

**“BIOECOLOGY AND CHEMICAL CONTROL OF  
PHYTOPHAGOUS MITE PESTS OF TOMATO  
(*Solanum lycopersicum* Linn.) UNDER POLYHOUSE  
CONDITION”**

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(AGRICULTURE)  
IN  
AGRICULTURAL ENTOMOLOGY**

**BY  
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B. Sc. (Agri.)**

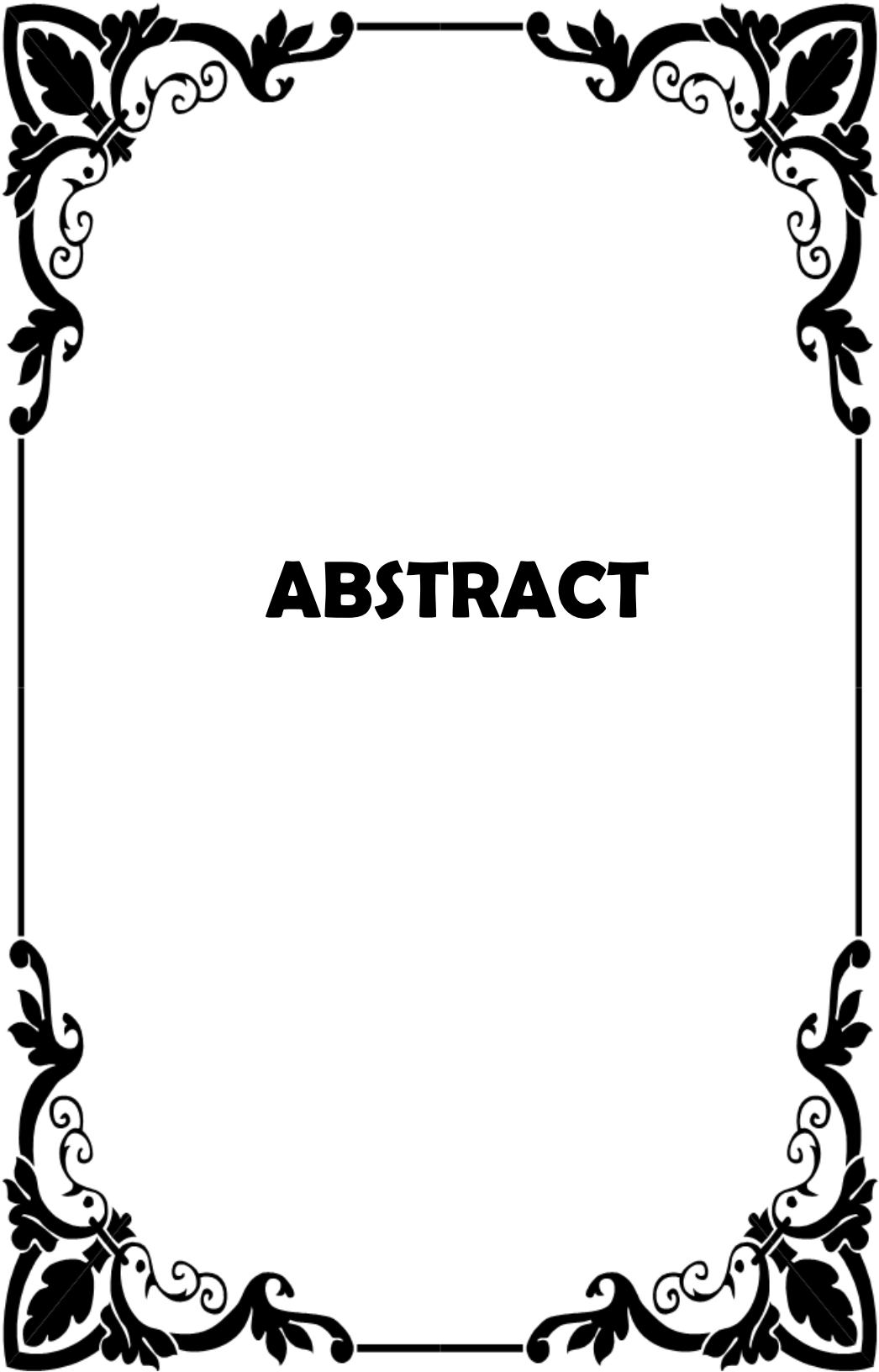
**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY  
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**DEDICATED**  
**TO**  
**MY BELOVED**  
**PARENTS**



**ABSTRACT**

**“BIOECOLOGY AND CHEMICAL CONTROL OF PHYTOPHAGOUS MITE  
PESTS OF TOMATO (*Solanum lycopersicum* Linn.) UNDER POLYHOUSE  
CONDITION”**

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**A B S T R A C T**

An investigation entitled “Bioecology and chemical control of phytophagous mite pests of tomato (*Solanum lycopersicum* Linn.) under polyhouse condition” were carried out at Navsari Agricultural University, Navsari, Gujarat during 2014. In the present investigation two phytophagous mites *viz.*, *T. urticae* and *A. lycopersici* were recorded on the tomato cv. Heemsohna under polyhouse.

