. But it varies from *A. largoensis* in its structural difference in spermatheca, ventrianal shield, spermatophoral

process and leg chaetotaxy. The detailed morphological descriptions will be made when it is published elsewhere.

Dorsal region bears 17 pairs of setae. Measurements of setae: j_1-60μm; j_4, z_4-6.3μm each; j_3-72μm; Z_4-138μm, Z_5 - 414μm, z_2 - 4.6μm each; s_4-156 μm; r_3 and R_1 - 9.2 μm each; J_2, J_5 - 4.6μm each, z_5, j_5, S_2, S_4, S_5, z_1-4.6μm each. Sternal shield 126 μm long and 63μm wide, bears 3 pairs of sternal setae (37.9μm), metasternal plates with setae (31μm) and genital shield (63μm wide) with a pair of setae (12.6μm). Ventrianal shield 138μm long, 111 μm wide with 3 pairs of pre-anal setae, 2 pairs of setae on the membrane around ventrianal shield also observed. Smooth ventro caudal setae (88.4μm). Fixed digit of chelicera bears 3 teeth anterior to pilus dentilis and 4 teeth posterior to it, movable digit with 3 sharp teeth (Plate XXXIX C). Spermatheca as figured (Plate. XXXIX, Fig.D).

Leg (Plate XXXIX, Fig. E):

Macrosetae on leg IV: genu 180μm, tibia 138μm, basitarsus 96μm; genu II-34, genu III-36 and tibia III- 44.

Leg chaetotactic formula – genu II $1\frac{1}{0}\ \frac{2}{0}1$, tibia II $1\frac{0}{1}\ \frac{2}{0}1$,
genu III $1\frac{1}{0}\ \frac{2}{1}1$, tibia III $1\frac{1}{1}\ \frac{2}{1}0$

Male (Plate XVIII, Fig. F; Plate XXXVIII, Figs. C & D)

Measurements : Length: 233-250 μm

Width: 147 - 160μm

Dorsal chaetotaxy same to that of female. Spermatophoral process as figured (Plate XXXIX, Fig. F).

III. E. MORPHOLOGICAL DESCRIPTIONS OF LIFE STAGES OF *PARAPHYTOSEIUS MULTIDENTATUS*

Egg (Plate XX, Fig. A)

Measurements : Length: 80 -100 μm

Width : 45 - 75 μm

Eggs transparent when laid, and become opaque as development proceeded. The surface of the egg appeared rough under higher magnification.

Larva (Plate XL, Figs. A & B)

Measurements : Length: 82 - 120 μm

Width : 58 - 80 μm

Dorsal region bears 10 pairs of setae. Measurements of setae; j_1-9.5μm; j_4, j_6-3.8μm; j_3-10.5μm; z_4-17μm; s_4-20μm; Z_5-24.7μm; Z_4-33.3, z_2-11.4μm, z_5-3.8. j_5, j_6, J_5, z_5 and S_6 setae not developed. Sternal shield bears 3 pairs of setae (ST_1, ST_2, ST_3 -7.6μm each), genital shield and ventrianal shield not developed. 3 pairs of pre-anal setae, 1 pair of anal setae and a single post-anal seta present. JV_5 not developed.

Protonymph (Plate XL, Figs. C & D)

Measurements : Length: 140 – 172 μm

Width : 85 – 103 μm

The dorsal region of protonymph bears 11 pairs of setae. Measurements of setae: j_1–25 μm; j_4-3.1, j_6–12.36μm each; j_3–27.8μm; z_2–2.3μm, z_4-23.2μm, $_{S4}$-52.6μm; Z_4-40.2μm; Z_5-23.2μm; z_5-4.6μm. j_5-4.6μm.

Ventral region possesses 3 pairs of sternal setae (13.9 μm), 3 pairs of pre-anal setae, one pair of anal setae, a single post-anal seta and one pair of ventro-caudal setae (JV_5 - 17μm).

Deutonymph (Plate XLI, Figs. A & B)

Measurements : Length: 351 - 370 μm

Width: 175 - 194 μm

Dorsal region possesses complete set of setae (14 pairs). Measurements of Setae: j_1-44 μm; j_4, j_6, j_5 - 6.3 μm each; j_3 - 101 μm, z_2-19, z_4 - 53.7μm; s_4-139μm; z_1-6.3 μm; S_5-6.3μm; Z_5-63μm; z_5-6.3 μm and Z_4-60μm. Ventral region bears 3 pairs of sternal setae (22 μm each), 1 pair of genital setae (G-19μm), 1 pair of metasternal setae, 3 pairs of pre-anal setae, 1 pair of anal setae, 1 pair of ventro-caudal setae (JV_5-25.3μm) and a single post-anal seta.

Adult

Female (Plate. XLII, Figs. A & B)

Measurements : Length: 445 – 500 μm

Width: 252 – 315 μm

Dorsal region bears 13 pairs of setae. j_1, j_3, s_4, z_5, z_4 being long, thick and serrated. Measurements of setae: j_1-44.2 μm; j_4-6.3μm; z_4-56.8μm each;

j_3-158μm; Z_4-88.4μm, Z_5-97.9μm, z_2-1.14μm; s_4-161 μm; r_3-72.6 and R_1- 41 μm each. Sternal shield with 123μm long and 113μm wide, bears 3 pairs of sternal setae (28.4μm), metasternal plates with setae (25.3μm) and genital shield (101μm wide) with a pair of setae (15.8μm). Ventrianal shield 126 μm long, 110 μm wide with 3 pairs of pre-anal setae, 3 pairs of setae on the membrane around ventrianal shield are also observed. Serrated ventro caudal setae (41 μm), chelicerae with multidentate fixed digit, movable digit with 2 sharp teeth (Plate XLII, Fig. C). Spermatheca as figured (Plate. XLII, Fig.D).

Leg (Plate XLII, Fig. E):

Macrosetae on leg IV: genu 30 μm, tibia 35 μm, basitarsus 50 μm; all with knobed tip.

Leg chaetotactic formula – genu II $2\frac{2}{0}\ \frac{2}{0}1$, tibia II $1\frac{1}{1}\ \frac{2}{1}1$,

genu III $1\frac{2}{1}\ \frac{2}{0}1$, tibia III $1\frac{1}{1}\ \frac{2}{1}1$

Male (Plate XX, Fig. F; Plate XLI, Figs. C & D)

Measurements : Length: 350 - 398 μm

Width: 202 - 225μm

Dorsal chaetotaxy same to that of female. Spermatophoral process as figured (Plate XLII, Fig. F).

III. F. MORPHOLOGICAL DESCRIPTIONS OF THE LIFE STAGES OF *PHYTOSEIUS RACHELAE*

Egg (Plate. XXI, Fig. A)

Measurements : Length : 90-100 μm

Width : 70-76 μm

Freshly laid eggs are transparent, clear and shiny.

Larva (Plate XLIII, Figs. A & B)

Measurements : Length: 116-125 μm

Width : 75-82 μm

Dorsal region bears 6 pairs of setae. Measurements of setae; j_1-j_3-6.6μm; j_4, z_4-2.9μm; s_4-44μm; Z_5 - 66μm; z_4, j_5, j_6, z_5, r_3 and S_6 setae not developed.

Sternal shield bears 3 pairs of setae (ST_1, ST_2, ST_3-80μm each), genital shield and ventrianal shield not developed. 1 pair of pre-anal setae, & 1 pair of anal setae present, JV_5 not developed.

Protonymph (Plate XLIII, Figs. C & D)

Measurements : Length : 150-172 μm

Width : 75- 82 μm

The dorsal region of protonymph bears complete set (13 pairs) of setae. Measurements of setae: j_1-15.2 μm; j_4, j_6, j_5, J_2-4.8μm each; j_3-19.98 μm; z_2-4.8μm; z_4-9.5μm each; s_4-33.3μm; S_6-40μm; Z_4-24.7μm; Z_5-21μm; z_5-4.3μm; z_5 - 4.8, J_5 – 29; r_3 and R_2 also developed and 27.59 μm long.

Ventral region possesses 3 pairs of sternal setae (7.6 μm), 2 pairs of pre-anal setae, 1 pair of anal setae and a single post-anal seta and 1 pair of ventro-caudal setae (JV_5 – 5.7μm).

Deutonymph (Plate XLIV, Figs. A & B)

Measurements : Length: 185 – 200 μm

Width: 110 – 120 μm

Dorsal region possesses complete set of setae (13 pairs). Measurements of Setae: j_1-18.5μm; j_5-15.5μm each; j_4, j_6-4.8μm each; j_5-9.5μm; j3- 32.3μm, z_2- 4.8μm, z_4-10.5 each; s_4-49.5μm; S_6 -51μm; Z_5-38.6μm; z_5-7.7μm and Z_4-40.2μm. Ventral region bears 3 pairs of sternal setae (26μm each), 1 pair of genital setae (G- 6.8μm), 1 pair of metasternal setae, 3 pairs of pre-anal setae, 1 pair of anal setae, 1 pair of ventro-caudal setae (JV_5 - 23.2μm) and a single post-anal seta.

Adult

Female (Plate XLV, Figs. A & B)

Measurements : Length: 423 – 450 μm

Width: 221 – 245 μm

Dorsal region bears 13 pairs of setae. Measurements of setae: j_1-50.5μm; j_4, j_5, j_6-J_5-9.5μm each; j_3-72.6μm; Z_4-126.3μm, Z_5 – 75.78μm, z_4-31.6μm, z_2-12.6; s_4-110.5 μm; r_3 72.6 μm.

Sternal shield 142 μm long and 110 μm wide, bears 3 pairs of sternal setae (26μm), metasternal plates with setae (28μm) and genital shield (84μm wide) with a pair of setae (19 μm). Ventrianal shield 123.2μm long, 21.7 μm wide with 3 pairs of pre - anal setae. 2 pairs of setae on the membrane around ventrianal shield also observed. Ventro caudal setae (63.2 μm). Fixed digit of chelicera bears 2 teeth it, movable digit with 1 tooth (Plate XLV, Fig.C). Spermatheca as figured (Plate XLV, Fig. D).

Leg (Plate XLV, Fig. E)

Macrosetae on leg IV: genu 20μm, tibia 60μm, basitarsus 35μm; all with spatulate tip.

Male (Plate XXI, Fig. F; Plate XLIV, Figs. C & D)

Measurements : Length: 145.3 – 154.5

Width : 112.8 – 123.4

Dorsal chaetotaxy same to that of female. Spermatophoral process as figured (Plate XLV, Fig. F).

IV. FIELD EVALUATION OF BIOCONTROL POTENTIAL OF *T. SUKNAENSIS* ON THE PEST MITE *T. NEOCALEDONICUS*

The phytoseiid predator, *T. suknaensis* was released in to the experimental plot, when the population of *T. neocaledonicus* was found very high and homogenous both in the experimental and control plots (34.2 and 34.2/2cm^2). A rapid increase in *T. neocaledonicus* population was observed

in the control plot after a period of 3 weeks (54.65/2cm^2 area of leaf). While the pest population on the experimental plants was found decreased (28.7 individual/2cm^2 area of leaf) along with a predatory mite population to the tune of a 1.16/2cm^2 (Table XLIV). With the advancement of time, a gradual decrease in the population density of the pest mite in the control plots could be observed (Table XLIV). The average number of *T. neocaledonicus* on the 6th, 9th, 12th and 15th weeks of observation recorded was 47.2, 35.3, 32.5 & 23.6 respectively. In the experiment plots, where the predatory mite *T. suknaensis* population was released, a decrease in the population size of *T. neocaledonicus* was found comparatively low than that in the control plots. The respective mean number of *T. neocaledonicus* on plants grown in experiment plots were, 27.1, 18.9, 15.49 and 10.85 on the 6th, 9th, 12th and 15th week of observation. The corresponding number of *T. suknaensis* recorded was 3.3, 2.9, 2.3 & 1.9 respectively (Table XLIV). At the end of the observation (15th week), a decrease in the population size of pest in the tune of 30.14% could be recorded in the control plots. But in the presence of high population of *T. neocaledonicus*, most of the leaves were heavily damaged by losing chlorophyll (Plate XLVI, Fig.B). At the peak time of infestation in the 3rd and 6th weeks, the pest population was found to spread to both sides of the leaves and even leaf petioles, stems etc. also disclosed high incidence of pests. Moreover, in the 10th week, the plants almost lost their vigour (Plate XLVI, Fig.D). As a consequence, the yield from the control plants was

negligible. At the same time in the presence of the predator *T. suknaensis* in the experimental plots, a 66.3% decrease in the pest population size was observed and the leaves of the plants were green with less symptoms of pest attack (Plate XLVI, Fig. E). Moreover, the plants were healthy and yield was also profitable (Plate XLVI, Figs. F & G).

Statistical Analysis

Prior to introduction of the predatory mite, *T. suknaensis*, both the experimental and control plots were homogenous, without having any significant difference in the population of the pest mite, *T. neocaledonicus* ($F = 0.122$, $P= 0.7280$). In the 3rd week, following the release of the predator, population density of the pest *T. neocaledonicus* showed significant variation between the control and experimental plots ($F=101.43$, $P < 0.01$). Similarly, significant differences were also found in the 6th, 9th, 12th and 15th week of observation ($P=0.01$). The population density of the predator, *T. suknaensis* was found to increase first in par with the increase in pest population, followed by a decrease (Plate XLVII, Fig.2). After 3 weeks, the predator-prey ratio was found to be 1:23. When the population of the predator, *T. suknaensis* increased, the above ratio was found decreased on the 6th week so that the predator-pest population could be recorded as 1:8. Then a comparatively consistent ratio (1:6.5; 1:1.67 and 1:5.4) was observed on the 9th, 12th and 15th weeks of observation respectively. *T. suknaensis* was found established in the experimental plot, 3 weeks after its release in the plot, its

population could be recorded as 1.16/2cm^2 area of leaf. As the observation proceeded, significant differences in the population size of *T. suknaensis* were observed (P >0.01) (Plate XLVII, Fig.1). The introduction of *T. suknaensis* was found to cause a significant decline in pest population and about 66% reduction was observed in the initial population of *T. neocaledonicus*. On statistical analysis, following regression correlation, a negative correlation could be established between the pest and predator density during the 6th week of observation. This clearly revealed the potential of the predator to suppress the pest population in the experimental plots. However, in subsequent periods of observation (9th, 12th and 15th weeks), a positive correlation was observed between the pest and predator (Plate XL VII, Fig.2). This was a clear evidence that when the pest population declined, the predator population also got reduced, owing to non-availability of adequate supply of food. In the end of the experiment (after 15th week) the predator population was found to follow the same trend as in the initial stage.

DISCUSSION

Phytoseiid mites exhibit a ubiquitous distribution pattern, from the Artic to the Tropics. They feed on pest mites belonging to families Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae. Besides, insect pests representing aphids, coccids, thrips etc. are also their known preys. Thus, they play very important roles in biological control programmes and have become one of the most active ingredients in IPM strategies. The systematic studies of these mites showed a tremendous advance in the past few decades on a global level. Despite this, the biological studies of phytoseiid mites still remain as a less explored area. This is especially true as far as India is concerned. Comparative studies on the varied parameters of the characteristics related to development, reproduction and prey consumption which still remain as largely unexplored in the case of phytoseiid mites, could yield important information for selection of new biocontrol agents. In this context, the selection of the present topic dealing with comparative biological studies of 5 phytoseiid mites belonging to 4 genera namely *Amblyseius*, *Typhlodromips*, *Paraphytoseius* and *Phytoseius* seems to be most appropriate to satisfy the need of the hour.

The results of the general survey carried out during the present study clearly established that among the natural invertebrate predators, phytoseiid mites were the most common group on all 77 plants surveyed. Hardly, no

plant could be collected during the present study, without a single phytoseiid mite. They were the most active predators of the spidermites, tenuipalpids and eriophyids and were noticed on all the plants surveyed irrespective of the species difference in pest incidence. Moreover, they could be collected in all seasons, but with variation depending on the species composition and abundance of the pests. The general survey results also helped to record that, among the 18 species of phytoseiid mites collected, 5 species viz. *A. largoensis, T. suknaensis, A. guptai* sp. nov. *P. multidentatus* and *P. rachelae* were the most common and abundant phytoseiid predators on most of the host plants. Among these, *A. largoensis* was the very common phytoseiid predator, found in association with the pests, *T. neocaledonicus, T. cinnabarinus, E. orientalis, T. ludeni, T. fijiensis, B. phoenicis* and scale insects, on various host plants such as *A. vasica, R. indica, M. oleifera, M. charantia, V. unguiculata, P. sativum, O. sanctum, O. gratissimum, A. tricolor, C. limon and G. sepium.* This species had been recorded previously from more than 75 plants by several scientists (Gupta, 2003), from most of the states in India and also from more than 14 foreign countries like Japan, U.S.A., S. Africa, and Brazil etc. (Gupta, 2003). Several reports have been available from many regions of India on their efficacy as a mite predator of several spider mites, eriophyid mites and tenuipalpid mites. It also proved its potentiality in biological control programmes.

T. suknaensis, an active phytoseiid predator of *T. neocaledonicus, T. cinnabarinus, T. fijiensis, R.indica, D. minutus* and A. *destructor* was

usually found in association with *T. neocaledonicus*, *T. cinnabarinus* and *A. adoratus* on *C. odorata*, *P. sativum*, *M. oleifera*, *C. floribunda*, *A. tricolor*, *A.viridis* and several species of grasses collected from Olavanna, a rural area in Calicut district. Originally this species was described from West Bengal on *Colocasia* sp (Gupta, 2003). Now it has been reported from more than 20 species of host plants, distributed over more than 11 states of India including Kerala. *A. guptai* sp. nov. collected from the leaves of *C. nucifera*, was found living in association with *A. destructor*, *R. indica*, *T. fijiensis* and *T. neocaledonicus*. It was found actively feeding on all these pests. *A.guptai* sp.nov. showed close resemblance to *A. largoensis* in its morphological characters and was found distributed on plants viz. *A. viridis*, *A. tricolor*, *P. amaras* and *B. diffusa* grown in the nearby areas of Calicut University Campus.

P. multidentatus was found in association with any one of the pests viz. *A. vitexae*, *D. minutus*, *E. orientalis* and *B. phoenicis* on many host plants such as *V. negundo*, *C. odorata*, *L. aspera*, *C. pubescens*, *Q. indica* and *C. ternatea*. This species was first described from Hong Kong on *Bambusa* sp. and *Jasminum* sp. (Gupta, 2003), there after it was recorded in the world from more than 37 plants comprising both vegetables and medicinal plants. In India, this species has been reported from about 15 states. It was also reported from Thailand, Philippines, Nigeria, Madagascar, Malaysia and China. *P. multidentatus* was externally distinguished by the

rugose dorsal shield, large serrated setae and legs with knobed tip. *P. multidentatus* was recognized as an efficient predator of *D. minutus* than the other mite pests offered in laboratory condition, even though they showed feeding activities on phytophagous mites also. But there have been reports on *P. multidentatus* as good predators of phyophagous mites such as *T. urticae* in Punjab (Dhooria, 1990). *P. rachelae*, the highly populous phytoseiid predator found in association with *A. adoratus* on *C. odorata*, distributed over Kozhikode and Malappuram districts was also found to feed on *D. minutus*, *A. destructor* and some other scale insects. The first description of *P. rachelae* was from Hong Kong (Gupta, 2003). In India, it was reported firstly from West Bengal and later from Kerala.

Compared to the other phytoseiid mites collected, the above 5 species of predators were highly accessible and sustainable in the laboratory conditions. More over, results of field observation provided substantial evidence on the predatory habit of these species on spider mites, leading to their population decline. This prompted to design studies on the food preference of these predators towards the different life stages of individual pest species and also to the different pests comprising mites/insects associated with these predators in the field. Attention was made in the present study to focus on the influence of different food items on the developmental and reproductive strategies of these selected phytoseiids. Attempt was also made to evaluate the predatory potential of *T.suknaensis* on

the pest mite *T.neocalidonicus* in field conditions, through inoculative release.

The pest mites of the families tetranychidae, tenuipalpidae and eriophyidae were the most widely distributed and dominant groups encountered on most of the plants surveyed. Among these, 3 species of spider mites viz. *T. neocaledonicus, T.cinnabarinus* and *T.fijiensis* were considered as the test prey items because they were recognized as the most threatening species infesting on a wide variety of economically important plants during the survey. *T. neocaledonicus* was reported as a serious pest on more than 110 species of plants from various parts of the world (Jepson *et al.,* 1975). The present survey enabled to record an array of host plants like *M. oliefera, P. sativum, M. esculenta, V. unguiculata, A. tricolor, C. limon, A. vasica, P. amarus, S.alnifolia, R. indica, A. indica, C. occidentalis, A. esculentus, S. melongena, C. indica, C. papaya, A.viridis, C. pubescens, C. ternatea, U. lobata, Q. indica E. ankenda* and *Z. oenoplia. T.cinnabarinus* was found infesting plants like *C. pubescens, C. ternatea, U. lobata, Q. indica* and *Z. oenoplia, A. tricolor, C. limon, A. vasica, P. amarus, S. alnifolia, D. gangeticum, D.motorium, A. fruticosa, S. dulcis, C. nucifera and C.occidentalis*. *T.fijiensis,* another important spider mite species was detected as a major pest on *C. nucifera, G. sepium, P. amarus, S. alnifolia, A.tricolor, A.viridis, C. indica, C. limon* and several species of grasses. The species is widely distributed throughout the tropical and subtropical countries of the

world including, Hawai, Fiji, Venezuela, South America and India (Rahman and Sapra, 1946; Sidhu and Singh, 1976; Puttaswamy and ChannaBasavana, 1980; Sharma and Kashwaha, 1988; Manjunatha and Puttaswamy, 1989). Indiscriminate use of chemical pesticides and introduction of new agricultural practices are known to exert their own impact leading to outbreak of spidermites on various crops (Wei and Laing 1973). Availability of enhanced nutritious status promoted through the application of nitrogenous fertilizers, infact, support increased fecundity of pest mites, leading to their population outbreak, independent of the action of natural enemies (Dhooria *et al*. 2002). This is well evident in areas where application of chemicals and pesticides were highly restricted. Such areas were reported to have relatively good control by their natural enemies (Putman and Herne 1959; Chant 1963; Huffaker and Flaherty 1968). Of the various natural enemies of spidermites reported so far, predatory mites of the family phytoseiidae represent one of the most promising group with high potential to regulate phytophagous mite populations (Mc Murtry and Scriven 1965).

The red palm mite (*R.indca*), the most notorious tenuipalpid mite was selected, in order to know its predatory mite complex under laboratory conditions. It was proved as a serious pest of several ornamental and fruit-producing palm species such as coconut and areca palms, and has been found

attacking bananas and plantains (Omkar, 2003). The red palm mite causes considerable economic damage to the tropical and subtropical agriculture and to urban and indoor environments too. Palm nurseries, landscape palms, and horticultural gardens are found be affected by this invasive pest (Peter, 2006). Considering the negative impact of this invasive pest species on the agricultural output of Kerala, this species was included as a test food item during the present study. Of the various insect pests commonly encountered in many of our agro-ecosystems, *A. destructor* represents one of the most notorious scale insect pest, especially infesting the coconut palm. Being highly polyphagous, the pest can be easily be re-introduced, even after achieving, successful control on the primary host. Its hosts are typically perennial plants and include many fruit tree species, such as avocado, breadfruit, mango, guava and papaya. This pest is usually found in densely massed colonies on the lower surface of leaves, except in extremely heavy infestations where it may be present on both sides. It may also be found on petioles, peduncles and fruits. Mature scales are found on the older leaves. Infestation is typically associated with yellowing of the leaves in areas where the scales are present.

D. minutus, a small sized phytophagous species of thrips, infesting medicinal plants also was selected as test food item during the current study. The larva, the most active feeding stage, appeared transparent and found to assume the colour of the leaf on which it fed. The highly active larvae were

found mainly distributed on their sides of mid rib/veins of young leaves. Being a common pest distributed on many of the plants surveyed, this species was also selected to detect its biological enemies, like the predatory mites. All the above six species of prey items were designated as major pests of many economically important plants on a global level and hence were selected as test food items under laboratory conditions. The efficiency of the above predators to thrive on alternate food sources was also confirmed during the present study by offering pollen grain of castor, *R. communis*. Castor pollen was already confirmed as a favourable food item for several phytoseiid mites (Abdallah, *et al*., 2001, Gotoh *et al*., 2006).

Results of feeding studies revealed that, all species of predators under study preferred the immature stages of the prey, irrespective of the difference in prey species. However, the rate of consumption of the different stages of the predators showed variation with respect to change in prey. All instars of the predators showed a preference to the eggs of prey mites, thereby supporting the earlier findings on *A. bibens* (Blommers and Etten ,1975), on *T. occidentalis* (Pruszynski and cone, 1972), on *E. hibisci* (Badii *et al.*2004) and on *A. fallacis* (Santos, 1975). Contrary to these, *P. persimilis* showed more affinity to the adults and nymphs of *T. urticae* (Shehatha, 1973) and *A. alstoniae* preferred the larvae and protonymphs rather than the other stages of *E. orientalis* (Dhooria, 1980). The order of preference of the various stages of predators to the life stages of prey mites followed a decreasing

sequence as Egg> Larva> Protonymph> Deutonymph> Adult and in the case of insect pests, it was: eggs>nymphal stages> adults. Maximum rate of consumption was observed on the prey eggs and the lowest rate could be noted on prey adults when the predators were provided with pest mites. Thus, the feeding potential of different predators under study closely followed that of *T. occidentialis* which fed on *T. macdnanielli* (Croft and McMurtry, 1972; Sabelis, 1985) and on *T.urticae* (Pruszynski and cone, 1972) and by *E.hibisci* on *T.urticae* (Badii *et al.*, 2004). In terms of biological control, the preference of predators to prey eggs could be considered as an advantage, because, it would help to reduce the pest mite population well below the threshold level.

Similarly, as the development was progressed, the consumption rates were found to be increased in all predators. Similar results were recorded in other phytoseiid predators like *A. finlandicus* which fed on *T. ludeni* (Mallik, 1982; Momen and Borolessy,1997) and *N. anonymus* (Mesa and Bellotti, 1986) when fed on *T. urticae* and *A.cydnodactylon* (Benhawy *et al*. 2000) on 9 species of phytoseiid mites when fed with *E. orientalis.* The larval stages of all predators under study were found feeding on the eggs and nymphs of the prey species. The larvae initiated feeding shortly after hatching as reported earlier in the case of *I. denerans* (Takfugi and Chant, 1973), *T.sessor* (Sciarappa and Swift, 1977), *M. occidentalis* (Friese and Gilstrap, 1985), and in *A. californicus* (Testo Gotoh *et al*. 2004). However in species

like *P. persimilis* (Takafugi and Chant, 1976), *A. fustis* (Ezulike and Odebiyi, 1984) and *A. tetranychivorus* (Neelu Nangia and Channa Basavana, 1989), the larvae were reported as a non feeding stage. Possession of such non feeding larval phase was designated as an adaptation to avoid cannibalism in species which lay eggs close together (Chittenden and Saito, 2001). However, the feeding behaviour of larval stage may serve to enhance the predatory potential of the species on pest mite species tested. No cannibalistic trait could be observed in the larvae of any of the species studied, but instead they showed varying rates of consumption on the prey mites offered as test food. The consumption rates of larvae varied with respect to species variation and life stages of the pest species. Several other species of phytoseiid predators like *A. barkeri* (Momen, 1995) also showed a similar trend on *T. urticae* and *E. dioscoridis*.

Adults, especially the adult females of the predators consumed more number of pests than the other stages. The highest rate of predation by the female was observed during the oviposition period. The protonymphs and deutonymphs of the predators had higher feeding potential than the larvae, but the most voracious stage recognized during the study was the adult female with the maximum rate of consumption. The total consumption rates of adult females of *A.largoensis*, *T.suknaensis*, *A.guptai*. sp.nov., *P.multidentatus* and *P.rachelae* were also found varied with diet difference. Similarly, depending on the changes of insect pest offered, the mean number

of pest consumed found dropped significantly, as observed in *N.cucumeris* (Sarwar *et al*., 2009). The adult female of *A.largoensis* showed a maximum rate of consumption on *R.indica* (56%) and a minimum on the insect pest, *A.destructor* (20%). *A. guptai* sp.nov. also showed high consumption rate on *R.indica* (68%). The feeding potential of this species was greater than that of *A.largoensis* on the mite pests. It consumed a total of 62% each of *T.neocaledonicus* and *T.cinnabarinus*, 65% of *T.fijiensis*, 33% of *A.destructor* and 48% of *D.minutus* while *T.suknaensis* showed the highest feeding potential on *T.neocaledonicus* (68%) and the consumption rates on other species like *R.indica* was 66%, *T.fijiensis* was 64%, *T.cinnabarinus* was 60% and *D.minutus was* 62%. The lowest rate of predation was observed on the scale insect *A. destructor* (22%). *P. multidentatus* and *P. rachelae* on the other hand showed the lowest preference to pest mites when compared to insect pests. The respective consumption rates of the adult females of *P.multidentatus* and *P.rachelae* on the scale insect pest, *A.destructor* were 25% and 32% and those normal *D.minutus* were observed to be 64% and 60% respectively. While the adult female of *P.multidentatus* consumed a total of 24% *T.neocaledonicus*, 22% *T.cinnabarinus*, 20% *T.fijiensis*, and 35% *R.indica*. The respective percentage consumption of adult female of *P.rachelae* on the mite pests like *T.neocaledonicus*, *T.cinnabarinus*, *T.fijiensis*, and *R.indica* was 19%, 17%, 16% and 30%. This observation coincided with the earlier observations on *E.tularensis* (Cogdon and

McMurtry,1988) when it was provided with *S.citri* and *P.citri*. This differential rates of feeding by the adult female may be attributed to the rate of absorption of the nutrients by the female predator.

Generally, the predatory potential of the individual stages of each phytoseiid species was found varied remarkably. The feeding efficacy of the deutonymphs of all predators appeared more vigourous when compared to that of the larvae and protonymphs and which fed largely upon the eggs and early instars of the pest species. On the other hand, the adult males differed from the females in their predatory potential. Normally, the consumption rate of adult male predators was found comparable with that of the predator protonymphs and larvae. Similar results were recorded on *T.occidentalis* on *T.urticae* (Lee and Davis, 1968). However, the data obtained on the consumption rates of male predators when analysed statistically were found significant, thereby establishing them as potential predators. But the predatory potential of the predator under the study, decreased in the sequence of Female> Deutnonymph> male> Protonymph> Larva. The rate of consumption on both the prey mites by the predator/day was found to be statistically significant at 0.01 level. This clearly proved the potential of predators in suppressing the populations of all species of pests provided. Even though the various instars of the phytoseiids showed significant differences among the different test food items at $p<0.01$ level, the variation in food consumption between the individual predators also recorded

significant variation ($p<0.01$). All the life stages of the 5 species of the phytoseiids, except the larval stage showed high rates of food consumption on all the pest species tested.

In the present study, a good number of protonymphs of *A. largoensis*, *A.guptai* sp.nov. *P. multidentatus* and *P. rachelae* were proved more voracious feeders when compared to their respective males. They consumed more number of prey life stages in some cases. Such greater feeding potential exhibited by certain protonymphs would be a reflection of their developmental progression towards the females progeny, though no other morphological differences like the shape/size of the body could be evident at this stage, to distinguish between the male or female predators.

The life history characteristics of many phytoseiid mites have been reported to be greatly influenced by various biotic and abiotic factors like the food, temperature, humidity or other similar factors (Sabelis 1981: Gaede,1992: Gillespie and Quiring 1994: Takahasi and Chant1994). Quite often, temperature, humidity, food etc. have been found exerting a tremendous impact on the development of these mites (Chant, 1959; Swirski *et al*. 1967a; Sadana and Chhabra, 1974; Ragusa and Swirski, 1975, 1977; Metwally *et al*. 1984). A good number of predator species could thrive on tetranychids, eriophyids, pollen grains and also on coccids and mealy bugs. Some species of *Amblyseius* undergo rapid development and reproduction on a diet of pollen grains than on tetranychid mites (Mc Murtry and Scriven,

1964; Swirski *et al*. 1967; De Moraes and Mc Murtry, 1981). All the 5 species of phytoseiid mites under study were found completing their life cycle from egg to the adult stage successfully and significantly on all animate food items provided. Species like *A.largoensis, A.guptai* sp.nov. and *T.suknaensis* could also complete their life cycle on pollen grain of *R. communis*. Species like *A. swirskii* was also reported to complete its life cycle on varied food items like *E. dioscoridis, T. urticae* and pollen grain of *R. communis* (Momen and Saway, 1993). Contrary to this, species like *P.multidentatus* and *P.rachelae* could not complete their development on pollen grain of *R.communis*. This observation supports the earlier findings on *A. barkeri* (Momen, 1995). The potential of all these predators to develop over a wide range of food items comprising animal/plant matter would be relatively advantageous, ensuring better survival during critical periods of scarcity of preferred prey species.

Phytoseiid mites generally display an array of variations in their mating behaviour. Mating was found highly essential to induce oviposition and frequent mating was an important pre-requisite for reproductive success in all the phytoseiids studied. The process of mating was found to take place immediately after the final moult. Multiple copulation could be observed in *A. largoensis*, *A. guptai* sp. nov., *T. suknaensis* and *P. multidentatus*. Occurrence of such multiple mating was already reported in other phytoseiid species like *A. gossypii* (Elbadry and El Banhaway, 1968), *A. umbraticus*

(Kinsley and Swift, 1971), *A. brazilli* (El Banhawy, 1975), *A. swirskii* (Momen and El Saway, 1993) and *A. barkeri* (Momen, 1990). The multiple mating habits would serve to enhance egg production (shortening the post-oviposition period) and food uptake. Despite this, the females of *P.rachelae* was found to exhibit mating only once in its life time and this appear to be a very rare phenomenon. However, in all the 5 species of predators studied, the mating behviour was found more or less similar and resembled that of other members of the genus *Amblyseius* (El Banhawy, 1968a, b; El Banhawy, 1975; Amano and Chant 1978 a, b).