Studies on the biology of two spotted spider mite *T. urticae* and *A. lycopersici* were carried out on tomato under laboratory conditions. The biology of *T. urticae* on tomato were carried out in three seasons *viz.*, summer, monsson and winter and the findings revealed that both the sexes passed through five different dtages *viz.*, egg, larva, protonymph, deutonymph and adult with a short resting period known as

quiescent. Morphology of all the stages, period of immature stages and longevity of adults and reproductive potential of *T. urticae* were also studied. The biology of russet mite, *A. lycopersici* on tomato was also carried out during October-November 2014 under laboratory. The findings revealed that both the sexes passed through four stages viz., egg, larva, nymph and adult with a short resting period between larvae and nymph and nymph and adult stage which is known as quiescent. The morphological aspects of *A. lycopersici*, periods of immature stages, longevity of adults and their reproductive potential were studied.

The population dynamics of phytophagous mites infesting tomato under polyhouse conditions along with their natural enemies. The egg stage of *T. urticae* showed three distinct peaks during the crop season. The first peak was observed during 2<sup>nd</sup> SMW (3<sup>rd</sup> week of March), the second during 18<sup>th</sup> SMW (1<sup>st</sup> week of May) and the third one during 24<sup>th</sup> SMW (2<sup>nd</sup> week of June). The egg stage of *T. urticae* showed a significant positive correlation with average temperature and relative humidity of polyhouse. The mobile stage of *T. urticae* was recorded throughout the crop season. The first peak was recorded during 15<sup>th</sup> SMW (2<sup>nd</sup> week of April) and the second was observed during 24<sup>th</sup> SMW (2<sup>nd</sup> week of June). The mobile stage of *T. urticae* showed a significantly positive correlation with average temperature and relative humidity of polyhouse. Both the egg and mobile stages of *T. urticae* prefer top leaf strata of tomato plant. The activities of russet mites started during 4<sup>th</sup> SMW (3<sup>rd</sup> week of January) and it was maximum during 21<sup>st</sup> SMW (4<sup>th</sup> week of

May). The egg stage of *A. lycopersici* showed a significantly positive correlation with average temperature and relative humidity of polyhouse. The activities of mobile stages of russet mites started during 1<sup>st</sup> SMW (1<sup>st</sup> week of January) and reached to its peak during 21<sup>st</sup> SMW (4<sup>th</sup> week of May). The mobile stage of *A. lycopersici* showed significantly positive correlation with average temperature and relative humidity of polyhouse. Both the egg and mobile stages of *A. lycopersici* prefer top leaf strata of tomato plant. Under the present studies the activities of a phytoseiid predatory mite, *A. longispinosus* and predatory thrips, *S. indicus* were also recorded throughout the crop season. It was observed that the predatory mite, *A. longispinosus* had two distinct peaks, first during 13<sup>th</sup> SMW (4<sup>th</sup> week of March) and second during 25<sup>th</sup> SMW (3<sup>rd</sup> week of June) under polyhouse on tomato. The predatory mite, *A. longispinosus* showed a positive correlation with eggs and mobile stages of the prey mites. It also showed significantly positive correlation with average temperature and relative humidity of polyhouse. The activities of predatory thrips, *S. indicus* were also recorded throughout the crop season and peak activities of *S. indicus* was recorded during 26<sup>th</sup> SMW (4<sup>th</sup> week of June). The predatory thrips, *S. indicus* showed a positive correlation with eggs and mobile stages of the prey mites. The population of predatory thrips, *S. indicus* also showed significantly positive correlation with average temperature and relative humidity of polyhouse. The activities of both the predators were higher on top leaf strata of tomato plant.

The bioefficacy of different acaricidal treatments tested against eggs and mobile of *T. urticae* and *A. lycopersici* revealed that the acaricidal treatment diafenthiuron 50 WP was most effective and safer to the predatory mite, *A. longispinosus*. The higher net ICBR was obtained in the acaricidal treatment diafenthiuron (1:10.50) followed by fenazaquin (1:10.40).

The survey was also carried out to investigate the diversity of phytophagous mites fauna associated with vegetable crops. The following phytophagous mite species were recorded from different vegetables grown under polyhouse and open field conditions: *T. urticae*, *T. neocaledonicus*, *T. ludeni*, *T. macfarlanei*, *T. cinnabarinus*, *O. biharensis*, *B. californicus*, *B. phoenicis*, *E. orientalis*, *P. latus* and *A. lycopersici*.

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## **CERTIFICATE**

This is to certify that the thesis entitled “**Bioecology and chemical control of phytophagous mite pests of tomato (*Solanum lycopersicum* Linn.) under polyhouse condition**” submitted by **Mr. PANKAJ PRAKASH POKLE** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **AGRICULTURAL ENTOMOLOGY** of the **NAVSARI AGRICULTURAL UNIVERSITY, NAVSARI** is a record of bonafide research work carried out by him under my guidance and the thesis has not previously framed the basis for the award of any degree, diploma or other similar title.

**Place :** Navsari

**(Abhishek Shukla)**

**Date :**

**Major Advisor**

## **DECLARATION**

This is to declare that the whole of the research work reported in this thesis in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL ENTOMOLOGY** by the undersigned is the results of investigation done by me under direct guidance and supervision of **Dr. Abhishek Shukla**, Senior Acarologist, AINP on Agricultural Acarology, Department of Agricultural Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

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*Place: Navsari*

*Date:*

*(Pankaj P. Pokle)*

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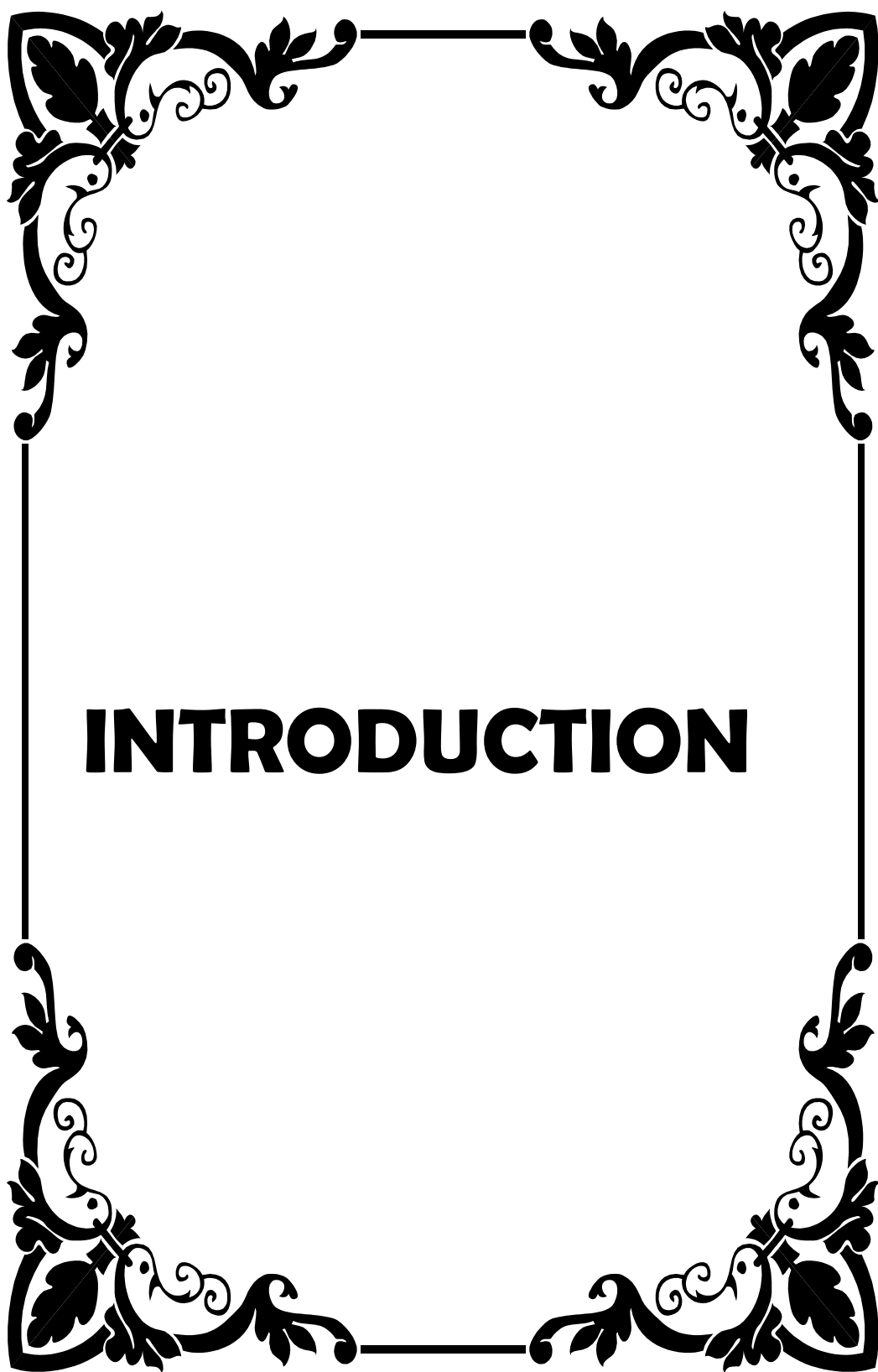
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# **INTRODUCTION**

## 1. INTRODUCTION

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With the globalization of trade and liberalization of Indian economy, there is an immense scope for the export of high value vegetables and flowers from India, besides meeting the ever increasing demand in domestic market. The need of the hour is to increase the productivity and quality of produce to fulfill the demand of quality of conscious consumers. In the changing scenario of increasing population, decreasing cultivable land/water resources, increasing urbanization/industrialization, there is a need to produce more from available land and water. A breakthrough in production technology that integrates market driven quality parameters with the production system, besides ensuring a vertical growth in productivity is required. One such technology is protected cultivation or generally called greenhouse or polyhouse technology.

Protected cultivation is a technique to create a favourable environment for the sustained growth of crop, offsetting the detrimental effects of prevailing abiotic and biotic factors. It offers several advantages to produce vegetables, flowers, hybrid seeds of high quality, through efficient land and resource utilization. In India, protected cultivation on commercial scale was started during early nineties and Maharashtra, Karnataka, Himachal Pradesh, Tamil Nadu, Gujarat and Punjab are leading states adopting this technology with approximate area of 30,000 hectares(Anonymous, 2010). The major crops being grown under polyhouse condition are

tomato, capsicum, cucumber, melons, strawberry, rose, gerbera, carnation and chrysanthemum.