Qualitative variation in food habits leads to considerable alteration in the rate of development, fecundity, survival etc in phytoseiid mites (Sharma and Sadana, 1989; Elbanhawy *et al*. 2000). Significant influence of diet variation on the development of the phytoseiid mite, *P.persimilis* was reported by Escudero and Feraragut (2005). The duration of development of all the five species under study was found greatly influenced by the diet difference. This variation could be noted not only between the various species but also within the different stages of the same species. The shortest duration of development in the three species viz. *A.largoensis*, *A.guptai* sp.nov. and *T.suknaensis* could be recorded on a diet of pollen grain of *R.communis* (171.7 hrs, 178.13 hrs and 184.32 hrs respectively). Such a positive impact of caster pollen of *R. communis* was also reported in the development of other members of the genus like *A. brazilli* (El Banhawy,

1975), *A. sojaensis* (Osakabe *et al*. 1986) and the above diet supported high reproductive success also. However, contradictory to this, during the present study, even though castor pollen shortened the duration of development, reproductive success was found lowered in *A.guptai* sp.nov. and *A.largoensis*, when compared to the diet comprised of mites and insect pests. Such an adverse effect on reproductive success by castor pollen was reported in other phytoseiid species like *A. swirskii* (Momen and El Saway, 1993) and *A. olivi* (Abou Awad, 1998). This observations would probably be a reflection of the inability of female predator to convert the pollen food in to resources for egg production (Afifi *et al.*,1988).

A positive relation was observed between the rate of food consumption and fecundity of the female predators as they produced more number of eggs at a higher rate of food consumption and the egg production was found decreased with a decrease in food intake. This observation concurred with the findings of Badii and Mc Murtry (1988), Momen (1996), Momen and Borolossy (1997). High fecundity on animal food enabled to confirm their feeding habits and indicated the efficiency of the female predator to convert the prey eaten into predator progeny. On the animal diet itself, the rate of mean oviposition varied with respect to the variation in pest species. *A. largoensis*, *T. suknaensis*, *P. multidentatus* and *P. rachelae* exhibited a high rate of oviposition on a diet comprised of pest mites while *A. guptai* sp. nov. showed its highest rate of oviposition on the scale insect

pest, *A. destructor* (28.5 eggs/mite). The reproductive rates of *A. largoensis*, *T. suknaensis*, *P. multidentatus* and *P. rachelae* were 24.7 eggs/mite (*T. neocaledonicus*), 28.1 eggs/mite (*T. neocaledonicus*), 10.8 eggs/mite (*R. indica*) and 18.9 eggs/mite (*T.neocaledonicus*) respectively. Such differences in the fecundity on preferred food items were also reported in species like *T.sessor* (Sciarappa and Swift, 1977), *A. scutalis* and *A. swirskii* (El Laithy and Fouly, 1982), *N. anonymous* (Mesa and Bellotti, 1980) and in *N.cucumeris* (Sarwar *et al*., 2009) .The oviposition rate of the predator may depend on the efficiency of the female predator to convert the absorbed nutrients in to the progeny.

Nutritional variation caused considerable alteration in other developmental aspects also such as, pre-oviposition and the duration of post-oviposition, incubation period, developmental duration of instars, sex ratio, longevity, mortality etc. Pre-oviposition and post-oviposition periods of the predators were found influenced by changes in the diet. The differences in the pre- and post-oviposition periods with respect to the diet difference were not found following a uniform pattern between the species but the periods of pre-oviposition and post-oviposition were found positively related. The influence of nutrition on the pre-and post-ovipositon periods was obvious within the species. Phytoseiids showed highest duration of oviposition on their preferred food items. Such a difference in pre-oviposition and oviposition periods with a variation in food item was recorded in *A. scutalis* and *A. swirskii* also (El-laithy and Fouly, 1982) on a diet of *T. urticae*.

The duration of development of individual life stages of the predators showed significant variation ($p<0.01$) according to the food items they consumed, there by altering the duration of development from egg to adult. The incubation period of *A.largoensis* was maximum (36 hrs) on a diet of *T. neocaledonicus* and the minimum duration (28.7 hrs) could be recorded on the scale insect, *A.destructor* which was comparable to those on pollen grain of *R. communis* (28.9 hrs). Compared to the incubation period of other phytoseiids, *T.suknaensis* had the shortest duration of incubation (21.8-24 hrs) on all the diets provided in the laboratory. An extended period of incubation was recorded in *P.multidentatus* (40-41.9 days). At the same time, the incubation period in *P.rachelae* averaged between 26.6-30.7 hrs. Such variations in the incubation was exhibited by *A. swirskii* on different food items (Momen and El Saway, 1993). A uniform pattern in the duration of development of nymphal stages of predators could not be recorded during the study. But in the case of *T.suknaensis*, *A.guptai*.sp.nov. and *P.multidentatus*, an extended period of nymphal development was observed when they were reared on a diet of scale insect, *A.destructor*. A deviation was observed in the case of *A.largoensis* and *P.rachelae* where the predators showed highest nymphal duration on mite pests.

The nutritional difference was also found exerting significant variation in the post-oviposition period and longevity of the species. Similar variation in longevity with respect to diet difference was reported in *N.californicus*

(Gotoh and Tsuchiya, 2009 and sarwar *et al*., 2009). A highest post-oviposition period with a lowest longevity was recorded in *A.largoensis, T.suknaensis* and *A.guptai* sp. nov. on a diet comprised of pollen grain of *R.communis*. The respective longevity and post-oviposition periods of *A.largoensis, T.suknaensis* and *A.guptai* sp.nov. on pollen grain of *R.communis* were 5.7 and 18 days; 3.7 and 15.9 days and 3.8 and 15.1 days. The remaining two species, *P.multidentatus* and *P.rachelae* showed highest post-oviposition period and longevity on diets comprised of pest mites (4.1 & 15.6 days and 3.4 &17.2 days) respectively. Although, sex ratio of the species was found altered greatly owing to qualitative changes in food, a shift towards high ratio of female was observed in all the 5 species of phytoseiid predators studied, which agreed with the results recorded earlier in the case of *A. finlandicus* (Sharma and Sadana, 1989) and in *A. barkeri* (Momen, 1996).

The survival rate of phytoseiid predators was found generally dependent greatly on the food items and a high survival rate or low mortality was observed on favoured food items. All the five species studied currently showed a comparatively higher mortality on the pollen grain of *R.communis*. *P.multidentatus* and *P.rachelae* showed 100% mortality when reared on pollen grain of *R.communis* while in *A.largoensis, T.suknaensis* and *A.guptai* sp.nov., the mortality rates were 65%, 35% and 63% respectively. Contradictory to this, the survival of immatures of the predators was

significantly higher on ice plant pollen than that on other prey mites provided (Abou-Setta and Childers, 1989). Moreover, they showed differential survival rates also on animate food. This observation would further substantiate the dependence on the pests by the predators for the replenishment of their progeny, there by confirming their predatory potential on different pests.

Meanwhile, based on the laboratory results, field experiment was also conducted to evaluate the predatory efficacy of *T.suknaensis* against one of the most destructive mite pest, *T.neocaledonicus* in controlled field conditions. *T.suknaensis* consumed the highest number of *T.neocaledonicus*, even though the duration of its development from egg to adult on different diet could be compared to other phytoseiids under study. Moreover, the durations of active periods of nymphal stages of this predator were also found higher than those of *A. largoensis* and *A.guptai* sp.nov., which in turn would augment the management of pest population. A fundamental premise when using predators in biological control is their potential to consume large numbers of pest population. Besides, the longevity and fecundity of the adult female of *T. suknaensis* were also higher on *T.neocaledonicus*. A high survival rate coupled with relatively high rate of oviposition than the other 4 species studied under laboratory conditions were the additional criteria which prompted the selection of this species for field evaluation of its biocontrol potential.

Statistical analysis made on the predatory potential of *T.suknaensis* in the field condition revealed a significant interaction between the predator and the pest mite, *T.neocaledonicus* ($p<0.01$). The 'Pest in first' method (Havelka and Kindlmann, 1984) was followed in the field studies and the experiment was initiated with a homogenous group of pest population. A parallel increase in the populations of both the predator and pest mites could be observed after a period of 3 weeks of introduction of phytoseiid predator. This increase in predator density on the experimental plants revealed its successful establishment of the latter. A simultaneous decline in the population density of pest was observed in the succeeding periods of observation, followed by a substantial decrease in the population of predator also. This decline in predatory population could be a reflection of the food shortage experienced by the predators owing to pest suppression. Such fluctuations in predator-pest ratio were already reported in the case of *P. persimilis,* when it was released against pest mite, *T. urticae* (Havelka and Kindlmann, 1984) and in *P. macropilis* against *T. urticae* (Oliveira *et al*., 2009). An increase in the predator-pest ratio (1:6) from the initial ratio (1:23) indicated the predatory potential of *T.suknaensis* on *T.neocaledonicus* in the field conditions also. Moreover, a stabilized predator-prey population was also observed at the end of the experiment. This would suggest that *T. suknaensis* represents one of the most promising candidate to be exploited in devising successful biocontrol programmes against spider mite pests, as it possesses all relevant biological parameters. Similar results were also reported in the

case of *A.limonicus* (Opit *et al*, 2004), where a predator-prey ratio of 1:4 was recommended for a successful control of *T.urticae* on Ivy geranium. *T.suknaensis* proved its efficacy as a biocontrol agent by giving a 66% diminution in the *T.neocaledonicus* population from the initial population.

Data obtained on the morpohological changes occurring during successive stages of development in the 5 species of predators enabled to record a progressive pattern both in size and setal complement. The eggs of all 5 species of phytoseiid mites under study were some what oval with one end broader than the other. A similar shape of eggs was already reported in other phytoseiid members also like *T. occidentalis* (Lee and Davis, 1968), *A. finlandicus* (Satpathy and Mania, 1969), *A. umbraticus* (Knisley and Swift, 1971) and *A. finlandicus* (Sadana and Sharma, 1989). The eggs were found laid singly near the mid rib or on the leaf hair tip or on the web of spider mites or in between erineal hairs or any other place. The eggs were usually seen adhered to the substratum by means of a sticky substance secreted by the female. Such mode of oviposition could be observed in other phytoseiid species also such as *T. occidentalis* (Lee and Davis, 1968), *A. umbraticus* (Knisley and Swift, 1971), *A. finlandicus* (Sadana and Sharma, 1989). However, of the above species, *A. finlandicus* alone was reported to produce a sticky substance for adhering its eggs to the substratum (Sadana and Sharma 1989). Attachment of eggs to the substratum through the secretion of a sticky substance would definitely ensure protection. The egg in progressive days of incubation showed a change from its clear transparent

nature to opaque or somewhat dirty white before hatching as observed in *A.largoensis, A guptai sp.nov, P.multidentatus* and *P.rachelae.* Contrary to this, in *T. occidentalis* (Lee and Davis, 1968) and *A. finlandicus* (Sadana and Sharma, 1989), the eggs became translucent. But in the case of *T.suknaensis* the eggs became opaque white and shining, as observed in *M. occidentalis* (Laing, 1969). These observations suggest that in phytoseiids, the colour change of eggs during incubation period is common and variation is species dependent.

In the larva, dorsum was found poorly developed while a well developed dorsum could be observed in other instars. Moreover, less number of setae could be observed in larvae. Similar observations in larval development were reported in *T. dossei* and *T. mcgregory* (Croft and Jorgensen 1969; Schicha, 1978) and *A.finlandicus* (Sadana and Sharma, 1989) also. The number of dorsal setae in the protonymph of phytoseiid predators also showed variation. The full complement of setae was found to be established in the deutonymphal stage. No heterogenity of sex could be observed on the venter, in larval and protonymphal stages. Similar observations were made in *P. macropilis* (Prasad, 1967), *T. occidentalis (Lee* and Davis, 1968), *A. finlandicus*, (Sadana and Sharma, 1989) also. But in *A. finlandicus*, male and female protonymphal and deutonymphal stages were distinguishable based on their nature of hysterosoma (Satpathy and Mania, 1969). Even though no heterogenity could be observed on the venter of the

male and female immature stages, spermatophoral process was well detected on the chelicerae of male larval, protonymphal and deutonymphal stages, in all the 5 species of phytoseiid predators studied, thereby indicating their development to the male progeny.

Similarly, the peritreme was not found developed in the larval and protnymphal stage and it made its appearance only in the deutonymphal stage. A similar trend in the development of peritreme was reported in *T. helinae, A. lentiginosus, P. fotheringlaminae* (Schicha, 1977), *T. dossei* (Schicha, 1978) and *A. finlandicus* (Sadana and Sharma, 1989). During the present study, the sternal, genital and anal shields showed incomplete development in the deutonymph where as in larva and protonymph it was completely absent. Thus, even though the changes in the number and size of setae during the development were not unique, the general mode of progression, regression and addition of setae appeared to be similar to that of related taxa of phytoseiid mites and which in turn would help to establish correlation between groups.

The five species were distinguished from each other, by their body size, number and nature of dorsal setae, shape of ventrianal shield, differences in the structure of spermatheca in adult female and spermatophoral process in male chelicera. The chaetotaxy of all phytoseiids showed difference with respect to species variation. *A guptai* sp. nov., the new phytoseiid predator explored during the present work showed close resemblance to

A. largoensis, in terms of the number of dorsal setae, sternal setae, genital setae and setae on and around ventri-anal setae but showed difference with respect to the structure of spermatheca in the adult male, spermatophoral process in male and in the shape of ventrianal shield in female.

SUMMARY AND CONCLUSION

Phytoseiid mites, one of the most important natural enemies of acarid pests are gaining much attention among the scientists, because of their potential in controlling the pest mites well below the economic threshold level on many crops. Several members of this family have been widely used in biological control programs around the world. Even though many studies have been devoted to explore the feeding strategies of phytoseiid mites, including their functional and numerical responses as well as prey preference and field application, an indepth study was found required on this blessed creatures for unveiling their efficacy as efficient predators and integrating them in various IPM programs. In this context, the present work was undertaken to compare the different biological aspects and feeding potential of 5 species of phytoseiid mites, viz. *A.largoensis*, *T.suknaensis*, *A.guptai* sp.nov., *P.multidentatus* and *P.rachelae* on 6 well known mite/insect pest species (*T.neocaledonicus*, *T.fijiensis*, *T.cinnabarinus*, *R.indica*, *A.destructor* and *D.minutus*) and pollen grain of *R.communis* at laboratory conditions of 30±2°C and 70±2% RH. Besides this, a preliminary attempt was made to evaluate the predatory potential of one of the most promising phytoseiid predator, *T.suknaensis* on the spider mite pest, *T. neocaledonicus* under field conditions.

During the present study, a general survey on the phytoseiid mites and associated pests was carried out, covering different ecosystems, comprising

agricultural fields, green houses, kitchen gardens and botanical gardens, located in different sites distributed over 2 districts of Kerala viz. Kozhikode and Malappuram. Leaves and twigs of host plants showing symptoms of pest infestation were cut with the help of scissors or blade, put in polythene bags and transported to the laboratory for in situ examination under a stereozoom microscope. Studies on both feeding and breeding biology of phytoseiid mites were carried out in the laboratory following leaf floatation technique.

Leaves of 77 plants, comprising vegetables, ornamental plants, medicinal plants, oil yielding plants, soft woods and many wild plants were examined during the present work. A negative correlation between the pests, especially pest mites and phytoseiid mites could be observed during the survey. More over the abundance of phytophagous mites and predatory mites showed variation in different ecosystems and also in plants with in the same ecosystem. *T.neocaledonicus, T.fijiensis, T.cinnabarinus* and *R.indica* were the most dominant mite pests encountered both in closed and open ecosystems, causing extensive damage to most of the plants surveyed. Apart from these, *A. destructor* and *D. minutus* were the other two important insect pests recovered during the survey period from *C. nucifera* and *V. negundo* respectively. Among the 18 species of phytoseiid mites identified, 5 species viz. *A.largoensis*, *T.suknaensis*, *A.guptai* sp.nov., *P.multidentatus*, and *P.rachelae* were recognized as the most common and abundant phytoseiid predators encountered during the study. Of these, *A.largoensis*, *T.suknaensis*

and *A.guptai* sp.nov. had more or less similar, broad range of feeding habits and they showed favourable results on the alternate food item viz. pollen of castor. On the other hand, *P.multidentatus* and *P.rachelae* showed more preference to insect pests than mite pests and were found unable to complete their development on pollen grain or spider mites. So, during the present study, attention was focused to gather information on the feeding and breeding biology of these predatory mites in laboratory conditions of 30±2°C and 70±2% RH by providing the various mite and insect pests mentioned above.

The feeding potential and feeding preference of different life stages of the predators followed a general pattern in laboratory condition irrespective of diet variation. The adult female was the most voracious life stage with maximum predatory potential, in all the 5 species studied, while the larva constituted the weakest one. However, the total consumption rates of adult females of *A.largoensis*, *T.suknaensis*, *A.guptai*.sp.nov., *P.multidentatus* and *P.rachelae* were also found varied with diet difference. Likewise, with the changes into insect pest diet, the rate of consumption was found dropped significantly. The adult female of *A.largoensis* showed a maximum rate of consumption on *R.indica* (56%) and a minimum on the insect pest, *A.destructor* (20%). *A. guptai* sp.nov. also showed high consumption rate on *R.indica* (68%). Similarly, it showed comparatively higher feeding potential than *A.largoensis* on mite pests. It consumed a total of 62% each of

T.neocaledonicus and *T.cinnabarinus*, 65% *T.fijiensis* , 33% *A.destructor* and 48% *D.minutus*. *T. suknaensis* showed the highest feeding potential on *T.neocaledonicus* (68%) followed by *R.indica* (66%), *T.fijiensis* (64%), *T.cinnabarinus* (60%) and *D.minutus* (62%), but a lowest rate of predation was observed on the scale insect, *A.destructor* (22%). *P.multidentatus* and *P. rachelae* on the other hand showed lowest preference to pest mites compared to insect pests. The respective total consumption rates of the adult females of *P.multidentatus* and *P.rachelae* on the scale insect pest, *A.destructor* were 25% and 32% and that *on D.minutus* were observed to be 64% and 60% respectively. The adult female of *P.multidentatus* consumed a total of 24% *T.neocaledonicus*, 22% *T.cinnabarinus*, 20% *T.fijiensis*, and 35% *R.indica*. The respective total percentage consumption of adult female of *P.rachelae* on the mite pests *T.neocaledonicus*, *T.cinnabarinus*, *T.fijiensis*, and *R.indica* were 19%, 17%, 16% and 35%. The feeding potential of the different life stages of the predators generally increased in the order of Larva < protonymph <adult male<deutonymph<adult female. But in some cases, the protonymph of *A. largoensis*, *A. guptai* sp. nov., *P. multidentatus* and *P. rachelae* consumed more number of prey stages than the adult males of Phytoseiid predator. Among the different life stages of the pests offered as the test food items, the eggs constituted the most preferred stage while the adults constituted the least preferred one. The order of preference of the various stages of predators to the life stages of prey mites followed a

decreasing sequence as Egg> Larva> Protonymph> Deutonymph> Adult and in the case of insect pests it was in the order of eggs > nymphal stages> adults.

All the 5 species of phytoseiid mites under study were found able to complete their life cycle from egg to adult stage successfully and significantly on all animate food items provided. Species like *A.largoensis*, *A.guptai* sp.nov. and *T.suknaensis* could also complete their life cycle on pollen grain of *R. communis.* Results of laboratory studies on the development of *A. largoensis* enabled to record a shortest duration of incubation period on insect pest, *A. destructor* and pollen of *R. communis* (28.9/29.9 hours) and a more extended period of incubation on the pest mites, *T. neocaledonicus* and *R. indica* (36/32 hours). The duration of larval period did not show any significant difference with respect to food variation. The observed duration of larval period ranged from 19.6–21.3 hours. The active durations of protonymphal and deutonymphal periods showed significant differences in accordance with the difference in the food items consumed. The lowest deutonymphal period was observed on pollen grains of *R. communis* (59.5 hours) where as it was more or less same on animal diets, which ranged from 68.5 – 70 hrs. The inactive phases of *A. largoensis* not showed much variation with respect to variation in food item. Statistical analysis following ANOVA on the total duration of development of *A. largoensis* showed significant difference with respect to diet variation .The lowest duration of development was recorded on pollen of *R. communis* (171.7 hrs) but on

which the predator exhibited highest mortality/escape rate (75%) and lowest fecundity (7.2 eggs). A more or less similar sor slightly higher developmental time, fecundity, longevity and survival could be recorded on animal diets, viz. *T. neocaledonicus, A. destructor* and *R. indica.*

Compared to other phytoseiid mites under study, *T. suknaensis* showed the lowest mortality/escape rate in the laboratory conditions (25% - 35%) on different food items. The species showed highest fecundity on the pest mite, *T. neocaledonicus* by producing 28.1 eggs/mite in an average of 14.2 days of oviposition, whereas on *R. indica* and *A. destructor*, the predator produced 22.4 eggs/mite and 18 eggs/ mite respectively in an average of 13.4 days of oviposition. Compared to the phytoseiid predators studied, *T. suknaensis* produced more number of eggs (10.1 eggs/mite) on the plant diet formed of pollen of *R. communis.* The influence of animal diets on incubation period in *T. suknaensis* was found to be insignificant. Similar observations were obtained in the case of larval period on all food items except that on *A. destructor*, where the period was found more extended (32 hrs). The active period of protonymph was longer on a diet of *R. indica* and *A. destructor* (46/47.6 hrs), but was found to be shorter on *T. neocaledonicus* (44.6 hrs) and pollen grains of *R. communis* (43.9 hrs). Similar influence of diet was observed on the durations of deutonymphal and quiescent phases also in *T. suknaensis*. Significant difference in the total duration of F_1 generation with respect to difference in food items consumed was observed

during the study. Development was found comparatively fastest on the prey mite, *T. neocaledonicus* and the plant diet, *R. communis*, whereas prolongation of development was observed on animal diets, *R. indica* and *A. destructor*.

A. guptai sp. nov. also showed variation on the developmental patterns on different food items. The longest duration could be recorded on the scale insect *A. destructor*, followed by *R. indica* and *T. neocaledonicus*. When the predator showed high mortality/escape ratio on *T. neocaledonicus* and pollen of *R. communis*, comparatively higher survivals was observed on *R. indica* and *A. destructor* (80%). Similarly, a highest fecundity was also observed on diets of *R. indica* (23.9 egg/mite) and *A. destructor* (28.5 eggs/mite) where as low egg production (20.4 egg/mite) was noted on *T. neocaledonicus* and *R. communis* (6.9 eggs/mite). A higher longevity was also observed on *A. destructor* (18.1 days) while it ranged from 15.1-17.2 days on *R. communis*, *R. indica* and *T. neocaledonicus* respectively. The incubation period of *A. guptai* sp.nov. ranged from 22-29 hrs on different diets, while the active periods of larva, protonymph and deutonymph were found significantly influenced by the variations in food item. The duration of inactive phases of *A. guptai* sp.nov. was more or less comparable on all food items even though slight variations could be observed in the same.

P. multidentatus successfully completed its development on all food items provided except pollen grain of *R. communis*. The total developmental

time from egg to adult was found shorter when the predator was fed with the pest mite, *T. neocaledonicus* and a longer duration of development was recorded on a diet of *A. destructor*, the scale insect pest. Additionally, *P. multidentatus*, showed significant variation in the pre-oviposition, oviposition and post-oviposition periods with respect to variation in food items consumed. Highest fecundity was observed on the diet, *R. indica* with a high rate of oviposition and longevity period followed by *T. neocaledonicus* and *A.destructor* with more/less similar reproductive parameters. Developmental period of all life stages of *P. multidentatus* was found influenced by the food items consumed, except in the egg stage. The observed incubation period was more or less the same on all the food items consumed. But the quiescent/inactive periods of the predator were found not much influenced by the diet difference.

P. rachelae, on the other hand took longer time to complete its development from egg to adult, on a diet of *T. neocaledonicus* and shorter time on *R. indica*. The species showed higher fecundity and longevity on *T. neocaledonicus* when compared to the other food item. The duration of development of the different life stages of *P.rachelae* viz. egg, larva, protonymph and deutonymph of *P. rachelae* also showed significant difference with respect to variation. All stages of the predator except the protonymphal stage appeared to have shorter duration on the scale insect pest, *A. destructor* while the protonymph completed its development with the

shortest time when it consumed *R. indica*. The 1st quiescent phase of the predator was found more ore less similar on all food items provided, while the 2nd and 3rd quiescent phases were found more extended on diets of *T. neocaledonicus* and *R. indica*. Comparative analysis of the total developmental time of the 5 species of predators studied revealed that, the total developmental time was not uniform on all the food items they consumed. Moreover, all the 5 phytoseiid species showed significant difference in the time taken to complete the development from egg to adult with variation in food items.

A. largoensis, the most common phytoseiid predator encountered during the survey, showed its highest feeding potential on *R. indica* followed by *T. cinnabarinus* and *T. neocaledonicus*, while the predator took shortest time to complete its life cycle from egg to adult on *A. destructor* to which the predator showed least preference. At the same time, the number of eggs laid/female mite was found not much influenced when the predator was reared on animal food items. The new phytoseiid species included in the study, *A. guptai* sp. nov., which showed close morphological resemblance to *A. largoensis*, proved its efficacy as an active predator of all the pest species offered, with a highest preference to *R. indica* and a more or less similar feeding potential (61%-67%) towards the spider mite pests. But it showed the highest fecundity on the insect pest, *A. destructor* (28.5 eggs/mite), on which it showed a total percentage consumption of 48%. The shortest period of development of the predator could be recorded on a diet of *T. neocaledonicus*

with the fecundity of 20 eggs/mite, which was lower when compared to those on *A. destructor* and *R. indica*.

Among the 5 species of phytoseiid mites studied, *T. suknaensis* exhibited the highest feeding potential and fecundity on *T. neocaledonicus*. It also showed a more or less similar predatory behaviour on all other pest species provided. The feeding potential of *T. suknaensis* was found to decrease in the sequence of *T. neocaledonicus*> *R. indica*> *T. fijiensis*> *T. cinnabarinus*> *A. destructor*> *D. minutus*. Based on these laboratory results, field experiment was conducted to evaluate the predatory efficacy of *T.suknaensis* against the mite pest, *T.neocaledonicus*, one of the most destructive mite pests.

The 'Pest in first' method was used in the field studies and the experiment was initiated on a homogenous group with respect to the pest population. A parallel increase in the population of both the predator and pest was observed after a period of 3 weeks of introduction of phytoseiid predator. The increased number of predator on the experimental plant revealed the successful establishment of the latter. A decline in the population density of pest could be observed in the succeeding periods of observation followed by a substantial decrease in the population of predator also, owing to a lack of food. An increase in the predator-pest ratio (1:6) from the initial ratio (1:23) was observed during the study. A stabilized predator-prey population was also observed at the end of the experiment. Introduction of *T.suknaensis* was found to result in a 66% reduction in the

initial population of *T.neocaledonicus*. Moreover, statistical analysis of the data recorded on the predatory potential of *T.suknaensis* in the field condition revealed a significant interaction between the predator, *T.suknaensis* and the pest mite, *T.neocaledonicus* at $p<0.01$ level. This clearly indicated the efficiency of *T.suknaensis* as a biocontrol agent of spider mites in the field conditions also.

In concise, the comparative analysis made on the different functional responses of 5 phytoseiid predators did not give a uniform result in laboratory conditions. Moreover, the different developmental and feeding aspects of the 5 predators showed significant difference with respect to the different food items provided. But the method used in this study did not allow to determine the most favoured food items for the predators. Higher feeding potential of any one of the predator, on any one of the pest species does not mean that the concerned predator can not be a good predator of other pests. On the contrary, a higher performance of the phytoseiid predator towards one of the pest species suggested that they could be a good candidate for the control of that particular pest species. This principle was followed during the present work while conducting the field evaluation. It could therefore be expected that even though *A.largoensis*, *T.suknaensis*, *A.guptai* sp.nov., *P.multidentatus* and *P.rachelae* exhibited varying patterns of development and differential rates of prey consumption on different food items under laboratory conditions, all these predators could be rated as ideal

predators of any one or more of the pest species tested. More over, the broad host range, high fecundity and greater longevity shown by all these predators would make them as ideal candidates among beneficial predators on arboreal ecosystem and could be used as suitable biological control agents in various integrated pest management programs against corresponding pest species in different agricultural and horticultural systems.

REFERENCES

ABDALLAH (A.A.), ZHANG (Z.Q.), MASTERS (G.J.) AND MC NEILL (S.), 2001. – *Euseius finlandicus* (Acari: Phytoseiidae) as a potential biocontrol agent against *Tetranychus urticae* (Acari: Tetranychidae): Life history and feeding habits on three different types of food. *Experimental and Applied Acarology*, **25**(10/11): 833-847.

ABHILASH (B.) AND SUDHARMA (K.), 2002. – Biology and predatory potential of *Amblyseius longispinosus* (Evans). *Insect Environment*, **8**(4): 155-156.

ABOU AWAD (B.A.), EL-SHERIF (A.A.), HASSAN (M.F.) AND ABOU ELELLA (M.M.), 1998. – Studies on development, longevity, fecundity and predation of *Amblyseius olivi* Nasr and Abou-Awad (Acari: Phytoseiidae) on various kinds of prey and diets. *Zeitschrift fur pflanzenkrankheiten und Pflanzenschutz*, **105**(5): 538-544.

ABOU SETTA (M.M.) AND CHILDERS (C.C.), 1989. – Biology of *Euseius mesembrinus* (Acari: Phytoseiidae): Life tables and feeding behaviour on tetranychid mites on citrus. *Environmental Entomology*, **18**(4): 665-669.

ABOU SETTA (M.M.), FOULY (A.H.) AND CHILDERS (C.C.), 1997. – Biology of *Proprioseiopsis rotendus* (Acari: Phytoseiidae) reared on *Tetranychus urticae* (Acari: Tetranychidae) or pollen. *Florida Entomologist*, **80**(1): 27-34.

ABOU-EELLA (M.M.) AND ABOU-EELLA (G.M.A.), 2001.– Laboratory studies on development and oviposition of *Neoseiulus cucumeris* (Oudemans) (Acari: Phytoseiidae) fed on various preys. *Egyptian Journal of Biological Pest-control*, **11**(1/2): 115-118.

AFIFI (A.M.), POTTS (M.F.), PATTERSON (C.G.) AND RODRIGUEZ (J.G.), 1988. - Pollen diet of some predator mites. *Transactions of the Kentucky Academy and Science*, **49**(34): 96-100.

AHN (J.J.), KIM (K.N.) AND LEE (J.H.),2010. – Functional response of *Neoseiulus, californicus* (Acari: Phytoseiidae) to *T. urticae* (Acari: Tetranychidae) on Strawberry leaves. *Journal of Applied Entomology*, **134**: 98 – 104.

AMANO (H.) AND CHANT (D.A.), 1978a. – Some factors affecting reproduction and sex ratios in two species of predaceous mites, *Phytoseiulus persimilis*. Athias-Henriot and *Amblyseius andersoni* (Chant) (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, **56**: 1593-1607.

AMANO (H.) AND CHANT (D.A.), 1978b. – Mating behaviour and reproductive mechanisms of two species of predaceous mites, *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius andersoni* (Chant) (Acarina: Phytoseiidae). *Acarologia*, **20**: 196-213.

AMANO (H.) AND CHANT (D.A.), 1986. – Laboratory studies on the feeding habits, reproduction and development of three phytoseiid species, *Typhlodromus pomi, Phytoseius macropilis* and *Amblyseius finlandicus* (Acari: Phytoseiidae), occurring on abandoned apple trees in Ontario, Canada. *Experimental and Applied Acarology*, **2**(4):299-313.

ARBABI (M.) AND SINGH (J.), 1990. – Records of predatory fauna found associated with phytophagous mites in Varanasi. Fourth International Symposium in Acarology, Calicut, p.7-8.

ARTHURS (S.), MCKENZIE (C.L.), CHEN (J.), DOGRAMACI (M.), BRENNAN (M.), HOUBEN (K.) AND OSBORNE (L.), 2009. – Evaluation of *Neoseiulus cucumeris* and *Amblyseius swirskii* (Acari: Phytoseiidae) as biological control agents of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on pepper. *Biological control*, **49**(1): 91-96.

ASHIHARA (W.), INOUE (K.), OSAKABE (M.) AND HAMAMURA (T.), 1992. – Effectiveness of *Phytoseiulus persimilis* Athias Henriot (Acari:Phytoseiidae) as a control agent for the Kanzawa spider mite, *Tetranychus kanzawai* Kishida (Acarina: Tetranychidae) and occurrence of native natural enemies of the spider mite on grape vine in glass house. *Bulletin of the Fruit Tree Research Station*, **22:** 109-130.

BADII (M.H.) AND HERNANDEZ (E.), 1993. – Life cycle and tables of *Euseius mesembrinus* (Dean) (Acari: Mesostigmata: Phytoseiidae) with different types of food. *South Western Entomologist*, **18**(4): 305-314.

BADII (M.H.) AND MC MURTRY (J.A.), 1984. - Feeding behaviour of some phytoseiid predators on the broad mite, *Polyphagotarsonemus latus* (Acari: Phytoseiidae, Tarsonemidae). *Entomophaga*, **29**(1): 49-53.

BADII (M.H.), HERNANDEZ (E.) AND FLORES (S.), 1993. – Functional response of *Euseius mesembrinus* (Dean) as a function of the density of *Brevipalpus californicus* (Banks) (Acari:Phytoseiidae). *South Western Entomologist*, **18**(4):301-304.

BADII (M.H.), HERNANDEZ (E.), FLORES (A.E.) AND LANDEROS (J.), 2004. – Prey stage preference and functional response of *Euseius hibisci* to *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae). *Experimental and Applied Acarology*, **34**: 263-273.

BLACKWOOD (J.S.), SCHAUSBERGER (P.) AND CROFT (B.A.), 2001.- Prey stage preference in generalist and specialist phytoseiid mites (Acari: Phytoseiidae) when offered *Tetranychus urticae* (Acari: Tetranychidae) eggs and larvae. *Environmental Entomology*, **30**(6): 1103-1111.

BLOMMERS (L) AND ETTEN (J.V.), 1975. – *Amblyseius bibens* (Acarina: Phytoseiidae), a predator of spider mites (Tetranychidae) in Madagascar. *Entomologia Experimentalis et Applicata*, **18**(3): 329-336.

BLOMMERS (L.), LOBBES (P.), VINK (P.) AND WEGDAM (F.), 1977.– Studies on the response of *Amblyseius bibens* (Acarina: Phytoseiidae) to conditions of prey scarcity. *Entomophaga*, **22**(3): 247-258.

BONDARENKO (N.V.), 1974. – Method of rearing and using *Phytoseiulus*. *Zashchita Rastenii*, (11): 33-35.

BONDE (J.), 1989. – Biological studies including population growth parameters of the predatory mite *Amblyseius barkeri* (Acarina: Phytoseiidae) at 25^0C in the laboratory. *Entomophaga*, **34**(2): 275-287.

BOUNFOUR (M.) AND MC MURTRY (J.A.), 1987. – Biology and ecology of *Euseius scutalis* (Athias-Henriot) (Acarina:Phytoseiidae). *Hilgardia*, **55**(3): 1-21.

BROUFAS (G.D.) AND KOVEOS (D.S.), 2000. – Effect of different pollens on development, survivorship and reproduction of *Euseius finlandicus* (Acari: Phytoseiidae). *Environmental Entomology*, **29** (4): 743-749.

BRUCE OLIVER (S.J.) AND HOY (M.A.), 1990. – Effect of prey stage on life table attributes of a genetically manipulated strain of *Metaseiulus occidentalis* (Acari : Phytoseiidae). *Experimental and Applied Acarology*, **9**(3-4): 201-217.

BURRELL (R.W.) AND MC-CORMICK (W.J.), 1964.– *Typhlodromous* and *Amblyseius* (Acarina: Phytoseiidae) as predators on Orchard mites. *Annals of the Entomological Society of America*, **57**: 483-487.

CACERES (S.) AND CHILDERS (C.C.), 1991. – Biology and life tables of *Galendromus helveolus* (Acari: Phytoseiidae) on Florida Citrus. *Environmental Entomology*, **20**(1): 224-229.

CAMPORESE (P.) and DUSO (C.), 1995. – Life history and life table parameters of the predatory mite *Typhlodromus talbii. Entomologia Experimentalis et Applicata*, **77**(2): 149-157.

CARLOS (H.W.) AND JAMES (A.), 1992. – Studies on how phytoseiid mites feed on spider mites and pollen. *International Journal of Acarology*, **18**(3): 157-162.

CASTAGNOLI (M.) AND LIGUORI (M.), 1986. – Development and oviposition times of *Typhlodromus exhilaratus* Ragusa (Acarina: Phytoseiidae) reared on various types of food. *Redia*, **69**: 361-368.

CASTAGNOLI (M.) AND SIMONI (S.), 1999. – Effect of long-term feeding history on functional and numerical response of *Neoseiulus californicus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **23**(3): 217-234.

CASTAGNOLI (M.), SIMONI (S.) AND NACHMAN (G.), 2001. – Short term changes in consumption and oviposition rates of *Neoseiulus californicus* strains (Acari: Phytoseiidae) after a diet shift. *Experimental and Applied Acarology*, **25**(12): 969-983.

CHANT (D.A.), 1963. – Some mortality factors and the dynamics of orchard mites. *Memoires of the Entomological Society of Canada*, **32**:33-40.

CHANT (D.A.) AND YOSHIDA – SHAUL (E.), 1991. – Adult ventral setal patterns in the family phytoseiidae (Acari: Gamasina). *International Journal of Acarology*, **17**(3): 187-199.

CHANT (D.A.) AND YOSHIDA-SHAUL (E.), 1989. – Adult dorsal setal patterns in the family phytoseiidae (Acari; Gamasina). *International Journal of Acarology*, **15** (4): 219-233.

CHANT (D.A.) AND YOSHIDA-SHAUL (E.), 1992. – Adult idiosomal setal patterns in the family phytoseiide (Acari: Gamasina). *International Journal of Acarology*, **18**(3): 177-193.

CHITTENDEN (A.R.) AND SAITO (Y.), 2001. – Why are there feeding and non feeding larvae in phytoseiid mites (Acari: Phytoseiidae)?. *Journal of Ethology*, **19**(1): 55-62.

CLOUTIER (C.) AND JOHNSON (S.G.), 1993. – Interaction between life stages in a phytoseiid predator: Western flower thrips prey killed by adults as food for protonymphs of *Amblyseius cucumeris*. *Experimental and Applied Acarology*, **17**(6): 441-449.

COLFER (R.G.), ROSENHEIM (J.A.), GODFREY (L.D.) AND HSU (C.L.), 2004. – Evaluation of large-scale releases of western predatory mite for spider mite control in cotton. *Biological control*, **30**: 1-10.

CONGDON (B.D.) AND MC MURTRY (J.A.), 1988. – Prey selectivity in *Euseius tularensis* (Acari: Phytoseiidae). *Entomophaga*, **33**(3): 281-287.

CROFT (B.A.) AND CROFT (M.B.), 1993. – Larval survival and feeding by immature *Metaseiulus occidentalis*, *Neoseiulus fallacis*, *Amblyseius andersoni* and *Typhlodromus pyri* on life stage groups of *Tetranychus urticae* Koch and phytoseiid larvae. *Experimental and Applied Acarology*, **17**(9): 685-693.

CROFT (B.A.) AND JORGONSEN (C.D.), 1969. – Life history of *Typhlodromus mcgregori* (Acarina: Phytoseiidae). *Annals of Entomological Society of America*, **62**(6): 1261-1267.

CROFT (B.A.) AND MC MURTRY (J.A.), 1972. – Minimum release of *Typhlodromus occidentalis* to control *Tetranychus mcdanieli* on apple. *Journal of Economic Entomology*, **65**: 188-191.

CROFT (B.A.), MC MURTRY (J.A.) AND LUH (H.K.), 1998. – Do literature records of predation reflect food specialization and predation types among phytoseiid mites (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **22**(8): 467-480.

CUELLAR (M.E.), CALATAYUD (P.A.), MELO (E.L.), SMITH (L.) AND BELLOTTI (A.C.), 2001. – Consumption and oviposition rates of six phytoseiid species feeding on eggs of the cassava green mite, *Mononychellus tanajoa* (Acari: Tetranychidae). *Florida Entomologist*, **84** (4): 602-607.

DAFTARI (A.), 1979. – Studies on feeding, reproduction and development of *Amblyseius aberrans* (Acarina: Phytoseiidae) on various food substances. *Zeitschrift fan Angewandte Entomologie*, **88**(5): 449-453.

DE MORAES (G.J.) AND MC MURTRY (J.A.), 1981. – Biology of *Amblyseius citrifolius* (Denmark and Muma) (Acarina: Phytoseiidae). *Hilgardia*, **49**: 1-26.

DECOURCY WILLIAMS (M.E.) KRAVAR- GRADE (L.), FENLON (J.S.) AND SUNDERLAND (K.D.), 2004. – Phytoseiid mites in protected crops: the effect of humidity and food availability on egg hatch and adult life span of *Iphiseius degenerans*, *Neoseiulus cucumeris*, *N. californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **32**: 1-13.

DHOORIA (M.S.), 1981. – Feeding behaviour of predatory mites, thrips and beetles of the citrus mite, *Eutetranychus orientalis*. *Acarology Newsletter*, **10**: 4-6.

DHOORIA (M.S.). 1990.- Predatory mites of the family phytoseiidae found associated with phytophagous mites in Punjab. *Acarology Newsletter*, 17-18.

DHOORIA (M.S.), 2002. – Mite pests and their management in Punjab. In: Yadav P.R., Chauhan, Putatunda, B.N. and Chhillar B.S. (Eds.). Mites, Their Identification and Management. ICAR Centre of Advanced Studies, Department of Entomology, CCS Haryana Agricultural University, Hisar, pp. 41-47.

DICKE (M.), SABELIS (M.W.) AND BERG (H.), 1989. – Does prey preference change as a result of prey species being presented together? Analysis of prey selection by the predatory mite *Typhlodromus pyri* (Acarina: Phytoseiidae). *Oecologia*, **81** (3): 302-308.

DICKE (M.), SABELIS (M.W.), JONG (M.), AND ALERS (M.P.T.), 1990.– Do phytoseiid mites select the best prey species in terms of reproductive success?. *Experimental and Applied Acarology*, **8**(3): 161-173.

DRIESCHE (R.G.V.), LYON (S.) AND NUNN (C.), 2006. – Compatibility of spinosad with predaceous mite (Acari: Phytoseiidae) used to control western flower thrips (Thysanoptera: Thripidae) in green house crops. *Florida entomologist*, **89** (3): 396-401.

DRUKKER (B), BRUIN (J.), JACOBS (G.), KROON (A) AND SABELIS (M.W.), 2000. – How predatory mites learn to cope with variability in volatile plant signals in the environment of their herbivorous prey. *Experimental and Applied Acarology*, **24**: 881-895

DUSO (C.) AND CAMPORESE (P.), 1991. – Developmental times and oviposition rates of predatory mites *Typhlodromus pyri* and *Amblyseius andersoni* (Acari:Phytoseiidae) reared on different foods. *Experimental and Applied Acarology*, **13**(2):117-128.

DYER (J.G.) AND SWIFT (F.C.), 1979. – Sex ratio in field populations of phytoseiid mites (Acarina: Phytoseiidae). *Annals of Entomological Society of America*, **72**(1): 149 – 154.

EBSSA (L.), BORGEMEISTER (C.) AND POELLING (F.M.), 2006. – Simultaneous application of entomopathogenic nematodes and predatory mites to control western flower thrips, *Frankliniella occidentalis*. *Biological control*, **39**: 66-74.

EL-BADRY (E.A.) AND EL-BANHAWY (E.M.), 1968. – The effect of non prey food, mainly pollen, on the development, survival and fecundity of *Amblyseius gossypii* (Acarina: Phytoseiidae). *Experimental and Applied Entomology*, **11**: 269-272.

EL-BANHAWY (E.M.), 1975. – Biology and feeding behaviour of the predatory mite, *Amblyseius brazilli* (Mesostigmata: Phytoseiidae). *Entomophaga*, **20**(4): 353-360.

EL-BANHAWY (E.M.), AMER (S.A.A.) AND SABER (S.A.), 2000. – Development and reproduction of the predaceous mite, *Amblyseius cydnodactylon* on different prey species: Effect of plant leaf texture on the behaviour and reproduction of the predator. *Zeitschrift fur Pflanzenkrankheiten und Pflandzenschtuz*, **107**(2): 218-224.

EL-LAITHY (A.Y.M.) AND FOULY (A.H.), 1992. – Life table parameters of the two phytoseiid predators *Amblyseius scutalis* (Athias-Henriot) and *A. swirskii* A-H. (Acari: Phytoseiidae) in Egypt. *Journal of Applied Entomology*, **113**:8-12.

EL-LAITHY (A.Y.M.) AND EL-SAWI (S.A.), 1998. – Biology and life table parameters of the predatory mite *Neoseiulus californicus* fed on different diet. *Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz*, **105**(5): 532-537.

ELSAWI (S.A.) AND ABOU-AWAD (B.A.), 1992. – Starvation and fertilization affecting reproduction in *Amblyseius swirskii* Athias-Henriot and *A. gossypii* El-Badry (Acari: Phytoseiidae). *Journal of Applied Entomology*, **113**: 239-243.

ENGEL (V.R.) AND OHNESORGE (B.), 1994. – The role of alternative food and microclimate in the system *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae) and *Panonychus ulmi* Koch (Acari: Tetranychidae) on grape vines, laboratory investigations. *Journal of Applied Entomology*, **118**(2): 129-150.

ESCUDERO (L.A.) AND FERRAGUT (F.), 2005. – Life history of predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae) on four spider mite species as prey, with special reference to *Tetranychus evansi* (Acari: Tetranychidae). *Biological control*, **32**: 378-384.

EVANS (G.O.), 1963. – Observation on the classification of the family Otopheidomenidae (Acari: Mesostigmata) with descriptions of two new species. *Annals and Magazine of Natural History*, **5**(13): 609-620.

EVELEIGH (E.S.) AND CHANT (D.A.), 1981a. – Experimental studies on acarine predator-prey interactions: Effects of predator age and feeding history on prey consumption and the functional response (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, **59**(7): 1387-1406.

EVELEIGH (E.S.) AND CHANT (D.A.) 1981b. – Experimental studies on acarine predator-prey interactions: The numerical response of immature and adult predators (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, **59**(7): 1407-1418.

EVELEIGH (E.S.) AND CHANT (D.A.),1981c. – The feeding and searching behaviour of two species of phytoseiid mites, *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius degenerans* (Berlese), at different prey densities (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, **59**(7): 1419:1430.

EVELEIGH (E.S.) AND CHANT (D.A.), 1982. – Experimental studies on acarine predator-prey interactions: Distribution of search effort and predation rates of a predator population in a patchy environment (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, **60**(12): 3001-3009.

EWING (H.E.), 1914. – The common red spider or spider mite. *Bulletin of the Oregon Agricultural Experiment Station*, **121**: pp. 95.

EZULIKE (T.O.) AND ODEBIYI (J.A.), 1984. – Feeding habit of *Amblyseius fustis* (Acarina: Phytoseiidae), a predator of the cassava red mite, *Oligonychus gossypii* (Acarina: Tetranychidae). *Biologia Africana*, **1**(2): 30-34.

EZULIKE (T.O.) AND ODEBIYI (J.A.), 1985. – Life history of *Amblyseius fustis* (Pritchard and Baker), an indigenous predator of the cassava red mite, *Oligonychus gossypii* (Zacher) in South Western Nigeria. *Insect Science and its Application*, **6**(2): 193-197.

FERRAGUT (F.), GARCIAMARI (F.), COSTA-COMELLES (J.) AND LABORDA (R.), 1987. – Influence of food and temperature on development and oviposition of *Euseius stipulatus* and *Typhlodromus phialatus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **3**(4): 317-329.

FERRAGUT (F.), LABORDA (R.), COSTA COMELLES (J.) AND GARCIA MARI (F.), 1992. – Feeding behavior of *Euseius stipulatus* and *Typhlodromus phialatus* on the citrus red mite *Panonychus citri* (Acari:Phytoseiidae: Tetranychidae). *Entomophaga*, **37**(4): 537-543.

FLECHTMAN (C.H.W.) AND MC MURTRY (J.A.), 1992. – Studies on how phytoseiid mites feed on spider mites and pollen. *International Journal of Acarology*, **18**(3): 157-162.

FRAULO (A.B.) AND LIBURD (O.E.), 2007. – Biological control of two spotted spider mite, *Tetranychus urticae*, with predatory mite, *Neoseiulus californicus*, in strawberries. *Experimental and Applied Acarology*, **43**: 109-119.

FRIESE (D.D.) AND GILSTRAP (F.E.), 1985. – Prey requirements and developmental times of three phytoseiid species predaceous on spider mites. *South Western Entomologist*, **10**(2): 83-88.

FURTADO (I.P.), MORAES (G.J.), KREITER (S.), TIXIER (M.S.) AND KNAPP (M.), 2007. – Potential of a Brazilian Population of the Predatory mite *Phytoseiulus longipes* as a biological control agent of *Tetranychus evansi* (Acari: Phytoseiidae, Tetranychidae). *Biological control*, **42**: 139-147.

GAEDE (R.), 1992. - On the water balance of *Phytoseiulus persimilis* A-H and its ecology significance. *Experimental and Applied Acarology*, 15:181-198.

GERLACH (S.) AND SENGONCA (C.), 1985. – Comparative studies on the effectiveness of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot, and the predatory thrips, *Scolothrips longicornis* Priesner. *Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz*, **92**(2): 138-146.

GILLESPIE (D.R.) AND QUIRING (D.J.M.), 1994.- Reproduction and longevity of the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae) and its prey, *Tetranychus urticae* (Acari: Tetranychidae) on different host plants. *Journal of the Entomological Society of British Columbia*, 91: 3-8.

GILLIAT (F.C.), 1935. – Some predators of the European red mite, *Paratetranychus pilosus* C. and F. in Nova Scotia. *Canadian Journal of Research and Developmental Zoology,* **13**: 19-38.

GNANVOSSOU (D.), YANINEK (J.S.), HANNA (R.) AND DICKE (M.), 2003. – Effect of prey mite species on life history of the phytoseiid predators *Typhlodromalus manihoti* and *Typhlodromalus aripo*. *Experimental and Applied Acarology*, **30**(4): 265-278.

GOTOH (T.) AND TSCHIYA (A.), 2008. – Effect of multiple mating on reproduction and longevity of the phytoseiid mite *Neoseiulus californicus. Experimental and Applied Acarology*, **44**: 185-197.

GOTOH (T.) AND TSUCHIYA (P.), 2009- Food scarcity reduces female's longevity of *Neoseiulus californicus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **47**: 249-256.

GOTOH (T.), TSUCHIYA (A.) AND KITASHIMA (Y.), 2006. – Influence of prey on developmental performance, reproduction and prey consumption of *Neoseiulus californicus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **40**: 189-204.

GRECO (N.M.), SANCHEZ (N.E.) AND LILJESTHROM (G.G.), 2005. – *Neoseiulus californicus* (Acari: Phytoseiidae) as a potential control agent of *Tetranychus urticae* (Acari: Tetranychidae): Effect of pest/predator ratio on pest abundance on strawberry. *Experimental and Applied Acarology*, **37**: 57-66.

GUPTA (S.K.), 1985. – Hand Book: Plant mites of India. *Zoological Survey of India*, Calcutta, 520pp.

GUPTA (S.K.), 1986. – Fauna of India (Acari: Mesostigmata) Family: Phytoseiidae. *Zoological Survey of India*, Calcutta, 350pp.

GUPTA (S.K.), 2003. – A monograph on plant inhabiting predatory mites of India Part II. Order: *Mesostigmata Memoirs of the Zoological Survey of India*, **20**(1): 185 pp.

HAMLEN (R.A.), 1978. – Biological control of spider mites on green house ornamentals using predaceous mites. *Proceedings of the Florida State Horticultural Society*, **91:**247-249.

HARDMAN (J.M.) AND ROGERS (M.L.), 1991. – Effects of temperature and prey density on survival, development, and feeding rates of immature *Typhlodromus pyri* (Acari : Phytoseiidae). *Environmental Entomology*, **20**(4): 1089-1096.

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). *Journal of Biological Control*, **2**(2): 131-132.

HAYES (A.J.) AND MC ARDLE (B.H.), 1987. - A laboratory study on the predatory mite *Typhlodromus pyri* (Acarina: Phytoseiidae):I. The effect of temperature and food consumption on the rate of development of the eggs and immature stages. *Researches on Population Ecology*, **29**(1): 73-83.

HEADRICK (D.H.) AND GOEDEN (R.D.), 2001. – Biological control as a tool for Ecosystem Management. *Biological Control*, **21**: 249-257.

HO-CHYICHEN AND CHEN-WENHUA, 1999. – Evaluation of feeding and ovipositing responses of three phytoseiid mites to amounts of kanzawa spider mite eggs (Acari: Phytoseiidae: Tetranychidae). *Chinese Journal of Entomology*, **19**(3): 257-264.

HUFFAKER (C.B.) AND FLAHERTY (D.L.), 1966. – Potential of biological control of two spotted spider mites on strawberries in California. *Journal of Economic Entomology*, **59**: 786-792.

JAGADISH (P.S.), CHANNA BASAVANNA (G.P.) AND NANGIA (N.), 1994. – Biology of the predatory mite *Euseius concordis* (Chant) (Acari: Phytoseiidae), an effective predator on *Tetranychus neocaledonicus* Andre (Acari: Tetranychidae). *Mysore Journal of Agricultural Sciences*, **28**(3): 244-248.

JAMES (D.G.), 1990. - Biological Control of *Tetranychus urticae* (Koch) (Acari: Tetranychidae) in Southern New South Wales peach orchards: the role of *Amblyseius victoriensis* (Acarina: Phytoseiidae). *Australian Journal of Zoology*, **37**(6): 645-655.

JAMES (D.G.), WHITNEY (J.) AND RAYNER (M.) 1995. – Phytoseiids (Acari: Phytoseiidae) dominate the mite fauna on grapevines in Canberra district Vineyards. *Journal of Australian Entomological Society*, **34**: 79-82.

JEPPSON (L.R.), KEIFER (H.H.) AND BAKER (E.W.), 1975. – Mites injurious to economic plants. University of California Press, Berkley, Los Angeles, London, 614 pp.

JOSE (V.T.), SHAH (A.H.) AND PATEL (C.B.), 1989. – Feeding potentiality of some important predators of the spider mite, *Tetranychus macfarlane*, a pest on cotton. In: ChannaBasvanna (G.P.) and Viraktamath (C.A.) (Eds.), *Progress in Acarology*, vol. **2**, Oxford IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 367-360.

KABICEK (J.), 1995. – Development and predation by *Amblyseius barkeri* (Acarina: Phytoseiidae) on the mite, *Phytoseiulus persimilis* (Acarina:Tetranychidae). *Ochrana Rostlin*, **31**(1): 57-62.

KAZAK (C), ASLAM (M.M.) AND SEKEROGLU (E.), 1998.- Population growth and compatibility of *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius bibens* Blommers (Acari: Phytoseiidae) feeding on *Tetranychus cinnabarinus* Boisd. (Acari: Tetranychidae) under laboratory conditions. *Turkiye Entomologi Dergisi*, **22**(2): 83-92.

KERGUELEN (V.) AND HODDLE (M.S.), 1999. – Biological control of *Oligonychus perseae* (Acari: Tetranychidae) on avocado: II. Evaluating the efficacy of *Galendromus helveolus* and *Neoseiulus californicus* (Acari: Phytoseiidae). *International Journal of Acarology*, **25**(3): 221-229.

KNISLEY (C.B.) AND SWIFT (F.C.), 1971. – Biological studies of *Amblyseius umbraticus* (Acarina: Phytoseiidae). *Annals of Entomological Society of America*, **64**(4): 813-822.

KOBAYASHI (M.) AND KADAKAO (S.), 1976. – *Amblyseiius* species (Phytoseiidae), a predaceous mite of the rice gall midge, *Orseolia oryzae*, in Thailand. *Japan Agricultural Research Quarterly*, **10**(2): 107-108.

KOLODOCHKA (L.A.), 1983. - Ecological characteristics of the predaceous mite *Amblyseius longispinosus*. *Vestnik Zoologii*, **5**:36-42.

KOLODOCHKA (L.A.), 1985.-Possibility of feeding by the phytoseiid mite *Phytoseiulus persimilis* (Parasitiformes: Phytoseiidae) on the bryobiid mite *Bryobia lagodechiana* (Trombidiformes: Bryobiidae). *Vestnik Zoologii*, (2): 54.

KONDO (A.), 2004. – Colonizing characteristics of two phytoseiid mites, *Phytoseiulus persimilis* (Schicha) (Acari: Phytoseiidae) on green house grape vine and effects of their release on the Kanzawa spider mite, *Tetranychus kanzawai* Kishida (Acari: Tetranychidae). *Applied Entomology and Zoology*, **39**(4): 643-649.

KREITER (S.), 1992. - Biological control of mites using predatory mites: Biological characteristics and use of phytoseiidae. *Paysan Francais*, **875**: 31-47.

KRIPS (O.E.), WILLEMS (P.E.L.) AND DICKE (M.), 1999.– Compatibility of host plant resistance and biological control of the two-spotted spider mite *Tetranychus urticae* in the ornamental crop Gerbera. *Biological control*, **16**: 155-163.

KRISHNAMOORTHY (A.), 1982a. - Effect of temperature on the development, survival and fecundity of the predatory mite, *Amblyseius tetranychivorus* (Gupta) (Acarina: Phytoseiidae). *Entomon*, **7**(4): 447-450.

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

KRISHNAMOORTHY (A.), 1988. - Releases and recoveries of an exotic predatory mite, *Phytoseiulus persimilis* (Acarina: Phytoseiidae). *Entomon*, **13**(1): 95-97.

KROPCZYNSKA LINKIEWICZ (D.), 1973. – Studies on the feeding of four species of Phytoseiid mites (Acarina: Phytoseiidae). Proceedings of the 3rd International Congress of Acarology, *Prague, Czechoslovakia*, pp. 225-227.

LAING (J.E.), 1969. – Life history and life table of *Metaseiulus occidentalis*. *Annals of Entomological Society of America*, **62** (5): 978-982.

LEE (M.S.) AND DAVIS (D.W.), 1968. – Life history and behavior of the predatory mite *Typhlodromus occidentalis* in Utah. *Annals of the Entomological society of America*, **61**(2): 251-255.

LIBURD (O.E.), WHITE (J.C.), RHODES (E.M.) AND BROWDY (A.A.), 2007. – The residual and direct effects of reduced-risk and conventional miticides on two spotted spider mites, *Tetranychus urticae* (Acari: Tetranychidae) and predatory mites (Acari: Phytoseiidae). *Florida Entomologist*, **90** (1): 249 – 257.

MALLIK (B.) AND CHANNABASAVANNA (G.P.), 1983. – Life history and life tables of *Tetranychus ludeni* and its predator *Amblyseius longispinosus* (Acari: Tetranychidae:Phytoseiidae). *Indian Journal of Acarology*, **8**: 1-12.

MANJUNATHA (M.) AND PUTTASWAMY, 1989. – Life history of *Tetranychus neocaledonicus* under green house conditions. *Journal of Acarology*, **11** (1&2): 35-40.

MANJUNATHA (M.), HANCHINAL (S.G.) AND KULKARNI, (S.V.) 1999. – Mass multiplication of predatory mite, *Amblyseius ovalis* (Acari: Phytoseiidae) and field release against yellow mite and thrips on Chilli. *Journal of Acarology*, **14** (1&2): 16-21.

MANJUNATHA (M.), HANCHINAL (S.G.) AND KULKARNI (S.V.), 2001.–Feeding and host specificity of *Amblyseius ovalis* (Phytoseiidae: Acari) and *Orius maxidentex* (Anthocoridae: Hemiptera). *Karnataka Journal of Agricultural Sciences*, **14**(1): 151-153.

MANSOUR (F.), BERNSTEIN (E.) AND ABOMOCH (F.), 1995. – The potential of spiders of different taxa and a predaceous mite to feed on the carmine spider mite – a laboratory study. *Phytoparasitica*, **23**(3): 217-221.

MARILYN (A.H.), 1994. – Ecological and Evolutionary Analysis of life history patterns. Chapman & Hall Penn Plaza, New York, 357pp.

MC MURTRY (J.A.) AND CROFT (B.A.), 1997. - Life styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology*, **42**: 291-321.

MC MURTRY (J.A.) AND DE MORAES (G.J.), 1984. - Some phytoseiid mites from the South Pacific, with descriptions of new species and a definition of the *Amblyseius largoensis* species group. *International Journal of Acarology*, **10**(1): 27-37.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1964(a) ,– Studies on feeding, reproduction and development of *Amblyseius hibisci* (Acarina: Phytoseiidae) on various food substances. *Annals of Entomological Society of America*, **57**: 649-655.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1964(b). – Predation by *Amblyseius limonicus* on *Oligonychus punicae* (Acarina): Effects of initial predator – prey ratios and prey distribution. *Annals of the Entomological Society of America*, **64**(1): 219-223.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1965. – Insectary production of phytoseiid mites. *Journal of Economic Entomology*, **58**: 282-284.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1966(a). - The influence of pollen and prey density on the number of prey consumed by *Amblyseius hibisci* (Acarina: Phytoseiidae). *Annals of the Entomological Society of America*, **59**(1): 147-149.

MC MURTRY (J.A.) AND SCRIVEN(G.T.), 1966(b). – Effects of artificial foods on reproduction and development of four species of phytoseiid mites. *Annals of the Entomological Society of America*, **59** (1): 267-269.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1975. - Population increase of *Phytoseiulus persimilis* on different insectary feeding programs. *Journal of Economic Entomology*, **68**(3): 319-321.

MC MURTRY (J.A.) AND SCRIVEN (G.T.), 1968. – Studies on predator-prey interactions between *Amblyseius hibisci* and *Oligonychus punicae*: Effects of host-plant conditioning and limited quantities of an alternate food. *Annals of the Entomological Society of America*, **61** (2): 393-397.

MESA (C.N.C.) AND BELLOTTI (A.C.), 1986. - Life cycle and feeding habits of *Neoseiulus anonymus*, predator of tetranychid mites in cassava. *Revista Colombiana de Entomologia*, **12**(1): 54-66.

MESZAROS (A.), TIXIER (M.S.), CHEVAL (B.), BARBAR (Z.) AND KREITER (S.), 2007. – Cannibalism and intraguild predation in *Typhlodromus exhilaratus* and *T. phialatus* (Acari: Phytoseiidae) under laboratory conditions. *Experimental and Applied Acarology*, **41**: 37-43.

METWALLY (A.M.), ABOU EL. NAGA (M.M.), TAHA (H.A.) AND HODA (F.M.), 1984.- Studies on feeding, reproduction and development of *Amblyseius swirskii* (A.H.) (Acarina: Phytoseiidae). *Review of Agricultural Research*, **62**: 323-326.

MEYERDIRK (D.E.) AND COUDRIET (D.L.), 1985. - Predation and developmental studies of *Euseius hibisci* (Chant) (Acarina: Phytoseiidae) feeding on *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae*). Environmental Entomology*, **14**(1): 24-27.

MOCHIZUKI (M.), 1996. – Development, fecundity, diapause attribute, and reproductive compatibility of the pesticide- resistant strain of the predatory mite, *Amblyseius womersleyi* Schicha (Acari: Phytoseiidae). *Japanese Journal of Applied Entomology and Zoology*, **40**(2): 121-126.

MOMEN (F.M.), 1995. - Feeding, development and reproduction of *Amblyseius barkeri* (Acarina:Phytoseiidae) on various kinds of food substances. *Acarologia*, **36**(2): 101-105.

MOMEN (F.M.), 1996. - Effect of prey density on reproduction, prey consumption and sex-ratio of *Amblyseius barkeri* (Acari: Phytoseiidae). *Acarologia*, **37**(1): 3-6.

MOMEN (F.M.), 1999. – Feeding behaviour of some phytoseiid predators on the two spotted spider mite eggs (Acari: Phytoseiidae: Tetranychidae). *Phytophaga Palermo*, **9**: 85-92.

MOMEN (F.M.), 2001. – Biology of *Euseius yousefi* (Acari: Phytoseiidae): Life tables and feeding behaviour on different diets. *Acta Phytopathologica et Entomologica Hungarica*, **36**(3/4): 411-417.

MOMEN (F.) AND EL BOROLOSSY (M.), 1997. – Suitability of the citrus brown mite, *Eutetranychus orientalis* (Acari: Tetranychidae) as prey for nine species of phytoseiid mites. *Anzeiger fur Schadlingskunde Pflanzenschutz Umweltschutz*, **70**(8): 155-157.

MOMEN (F.) AND HUSSEIN (H.), 1999. – Relationships between food substances, developmental success and reproduction in *Typhlodromus transvaalensis* (Acari: Phytoseiidae). *Acarologia*, **40** (2): 107-111.

MOMEN (F.M.) AND AMER (S.A.A.), 1994. – Effect of some foliar extracts on the predatory mite *Amblyseius barkeri* (Acarina: Phyotseiidae). *Acarologia*, **35**(3): 223-228.

MOMEN (F.M.) AND EL-SAWAY (S.A.), 1993. – Biology and feeding behaviour of the predatory mite, *Amblyseius swirskii* (Acari: Phytoseiidae). *Acarologia*, **34**(3): 199-204.

MOMEN (F.M.) AND KHALEK (A.A.), 2008. – Effect of the tomato rust mite *Aculops lycopersici* (Acari: Eriophyidae) on the development and reproduction of three predatory phytoseiid mites. *International Journal of Tropical Insect Science*, **28**(1): 53-57.

MONETTI (L.N.) AND CROFT (B.A.), 1997. – *Neoseiulus californicus* (Mc Gregor) and *Neoseiulus fallacis* (Garman): Larval responses to prey and humidity, nymphal feeding drive and nymphal predation on phytoseiid eggs. *Experimental and Applied Acarology*, **21**(4): 225-234.

MORAES (G.J.) AND LIMA (H.C.), 1983. – Biology of *Euseius concordis* (Chant) (Acarina: Phytoseiidae), a predator of tomato russet mite. *Acarologia*, **24**(3): 251-255.

MORAES (G.J.) AND MC MURTRY (J.A.), 1986. – Suitability of the spider mite *Tetranychus evansi* as prey for *Phytoseiulus persimilis*. *Entomologia Experimentalis et Applicata*, **40**(2): 109-115.

MORI (H.), 1977. - Notes on the biology of phytoseiid mites (Acarina: Phytoseiidae) as predators of tetranychid mites in Japan. *Review of Plant Protection Research*, **1**(10): 91-101.

NAKAGAWA (T.), 1985. – Effect of humidity on the development, reproduction and predatory activity of *Amblyseius longispinosus* (Evans), a predator of *Tetranychus kanzawai* Kishida. *Proceedings of the Association for plant protection of* Kyushu, **31**:220-222.

NANGIA (N.) AND CHANNA BASAVANNA (G.P.), 1982.- Effect of castor pollen on the density of *Typhlodromips tetranychivorous* Gupta (Acari: Phytoseiidae). *Indian Journal of Acarology*, **7**(1): 1-4.