Among vegetables, tomato (*Solanum lycopersicum* Linn.) is the preferred crop grown in greenhouse or polyhouse worldwide (Singh, 2005). However, tomato is largely cultivated under open conditions in the world in about 4,412.70 thousand hectares and production of 151699.4 thousand metric tones (Anonymous, 2010). But, the year-round demand for quality tomatoes can be achieved through the polyhouse cultivation only. It is also the most remunerative cash crop for the farmers, but with the advent of horticultural technology and protected cultivation has opened new opportunities to the farmers in this high earning cropping system. The current area under protected cultivation has opened new opportunities to the farmers in this high earning cropping system. The present area under protected environment in Gujarat is about 4,720.72 hectares and it has been envisaged to establish polyhouses in the state. With the increasing acreage under protected cultivation the availability of quality tomato can be increased manifold during off seasons.

Heavy incidence of insect and mite pests has been observed under protected cultivation due to congenial environmental conditions. Major insect and mite pests of polyhouse cultivation belongs to order Homoptera (aphids, whiteflies and mealybugs), Thysanoptera (Thrips), Diptera (Leafminers) and Acarina (Mites) (Papasolomontos, 2004, Perdikis *et al.* 2008, Mehta *et al.*, 2012). Among them,

important ones causing economic damage to tomato crop under polyhouse conditions are greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), serpentine leaf miner, *Liriomyza trifolii* (Burgess) and Spider mite (*Tetranychus urticae* Koch.). Beside these, tomato russet mite, *Aceria lycopersici* (Wolffenstein) has been observed to cause heavy loss to tomato under polyhouse conditions.

Mites of the family Tetranychidae are among the destructive pests of agri-horticultural crops in many parts of the world. *T. urticae* is one of the cosmopolitan spider mite pest reported as serious pest on many plants like tomato, okra, brinjal, french bean, cucurbits, cotton, alfalfa, flowers, etc. (Meyer and Rodriguez, 1966; Manjulata *et al*, 2002).

The spider mite generally feed on the lower surface of the leaves as a result the infested leaves initially show speckling and later turn yellowish, finally leading to defoliation. The mites spread to all parts of the plants as the population increases especially during day period and produce webbing over the entire plants. Moderate population may greatly affect crop production and heavy infestation results in death of the plant (Jeppson *et al.*, 1975). Spider mites are generally known to puncture the epidermal layers and suck the oozing sap, in the process they also damage the internal tissues surrounding the area puncture by their chelicera. The spider mite remains active throughout the year in polyhouse and cause damage to the high value crops including tomato.

Jayasinghe and Mallik (2010) in a study on tomato reported that one spider mite, *T. urticae* released to a tomato

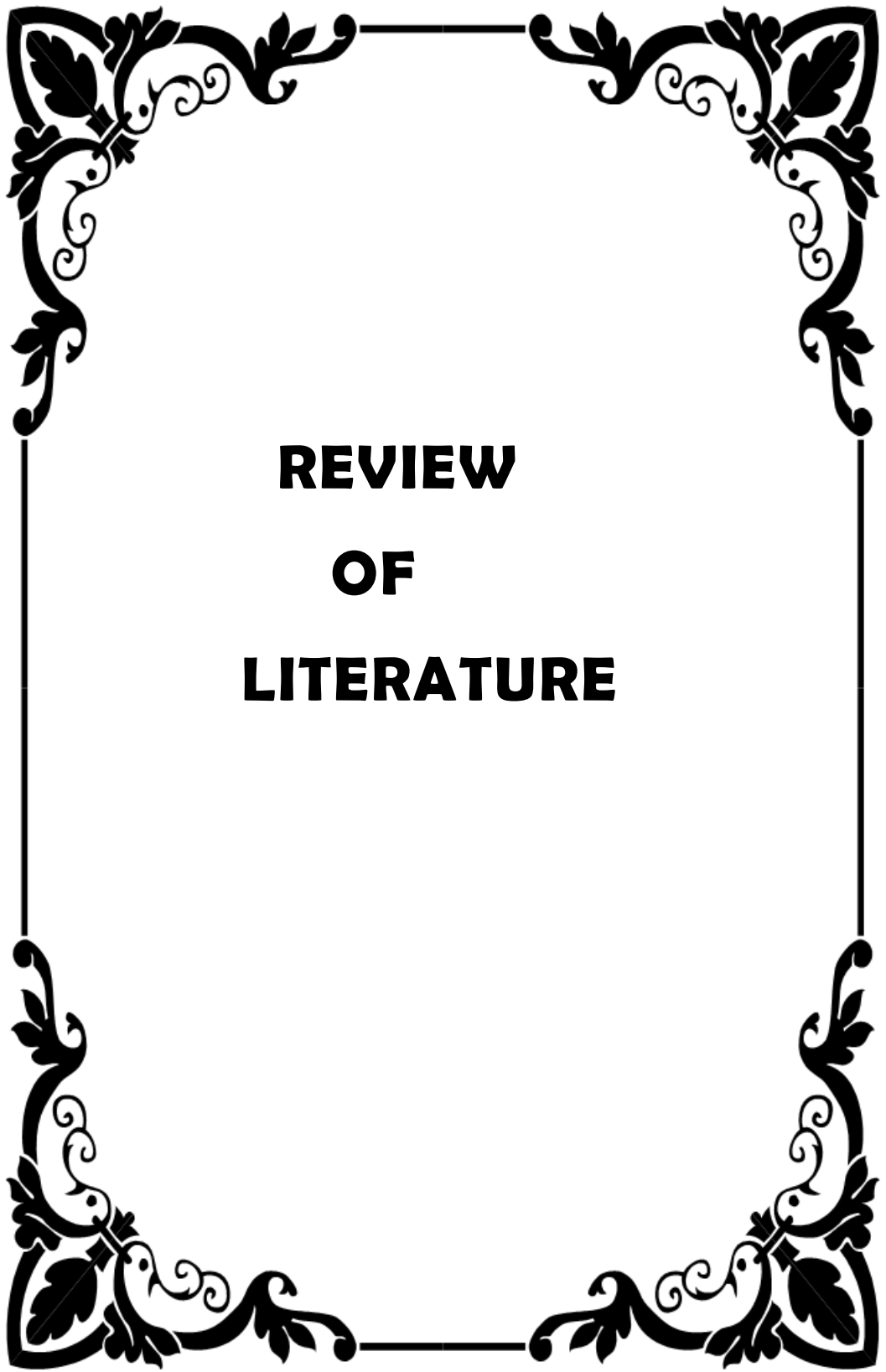
plant 6 weeks after planting and allowed to feed for 3, 6, 9 and 12 weeks, reduced the final yield by 0.233, 0.689, 1.291 and 1.624 g per plant, respectively. Under similar conditions with same treatments a mite day reduced 16.4, 1.80, 0.96 and 1.18 mg of the final yield, respectively. Middle stage of the crop was the most critical period and mite infestation initiated at this stage can contribute to more than 50 per cent of total yield loss due to leaf defoliation and reduction of chlorophyll content of the leaves.