NANGIA (N.) AND CHANNA BASAVANNA (G.P.), 1989. - Feeding potential of *Amblyseius tetranychivorus* (Acari: Phytoseiidae), an indigenous predator on selected tetranychid and tenuipalpid mites. *Indian Journal of Acarology*, **10**(1 & 2): 75-81.

NAVAJAS (M.), THISTLEWOOD (H.), LAGNEL (J.), MARSHALL (D.), TSAGKARA KOU (A.) AND PASTEUR (N.), 2001. – Field releases of the predatory mite, *Neoseiulus fallacis* (Acari: Phytoseiidae) in Canada, monitored by Pyrethroid resistance and Allozyme Markers. *Biological control*, **20**: 191-198.

NELSON (F.R.S.), 1973. - Reproduction and consumption rate of *Amblyseius hibisci* on a diet of pollen and *Panonychus citri*. *Annals of the Entomological Society of America*, **66**(4): 918-919.

NOMIKOU (M.), JANSSEN (A.), SCHRAAG (R.) AND SABELIS (M.W.), 2001. – Phytoseiid predators as potential biological control agents for *Bemisia tabaci. Experimental and Applied Acarology*, **25**(4): 271-291.

NORONHA AC.Da (S.), MORAES DE (G.J.) AND CIOCIOLA (A.I.), 1995. – Biology of *Amblyseius manihoti* Moraes n. sp. with *Mononychellus tanajoa* (Bondar) (Acari: Phytoseiidae: Tetranychidae) on cassava varieties. *Anais da Sociedade Entomologica do Brazil*, **24**(2): 305-313.

OHNESORGE (B.), 1981.-Food preference of the predaceous mite *Phytoseiulus persimilis* A.-H. and nutritional value of the stages of its prey *Tetranychus urticae* Koch. *Mitteilungen der Deutschen Gesellschaft fur Allgemeine and Angewandte. Entomologie,* **3**(1/3): 114-117.

OMKAR (A.P.), 2003. – Ecology and Biocontrol Potential of a Scale Predator, *Chilocorus nigritus*. *Biocontrol Science and Technology,* **13**(4): 379.

OPIT (G.P.), NECHOLS (J.R.) AND MARGOLIES (D.C.), 2004. – Biological control of two spotted spider mites, *Tetranychus urticae* Koch (Acari: Tetranychidae); using *Phytoseiulus persimilis*. Athias – Henriot (Acari: Phytoseiidae) on ivy geranium: assessment of predator release ratios. *Biological control*, **29**: 445-452.

OPIT (G.P.), PERRET (J.), HOLT (K.), NECHOLS (J.R.), MARGOLIES (D.C.) AND WILLIAMS (K.A.), 2009. – Comparing chemical and biological control strategies for two spotted spider mites (Acari:Tetranychidae) in commercial green house production of bedding plants. *Journal of Economic Entomology*, **102** (1): 336-346.

OSAKABE (M.H.),2002. – Which predatory mite can control both a dominant mite pest, *Tetranychus urticae*, and a latent mite pest, *Eotetranychus asiaticus*, on strawberry?. *Experimental and Applied Acarology*, **26**(3/4): 219-230.

OSAKABE (M.), INOUE (K.) AND ASHIHARA (W.), 1986.- Feeding, reproduction and development of *Amblyseius sojaensis* Ehara (Acarina: Phytoseiidae) on two species of spider mites and on tea pollen. *Applied Entomology and Zoology*, **21**(2): 322-327.

OVERMEER (W.P.J.), 1981.- Notes on breeding phytoseiid mites from orchards (Acarina: Phytoseiidae) in the laboratory. *Mededelingen Van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*, **46**(2): 503-509.

PARROT (P.J.), HODGKISS (H.E.) AND SCHOENE (W.J.), 1906. – The Eriophyidae Part I. The apple and pear mites. *NewYork State Agricultural Experiment Station Bulletin*, 283: 302-303.

PENA (J.E.), 1992.- Predator-prey interactions between *Typhlodromalus peregrinus* and *Polyphagotarsonemus latus*: Effects of alternative prey and other food resources. *Florida Entomologist*, **75**(2): 241-248.

PETER (A.F.), 2006. – Eradiation as a phytosanitary treatment for *Aspidiotus destructor* (Homoptera: Diaspididae). *Journal of Economic Entomology*, **99**(4): 1138-1142.

PETROVA (V.I.), 1972.- The effects of the feeding and temperature factors on ovo- and spermatogenesis in the predaceous mite *Phytoseiulus. The pathology of insects and mites Riga,Izdatel'stvozinatne,Latvian SSR*: 191-206.

PILLAI (K.S.) AND PALANISWAMI (M.S.), 1983.- Economics on the control of spider mites on cassava. *Entomon,* **8**(4): 373-375.

PRASAD (V.), 1967. – Biology of the predatory mite *Phytoseiulus macropilis* in Hawaii (Acarina: Phytoseiidae). *Annals of Entomological Society of America,* **60**(5): 905-910.

PRASAD (V.), 1973. – The role of *Phytoseiulas macropilis* (Banks) (Acarina: Phytoseiidae) in control of the spider mites in Hawaii. *Acarologia*, **15**(3): 400 – 405.

PRUSZYNSKI (S.), 1978.- From studies on the predaceous mite *Phytoseiulus persimilis* Athias-Henriot IV. Some aspects of the practical use of *Phytoseiulus persimilis* in the biological control of mites (Tetranychidae). *Roczniki Nauk Rolniczzche*, **7**(2): 193-208.

PRUSZYNSKI (S.) AND CONE (W.W.), 1973. – Biological observations of *Typhlodromus occidentalis* (Acarina: Phytoseiidae) on hops. *Annals of the Entomological Society of America*, **66**(1): 47-51.

PUTATUNDA (B.N.), 2002. – Role of predatory mites study in mite pest management. *Plant Protection Bulletin Faridabad,* **54**(1/2): 17-20.

PUTMAN (W.L.) AND HERNE (D.C.), 1958. – Natural control of Phytophagous mites (Tetranychidae And Eriophyidae) in Ontario peach orchards. *Proceedings of 10th International Congress of Entomology*, Montreal, 1956, **4**: 667-673.

PUTTASWAMY AND CHANNABASAVANNA (G.P.), 1979.- *Typhlodromips tetranychivorus* (Acari: Phytoseiidae) feeding on *Tetranychus ludeni* (Acari:Tetranychidae) at Bangalore. *Acarology Newsletter*, 8:5.

PUTTASWAMY AND CHANNABASAVANNA (G.P.), 1980.– Competition between *Tetranychus neocaledonicus* and *T. ludeni* (Acari: Phytoseiidae). *Indian Journal of Acarology*, **4**(2): 49-54.

QUALE (H.J.), 1912. – Red spiders and mites of citrus tree. California Agricultural Experiment Station Bullettin, **234**: 483-530.

RACHID HANNAA (A.O.), NEGLOH (K.), TOKO (M.) AND SABELIS (M.W.), 2005.– Biological control of Cassava green mite with exotic and indigenous phytoseiid predators – Effects of intraguild predation and supplementary food. *Biological Control*, **33**: 143-152.

RAFARTI-FARD (M.), HAJIZADEH (J.) AND ARBABI (M.),2004. – Biology of *Typhlodromips caspiansis* (Acari: Phytoseiidae) predator of some spider mites (Acari: Tetranychidae) under laboratory condition. *Journal of Entomological Society of Iran*, **24**(1): 49-65.

RAGUSA (S.) AND SWIRSKI (E.), 1975.- Feeding habits, development and oviposition of the predaceous mite *Amblyseius swirskii* Athias-Henriot (Acarina: Phytoseiidae) on pollen of various weeds. *Israel Journal of Entomology*, 10: 93-103.

RAGUSA (S.) AND SWIRSKI (E.), 1977.- Feeding habits, post-embryonic and adult survival, mating, virility and fecundity of the predaceous mite *Amblyseius swirskii* (Acarina: Phytoseiidae) on coccids and mealybugs. *Entomophaga*, **122** (4): 383-392.

RAHMAN (K.A.) AND SAPRA (A.N.), 1946. – On the biology of the vegetable mite *Tetranychus cucurbitae* (Rahman and Sapra: Family: Tetranychidae). *Indian Journal of Agricultural Science*, **15**(3): 124-130.

RASMY (A.H.) AND EL BANHAWY (E.M.), 1975. – Biology and predatory efficiency of two phytoseiid mites as affected by long-term pollen feeding. *Entomophaga*, **20**(1): 93-95.

RASMY (A.H.), MOMEN (F.M.), ZAHER (M.A.), NAWAR (M.S.) AND ABOU-ELELLA (G.M.), 2004. – Dietary effect on the development, reproduction and sex ratio of the predatory mite *Amblyseius denmarki* Zaher and El. Borolosy (Acari: Phytoseiidae). *International Journal of Tropical Insect Science*, **24**(2): 192-195.

RASMY (A.H.), ABDEL RAHMAN (H.A.), ABDEK KADER (M.M.) AND HUSSEIN (H.E.), 1990.- Effects of non-lethal attacks by three phytoseiid species on subsequent development, fecundity and mortality of the two-spotted spider mite. *Experimental and Applied Acarology*, **10**(3): 151-155.

REIS (P.R.), SOUSA (E.O.), TEODORA (A.V.) AND PEDRO NETO (M.), 2003.–Effect of two species of predaceous mites (Acari: Phytoseiidae). *Neotropical Entomology*, **32**(3): 461-467.

REUVENY (H.), PALEVSKY (E.) AND GERSON (U.), 1996. – Laboratory life history studies of the predaceous mite, *Typhlodromus athiasae* (Acari: Phytoseiidae*). Systematic and Applied Acarology*, 1: 45-53.

RIJIN VAN (P.C.J.) AND SABELIS (M.W.), 1993. – Does alternative food always enhance biological control? The effect of pollen on the interaction between western flower thrips and its predators. *Bulletin of Organisation Internationale de Lutte Biologique et Intigie Contre les Animaux et les Plantes Nuisibles, Section Regionale Ouest patearctique,* **16**(8): 123-125.

RIJIN VAN (P.C.J) AND TANIGOSHI (L.K.), 1999. – Pollen as food for the predatory mites *Iphiseius degenerans* and *Neoseiulus cucumeris* (Acari: Phytoseiidae): dietary range and life history. *Experimental and Applied Acarology,* **23**: 785-802.

RODRIGUEZ (H.) AND RAMOS (M.), 2004. – Biology and feeding behaviour of *Amblyseius largoensis* (Muma) (Acari: Phytoseiidae) on *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae). *Revista de Protection Vegetal,* **19**(2): 73-79.

RODRIGUEZ (J.M.), FERRAGUT (F.), CARNERO (A.) AND PENA (M.A.), 1994.– Diapause in the predaceous mites *Amblyseius cucumeris* (Oud.) and *Amblyseius barkeri* (Hug.): Consequences of use in integrated control programmes. *Journal of Applied Entomology,* **118**: 44-50.

ROWELL (H.J.), CHANT (D.A.), HANSELL, (R.I.C.), 1978. – The determination of steal homologies and setal patterns on the dorsal shield in the family phytoseiidae (Acarina: Mesostigmata). *Canadian Entomology*, 110: 859-876.

SABELIS (M.W.), 1981.- Biological control of two-spotted spider mites using phytoseiid predators. Part I. Modelling the predator-prey interaction at the individual level. *Agricultural Research Report, Agricultural University*, Wageningen, 910: 1-242.

SADANA (G.L.) AND CHHABRA (S.C.), 1974. – New records on hosts and predators of the phytophagous mite, *Oligonychus mangiferus* (Rahman and Sapra). *Science and Culture*, **40**: 362-363.

SADANA (G.L.) and GUPTA (B.K.), 1983.- Phytophagus mite fauna of Assam together with new records and new species. *Entomon*, **8**(1):1-6.

SADANA (G.L.), AND SHARMA (N.K.), 1989. – Developmental stages of the predatory mite, *Amblyseius finlandicus* (Acari: Phytoseiidae). *Indian Journal of Acarology*, **10** (1 &2): 65-74.

SAITO (Y.), 1990.- Life history and feeding habit of *Typhlodromus bambusae*, a specific predator of *Schizotetranychus celarius* (Acari:Phytoseiidae: Tetranychidae). *Experimental and Applied Acarology*, **10**(1): 45-51.

SANTOS (M.A.), 1975.- Functional and numerical responses of the predatory mite, *Amblyseius fallacis* to prey density. *Environmental Entomology*, **4**(6): 989-992.

SARWAR (M.), WU (K.) AND XU (X.), 2009. – Evaluation of biological aspects of the predaceous mite, *Neoseiulus cucumeris* (Oudemans) (Acari: Phytoseiidae) due to prey changes using selected arthropods. International Journal of Acarology, **35**(6): 503-509.

SATO (M.E.), SILVA (M.Z.), FILHO (M.F.D.S), MATIOLI (A.L.) AND RAGA (A.), 2007. – Management of *Tetranychus urticae* (Acari: Tetranychidae) in strawberry fields with *Neoseiulus californicus* (Acari: Phytoseiidae) and acaricides. *Experimental and Applied Acarology*, 42(2): 107-120.

SATPATHY (J.M.) AND MANIA (P.K.), 1969. – New record of a phytoseiid mite, *Amblyseius finlandicus* occurring on sugarcane with notes on its life history and binomics. *Journal of Bombay Natural History Society*, **66**(3): 648-655.

SCHAUSBERGER (P.), 1992. – Comparative investigations on the effect of different foods on development and reproduction of *Amblyseius aberrans* Oud. and *Amblyseius finlandicus* Oud. (Acarina:Phytoseiidae*). Journal of Applied Entomology*, **113** (5): 476-486.

SCHICHA (E.), 1977. – Immature stages of three mite species (Acari: Phytoseiidae) from apple in Australia. *Proceedings of Linnaean Society, New South Wales*, **101**(3): 317-326.

SCHICHA (E.), 1978. – Two new species of *Typhlodromus* from Australia and *Typhlodromus caudiglans* redescribed (Acari : Phytoseiidae). *Acarologia*, **20**(3): 317-326.

SCHLIESSKE (J.), 1981. – On the technique for mass-rearing of predatory mites (Acari:Phytoseiidae)under controlled conditions. *Mededelingen Van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*, **46**(2): 522-527.

SCIARAPPA (W.J.) *AND SWIFT (F.C.), 1977.* – Biological studies of *Typhlodromips sessor* (Acarina: Phytoseiidae). *Annals of the Entomological Society of America*, **70**(2): 285-288.

SCIARAPPA(W.J.), SWIFT (J.F.) AND KNISLEY (C.B.), 1977.–Distribution, Abundance, and Interspecific associations of *Typhlodromips sessor* (Acarina: Phytoseiidae), *Annals of Entomological Society of America*, **70**(6): 955-959.

SENGONCA (C.). KHAN (I.A.) AND BLASESER (P.), 2003. – Prey consumption during development of *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae) at higher temperatures in the laboratory. *Anzeigerfur Schadling Skunde*, **76**(3): 57-64.

SHARMA (A.) AND KUSHWAHA (K.S.), 1984. – Susceptibility of different varieties of brinjal to *Tetranychus neocaledonicus* (Acari: Tetranychidae). *Indian Journal of Acarology*, **6**(2): 100-103.

SHARMA (N.K.) AND SADANA (G.L.), 1985.- Influence of temperature on the development of the predatory mite, *Amblyseius finlandicus* (Acari: Phytoseiidae). *Indian Journal of Acarology*, (9): 57-62.

SHARMA (N.K.) AND SADANA (G.L.), 1987.- Effect of predator-prey density on the prey consumption and daily rate of egg production of the predatory mite, *Amblyseius finlandicus* (Oudemans) (Acarina: Phytoseiidae). *Entomon*, **12**(3): 191-195.

SHARMA (N.K.) AND SADANA (G.L.), 1989.- Development of *Amblyseius finlandicus* (Acari:Phytoseiidae) on its prey, *Eutetranychus orientalis* (Acari : Tetranychidae). *Journal of Acarology*, **11**(1&2): 51-54.

SHEHATA (K.K.), 1973.- Prey type and density and their effect on the potentiality of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae). *Biologia Czechoslovakia*, **28**(8): 619-626.

SHIBAO (M.), EHARA (S.), HOSOMI (A.) AND TANAK (H.), 2004. – Seasonal fluctuation in population density of phytoseiid mites and the yellow tea thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) on grape and predation of the thrips by *Euseius sojaensis* (Ehara) (Acari: Phytoseiidae). *Applied Entomology and Zoology*, **39**(4): 727-730.

SHIH (C.I.T.) AND WANG (C.), 2001. – Functional responses of *Amblyseius ovalis* (Evans) (Acari: Phytoseiidae) on *Tetranychus urticae* Koch (Prostigmata: Tetranychidae): Effects of prey stages. Acarology*: Proceedings of the 10th International Congress of Acarology, CSIRO publishing, Collingwood, Australia*, pp. 498-505.

SHIH (C.I.T.), CHANG (H.Y.), HSU (P.H.) AND HWANG (Y.F.), 1993. – Responses of *Amblyseius ovalis* (Evans) (Acarina: Phytoseiidae) to natural food resources and two artificial diets. *Experimental and Applied Acarology*, **17**(7): 503-519.

SHIPP (J.L.) AND WANG (K.), 2003. – Evaluation of *Amblyseius cucumeris* (Acari: Phytoseiidae) and *Orius insidiosus* (Hemiptera: Anthocoridae) for control of *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Biological control*, **28**: 271-281.

SHREWSBURY (P.M.) AND HARDIN (M.R.), 2003. – Evaluation of predatory mite (Acari: Phytoseiidae) releases to suppress spruce spider mites, *Oligonychus ununguis* (Acari: Tetranychidae), on Juniper. *Journal of Economic Entomology*, **96**(6): 1675-1684.

SIDHU (A.S.) AND SINGH (G.), 1972. – Laboratory studies on the host range of vegetable mite, *Tetranychus cucurbitae* (Rahman and Sapra). *Journal of Research Punjab Agricultural University*, **9**: 313-314.

SIMOVA (S.), 1976.- Predaceous mites of the family phytoseiidae on plum and their populations and effect on plant feeding mites. *Rastite Inozashehita Nauka*, (3): 77-86.

STEINER (M.Y.), GOODWIN (S.), WELLHAM (T.M.), BARCHIA (I.M.) AND SPOHR (L.J.), 2003. – Biological studies of the Australian predatory mite, *Typhlodromus montdorensis* (Schicha) (Acarina: Phytoseiidae), a potential biocontrol agent for western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Australian Journal of Entomology*, **42** (2): 124-130.

SWIRSKI (E.) AND DORZIA (N.), 1969. – Laboratory studies on the feeding, development and fecundity of the predaceous mite *Typhlodromus occidentalis* Nesbitt (Acarina: Phytoseiidae) on various kinds of food substances. *Israel Journal of Agriculture and Research*, **19**(3): 143-145.

SWIRSKI (E.), AMITAI (S.) AND DORZIA (N.), 1967a. – Laboratory studies on the feeding, development and reproduction of the predaceous mites *Amblyseius rubini* Swirski and Amitai and *Amblyseius swirskii* Athias (Acarina: Phytoseiidae) on various kinds of food substances. *Israel Journal of Agricultural Research*, **17**:101-119

SWIRSKI (E.), AMITAI (S) AND DORZIA (N.),1967b. – Laboratory studies on the feeding, development and oviposition of the predaceous mite, *Typhlodromus athiasae* P.and S. (Acarina: Phytoseiidae) on various kinds of food substances. *Israel Journal of Agricultural Research*, **17**: 213-218

SWIRSKI (E.), AMITAI (S) AND DORZIA (N.), 1967c. – Laboratory studies on the feeding habits, postembryonic survival and oviposition of the predaceous mites *Amblyseius chilensis* Dosse and *Amblyseius hibisci* Chant (Acari: Phytoseiidae) on various kinds of food substances. *Entomophaga* ,15:93-106.

TAKAFUJI (A.) AND CHANT (D.A.), 1976. – Comparative studies of two species of predaceous phytoseiid mites (Acarina: Phytoseiidae), with special reference to their responses to the density of their prey. *Researches on Population Ecology*, **17**(2): 255-310.

TAKAHASHI (F.) AND CHANT (D.A.), 1992.- Adaptive strategies in the genus *Phytoseiulus evansi* (Acari: Phytoseiidae):1. Developmental times. *International Journal of Acarology*, **18**(3): 171-176.

TAKAHASHI (F.) AND CHANT (D.A.), 1994.- Adaptive strategies in the genus *Phytoseiulus evansi* (Acari: Phytoseiidae):II. Survivorship and reproduction. *International Journal of Acarology*, 20: 87-97.

TANIGOSHI (L.K.), FARGERLUND (J.) AND NISHIO-WONG (J.Y.), 1981. – Significance of temperature and food resources to the developmental biology of *Amblyseius hibisci* (Chant) (Acarina: Phytoseiidae*). Zeitschrift fur Angewante Entomologie*, **92**(4): 409-419.

TETSUO (G.), KOICHI (Y.) AND KATSUHIKO MORI, 2004. - Effect of temperature on the life history of the predatory mite, *Amblyseius* (*Neoseiulus*) *californicus* (Acari:Phytoseiidae). *Experimental and Applied Acarology*, **32**:15-30.

TETSUO (G.), MITSUYOSHI AND KOICHI (Y.), 2004. - Prey consumption and functional response of three acarophagus species to eggs of the two spotted spider mite in the laboratory. *Applied Entomology*, **39** (1):97-105.

TOKO (M), O'-NEIL (R.J.) AND YANINEK (J.S.), 1994. – Effect of cassava exudate and prey densities on the survival and reproduction of *Typhlodromalus limonicus* (Garman and Mc Gregor) S.I. (Acari: Phytoseiidae), a predator of the cassava green mite, *Mononychellus tanajoa* (Bondar) (Acari: Tetranychidae*). Experimental and Applied Acarology*, **18**(4): 221-231.

TOYOSHIMA (S.), 2003. – A candidate of predatory phytoseiid mite (Acari: Phytoseiidae) for the control of the European red mite *Panonychus ulmi* (Koch), (Acari: Tetranychidae) in Japanese apple orchards. *Applied Entomology and Zoology*, **38** (3): 387-391.

TSUNODA (T.) AND AMANO (H.), 2001. Female mate-receptivity behaviour in multiple matings of a predacious mite, *Amblyseius womersleyi* Schicha (Acari: Phytoseiidae). *Applied Entomology and Zoology*, **36**(3): 393-397.

VANTORNHOUT (I.), MINNAERI (H.L.), TIRRY (L.) AND CLERCQ (P. DE), 2005. – Influence of diet on life table parameters of *Iphiseius degenerans* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, **35**: 183-195.

WALZER (A.), BLUMEL (S.) AND HAUDORF (H.), 2003. – Use of beneficials in theory and practice: the combined use of two predatory mite species for spider mite control in protected crops. *Landlicher Raum* Print, 1: 23.

WEI- QINGCAI AND WALDE (S.J.), 1997. – The functional response of *Typhlodromus pyri* to its prey, *Panonychus ulmi*: the effect of pollen. *Experimental and Applied Acarology*, **21**(10/11): 677-684.

WEI-LAN (M.A.) AND LAING (J.E.), 1973.- Biology, potential for increase and prey consumption of *Amblyseius chilensis* (Dossae) [Acarina: Phytoseiidae]. *Entomophaga*, **18** (1): 47-60.

YASTREBSTOV (A.), 1992. - Embryonic development of gamasid mites (Parasitiformes: Gamasida). *International Journal of Acarology,* **18**(2): 121-140.

YOUSEF (A.E.T.A.) AND EL-HALAWANY (M.E.), 1982. - Effect of prey species on the biology of *Amblyseius gossypii* El Badry (Acari: Mesostigmata: Phytoseiidae). *Acarologia*, **23**(2): 113-117.

YOUSEF (A.E.T.A.), ZAHER (M.A.) AND EL-HAFIEZ (A.M.A.), 1982.- Effects of prey on the biology of *Amblyseius gossypii* Elbadry and *Agistemus exsertus* Gonzalez (Acari: Phytoseiidae, Stigmaeidae). *Zeitschrift fur Angewandte Entomologia*, **93**(5): 453-456.

ZAMAN (K.) AND SEKEROGLU (E.), 1992.- Biology, feeding characteristics and life tables of *Amblyseius bidens* Blommers (Acarina: Phytoseiidae) on two different host plants. *Proceedings of the Second Turkish National Congress of Entomology,* 157-169.

ZANNOU(I.D.), HANNA (R.), AGBOTON (B.), MORAES (G.J.de), KREITER (S.), PHIRI (G.) AND JONE (A.), 2007. – Native phytoseiid mites as indicators of non-target effects of the introduction of *Typhlodromalus aripo* for the biological control of Cassava green mite in Africa. *Biological Control*, **41**: 190-198.

ZEMEKA (R.), 1993a. – Characteristics of development and reproduction in *Typhlodromus pyri* on *Tetranychus urticae* and *Cecidophyopsis ribis* .I Over wintered females. *Experimental and Applied Acarology,* **17**(6): 405-421.

ZEMEKA (R.), 1993b. – Characteristics of development and reproduction in *Typhlodromus pyri* on *Tetranychus urticae* and *Cecidophyopsis ribis*. II. Progeny of overwintered females. *Experimental and Applied Acarology*, **17**(11): 847-858.

ZEMEKA (R.) AND PRENEROVA (E.), 1997. – Powdery mildew (Ascomycotina : Erysiphales)- an alternative food for the predatory mite *Typhlodromus pyri* Scheuten (Acari:Phytoseiidae). *Experimental and Applied Acarology*, **21**(6/7): 405-414.

ZHANG (Z.Q.), 2007. – Mites of green houses, identification, Biology and control. CABI, Nosworthy way Wallingford Oxford Shine, 244pp.

ZHANG (N.X.) AND KONG (J.A.), 1985. – Studies on the feeding habits of *Amblyseius fallacis*. *Chinese Journal of Biological Control*, **2**(1): 10-13.

ZHANG (N.X.) AND KONG (J.A.), 1986. - Studies on the feeding habit of *Amblyseius fallacis*. *Chinese Journal of Biological Control*, **2**(1): 10-13.

ZHANG (N.X.) AND LI (Y.X.), 1989a.- An improved method of rearing *Amblyseius fallacis* (Acari: Phytoseiidae) with plant pollen. *Chinese Journal of Biological Control*, **5**(4): 149-152.

ZHANG (N.X.) AND LI (Y.X.), 1989b. - Rearing of the predaceous mite, *Amblyseius fallacis* (German) (Acari: Phytoseiidae) with plant pollen. *Chinese Journal of Biological Control*, **5**(2): 60-63.

ZHANG (Y.X.) and LIN (J.Z.), 1989. – Role of *Gnorimus chaudhirii* (Acari: Phytoseiidae) in controlling tarsonemid mite in paddy fields in China. *Indian Journal of Acarology*, **10**(1-2): 83-86.

ZHANG (Y.), LIN (J.Z.), JI (J.), SAITO (Y.) AND ZHANG (Z.Q.) 2004. – Studies on the potential of *Typhlodromus bambusae* (natural) and *Amblyseius cucumeris* (introduced) (Acari : Phytoseiidae) as a biocontrol agent against pest mites of Moso Bamboo. *Scientia Silvae Sinicae,* **40**(5): 132-137.

ZHANG (Y.), LIN (J.Z.), ZHANG (Z.Q.), SAITO(Y.) AND JI (J.), 2003. – Studies on the life history of *Amblyseius cucumeris* (Acari: Phytoseiidae) feeding on *Aponychus corpuzae* (Acari: Tetranychidae). *Systematic and Applied Acarology*, (8): 67-74.

ZHANG (Y.), ZHANG (Z.Q.), JI (J.) AND LIN (J.Z.), 1999. – Predation of *Amblyseius longispinosus* (Acari: Phytoseiidae) on *Schizotetranychus nanjingensis* (Acari: Tetranychidae), a spider mite injurious to bamboo in Fujian, China. *Systematic and Applied Acarology*, **4**: 63-68.

ZHANG (Y.), ZHANG (Z.Q.), LIN (J.Z.) AND JI (J.), 2000. – Potential of *Amblyseius cucumeris* (Acari: Phytoseiidae) as a biocontrol agent against *Schizotetranychus nanjingensis* (Acari: Tetranychidae) in Fujian, China. *Systematic and Applied Acarology* special publications, 4: 109-124.

ZHANG (Z.Q.) AND CROFT (B.A.), 1994.- A comparative life history study of immature *Amblyseius fallacis*, *Amblyseius andersoni*, *Typhlodromus occidentalis* and *Typhlodromus pyri* (Acari: Phytoseiidae) with a review of larval feeding patterns in the family. *Experimental and Applied Acarology*, **18**(11/12): 631-657.

ZILAHI – BALOGH (G.M.G.), SHIPP (J.L.), CLOUTIER (C.) AND BRODEUR (J.), 2007. – Predation by *Neoseiulus cucumeris* on Western flower thrips, and its oviposition on greenhouse cucumber under winter vs. summer conditions in a temperate climate. *Biological control*, **40**: 160-167.

PLATE III

Total percentage consumption of life stages of

***A. largoensis* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

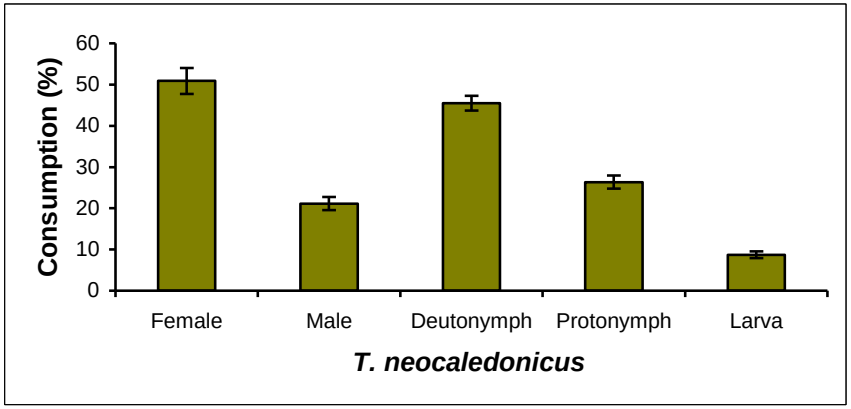

Figure 1

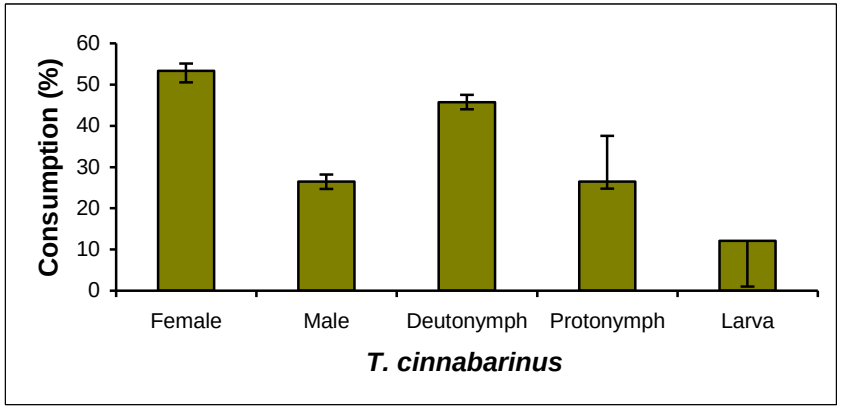

Figure 2

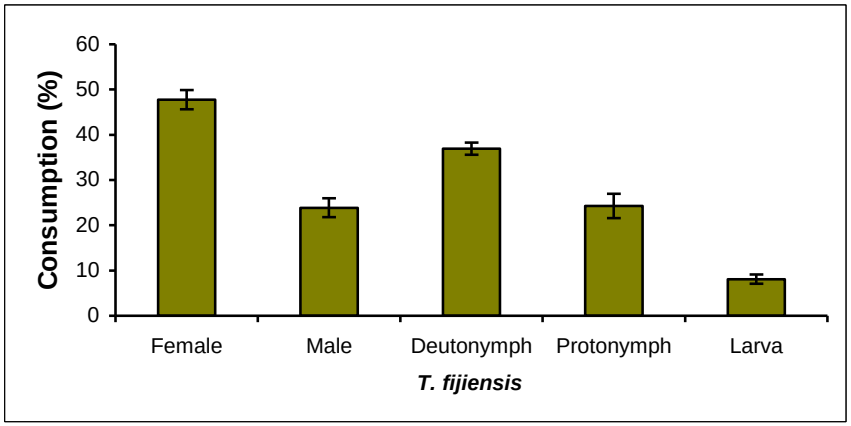

Figure 3

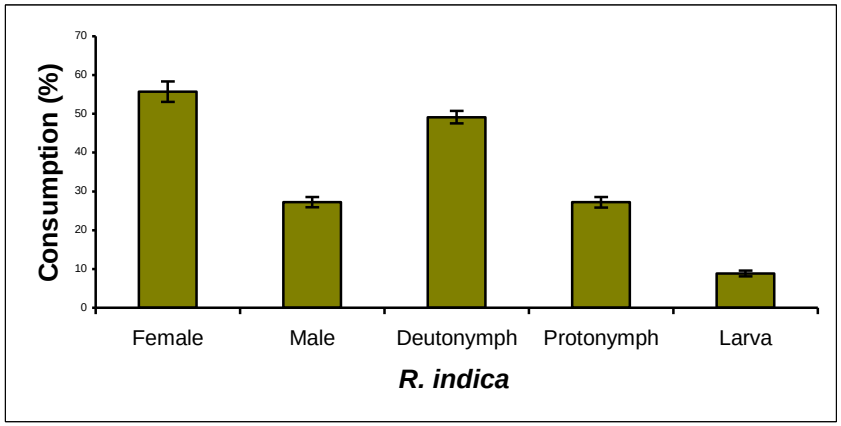

Figure 4

PLATE IV

Total percentage consumption of life stages of

***A. largoensis* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

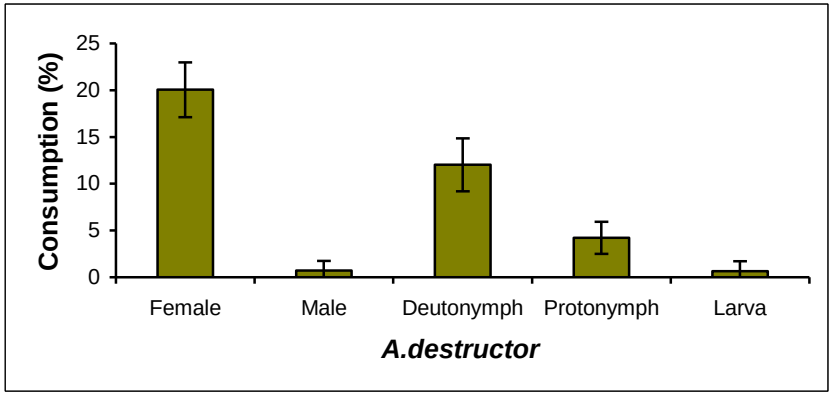

Figure 1

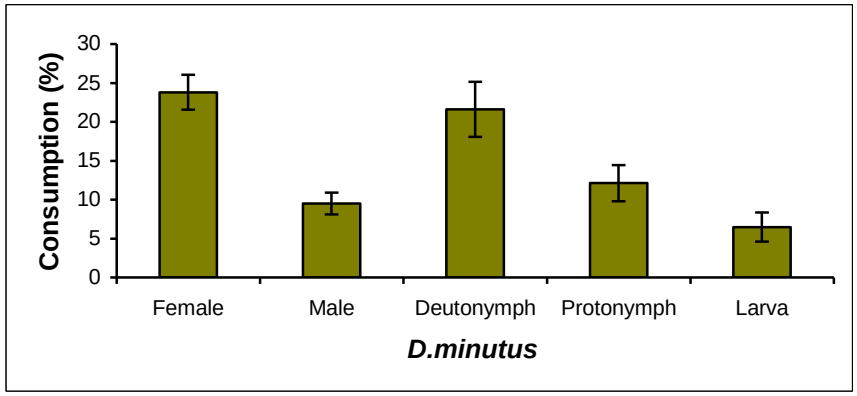

Figure 2

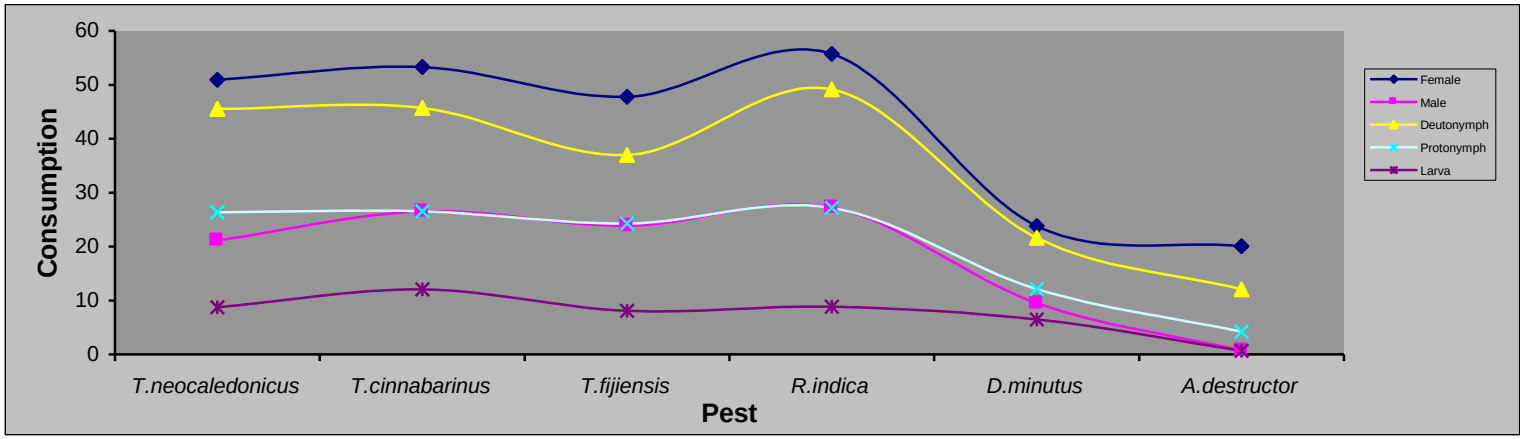

Figure 3

PLATE V

Total percentage consumption of life stages of

***T. suknaensis* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

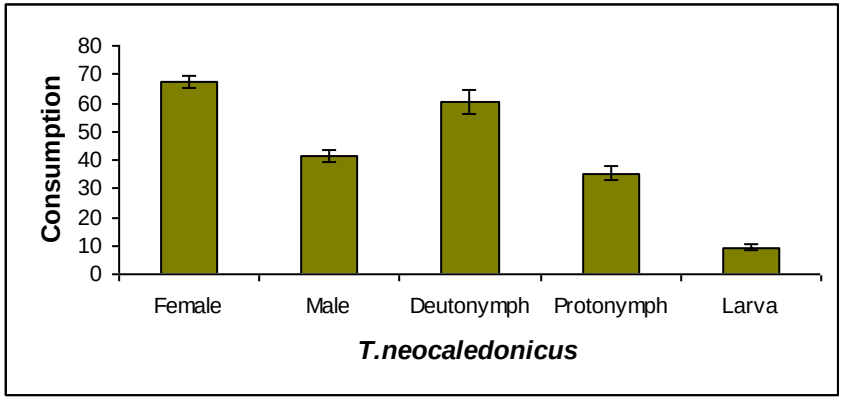

Figure 1

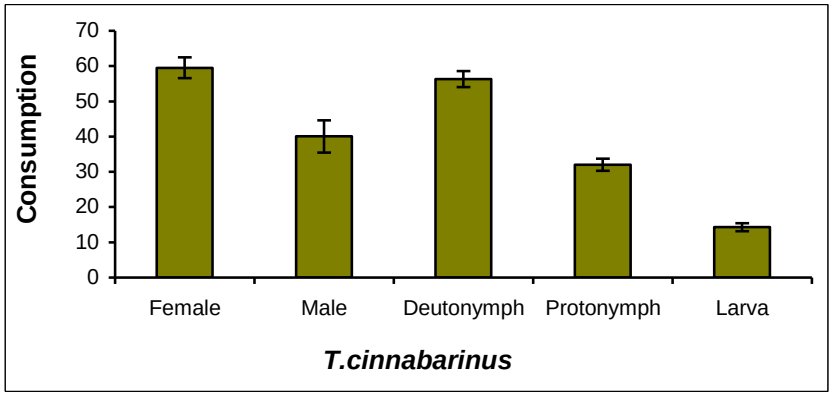

Figure 2

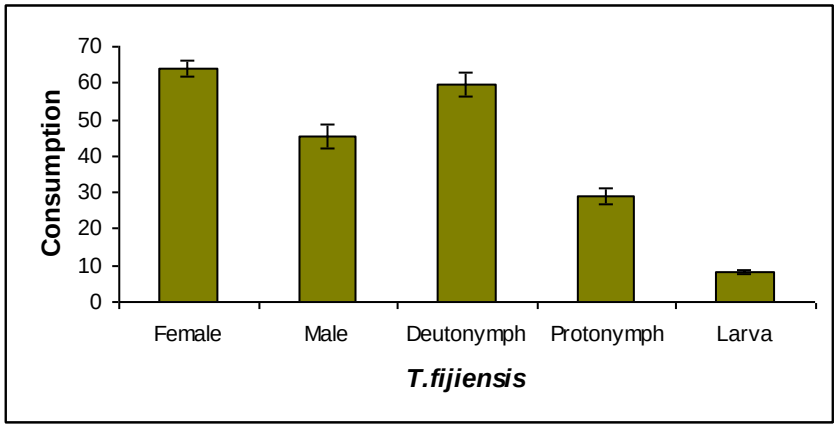

Figure 3

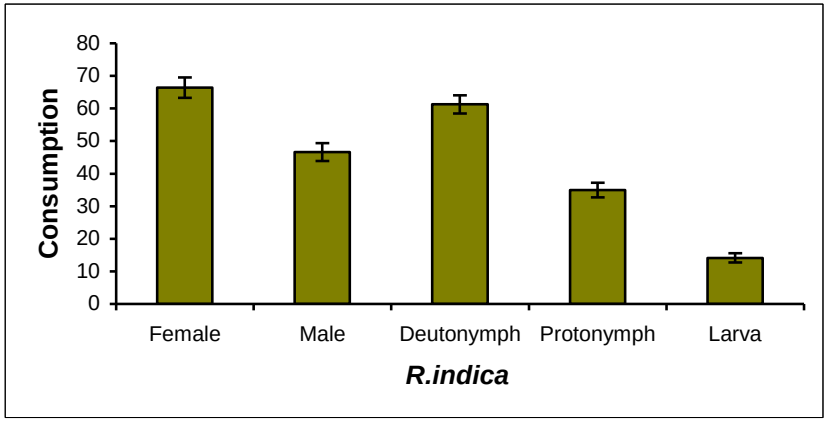

Figure 4

PLATE VI

Total percentage consumption of life stages of

***T. suknaensis* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

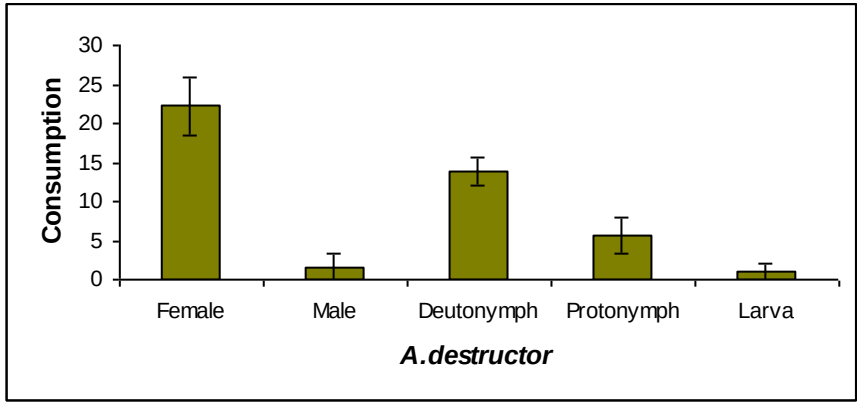

Figure 1

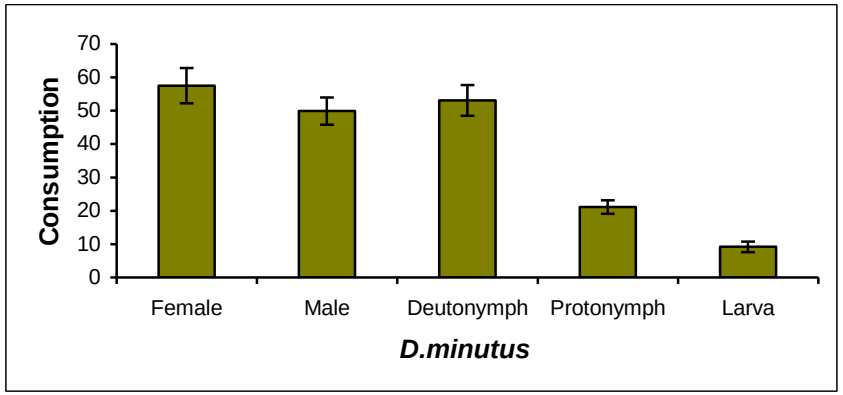

Figure 2

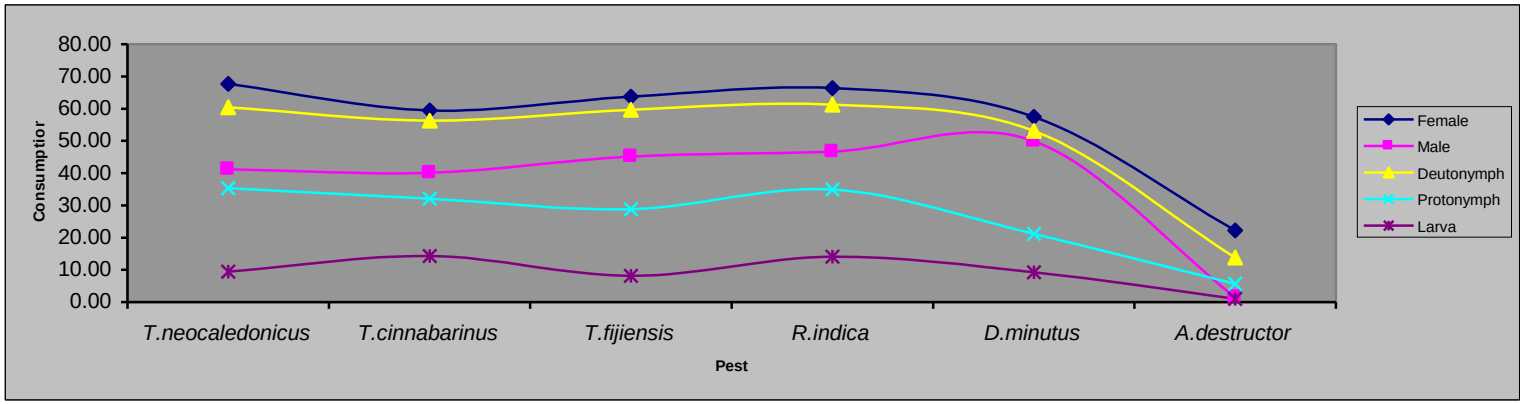

Figure 3

PLATE VII

Total percentage consumption of life stages of

***A. guptai* sp. nov on different pests at a temperature of 30±2^{0}C and 70±2% RH**

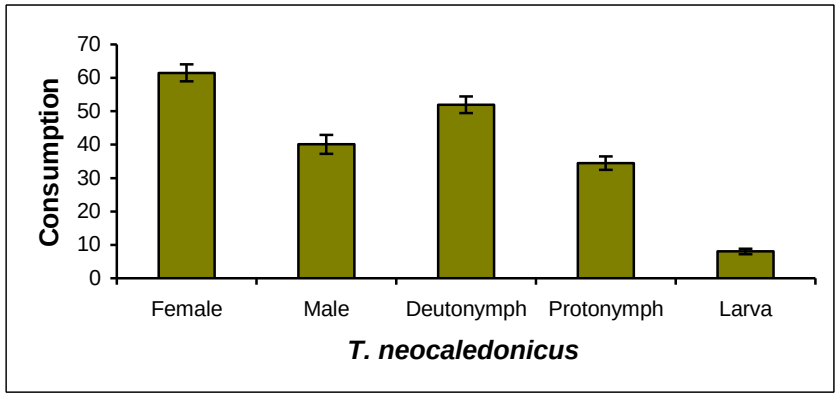

Figure 1

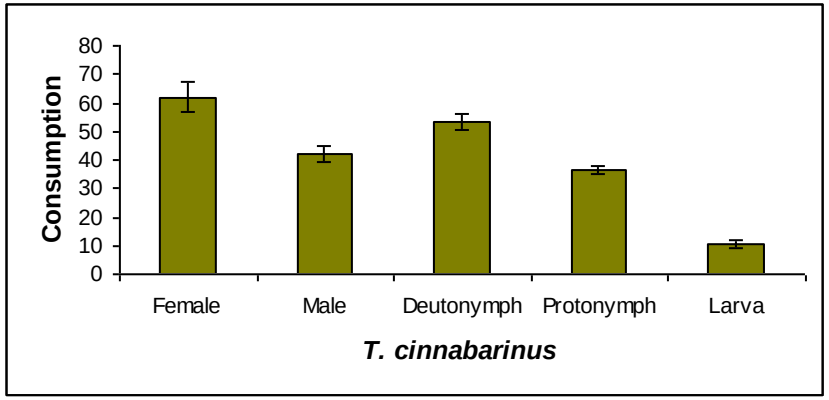

Figure 2

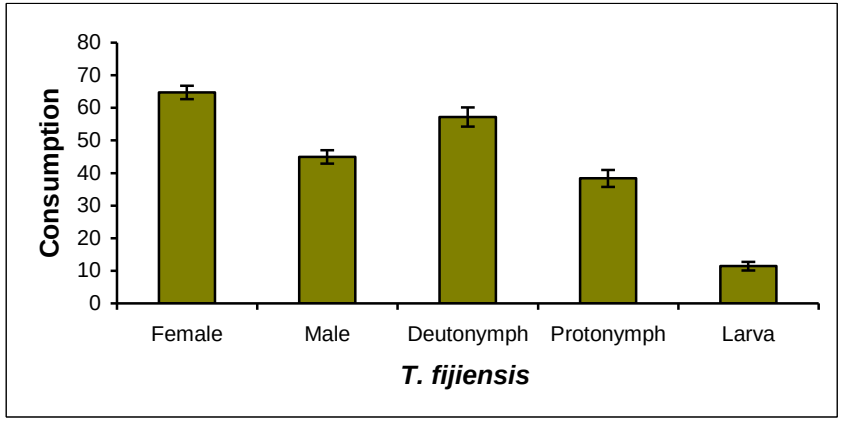

Figure 3

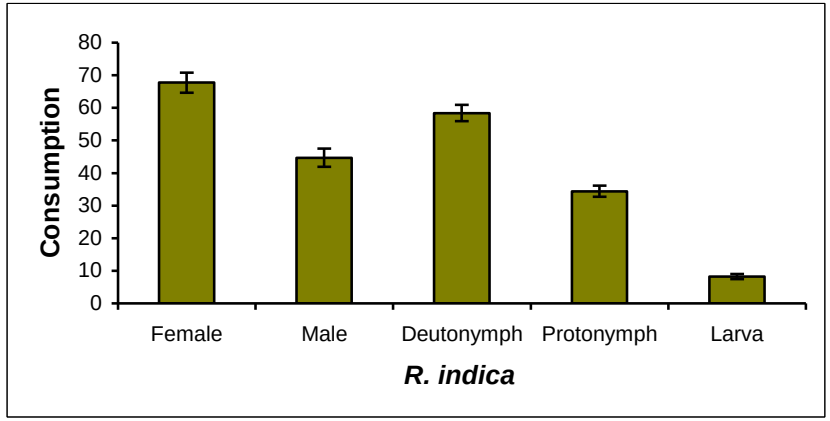

Figure 4

PLATE VIII

Total percentage consumption of life stages of

***A. guptai* sp. nov. on different pests at a temperature of 30±2^{0}C and 70±2% RH**

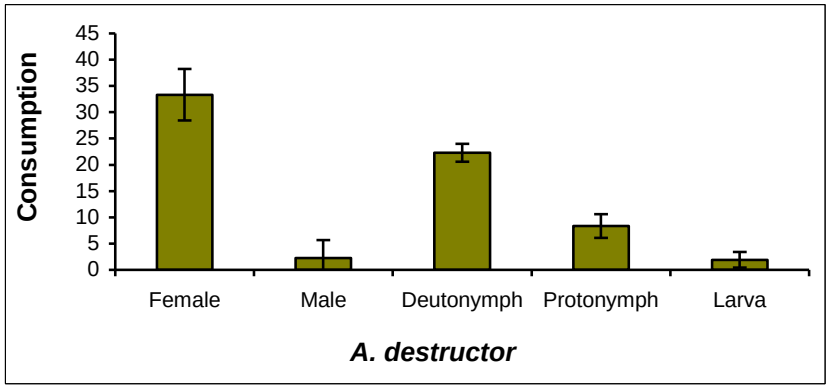

Figure 1

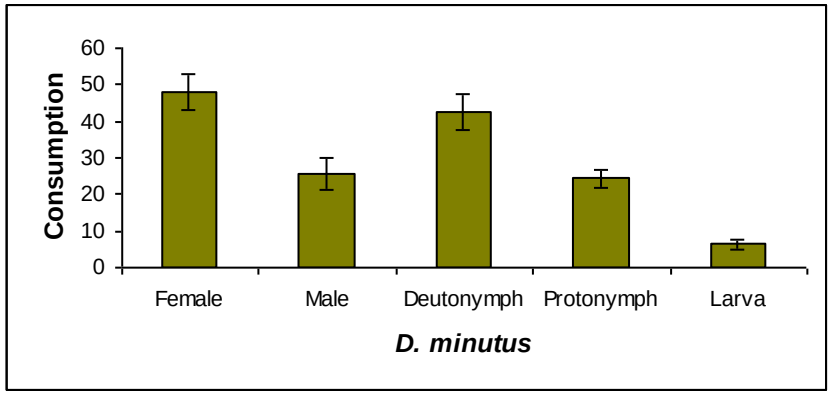

Figure 2

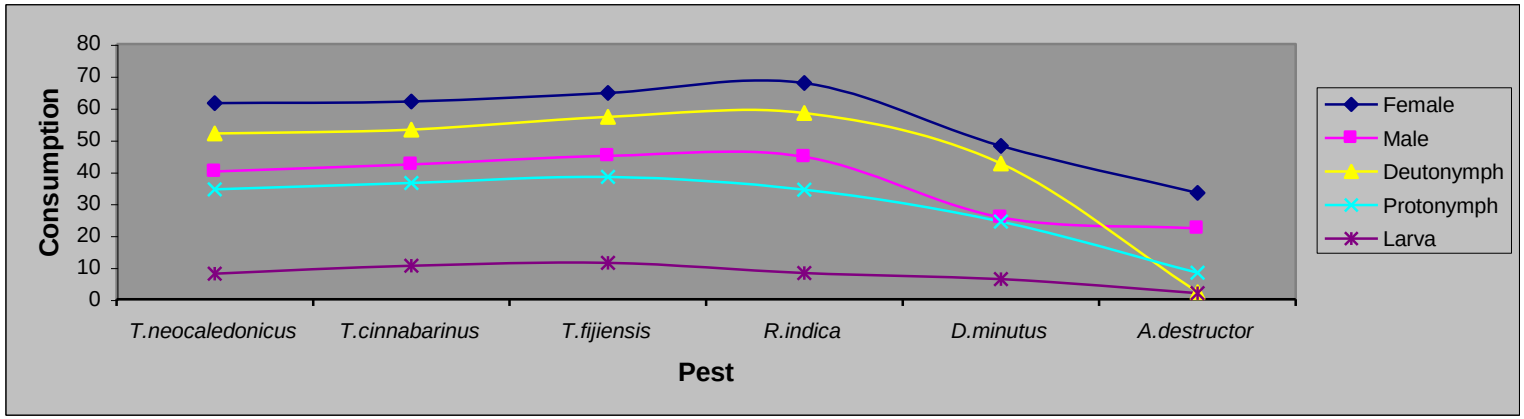

Figure 3

PLATE IX

Total percentage consumption of life stages of

P. multidentatus **on different pests at a temperature of 30±2^{0}C and 70±2% RH**

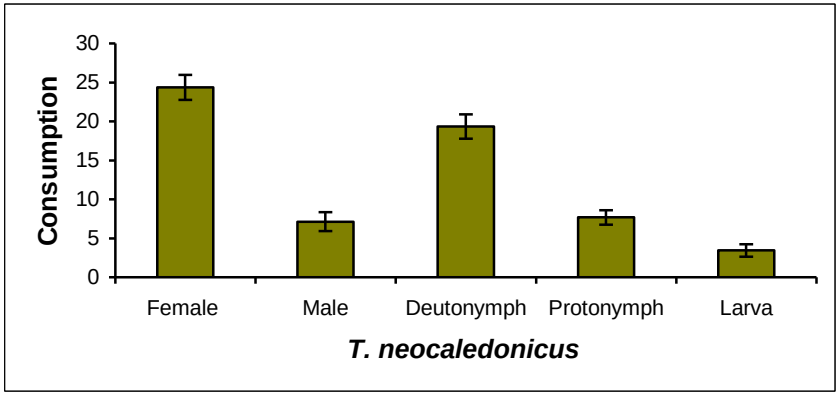

Figure 1

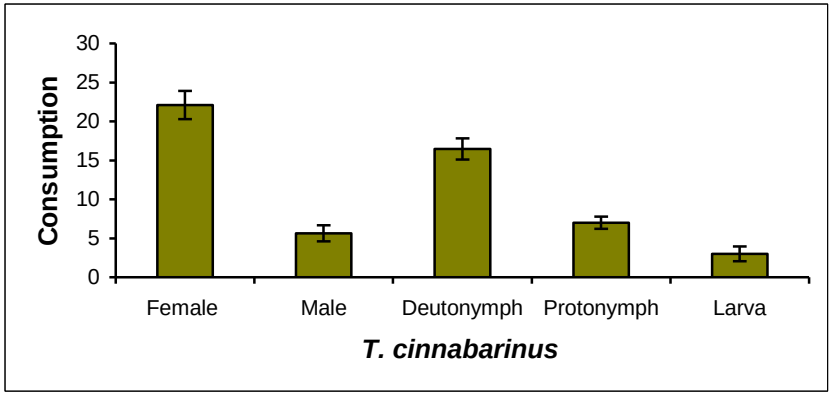

Figure 2

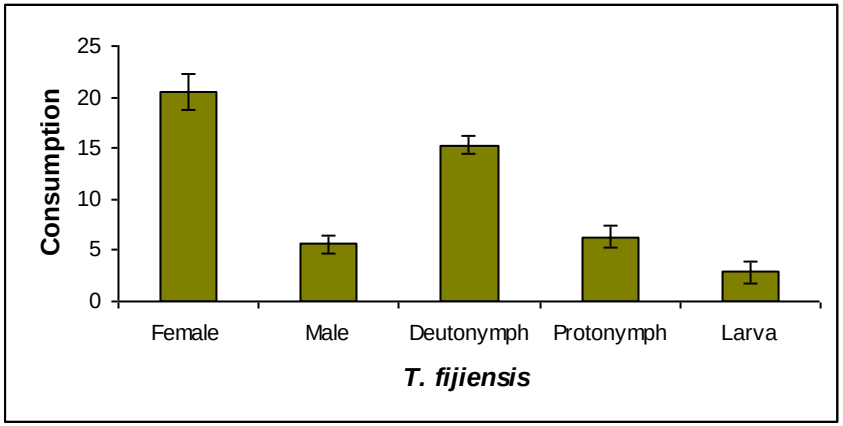

Figure 3

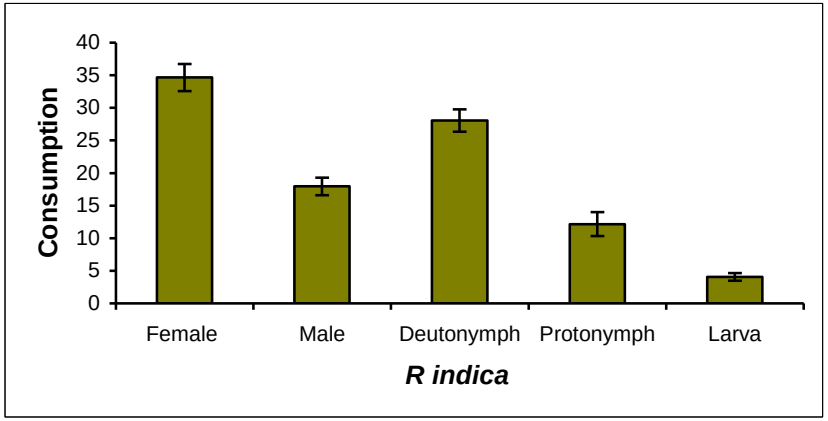

Figure 4

PLATE X

Total percentage consumption of life stages of

***P. multidentatus* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

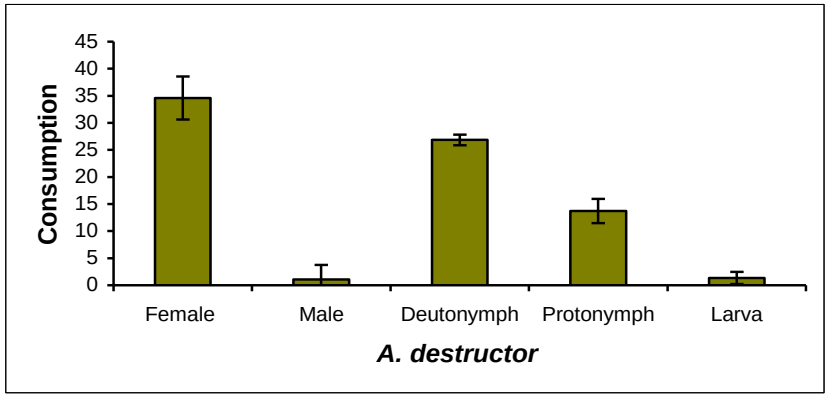

Figure 1

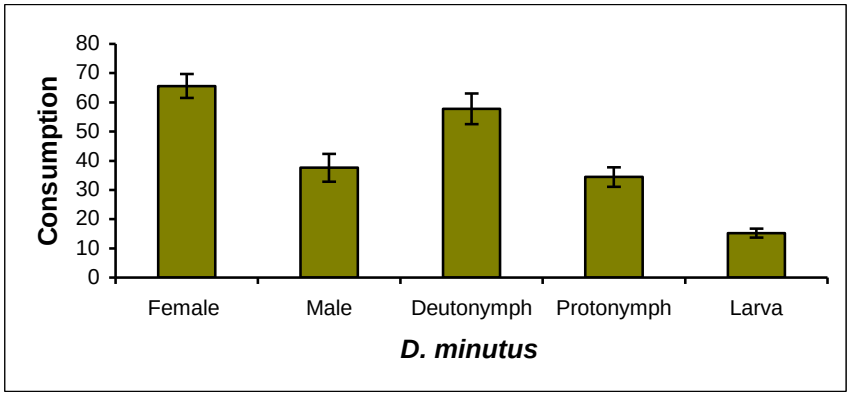

Figure 2

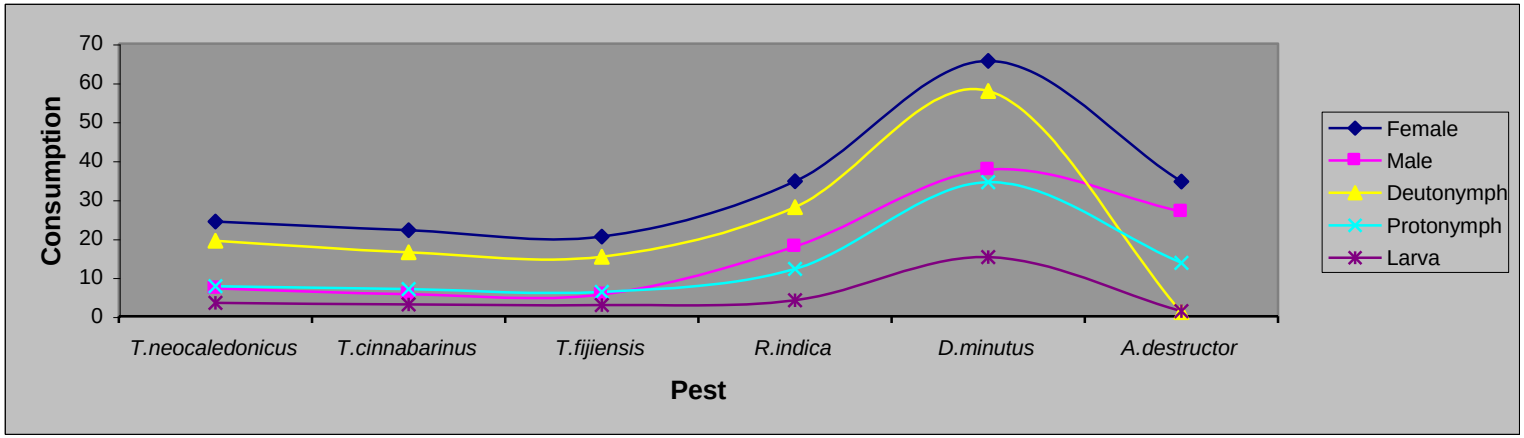

Figure 3

PLATE XI

Total percentage consumption of life stages of