Under the polyhouse conditions another phytophagous mite belonging to family Eriophyidae which are among the most specialized plant feeders cause damage to tomato crop. The tomato russet mite *Aceria lycopersici* is a serious pest throughout the Mediterranean region, whereas the tomato is grown. This minute mite forms huge colonies on the leaves and stems of tomato which show up as a rust coloured mass which spreads along the stem. Later on it form such colonies on leaf and many times on developing fruits (Anonymous, 2012).

*A. lycopersici* also occurs on some Solanaceae, few Convolvulaceae and Rosaceae plants. It is mostly known as a pest of tomatoes, but also damage potato, brinjal, tobacco, bell pepper, Jerusalem cherry, petunia, tomatillo, cherry pepper and many weed plants (Duso *et al.* 2010).

Understanding the impact of the damage caused by the phytophagous mites to the important crop like tomato and causing economic loss to the growers, the present investigation were carried out with following objectives:

1. To study the biology of two spotted spider mite, *Tetranychus urticae* (Koch.) and russet mite, *Aceria lycopersici* (Wolffenstein) under laboratory conditions.
2. To investigate the seasonal incidence of two spotted spider mite, *T. urticae* and russet mite, *A. lycopersici* under polyhouse conditions.
3. Chemical control of mite pests of tomato under polyhouse condition.
4. To study the biodiversity of phytophagous mites in different vegetable crops under polyhouse and open field conditions.



**REVIEW  
OF  
LITERATURE**

## 2. REVIEW OF LITERATURE

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### 2.1 Biology of phytophagous mites

#### 2.1.1 *Tetranychus urticae* and other spider mites:

Davis (1961) observed that, the diameter of eggs was 0.117 to 0.143 mm. Larvae, protonymph, female deutonymph, male deutonymph and adult male and female of *T. cinnabarinus* was 0.15 and 0.12, 0.24 and 0.16, 0.35 and 0.20, 0.27 and 0.17, and 0.33 and 0.18, 0.43 mm. long and 0.27 mm wide, respectively and also recorded the duration of each stage viz., eggs hatched in 2 days and larva, 1<sup>st</sup> quiescent stage, protonymph, 2<sup>nd</sup> quiescent stage, male and female deutonymph 3<sup>rd</sup> quiescent stage varied from 0.7 to 6, 0.5 to 5 days, 6.00 to 8.00, 8.00 to 15.00, 8.00 to 16.00, 4.00 to 8.00, 16.00 to 29.00, 16.00 hrs. to 9.00 days, respectively. The adult stage was also recorded from 1 to 3 days

Lall *et al.* (1965) found that the eggs were laid on the under surface of leaves of bhendi by *T. telarius*. The number of eggs laid by female varied from 61 to 74. The number of eggs laid by unfertilized female was 25.80. The incubation, larval, protonymphal and duetonymphal period was 3.05, 2.35, 2.47, and 2.78 days, respectively. While, total life cycle was completed in 10.65 days.

Rishi and Rather (1983) revealed that the egg laying of female *T. urticae* continued for 3 days and each female laid 40 to 50 eggs on the under surface of french bean leaves. The incubation period varied from 12 to 15 days. The newly hatched larvae were fed for 1 to 2 days. Later, they

entered into quiescent stage lasting 2 to 3 days. After 3 days of subsequent feeding again a short quiescent stage existed and finally moulted in to duetonymph. The duetonymph after active feeding for 2 to 3 days passed through resting period for 2 days before moulting to adult stage. The fecundity of fertile female was ranged from 60 to 120 eggs in the laboratory condition.