***P. rachelae* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

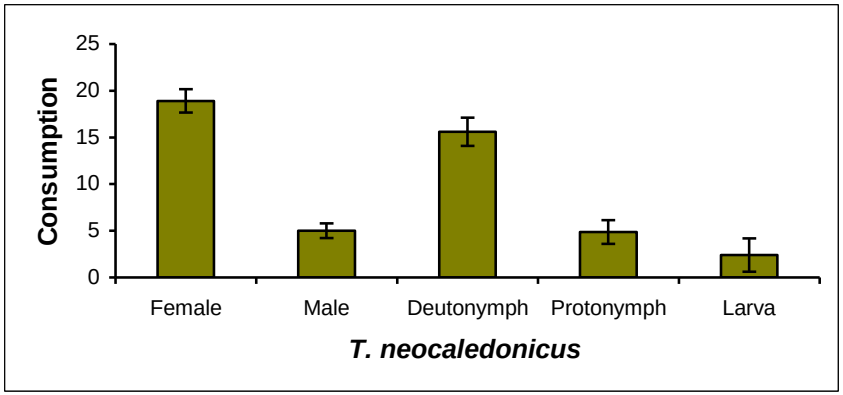

Figure 1

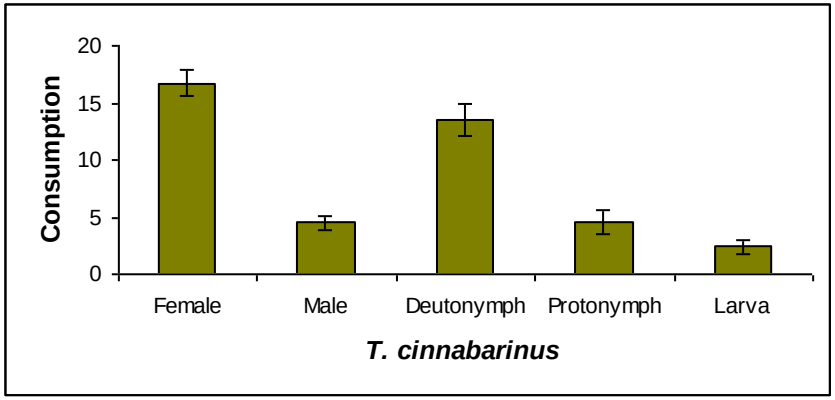

Figure 2

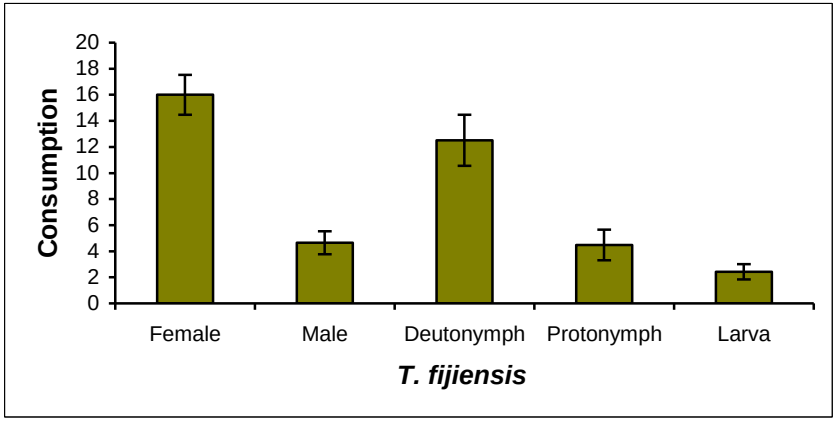

Figure 3

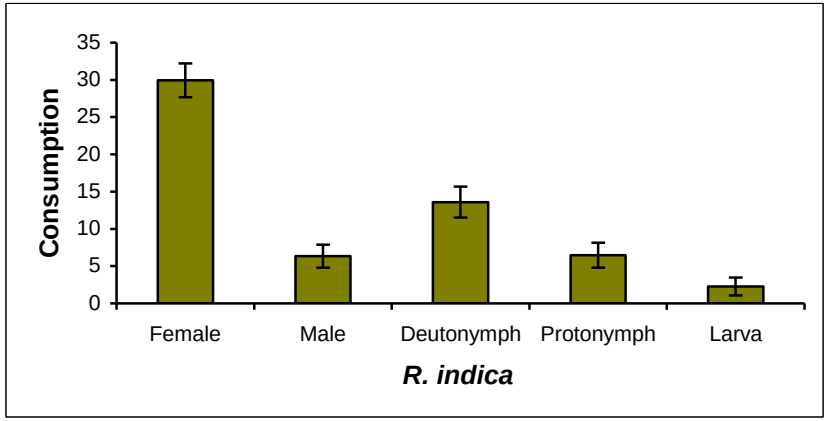

Figure 4

PLATE XII

Total percentage consumption of life stages of

***P. rachelae* on different pests at a temperature of 30±2^{0}C and 70±2% RH**

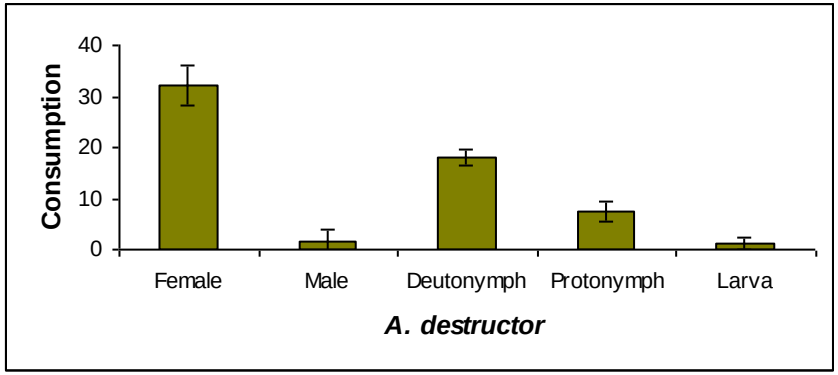

Figure 1

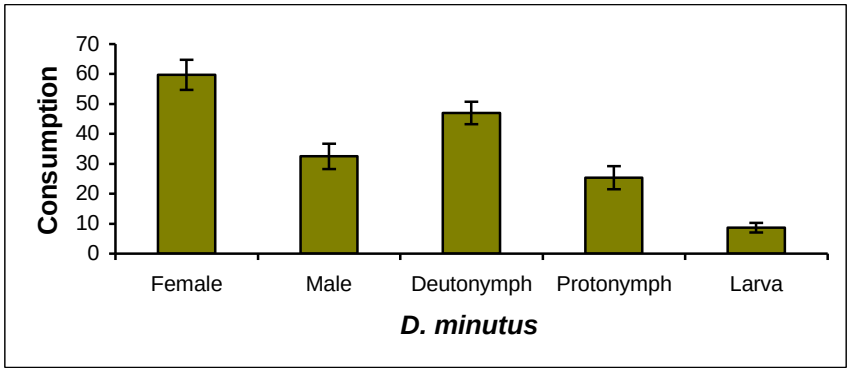

Figure 2

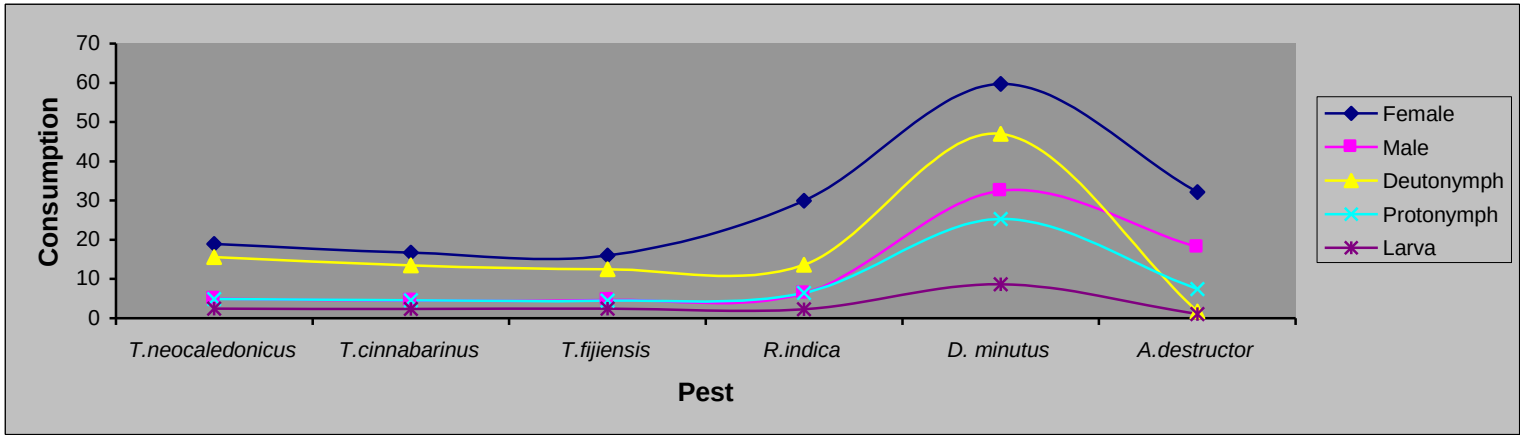

Figure 3

PLATE XIV

Figure 1: Number of pre-oviposition, oviposition and post-oviposition days of *A. largoensis* at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

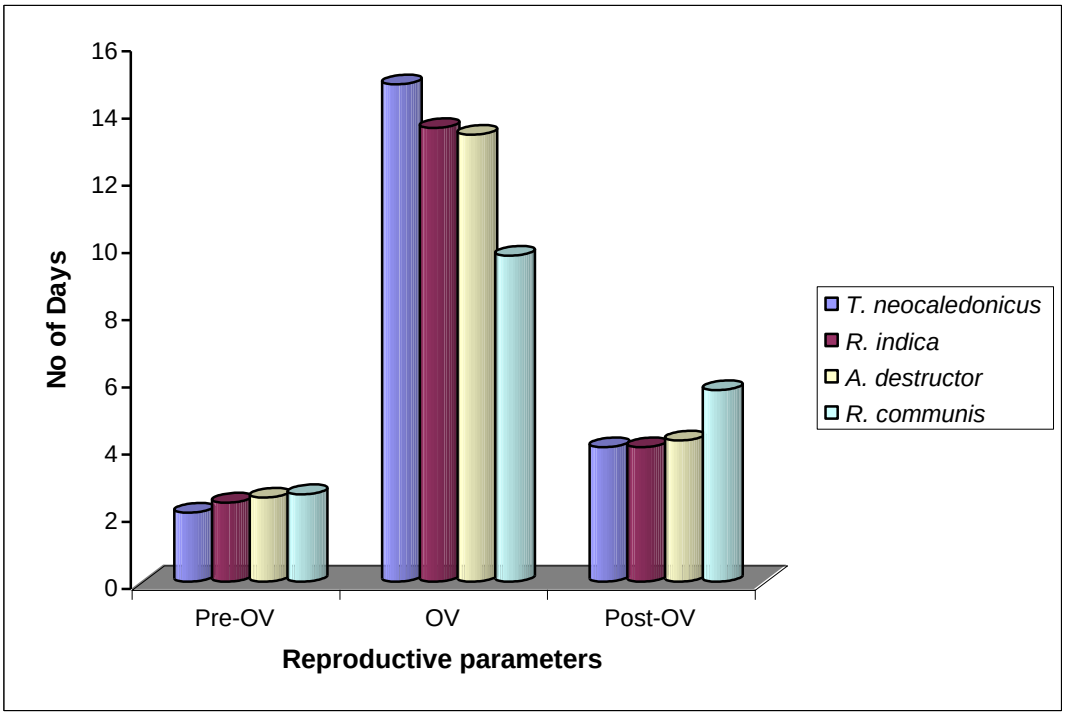

Figure 2: Number of eggs laid by *A. largoensis* per day at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

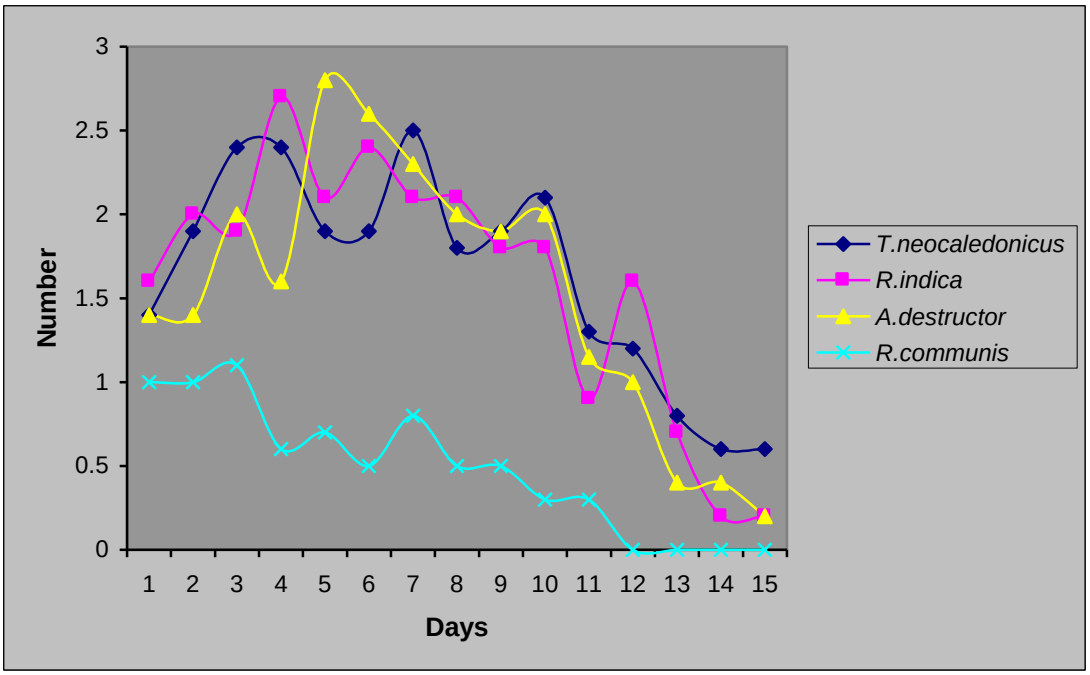

PLATE XV

Figure 1: Pre-oviposition, oviposition and post-oviposition periods of *T. suknaensis* at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

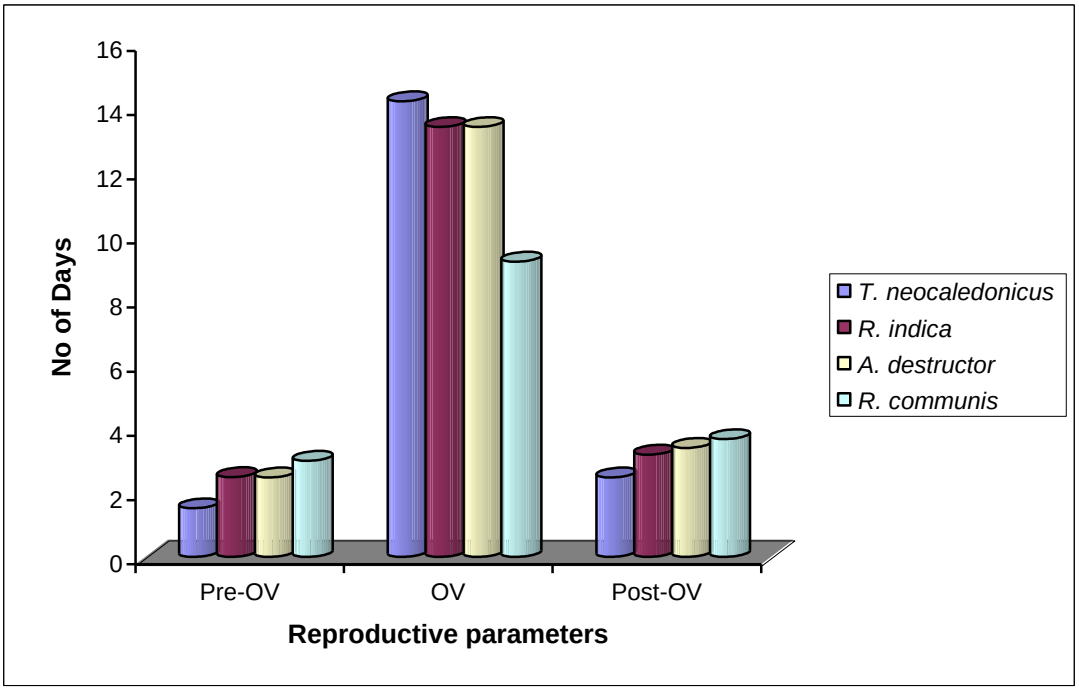

Figure 2: Number of eggs laid by T. *suknaensis* per day at a temperature of 30 ± 2^{0}C and 70 ± 2%RH

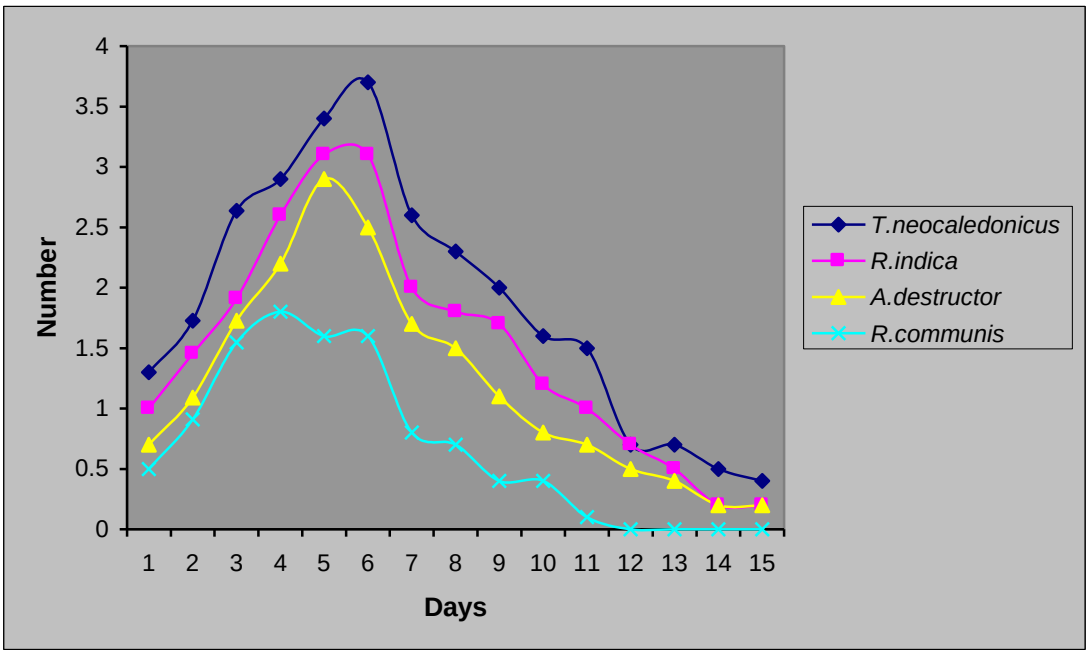

PLATE XVII

Figure 1 Pre-oviposition, oviposition and post-oviposition periods of *A. guptai* sp. nov. at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

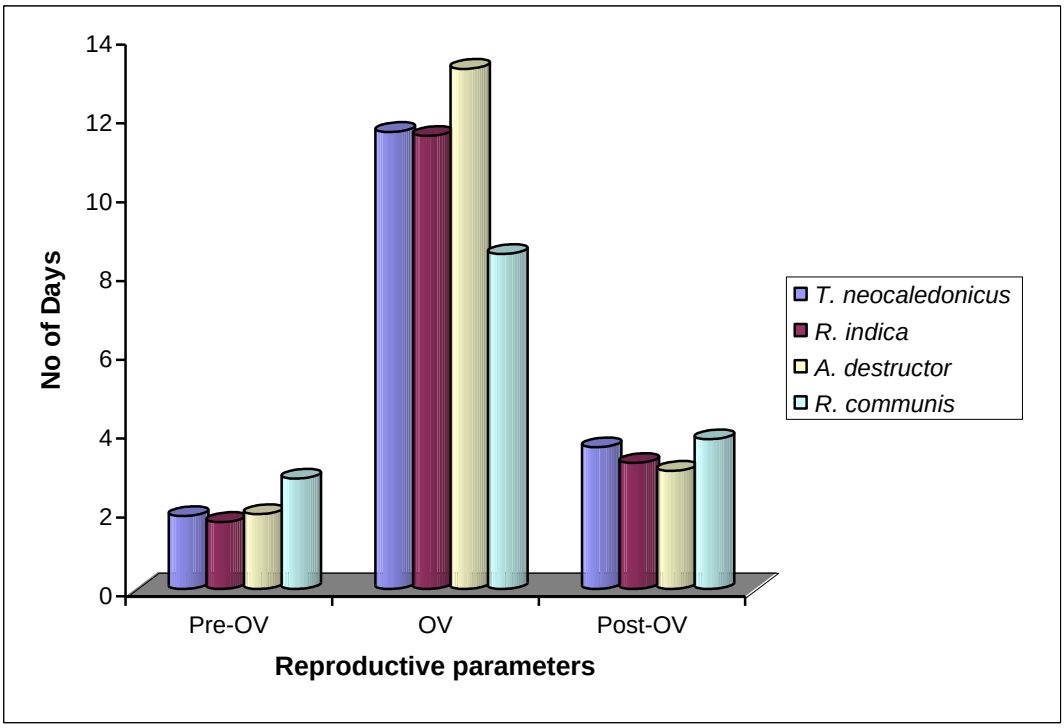

Figure 2: Number of eggs laid by *A. guptai* sp. nov. per day at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

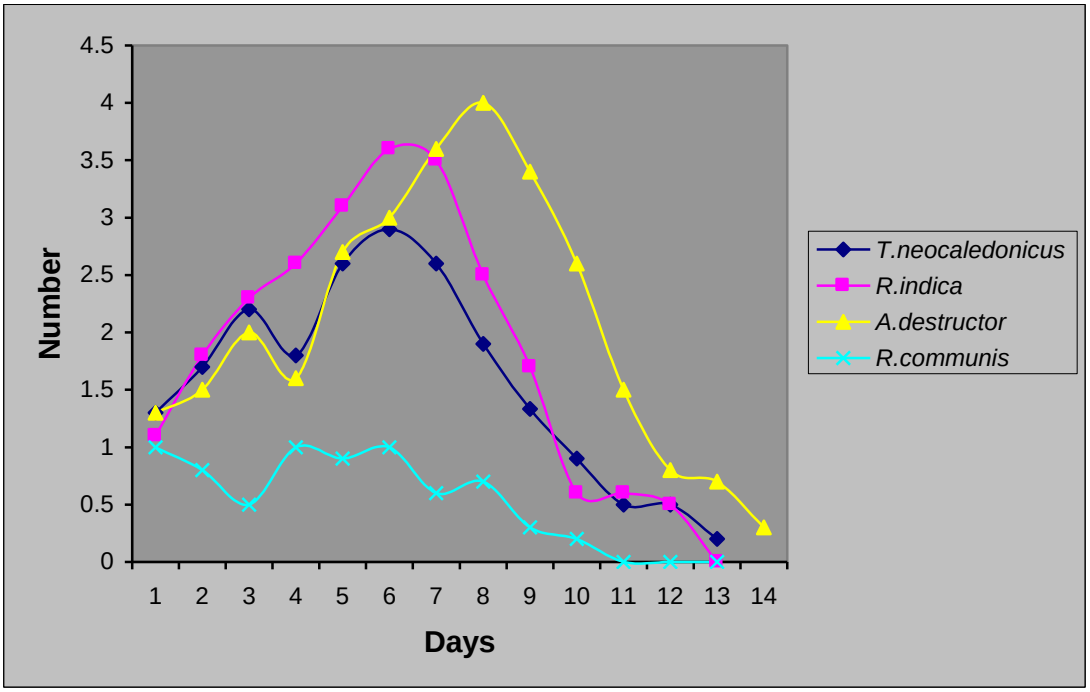

PLATE XIX

Figure 1: Pre-oviposition, oviposition and post-oviposition periods of *P. multidentatus* at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

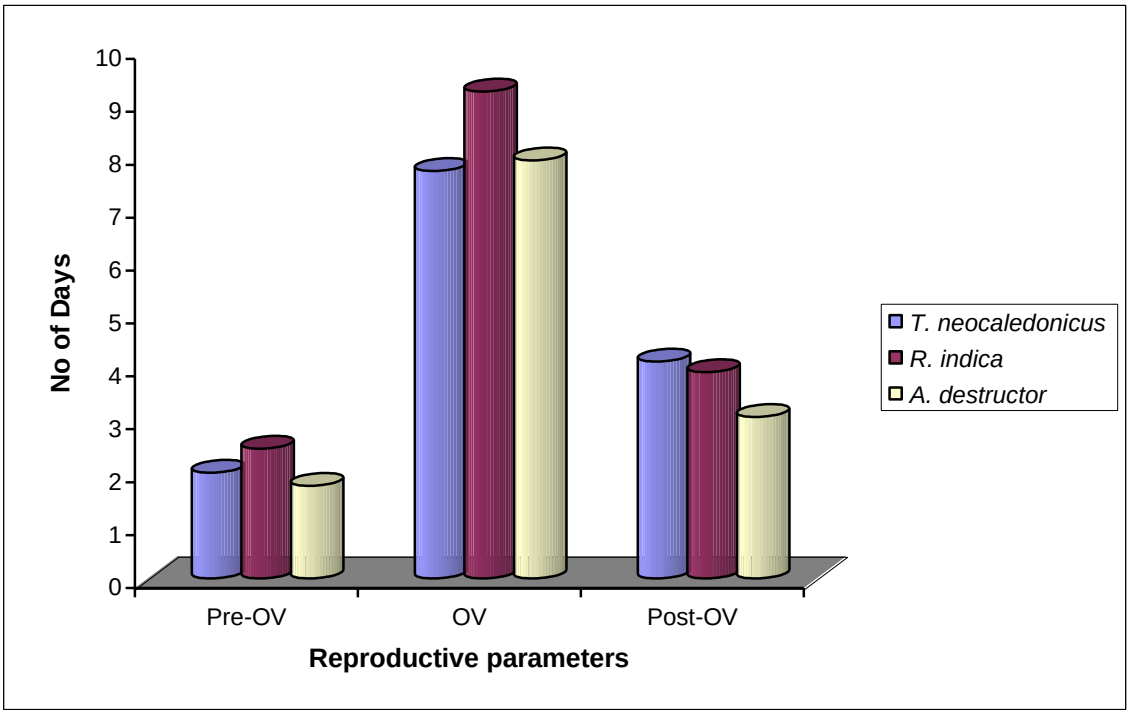

Figure 2: Number of eggs laid by *P. multidentatus* per day at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

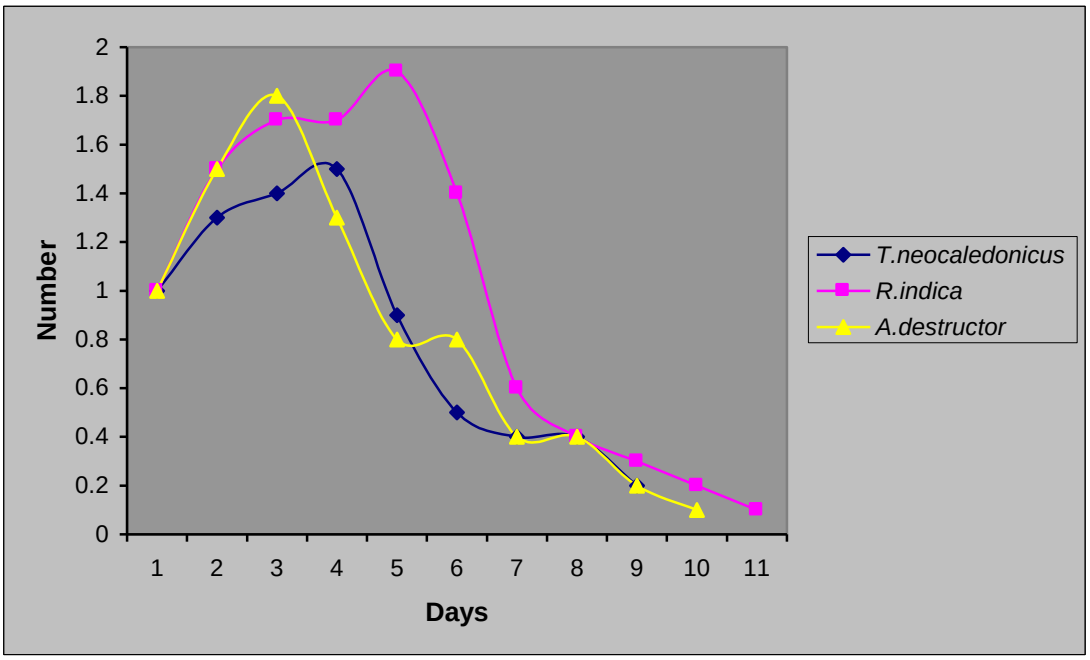

PLATE XXII

Figure 1: Pre-oviposition, oviposition and post-oviposition periods of *P. rachelae* at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

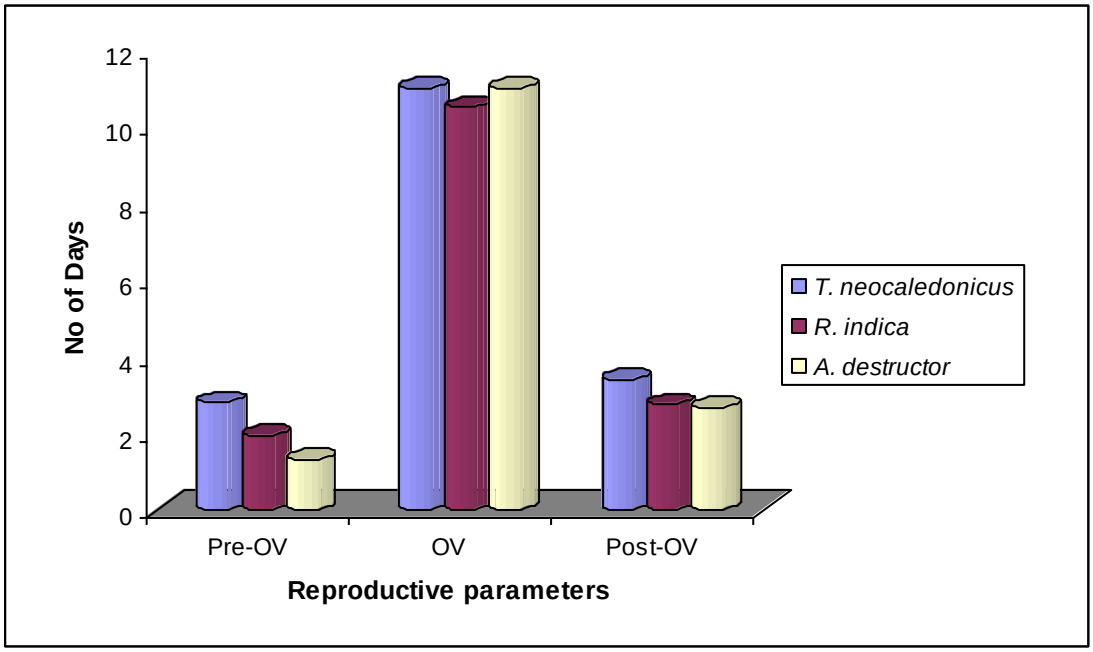

Figure 2: Number of eggs laid by *P. rachelae* per day at a temperature of 30 ± 2^{0}C and 70 ± 2% RH

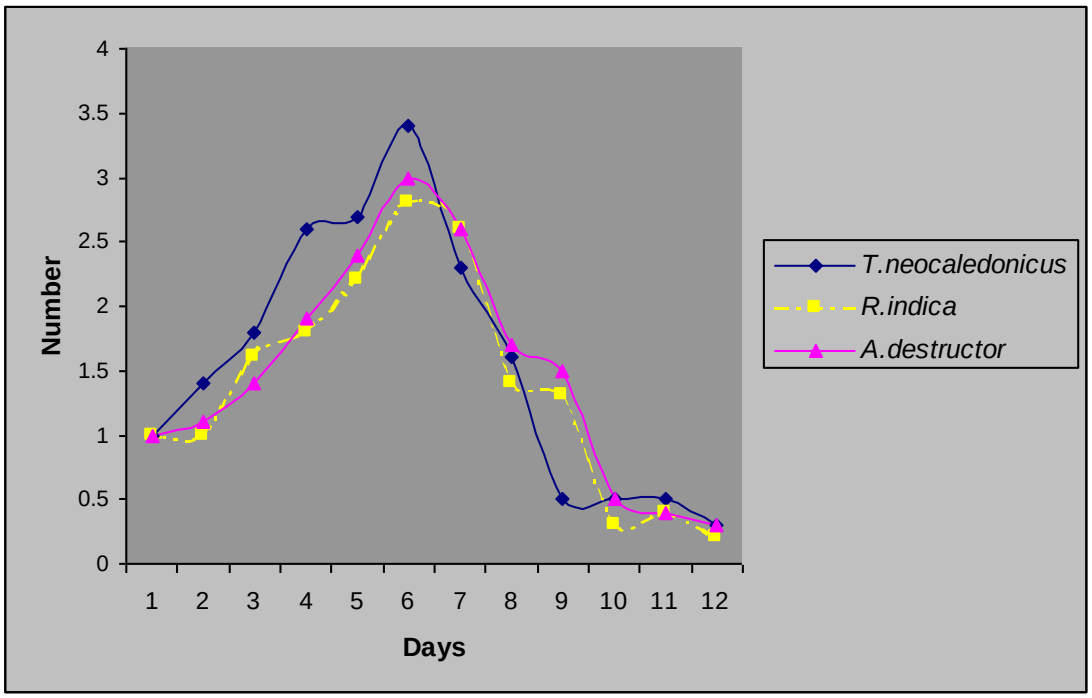

PLATE XXIII

Figure 1: Mean duration of development (in hours) of *A. largoensis* on different food items at a temperature of 30±2^{0}C and 70±2% RH

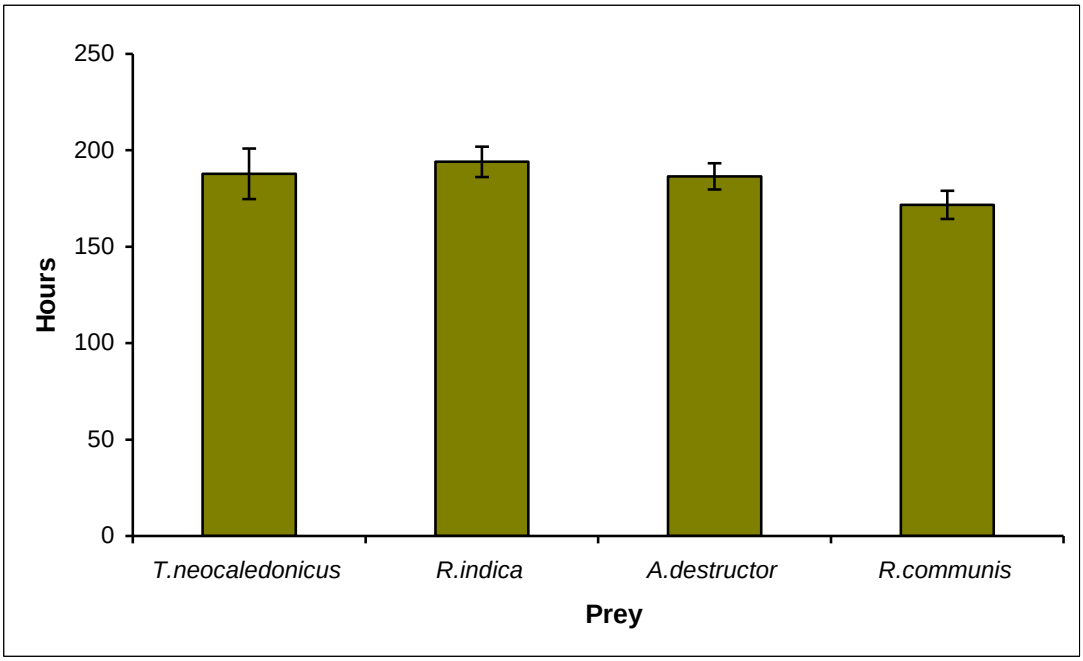

Figure 2: Mean duration of development (in hours) of life stages of *A. largoensis* on different food items at a temperature of 30±2^{0}C and 70±2% RH

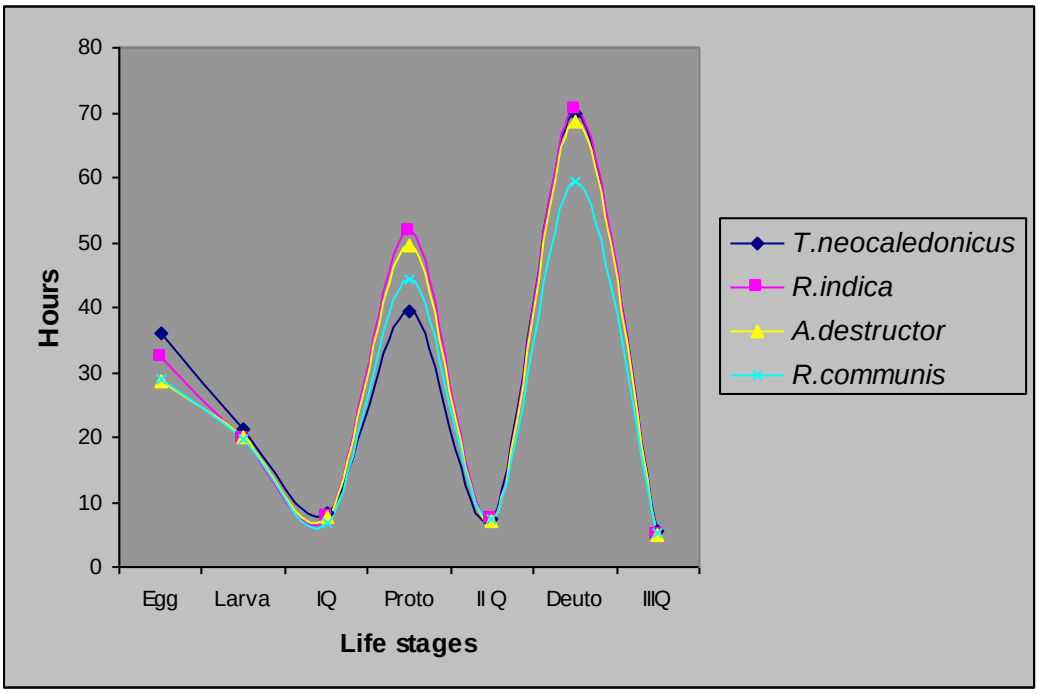

PLATE XXIV

Figure 1: Mean duration of development (in hours) of *T. suknaensis* on different food items at a temperature of 30±2^{0}C and 70±2% RH

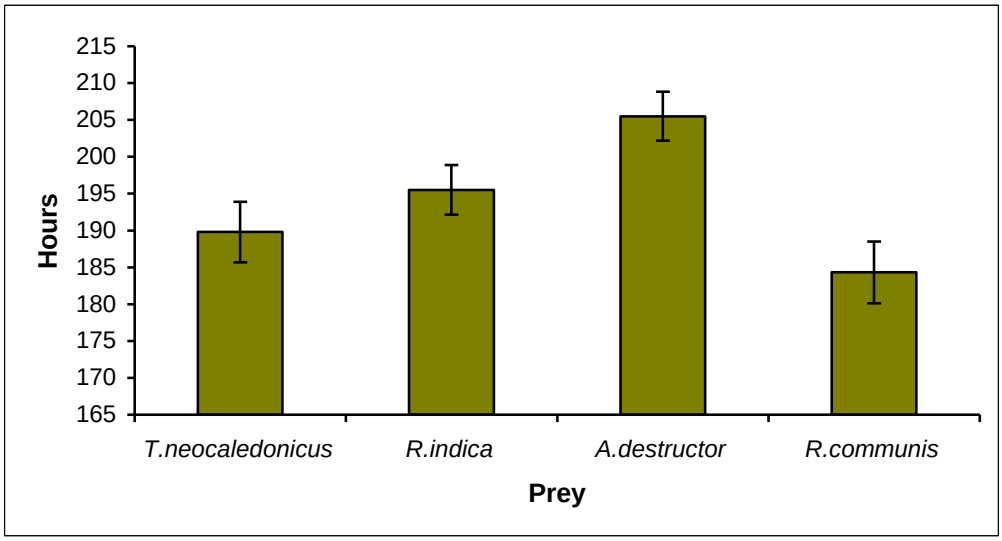

Figure 2: Mean duration of development (in hours) of Life Stages of *T. suknaensis* on Different Food Items at a temperature of 30±2^{0}C and 70±2% RH

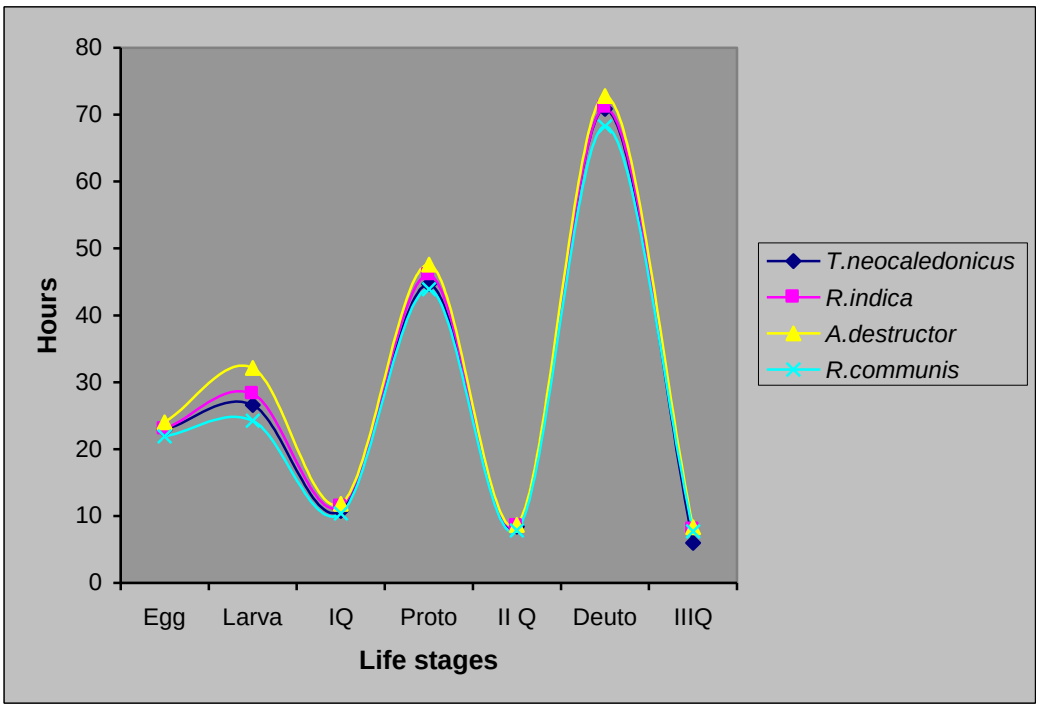

PLATE XXV

Figure 1: Mean duration of development (in hours) of *A. guptai* sp. nov. on different food items at a temperature of 30±2^{0}C and 70±2% RH

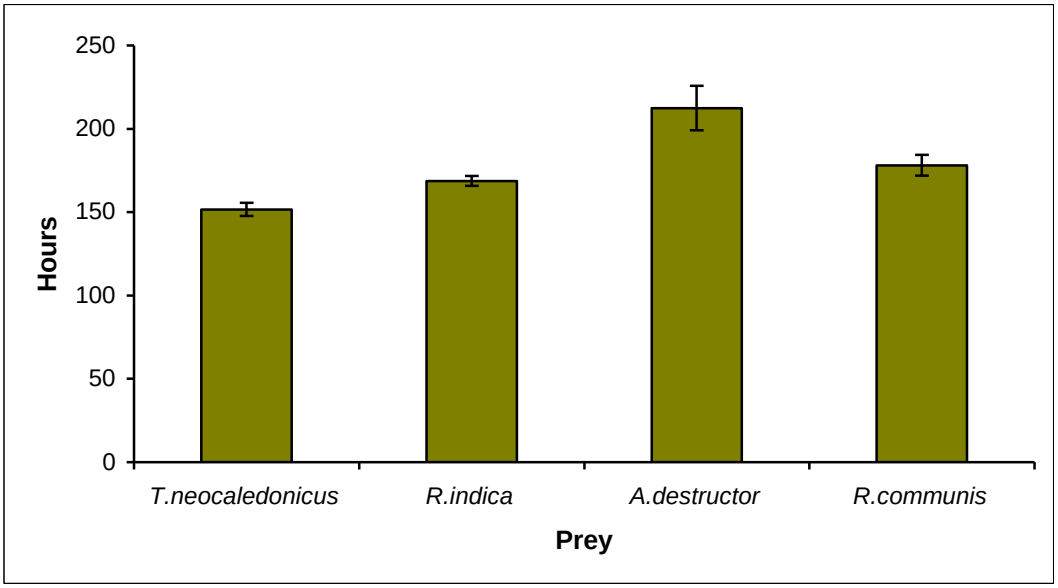

Figure 2: Mean duration of development (in hours) of Life Stages of *A. guptai* sp. nov.on Different Food Items at a temperature of 30±2^{0}C and 70±2% RH

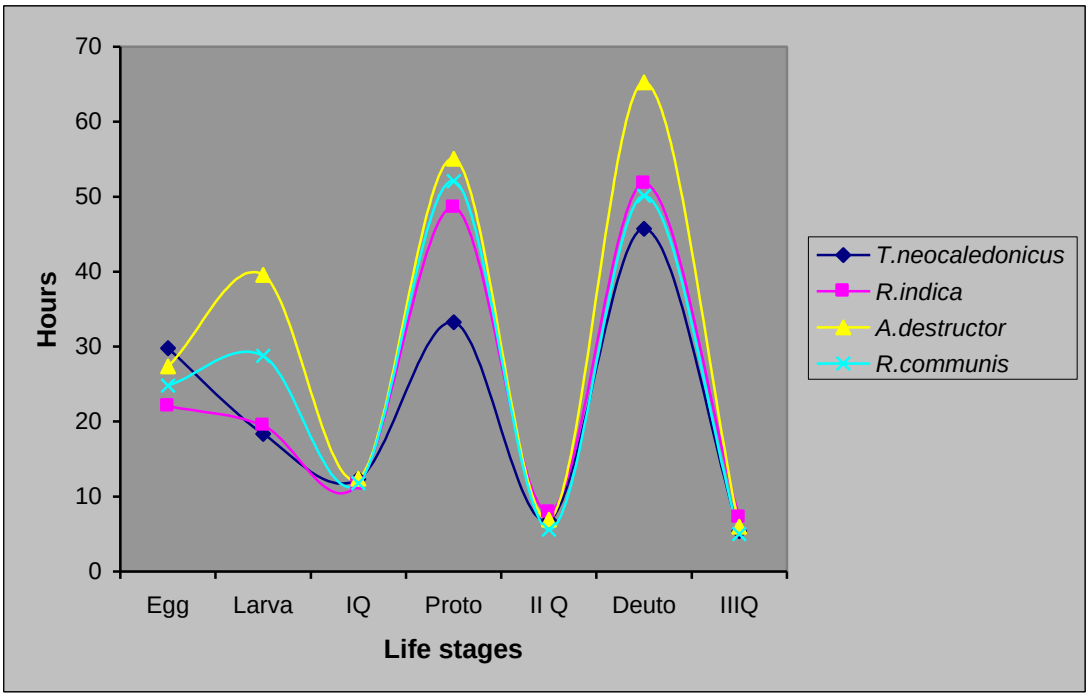

PLATE XXVI

Figure 1: Mean duration of development (in hours) of *P. multidentatus* on different food items at a temperature of 30±2^{0}C and 70±2% RH

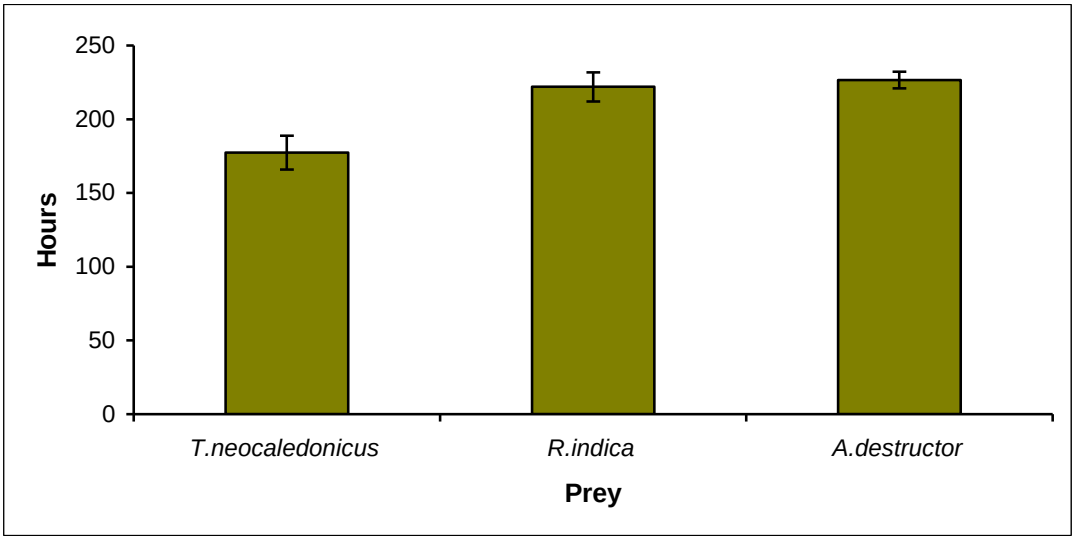

Figure 2: Mean duration of development (in hours) of life stages of *P. multidentatus* on different food items at a temperature of 30±2^{0}C and 70±2% RH

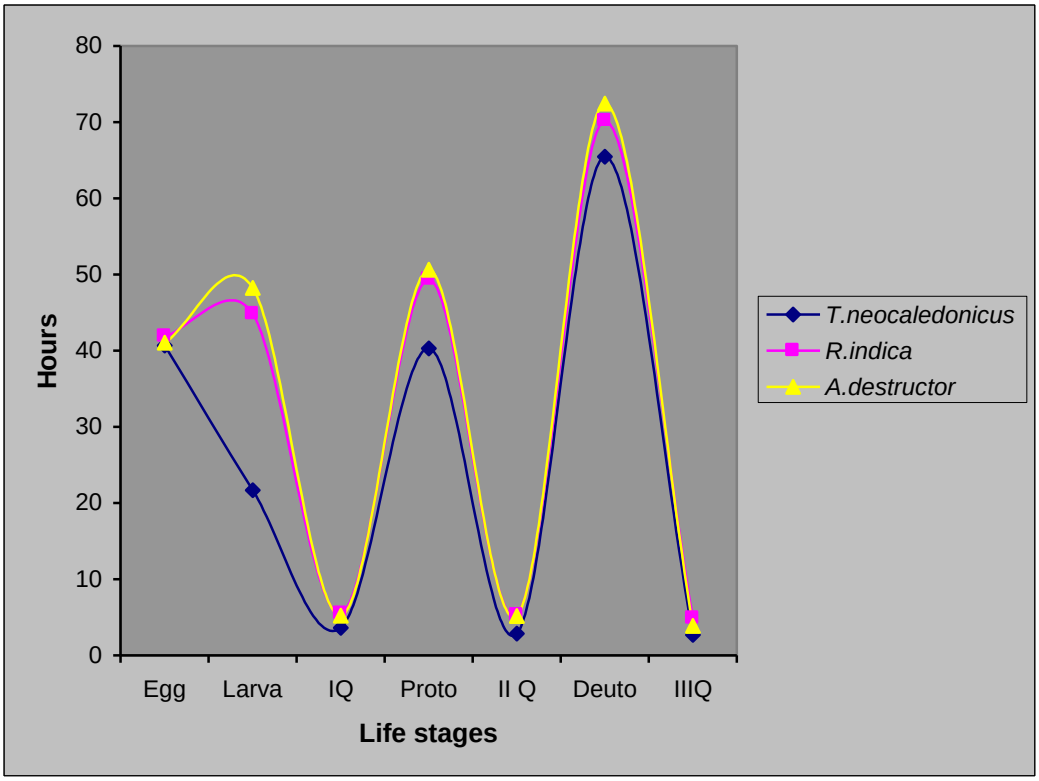

PLATE XXVII

Figure 1: Mean duration of development (in hours) of *P. rachelae* on different food items at a temperature of 30±2^{0}C and 70±2% RH

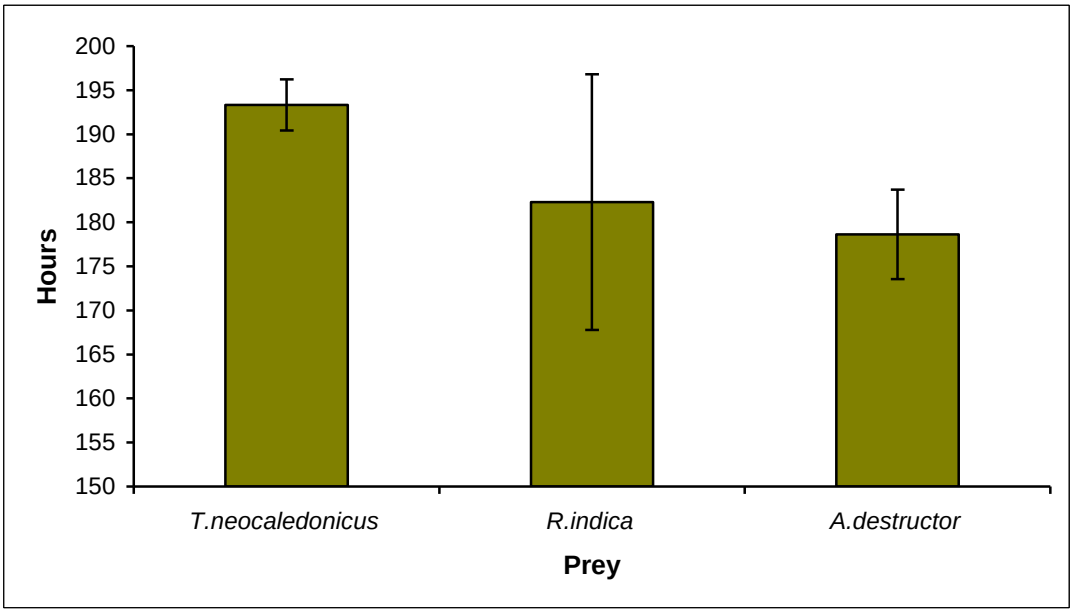

Figure 2: Mean duration of development (in hours) of life stages of *P. rachelae* on different food items at a temperature of 30±2^{0}C and 70±2% RH

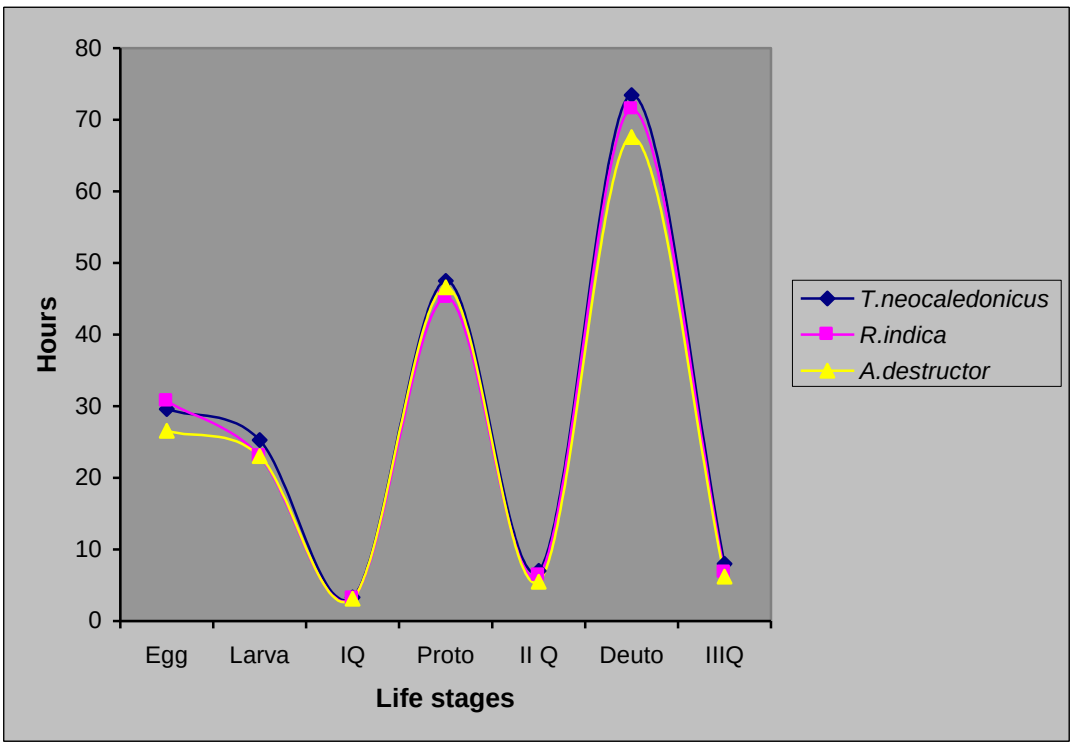

PLATE XXVIII

Figure 1: Mean duration of development (in hours) of different phytoseiids on different food items at a temperature of 30±2^{0}C and 70±2% RH

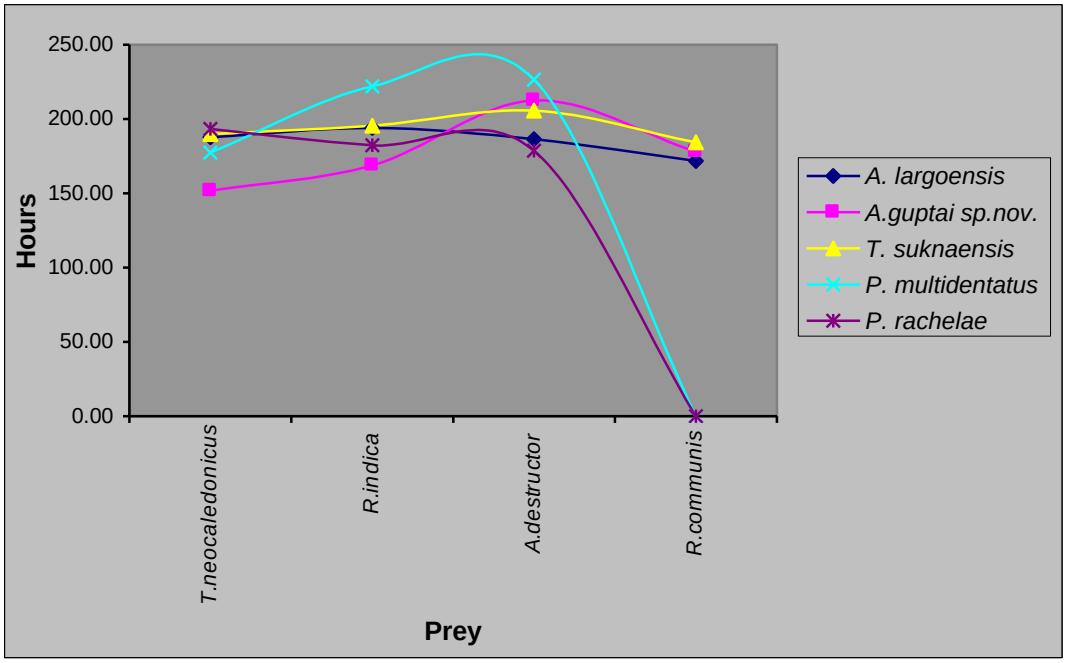

Figure 2: Average fecundity of different phytoseiids on different food items at a temperature of 30±2^{0}C and 70±2% RH

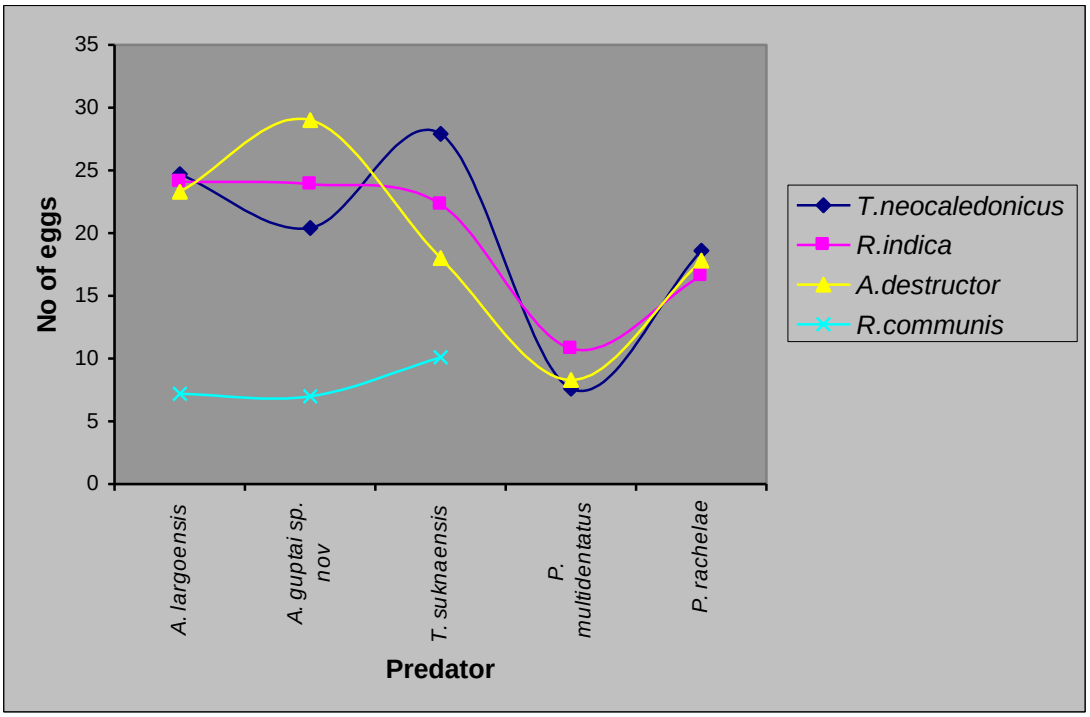

PLATE XLVII

Figure 1: Population size of *T. suknaensis* on experimental plant under field conditions

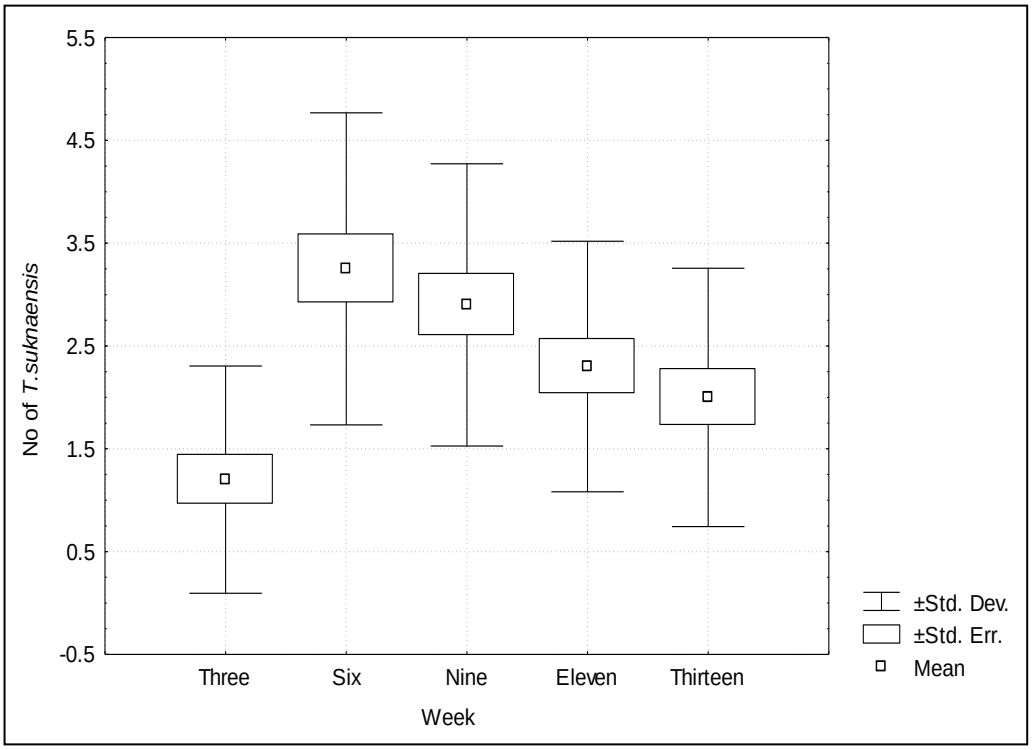

Figure 2: Graph showing relative abundance of *T. suknaensis* and *T. neocaledonicus* on experimental plant under field conditions

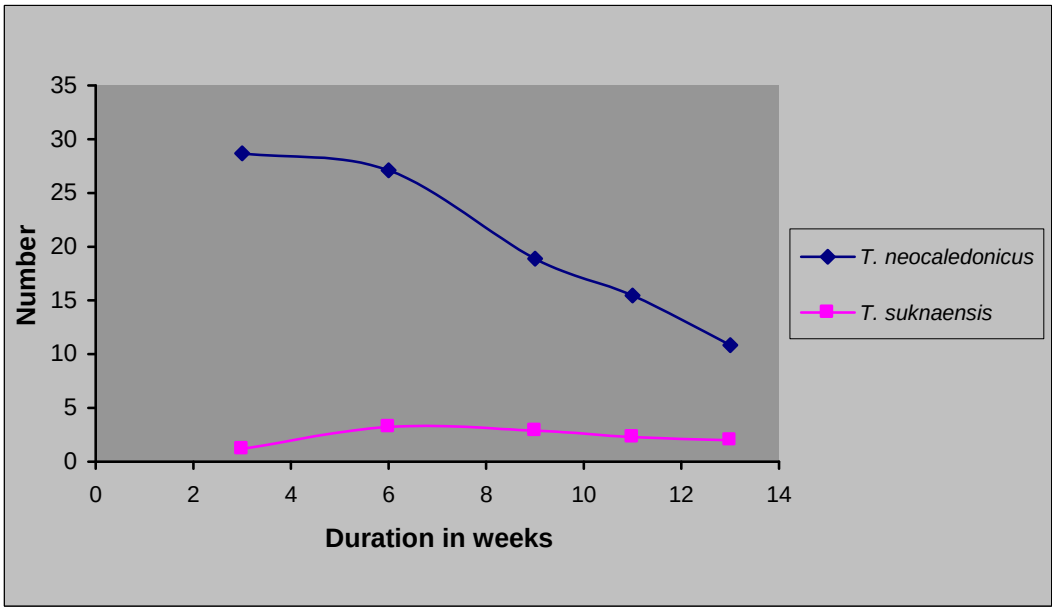

TABLE. I:

Details of the Various Species of

Plants Surveyed with Respect to Pest Infestation

SI. No.	Host plant	Family	Pests	
	VEGETABLES		**Acarid pest**	**Abundance**
1	*Amaranthus viridis* Linn.	Amaranthaceae	Tetranychidae	+++++
2	*A. tricolor* Linn.	Amaranthaceae	Tetranychidae	+++++
3	*Carica papaya* Linn.	Caricacae	Tetranychidae	+++++
4	*Cucumis sativus* Linn.	Cucurbitaceae	Tenuipalpidae	++
5	*Citrus limon* (Linn) Osbeck.	Rutaceae	Tenuipalpidae	++
6	*Manihot esculenta* Crantz	Euphorbiaceae	Tetranychidae	+++++
7	*Abelmoschus esculentus* (Linn) Moench	Malvaceae	Tetranychidae	++
8	*Mucuna deeringiana* (Bort) Merr	Fabaceae	Tetranychidae	+++++
9	*Momordica charantia* Linn.	Cucurbitaceae	Tetranychidae	++
10	*Moringa oleifera* Lam.	Moringaceae	Tetranychidae	+++++
11	*Ipomoea batatus* (Linn) Lam.	Convolvulaceae	Tetranychidae Tenuipalpidae	+++++ ++
12	*Pisum sativum* Linn.	Fabaceae	Tetranychidae	+++++
13	*Vigna unguiculata* (Linn.) Walp	Fabaceae	Tetranychidae	+++++
14	*Solanum melongena* Linn.	Solanaceae	Tetranychida	+++
			Tenuipalpidae	+
15	*Dolichos lablab* Linn.	Fabaceae	Tetranychidae	+++++
16	*Capsicum* spp*.	Solanaceae	Ttetranychidae	++
17	*Musa superba* Roxb.	Musaceae	Tenuipalpidae	++++
18	*Dioscorea alata* Linn.	Dioscoreaceae	Tetranychidae	+++
19	*Hibiscus longifolius* Wild.	Malvaceae	Tetranychidae	+++
20	*Curcuma longa* Linn.	Zingiberaceae	Tetranychidae	+++
21	*Solanum ferox* Linn.	Solanaceae	Tetranychidae	+++
22	*Senna torra* (Linn.) Roxb.	Caesalpiniaceae	Tetranychidae	+++++