Sejalia *et al.* (1993) studied the incubation period of *T. macfarlanei* Baker and Pritchard for female it was  $4.31 \pm 0.46$  days in March-April, while it was  $3.06 \pm 0.23$  days during July-August. Moreover, larval nymphal period was  $5.69 \pm 1.55$  days for male and  $6.13 \pm 0.41$  days for female during March-April, while it was  $4.30 \pm 0.39$  days and  $5.07 \pm 0.23$  days, for respective sexes, during July- August. The adult period was  $11.2 \pm 3.71$  days in July- August which was less during March- April and it was  $4.31 \pm 0.88$  days. The fecundity of female *T. macfarlanei* was varied from  $25.78 \pm 10.63$  eggs and male to female sex ratio was 1:6.5 on okra.

Kasap (2004) studied the period of immature stages of *T. urticae* on apple cultivars ranging between 6.5 to 15.5 days for female and 5.9 to 14.5 days for male, respectively. The total life cycle of *T. urticae* was completed in 7.5 days at  $27 \pm 1^{\circ}$  C temperature and  $95 \pm 5$  per cent relative humidity. Mean generation time was 16.0 days. The quiescent period between deutonymph and active adult for females was 2.4 days with reproductive rate 7.97 eggs/female/day (Shih *et al.*, 1976).

Rajkumar *et al.* (2005a) studied the biology of *T. urticae* on Jasmine and observed egg to adult period as 10.70

$\pm 0.45$  days and  $12.36 \pm 0.68$  days, for male and female, respectively. The incubation, larval, protonymphal and deutonymphal period for male and female was  $4.30 \pm 0.43$ ,  $2.42 \pm 0.41$ ,  $1.66 \pm 0.37$ ,  $1.30 \pm 0.14$  and  $4.46 \pm 0.27$ ,  $2.72 \pm 0.18$ ,  $2.33 \pm 0.24$ ,  $1.50 \pm 0.28$  days, respectively. Pre oviposition and oviposition period recorded by them was  $1.82 \pm 0.40$  and  $14.5 \pm 2.55$  days, respectively. Moreover, the fecundity of the female was  $104 \pm 3.19$  eggs during its life span.

The duration of developmental stages of *Tetranychus urticae* Koch was studied in different months of a year at room temperature. In addition fecundity of this mite was also observed in winter, autumn and summer seasons. *T. urticae* eggs hatched to larvae in the shortest duration of  $1.07 \pm 0.26$  days and the longest duration of  $11.67 \pm 2.33$  days in April and January, respectively. The larval period of *T. urticae* took the shortest time of  $0.55 \pm 0.50$  days in May and  $2.93 \pm 1.07$  days in December. The protonymph transformed to deutonymph in  $0.89 \pm 0.32$  day in May and  $3.71 \pm 1.94$  days in December and January. The deutonymph required the shortest duration of  $0.92 \pm 0.41$  days in August and the longest of  $10.26 \pm 1.48$  days in January. The temperature played significant role on the duration of developmental stages of *T. urticae*. The high temperature accelerated the developmental rate and reduced the duration of developmental periods. Its life cycle completed within  $4.22 \pm 0.46$  days at  $28.53 \pm 3.17^\circ\text{C}$  but  $28.33 \pm 2.36$  days at  $13.78 \pm 2.36^\circ\text{C}$ . A female *T. urticae*

deposited  $82.46 \pm 4.11$  eggs in autumn,  $62.96 \pm 12.09$  eggs in summer and  $58.21 \pm 13.65$  eggs in winter (Naher *et al.* 2008).

Nayak *et al.* (2008) carried out biology of paddy leaf mite, *Oligonychus oryzae* Hirst under laboratory conditions. The study was conducted during *kharif* season (June to November). It indicated that the egg, larval, protonymphal and deutonymphal periods were  $4.70 \pm 1.09$ ,  $1.89 \pm 0.30$ ,  $1.89 \pm 0.18$ ,  $2.09 \pm 0.24$  and  $5.90 \pm 1.12$ ,  $2.23 \pm 0.36$ ,  $2.27 \pm 0.26$ ,  $2.42 \pm 0.28$  days for male and female, respectively. The total developmental period lasted for  $10.58 \pm 1.50$  days and  $12.64 \pm 1.57$  days for male and female, respectively.

Sekhar *et al.* (2008) reported that the *T. urticae* reared on grape cv. Thompson seedless required 3.68, 2.06, 0.74, 1.89, 0.79, 2.02 and 0.84 days for the eggs, larval, quiescent, protonymphal, 2<sup>nd</sup> quiescent, deutonymph and 3<sup>rd</sup> quiescent stages, respectively. Each female laid 73.20 eggs during its life span. The pre-oviposition, oviposition and post-oviposition period lasted for 1.96, 10.53 and 2.48 days, respectively. The total developmental period from egg to adult stage of males and females lasted for 8.60 and 14.60 days, respectively.

Singh and Dhooria (2008) studied the biology of *T. cinnabarinus* through leaf disc technique at  $27 \pm 1^\circ\text{C}$ . Minimum mortality during development, shorter larval plus nymphal development and higher fecundity and longevity was recorded on musk melon among different cucurbits. The female longevity was higher in cucumber, wanga, wild melon and ash gourd, but these cucurbits had prolonged larval plus

development and very poor egg laying as compared to that of preferred cucurbits.

Patil (2010) studied the biology of *T. urticae* on carnation and revealed that both the sexes passed through five stages *viz.* egg, larva, protonymph, deutonymph and adult with a short resting period known as quiescent.

Prasad and Singh (2010) at Varanasi studied the biology of *T. urticae* on okra and found that it passes through four active stages as well as three quiescent stages. Male had only two quiescent stages whereas female had three. The incubation, larval, protonymphal, deutonymphal and adulthood period for female were  $3.79 \pm 0.02$  and  $3.13 \pm 0.13$ ,  $1.25 \pm 0.17$  and  $0.72 \pm 0.03$ ,  $1.02 \pm 0.07$  and  $0.72 \pm 0.03$ ,  $1.47 \pm 0.26$  and  $1.31 \pm 0.24$ ,  $9.43 \pm 0.87$  and  $8.39 \pm 0.65$  days at  $25.46^\circ\text{C}$  and  $29.62^\circ\text{C}$ , respectively. Growth index was  $8.73 \pm 0.65$  and  $9.61 \pm 0.98$  at  $25.46^\circ\text{C}$  and  $29.62^\circ\text{C}$  temperatures, respectively.

Toke (2010) studied the biology of *T. urticae* on rose and found that both the sexes passed through five different stages. The average duration of egg, larva, protonymph, deutonymph and adult was  $3.29 \pm 0.62$ ,  $1.79 \pm 0.64$ ,  $2.54 \pm 0.50$ ,  $2.11 \pm 0.79$  and  $10.00 \pm 1.41$  days, respectively for male whereas, it was  $3.29 \pm 0.62$ ,  $2.71 \pm 0.57$ ,  $2.89 \pm 0.58$ ,  $2.71 \pm 0.71$  and  $12.49 \pm 1.52$  days, respectively for female. A short resting period is known as quiescent. The newly hatched larva was hexapodous while other nymphal instars were octopodous. Male as to female ratio was 1: 2.50. Males were produced parthenogenitically, while female were

produced bisexually. The detailed morphology of all the stages, longevity of adults and reproductive potential of *T. urticae* were also studied.

Bhusal (2011) studied biology of *T. urticae* on chrysanthemum and found that both the sexes passed through five different stages. The average duration of egg, larva, protonymph, deutonymph and adult was  $3.50 \pm 0.70$ ,  $1.71 \pm 0.67$ ,  $2.61 \pm 0.45$ ,  $2.29 \pm 0.64$  and  $8.93 \pm 1.44$  days, respectively for male whereas, it was  $3.50 \pm 0.70$ ,  $2.75 \pm 0.55$ ,  $2.89 \pm 0.57$ ,  $2.75 \pm 0.69$  and  $12.89 \pm 1.72$  days, respectively for female with a short resting period known as quiescent period. The newly hatched larva was hexapodous while other nymphal instars were octopodous. Male as to female ratio was 1: 2.57. Males were produced parthenogenetically while female were produced bisexually.

Sangeetha and Ramani (2011a) studied the Post embryonic development of the spider mite, *T. ludeni* Zacher infesting *Mucuna deeringiana* in the laboratory at  $30 \pm 2^\circ\text{C}$  and  $70 \pm 5\%$  relative humidity. Rearing of the life stages of the mite was carried out following leaf flotation technique. The durations of pre-oviposition period, oviposition period and post-oviposition period were recorded to be  $0.5 \pm 0$ ,  $11.5 \pm 0.38$  and  $0.5 \pm 0$  days respectively. Fecundity recorded was  $83.6 \pm 3.4$  eggs and longevity,  $12.6 \pm 0.37$  days. The total duration of sexual and parthenogenetic reproduction respectively were  $10.04 \pm 0.13$  days and  $9.04 \pm 0.13$  days respectively. The parthenogenetic development required comparatively shorter duration than sexual ones. Sex ratio (male: female) was 2: 10.

Sangeetha and Ramani (2011b) studied the development times of the carmine spider mite, *T. cinnabarinus* Boisval on excised leaf disc of lab lab bean, *Dolichos lablab* at  $30 \pm 2$  °C and  $70 \pm 5$  per cent relative humidity. Total development times from egg to adult stage were  $7.33 \pm 0.13$  days. The pre oviposition, oviposition and post oviposition periods were  $0.5 \pm 0$ ,  $8.05 \pm 0.14$  and  $0.65 \pm 0.07$  days respectively. Fecundity averaged  $42.5 \pm 1.7$  eggs per female and longevity averaged  $9.2 \pm 0.13$  days.

Kumar and Raghuraman (2013) carried out biological studies on spider mite, *T. urticae* on brinjal and revealed that life cycle of *T. urticae* was completed by passing through four active stages, viz., larva, protonymph, deutonymph and adult as well as three quiescent (chrysalis) stages, viz., nymphochrysalis, deutochrysalis and teliochrysalis. After each active stage (except adult), mite entered into quiescent stage for short period, and the mite passed through next successive stage after moulting. The total fecundity of fertilized female was  $59.50 \pm 5.06$  eggs per female and that of unfertilized was  $22.40 \pm 0.94$  eggs per female. The incubation, larval, protonymphal, and deutonymphal periods were  $4.59 \pm 0.31$ ,  $1.81 \pm 0.10$ ,  $1.40 \pm 0.16$  and  $1.68 \pm 0.40$  days, respectively, while the growth index of the mite was 6.6.