23	*Vanila planifolia* Andr.	Orchidaceae		
24	*Cassia tora* Linn.	Caesalpiniaceae	Tetranychidae	+++
MEDICINAL PLANTS				
25	*Aegle marmelose* Linn.	Rutaceae	Tetranychidae	+++
26	*Premna latifolia* Linn.	Verbenaceae	Tetranychidae	++++
27	*Emilia sonchifolia* Linn.	Asteraceae	Tetranychidae	++++
28	*Biophytum reinwardtti* Linn.	Geraniaceae	Tetranychidae	+++
29	*Solanum indicum* Linn.	Solanaceae	Tetranychidae	+++++
			Tenupalpidae	+++
30	*Boerhavia diffusa* Linn.	Nyctaginaceae	Tetranychidae	+++++
31	*Catharanthus roseus* (Linn.)	Apocynaceae	Tetranychidae	+++++
32	*Vernonia cinerea* (Linn.) Less	Asteraceae	Tetranychidae	++
33	*Lucas aspera* (Wild) Spreng	Lamiaceae	Tetranychidae	++++
34	*Ixora coccinea* (Linn.)	Rubiaceae	Tetranychidae	++
			Tenuipalpidae	++
35	*Adathoda vasica* Nees	Acanthaceae	Tetranychidae	+++++
			Tenuipalpidae	+++
36	*Vitex negundo* Linn.	Acanthaceae	Eriophyoidae Ttranychidae	++++ ++
37	*Sida alnifolia* Linn.	Malvaceae	Tetranychidae	+++++
38	*Phyllanthus amaras* Shumach and Thonn	Euphorbiaceae	Tetranychidae	+++++
39	*Clitoria ternatea* Linn.	Fabaceae	Tetranychidae	+++++
40	*Ocimum sanctum* Linn.	Lamiaceae	Tetranychidae	++++
			Tenuipalpidae	+++
41	*Azadirachta indica* A. Jass.	Meliaceae	Tetranychidae	+++++
42	*Acalypha fruticosa* Forssk.	Euphorbiaceae	Tetranychidae	+++++
43	*Aerva lanata* (Linn.) Juss.ex Schult.	Amaranthaceae	Tetranychidae	+++
44	*Eclipta alba* (L.inn) Hassk.	Asteraceae	Tetranychidae	++++
45	*Vernonia cinerea* (Linn.) Less.	Asteraceae	Tetranychidae	+++

46	*Emilia sonchifolia* (Linn.) DC.	Asteraceae	Tetranychidae	+++
47	*Hygrophila auriculata* (K. Schum.) Heine.	Acanthaceae	Tetranychidae	+++++
48	*Ocimum graticimum* Linn.	Lamiaceae	Tenuipalpidae	++++
			Tetranychidae	++
49	*Bramia indica* Lam.	Scrophulariaceae	Tetranychidae	++++
50	*Costus pictus* D. Don	Zingiberaceae	Tetranychidae	+++
51	*Scoparia dulcis* Linn.	Scrophulariaceae	Tetranychidae	++++
ORNAMENTAL PLANTS				
52	*Rosa indica* Hook.	Rosaceae	Tetranychidae	+++++
53	*Jasminum grandiflorum* Linn.	Oleaceae	Tetranychidae	+++
			Tenuipalpidae	++
54	*Hibiscus* spp*.	Malvaceae	Tetranychidae	+++
55	*Gomphrena globosa* Linn.	Amaranthaceae	Tetranychidae	++++
56	*Gomphrena serrata* Linn.	Amaranthaceae	Tetranychidae	++++
57	*Cassia fistula* Linn.	Caesalpiniaceae	Tetranychidae	+++
			Tenuipalpidae	+
58	*Anthurium andraeanum* Linden.	Araceae	Nil	Nil
SPICES				
59	*Piper nigrum* Linn.	Piperaceae	Nil	Nil
60	*Curcuma longa* Linn.	Zingiberaceae	Tetranychidae	+++
61	*Syzygium aromaticum* (Linn.) Merry and Perry	Myrtaceae	Nil	Nil
62	*Punica granatum* (Linn.)	Punicaceae	Tenuipalpidae	+++
63	*Zingium officinale*	Zingiberaceae	Tetranychidae	++
OIL YIELDING PLANTS				
63	*Cocos nucifera* Linn.	Arecaceae	Tetranychidae	+++++
			Tenuipalpidae	+++++
64	*Ricinus communis* Linn.	Euphorbiaceae	Tetranychidae	+++++

SOFT WOOOD				
65	*Morinda pubescens* Linn.	Rubaceae	Eriophyoidae	+++++
			Tetranychidae	+++
66	*Euodialuna ankenda* Linn.	Rutaceae	Eriophyidae	+++++
			Tetranychidae	+++
			Tenuipalpidae	++
67	*Pongamia pinnata* (Linn.) Pierre	Fabaceae	Nil	Nil
WEEDS				
68	*Centrosema pubescens* Benth.	Fabaceae	Tetranychidae	+++++
			Tenuipalpidae	+
69	*Zizyphus oenoplia* (Linn.) Mill	Ramnaceae	Tetranychidae	+++++
70	*Quisqualis indica* Linn.	Combretaceae	Tetranychidae	++++
71	*Urena lobata* Linn.	Malvaceae	Tetranychidae	+++++
72	*Lantana camera* Linn.	Verbenaceae	Tetranychidae	++++
73	Grass spp*.	Poaceae	Tetranychidae	+++++
74	*Gliricidia sepium* (Jacq.) Kunth ex Walp	Fabaceae	Tetranychidae	+++++
75	*Chromolaena odorata* (Linn.) R. M. King and H. Rob.	Asteraceae	Eriophyidae	+++++
76	*Ageratum conyzoides* Linn.	Asteraceae	Tetranychidae	++++
77	*Calycopteris floribundae*	Combretaceae	Tetranychidae	++++

***** *constitutes many species*

+++++/++++ *shows high incidence*

+++/++ *shows low incidence*

\+ *scarce*

TABLE II:

List of Phytoseiid Mites Collected from Various Localities

Sl. No.	Phytoseiids	Host Plant	Locality	District
1.	*Amblyseius* (*Euseius*) *alstoniae* Gupta	*Maranta arundinaceae*	Kuttiadi	Calicut
2	*A.*(*E.*) *coccineae* Gupta	*Dolichos lablab*	University campus,	Malappuram
3	*A.*(*E.*) *finlandicus* (Oudemans)	*Manihot esculenta*, *Amaranthus viridis*,	Pantheerankavu, Kotakadavu, Kunamangalam,olavanna, Edavannapara, villuniyal,	Calicut, Malappuram
4	*A.*(*A.*) *adathodae* Muma	*Vanilla planifolia*	IISR Experimental garden	Calicut
5.	*A.* (*A.*) *aerialis* (Muma)	*Citrus limon*	IISR Experimental garden	Calicut
6.	*A.* (*A.*) *channabasavannai* Gupta & Daniel	*Coccos nucifera*	University campus,	Malappuram
7	*A.*(*A.*) *indirae* Gupta	*Cucurbita maxima*, *C.nucifera*, *Piper longum*	The Malabar botanical garden at Pokkunu, The Coconut nursery at Thikkodi, IISR,Vlluniyal.	Calicut, Malappuram
8	*A.*(*E.*) *rhododendronis* Gupta	*Zingiber officinale*, *Momordica charantia*	IISR	Calicut
9	*A.*(*E.*) *sacchari* Ghai & Menon	*Ricinus communis*	Kottakadavu,Kadalundi,Kottakkal	Calicut, Malappuram
10	*A. (A.) largenosis* Muma.	*Adathoda. vasica, Pisum sativam, Rosa indica, Moringa olifera, Manihot esculenta, Momordica charatia, Vigna unguiculata, Ocimum sanctum, O.gratisimum, Amaranthus tricolor, A. Viridis, Citrus limon, Carica papaya, Dolicos lablab, Gliricidia sepium, Cucumis sativus, Manihot esculenta*	Chelari, Kondotty, Villoonniyal, Kottakkal, Thalappara, The Malabar botanical garden at Pokkunu, The Coconut nursery at Thikkodi, IISR, Kunnamangalam, Olavanna, Pantheerankavu, Edavannappara, Vazhakkad, Ramanatukkara, Azhinjilam ,	Calicut, Malappuram

Sl. No.	Phytoseiids	Host Plant	Locality	District
11	*Typhlodromips suknaensis* Gupta.	*C.odorata, P. sativum* *M. olifera* *C. floribunda,* *A. tricolor, H. longifolia, Hibisucs* spp*., B. diffusa, G. sepium, A. viridis, M. esculenta*	Olavanna	Calicut
12	*A. guptai* sp. nov.	*C. nucifera, A. tricolor, A. viridis, P. amaras, B. diffusa*	University Campus	Malappuram
13	*P. multidentatus* Swirski and Shechter	*V. negundo, C. odorata, L. aspera, C. pubescens, Q.indica,, C. ternatea, Z. Oenoplia*	University Campus	Malappuram
14	*P. rachelae* Swirski and Shechter	*C. odorata*	From all sites surveyed	.
15.	*A.*(*A.*) *hapoliensis* Gupta	*A. tricolor, H. longifolia,* *M. esculenta,* *M. charantia,*	Thalappara	Malappuram
16	*A.*(*A*) *muraleedharani* Gupta	*A. tricolor, C.limon,* *A. viridis*, *D. lablab*, *G. sepium*, *C.sativus*, *M. esculenta*	Thalappara	Malappuram
17	*A.*(*T.*) *eujaniae* Gupta	*M. paradisiaca*	IISR	Calicut
18	*A.herbicoloides* McMurtry &Moraes	*Z.officinale*	Olavanna	Calicut

TABLE III:

Distribution of Phytoseiid Predators Selected for Biological Studies

Sl. No.	Name of the Predator	Host plants of the predator and prey	Pest species associated with the Predator
1.	*A. largoensis* Muma.	*A. vasica, P. sativum, R. indica, M. oleifera, M. esculenta, M. charantia, V. unguiculata, O. sanctum, O.gratissimum, A. tricolor, C.limon, A. viridis, C. papaya, D. lablab, G. sepium, C.sativus, M. esculenta*	*T. neocaledonicus, T. cinnabarinus, E. orientalis, T. fijiensis, T. ludeni, B. phoenicis,* Scale insects, Aphids, Thrips, Chrisomelids
2.	*T.suknaensis* Gupta.	*C. odorata, P. sativum M. oleifera C. floribunda, A. tricolor, H. longifolia, Hibisucs* spp., *B. diffusa, G. sepium, A. viridis, M. esculenta*	*T. neocaledonicus T. cinnabarinus A. adoratus, Aphids,* scales.
3.	*A. guptai* sp. nov.	*C. nucifera, A. tricolor, A. viridis, P. amaras, B. diffusa*	*T.fijiensis, T. neocaledonicus, R. indica, A. destructor*
4.	*P. multidentatus* Swirski and Shechter	*V. negundo, C. odorata, L. aspera, C. pubescens, Q.indica, C. ternatea, Z. oenoplia*	*A. vitexae, D. minutus, E. orientalis, B. phoenicis, T. neocaledonicus.*
5.	*P. rachelae* Swirski and Shechter	*C. odorata*	*A. adoratus*, Scales, Apids

TABLE IV

Percentage consumption of different stages of *A. largoensis on* different stages of *T. neocaledonicus* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	64	57	50	29	18	51
	Male	29	23	22	15	12	21
Nymphal Stages	Deutonymph	59	51	44	23	15	46
	Protonymph	37	35	21	4	2	23
	Larva	20	6	4	1	0.4	9

TABLE V

Percentage consumption of different stages of *A. largoensis on* different stages of *T. cinnabarinus* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	69	58	52	31	19	53
	Male	36	27	22	19	13	27
Nymphal Stages	Deutonymph	61	52	40	23	14	46
	Protonymph	38	31	25	6	2	27
	Larva	28	9	4	1	1	12

TABLE VI

Percentage consumption of different stages of *A. largoensis on* different life stages of *T. fijiensis* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	60	46	46	43	26	48
	Male	34	24	19	16	11	24
Nymphal Stages	Deutonymph	51	38	30	28	18	37
	Protonymph	35	30	29	19	12	24
	Larva	22	19	19	1	1	8

TABLE VII

Percentage consumption of different stages of *A. largoensis on* different stages of *R. indica* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	68	58	50	46	32	56
	Male	40	27	21	18	14	27
Nymphal Stages	Deutonymph	64	53	40	39	23	49
	Protonymph	42	30	25	5	1	27
	Larva	18	8	4	2	1	9

TABLE VIII

Percentage consumption of different stages of *A. largoensis* on different stages of *A.desructor* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage consumption			Total
		Egg mass	Crawlers + Females	Males	
Adult	Female	49	17	1	20
	Male	3	0.2	0.1	1
Nymphal stages	Deutonymph	26	11	0.1	12
	Protonymph	11	4	0.1	4
	Larva	3	0.3	0	1

TABLE IX

Percentage consumption of different stages of *A. largoensis on* different stages of *D. minutus* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages				Total
		N_1	N_2	Prepupa + pupa	Adult	
Adult	Female	32	32	15	8	24
	Male	12	14	9	2	10
Nymphal Stages	Deutonymph	30	28	16	5	22
	Protonymph	13	20	14	1	12
	Larva	5	10	2	0.3	6

TABLE X

Percentage consumption of different stages of *T. suknaensis* on different stages of *T. neocaledonicus* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	86	74	71	32	22	68
	Male	57	42	41	23	13	41
Nymphal Stages	Deutonymph	76	68	64	24	21	60
	Protonymph	45	42	41	10	5	35
	Larva	19	8	7	1	0.3	9

TABLE XI

Percentage consumption of different stages of *T. suknaensis* on different stages of *T. cinnabarinus* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	77	64	63	27	21	60
	Male	49	46	42	17	17	40
Nymphal Stages	Deutonymph	69	65	61	23	17	56
	Protonymph	43	38	36	4	2	33
	Larva	22	17	13	2	0.4	14

TABLE XII

Percentage consumption of different stages of *T. suknaensis* on different stages of *T. fijiensis* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	78	71	71	26	25	64
	Male	51	49	41	24	2	45
Nymphal Stages	Deutonymph	74	68	64	23	22	60
	Protonymph	44	38	20	2	1	29
	Larva	15	10	7	1	0.3	8

TABLE XIII

Percentage consumption of different stages of *T. suknaensis* on different stages of *R. indica* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	84	71	69	40	21	66
	Male	46	42	37	9	3	35
Nymphal Stages	Deutonymph	78	71	66	21	15	61
	Protonymph	63	50	49	16	15	57
	Larva	19	18	8	2	1	14

TABLE XIV

Percentage consumption of different stages of *T. suknaensis* on different stages of *A.destructor* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage consumption of predator on Prey Stages			Total
		Egg mass	Crawlers+Females	Males	
Adult	Female	58	18	1	22
	Male	6	0.3	0.3	2
Nymphal stages	Deutonymph	37	11	0.1	14
	Protonymph	16	4	0.1	6
	Larva	4	0.3	0	1

TABLE XV

Percentage consumption of different stages of *T. suknaensis* on different stages of *D. minutus* in 24 hours at 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage consumption of predator on Prey Stages				Total
		N_1	N_2	Prepupa + pupa	Adult	
Adult	Female	76	74	62	23	58
	Male	63	62	49	14	50
Nymphal Stages	Deutonymph	67	66	51	15	54
	Protonymph	31	25	11	9	21
	Larva	13	13	6	2	9

TABLE XVI

Percentage consumption of different stages of *A. guptai* sp. nov. on different stages of *T. neocaledonicus* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	76	71	61	32	20	62
	Male	54	45	38	17	15	40
Nymphal Stages	Deutonymph	70	55	53	21	19	52
	Protonymph	45	40	39	9	3	34
	Larva	15	9	4	3	1	8

TABLE XVII

Percentage consumption of different stages of *A. guptai* sp. nov. on different stages of *T.cinnabarinus* in 24 hours at 30 ± 2ºc and 70 ±2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	77	65	62	42	29	62
	Male	57	48	39	16	16	42
Nymphal Stages	Deutonymph	70	56	54	25	22	53
	Protonymph	46	44	41	9	4	36
	Larva	16	14	13	1	1	11

TABLE XVIII

Percentage consumption of different stages of *A. guptai* sp.nov. on different life stages of *T. fijiensis* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	79	69	65	44	30	65
	Male	61	49	44	17	16	45
Nymphal Stages	Deutonymph	73	60	57	38	22	57
	Protonymph	51	45	36	19	7	38
	Larva	17	15	3	1	1	11

TABLE XIX

Percentage consumption of different stages of *A. guptai* sp. nov. on different life stages of *R. indica* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	85	75	67	42	26	68
	Male	56	49	48	22	14	45
Nymphal Stages	Deutonymph	71	65	63	29	23	58
	Protonymph	50	46	21	11	2	34
	Larva	14	11	7	1	1	8

TABLE XX

Percentage consumption of different stages of *A. guptai* sp. nov. on different life stages of *A.destructor* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage consumption of Predator on Prey Stages			Total
		Egg mass	Crawlers+Females	Males	
Adult	Female	63	34	1	33
	Male	9	1	0.1	2
Nymphal stages	Deutonymph	39	24	0.4	22
	Protonymph	23	6	0.1	8
	Larva	8	1	0	2

TABLE XXI

Percentage consumption of different stages of *A. guptai* sp. nov. on different life stages of *D. minutus* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages				Total
		N_1	N_2	Prepupa + pupa	Adult	
Adult	Female	62	56	43	18	48
	Male	35	26	18	14	26
Nymphal Stages	Deutonymph	61	55	25	12	43
	Protonymph	36	31	16	3	24
	Larva	12	8	1	0	6

TABLE XXII

Percentage consumption of different stages of *P. multidentatus* on different stages of *T. neocaledonicus* in 24 hours at a temperature 30±2^{0}C and70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	36	21	20	19	16	24
	Male	13	8	4	2	1	7
Nymphal Stages	Deutonymph	34	18	10	10	9	19
	Protonymph	14	8	5	2	0.4	8
	Larva	6	4	2	0.4	0	3

TABLE XXIII

Percentage consumption of different stages of *P. multidentatus* on different stages of *T. cinnabarinus* in 24 hours at a temperature of 30±2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	31	21	19	18	14	22
	Male	10	5	4	3	0.4	6
Nymphal Stages	Deutonymph	30	14	9	10	5	16
	Protonymph	13	8	4	1	0.3	7
	Larva	5	4	2	0.3	0	3

TABLE XXIV

Percentage consumption of different stages of *P. multidentatus* on different stages of *T. fijiensis* at in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	28	20	18	15	13	20
	Male	10	5	4	3	1	6
Nymphal Stages	Deutonymph	27	14	12	7	5	15
	Protonymph	11	7	4	0.4	0.3	6
	Larva	5	4	2	0.3	0	3

TABLE XXV

Percentage consumption of different stages of *P. multidentatus* on different stages of *R. indica* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	49	36	34	13	12	35
	Male	26	17	17	11	8	18
Nymphal Stages	Deutonymph	42	30	20	16	12	28
	Protonymph	23	13	6	1	0.1	13
	Larva	8	5	2	0.3	0	4

TABLE XXVI

Percentage consumption of different stages of *P. multidentatus* on different stages of *A. destructor* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage consumption of Predator on Prey Stages			Total
		Egg mass	Crawlers + Females	Males	
Adult	Female	60	37	1	35
	Male	3	1	0.3	1
Nymphal stages	Deutonymph	58	25	0.3	27
	Protonymph	26	14	0.1	14
	Larva	4	1	0	1

TABLE XXVII

Percentage consumption of different stages of *P. multidentatus* on different stages of *D. minutus* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages				Total
		N_1	N_2	Prepupa + pupa	Adult	
Adult	Female	78	77	61	36	64
	Male	62	39	39	10	38
Nymphal Stages	Deutonymph	74	71	58	14	58
	Protonymph	54	40	36	4	34
	Larva	26	17	15	1	15

TABLE XXVIII

Percentage consumption of different stages of *P. rachelae* on different stages of *T. neocaledonicus* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	31	16	16	12	11	19
	Male	9	5	3	1	1	5
Nymphal Stages	Deutonymph	29	14	9	7	7	16
	Protonymph	9	5	3	1	0.1	5
	Larva	5	2	1	0.1	0	2

TABLE XXIX

Percentage consumption of different stages of *P. rachelae* on different stages of *T. cinnabarinus* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	25	16	15	12	10	17
	Male	7	5	4	2	0.3	4
Nymphal Stages	Deutonymph	24	12	8	7	5	14
	Protonymph	8	5	2	0.3	0.1	5
	Larva	4	3	1	0	0	2

TABLE XXX

Percentage consumption of different stages of *P.*(*P.*)*rachelae* on different stages of *T. fijiensis* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	22	14	12	17	14	16
	Male	9	4	3	2	1	5
Nymphal Stages	Deutonymph	22	12	10	7	4	13
	Protonymph	8	5	3	0.3	0.1	5
	Larva	4	3	1	0.1	0	2

TABLE XXXI

Percentage consumption of different stages of *P. rachelae* on different stages of *R.indica* in 24 hours at a temperature of 30± 2^0C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages					Total
		Egg	Larva	Protonymph	Deutonymph	Adult	
Adult	Female	42	32	28	13	11	35
	Male	11	7	4	4	1	6
Nymphal Stages	Deutonymph	23	13	9	7	4	14
	Protonymph	12	7	4	2	0	7
	Larva	4	3	2	0	0	2

TABLE XXXII

Percentage consumption of different stages of *P. rachelae* on different stages of *A.destructor* in 24 hours at a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of Predator on Prey Stages			Total
		Egg mass	Crawlers + Females	Males	
Adult	Female	56	35	1	32
	Male	7	1	0.1	2
Nymphal stages	Deutonymph	38	17	4	18
	Protonymph	21	5	0.1	7
	Larva	5	0.3	0	1

TABLE XXXIII

Percentage consumption of different stages of *P. rachelae* on different stages of *D.minutus* at in 24 hours a temperature of 30± 2^{0}C and 70 ± 2% RH

Predator		Percentage Consumption of the Predator on Prey Stages				Total
		Larva	Protonymph	Deutonymph	Adult	
Adult	Female	72	69	54	33	60
	Male	49	39	33	9	33
Nymphal stages	Deutonymph	65	57	41	8	47
	Protonymph	37	32	26	1	25
	Larva	15	14	0.3	0	9

TABLE XXXIV

Reproductive parameters (in days) of adult female of *A.*(*A.*) *largoensis* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Reproductive parameters in days				
	Pre-Oviposition	Oviposition	Post-Oviposition	Fecundity	Longevity
T.neocaledonicus	2.05	14.8	4	24.7	20.8
R.indica	2.4	13.5	4	24.1	19.9
A.destructor	2.5	13.3	4.2	23.3	20
R.communis	2.6	9.7	5.7	7.2	18

TABLE XXXV

Mean duration (in hours) of development of *A.* (*A*) *largoensis* on different food items provided at laboratory conditions of 30±2°C and 70±2% RH

Prey	Mean ± S.D.							
	Egg	Larva	Q1	Protonymph	Q2	Deutonymph	Q3	Total
T.neocaledonicus	36±7.8	21.3±2.3	8.4±1.7	39.4±6.8	7.3±1.7	69.8±3.1	5.6±0.5	187.8±13.07
R.indica	32±7	19.7±2.7	7.6±1.4	51.6±2.3	7.2±1.4	70.6±2.7	5±0.4	194.03±7.9
A.destructor	28.7±4.9	20.2±2.7	7.7±1.4	49.6±2.5	7.2±0.9	68.5±3.2	4.8±0.5	186.5±6.8
R.communis	28.9±4.6	19.6±3.3	6.7±0.4	44.4±1.5	7.4±0.7	59.5±2.9	5.2±0.6	171.7±7.4

TABLE XXXVI

Reproductive parameters (in days) of adult female of *T. suknaensis* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Reproductive parameters in days				
	Pre-Oviposition	Oviposition	Post-Oviposition	Fecundity	Longevity
T.neocaledonicus	1.5	14.2	2.5	28.1	18.2
R.indica	2.5	13.4	3.2	22.4	19.1
A.destructor	2.5	13.4	3.4	18	19.3
R.communis	3	9.2	3.7	10.1	15.9

TABLE XXXVII

Duration (in hours) of development of *T.suknaensis* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Mean ± S.D.							
	Egg	Larva	Q1	Protonymph	Q2	Deutonymph	Q3	Total
T.neocaledonicus	22.8±1.2	26.6±1.8	10.8±0.6	44.6±1.1	8.4±0.6	70.9±2.9	6±0.5	189.8±4
R.indica	23±1.2	28.3±2.6	11.4±0.6	46±1.3	8.5±0.6	71±2.08	8±0.3	195.5±3.4
A.destructor	24±0.96	32±3.2	11.8±0.4	47.6±0.7	8.7±0.4	72.8±0.99	8.3±0.7	205.5±3.3
R.communis	21.9±1.5	24.2±0.8	10.4±0.6	43.9±1.3	7.9±0.5	68.2±3.1	7.7±0.4	184.3±4.2

TABLE XXXVIII

Reproductive parameters (in days) of adult female of *A. guptai* sp. nov. on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Reproductive parameters indays				
	Pre-Oviposition	Oviposition	Post-Oviposition	Fecundity	Longevity
T.neocaledonicus	1.9	11.7	3.6	20.4	17.2
R.indica	1.7	11.5	3.2	23.9	16.4
A.destructor	1.9	13.2	3	28.5	18.1
R.communis	2.8	8.5	3.8	6.9	15.1

TABLE XXXIX

Duration (in hours) of development of *A. guptai* sp. nov. on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Mean ± S.D.							
	Egg	Larva	Q1	Protonymph	Q2	Deutonymph	Q3	Total
T.neocaledonicus	29.8±3.7	18.3±2	12.3±1.3	33.2±3	6.8±0.7	45.7±2.6	5.4±0.8	151.7±3.9
R.indica	22.08±1.7	19.5±0.98	11.7±0.8	48.6±2.1	7.9±0.4	51.8±2	7.2±0.8	168.7±3
A.destructor	27.4±2.8	39.6±8.6	12.4±0.6	55±4.5	6.9±0.5	65.3±6.8	6±0.5	212±13.3
R.communis	24.8±1	28.8±4	11.8±0.7	52±1.7	5.6±0.5	50.1±1.5	5±0.3	178.1±6.2

TABLE XL

Reproductive parameters (in days) of adult female of *P.multidentatus* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Reproductive parameters in days				
	Pre-Oviposition	Oviposition	Post-Oviposition	Fecundity	Longevity
T.neocaledonicus	2	7.7	4.1	7.5	13.8
R.indica	2.5	9.2	3.9	10.8	15.6
A.destructor	1.8	7.7	3.05	8.3	12.6

TABLE XLI

Duration (in hours) of development of *P.multidentatus* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Mean ± S.D.							
	Egg	Larva	Q1	Protonymph	Q2	Deutonymph	Q3	Total
T.neocaledonicus	40. 7±2.5	21.7±1.8	3.6±0.4	40.3±4.9	2.9±0.7	65.5±5.8	2.7±0.4	177.3±11.5
R.indica	41.9±6.6	44.8±3.7	5.5±0.3	49.4±1.6	5.3±0.5	70.2±2.4	4.9±0.6	221.9±9.8
A.destructor	41.06±4.3	48.2±0.4	5.2±0.1	50.6±2.4	5.2±0.6	72.4±1.2	3.9±0.3	226.6±5.7

Table XLII

Reproductive parameters (in days) of adult female of *P. rachelae* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Reproductive parameters in days				
	Pre-Oviposition	Oviposition	Post-Oviposition	Fecundity	Longevity
T.neocaledonicus	2.8	11	3.4	18.9	17.2
R.indica	1.95	10.5	2.8	16.6	14.8
A.destructor	1.3	11	2.7	17.8	15

TABLE XLIII

Duration (in hours) of development of *P. rachelae* on different food items at laboratory conditions of 30±2°C and 70±2% RH

Prey	Mean ± S.D.							
	Egg	Larva	Q1	Protonymph	Q2	Deutonymph	Q3	Total
T.neocaledonicus	29.6±1.6	25.3±1	3.3±0.12	47.5±0.9	7±0.3	73.5±1.8	8±0.7	193.3±2.9
R.indica	30.7±1.1	23±1.5	3.2±0.2	45.2±2.6	6.4±0.4	71.5±2.6	6.8±0.3	182.3±14.5
A.destructor	26.6±2.2	23±1.4	3±0.2	46.6±1.8	5.5±0.3	67.6±3.4	6±0.4	178.6±5.07

TABLE XLIV

Average number of *T. neocaledonicus* (Larva, Protonymp and Adult) and *T.suknaensis*/ 2.5cm^2- Field experiment

SI. No.	Sampling period	Control	Experiment		P- value
		Pest	Pest	Predator	
1	Without predator	34.9	34.2	0	0.7280
2	Week 3	54.7	28.7	1.16	0.0000
3	Week 6	47.2	27.1	3.3	0.0000
4	Week 9	35.3	18.9	2.9	0.0000
5	Week 11	32.5	15.5	2.3	0.0000
6	Week 14	23.5	10.9	1.9	0.0000

PLATE –I

Different Species of Pests Offered as test Food Items to Phytoseiids

A - *A destructor*

B - *T. fijiensis*

C - *D. minutus*

D - *R. indica*

E - *T. neocaledonicus*

F - *T. cinnabarinus*

PLATE –II

Figure 1: Feeding Attributes of Phytoseiid Predators

A - Feeding on insect pest

B - Feeding on pest mite

Figure 2: Breeding Strategies of Phytoseiid Mites

A - Mating

B - Quiescence

C - Moulting

PLATE - XIII

Developmental Stages of *A. largoensis*

A - Egg

B - Larvae

C - Protonymph

D - Deutonymph

E - Adult Female

F - Adult Male – Lower Side

PLATE –XVI

Developmental Stages of *T. suknaensis*

A - Egg

B - Larvae

C - Protonymph

D - Deutonymph

E - Adult Female

PLATE –XVIII

Developmental Stages of *A. guptai* sp. nov.

A - Egg

B - Larvae

C - Protonymph

D - Deutonymph

E - Adult Female

F - Adult Male – Lower Side

PLATE –XX

Developmental Stages of *P. multidentatus*

A - Egg

B - Larvae

C - Protonymph

D - Deutonymph

E - Adult Female

F - Adult Male

PLATE –XXI

Developmental Stages of *P. rachelae*

A - Egg

B - Larvae

C - Protonymph

D - Deutonymph

E - Adult Female

F - Adult Male – Lower Side

PLATE –XXIX

General Morphology of Phytoseiid mites

A - Female- Dorsal Shield

B - Female- Ventral Shield

PLATE –XXX

General Morphology of Phytoseiid mites

A - Male- Ventral Shield

B - Spermatophoral process

C - Chelicera

D - Spermatheca

PLATE –XXXI

Morphological Descriptions of *A. largoensis*

A - Larva - Dorsal view

B - Larva – Ventral view

C - Protonymph – Dorsal view

D - Protonymph – Ventral view

PLATE –XXXII

Morphological Descriptions of *A. largoensis*

A - Deutonymph- Dorsal view

B - Deutonymph– Ventral view

C - Adult male – Dorsal view

D - Adult male – Ventral view

PLATE –XXXIII

Morphological Descriptions of *A. largoensis*

A - Adult Female - Dorsal view

B - Adult Female – Ventral view

C - Chelicera

D - Spermatheca

E - Leg

F - Spermatophoral process

PLATE –XXXIV

Morphological Descriptions of *T. suknaensis*

A - Larva - Dorsal view

B - Larva – Ventral view

C - Protonymph – Dorsal view

D - Protonymph – Ventral view

PLATE –XXXV

Morphological Descriptions of *T. suknaensis*

A - Deutonymph- Dorsal view

B - Deutonymph– Ventral view

C - Adult male – Dorsal view

D - Adult male – Ventral view

PLATE –XXXVI

Morphological Descriptions of *T. suknaensis*

A - Adult Female - Dorsal view

B - Adult Female – Ventral view

C - Chelicera

D - Spermatheca

E - Leg

F - Spermatophoral process

PLATE –XXXVII

Morphological Descriptions of *A. guptai* sp. nov.

A - Larva - Dorsal view

B - Larva – Ventral view

C - Protonymph – Dorsal view

D - Protonymph – Ventral view

PLATE –XXXVIII

Morphological Descriptions of *A. guptai* sp. nov.

A - Deutonymph- Dorsal view

B - Deutonymph– Ventral view

C - Adult male – Dorsal view

D - Adult male – Ventral view

PLATE –XXXIX

Morphological Descriptions of *A. guptai* sp. nov.

A - Adult Female - Dorsal view

B - Adult Female – Ventral view

C - Chelicera

D - Spermatheca

E - Leg

F - Spermatophoral process

PLATE –XL

Morphological Descriptions of *P. multidentatus*

A - Larva - Dorsal view

B - Larva – Ventral view

C - Protonymph – Dorsal view

D - Protonymph – Ventral view

PLATE –XLI

Morphological Descriptions of *P. multidentatus*

A - Deutonymph- Dorsal view

B - Deutonymph– Ventral view

C - Adult male – Dorsal view

D - Adult male – Ventral view

PLATE –XLII

Morphological Descriptions of *P. multidentatus*

A - Adult Female - Dorsal view

B - Adult Female – Ventral view

C - Chelicera

D - Spermatheca

E - Leg

F - Spermatophoral process

PLATE –XLIII

Morphological Descriptions of *P. rachelae*

A - Larva - Dorsal view

B - Larva – Ventral view

C - Protonymph – Dorsal view

D - Protonymph – Ventral view

PLATE –XLIV

Morphological Descriptions of *P. rachelae*

A - Deutonymph- Dorsal view

B - Deutonymph– Ventral view

C - Adult male – Dorsal view

D - Adult male – Ventral view

PLATE –XLV

Morphological Descriptions of *P. rachelae*

A - Adult Female - Dorsal view

B - Adult Female – Ventral view

C - Chelicera

D - Spermatheca

E - Leg

F - Spermatophoral process

PLATE –XLVI

Field Evaluation of Biocontrol Efficiency of *T. suknaensis* on *T. neocaledonicus* Infesting *V. unguiculata*

A - Experimental settings

B - Control 1

C - Control 2

D - Control 3

E - Experiment 1

F - Experiment 2

G - Experiment 3