Shah and Shukla (2014) studied the biology of two spotted spider mite, *T. urticae* on gerbera during summer, monsoon and winter seasons at Navsari, Gujarat. Duration of egg to adult stage was  $18.08 \pm 2.47$ ,  $21.54 \pm 1.60$  and  $25.36 \pm 1.59$  days for males and  $28.54 \pm 2.87$ ,  $30.18 \pm 2.55$  and  $53.65 \pm$

4.85 days for unmated females whereas it was  $24.81 \pm 2.57$ ,  $23.88 \pm 1.66$  and  $52.15 \pm 5.04$  days for mated females during three seasons, respectively. An unmated female laid  $26.06 \pm 8.33$ ,  $31.86 \pm 6.01$  and  $19.13 \pm 3.85$  eggs during her life while the mated female laid on an average  $59.24 \pm 13.84$ ,  $71.80 \pm 15.45$  and  $66.48 \pm 10.72$  eggs during three seasons, respectively. On an average the time taken for completion of the life cycle of the mite on gerbera leaves was 21.66 days for male, 37.47 days for unmated female and 37.29 days for mated female. The average fecundity was 25.77 eggs per unmated female and 64.50 per mated female.

### **2.1.2 *Aceria lycopersici* and other eriophyid mites:**

Cermeliz *et al.* (1982) recorded *A. lycopersici* for the first time from Venezuela. It was reported from tomatoes in the States of Lara, Aragua and Trujillo early in 1979; the geographical spread of these reports suggests that the mite had been present in the country for some time but had not been recognised. Notes are given on its external morphology, biology and food-plants.

Baradaran and Daneshwar (1992) from Iran reported that development of *A. lycopersici* from egg to adult took 8 days at  $25 \pm 1^\circ\text{C}$  and  $50 \pm 5\%$  RH. Mites overwinter on alternative hosts. Females begin to oviposit soon after the infestation of the host plant.

Celar and Valic (2001) reported that the development of *A. lycopersici* from egg to adult lasts for 7 days under optimum conditions. In a crop season upto 7 generations were recorded.

Sobha and Haq (2011) conducted experiment to evaluate details of the morphology of the immature stages and the development of *A. guerreronis* on coconut. It was conducted in a laboratory at  $28 \pm 2^\circ\text{C}$  and 80% RH. The eggs were small ( $66 \pm 4$  and  $41 \pm 2\mu\text{m}$  for long and short axes), and a single female laid on an average  $66 \pm 4$  eggs during 15 days of oviposition period. Incubation period lasted 2.5 to 3.5 days. Hatching was completed in about 30 minutes. The larva emerged through a longitudinal slit on the surface of the egg. Almost transparent, sluggish and measuring  $87 \pm 12\mu\text{m}$  long, it started feeding soon after emergence. The active period of the larva lasted 1.5 to 2.5 days, being followed by a quiescent period that lasted about one day. The nymph measured  $176 \pm 11\mu\text{m}$  in length, the active and quiescent periods of this stage lasted 2 and 0.5 to 1.5 days, respectively. Adult females had an average length of  $224 \pm 9\mu\text{m}$ . Eight to ten days were necessary for immature development.

Ansaloni and Perring (2014) stated that development of *A. guerreronis* from egg to adult required 30.5, 16.0, 11.5, 8.1 and 6.8 days at 15, 20, 25, 30 and  $35^\circ\text{C}$ , respectively, and the thermal maximum was estimated to be close to  $40^\circ\text{C}$ . Optimal development was determined from the total immature developmental rate curve to be at  $33.60^\circ\text{C}$ , while the lower threshold for development was  $9.36^\circ\text{C}$ . Using these values, they found that 172.71 degree days were required for mites to mature from the egg to the adult stage. As adults, fertilized females laid more eggs and lived longer than non-fertilized females, with a maximum of 51 eggs produced over

a maximum of 43 days longevity. Non-fertilized females laid eggs resulting only in male offspring, indicating this species is arrhenotokous.

## **2.2 Population dynamics of phytophagous mites :**

### **2.2.1 *T. urticae* and other spider mites:**

Lal (1982) reported that the population of *T. neocaledonicus* on cassava was very low or absent between June to December and thereafter increased suddenly. The infestation period was recorded from January to April. The increase in population of the spider mites was found to be significantly correlated with decrease in humidity and non-significantly correlated with increase in maximum temperature.

Dhar *et al.* (2000) studied the influence of important abiotic factors on population of red spider mite, *T. urticae* on okra and recorded that temperature was positively and relative humidity was negatively correlated with the population of mite. There was highest incidence of mite during the first week of June (50.50 mobile stage/2 sq. cm of leaf area) with an ambient temperature 31.30<sup>0</sup>C and 78.5 per cent relative humidity. Rainfall have no significant effect on the population build up of mite.

Rajkumar *et al.* (2005b) revealed that, the incidence of mite, *T. urticae* on Jasmine was maximum during the first week of November and there after no mite population was observed during third week of November to last week of January. Further they reported that, maximum and minimum

temperature has positive while, rainfall, morning and evening relative humidity recorded negative significant relationship with mite population.

Mandal *et al.* (2006) conducted an experiment to study the effect of meteorological parameters on population build up of red spider mite, *T. telarius* in okra at Pusa, Bihar during summer seasons of 2000 and 2001. Results indicated that the activity of the mite showed non-significant negative correlation with maximum temperature and positive correlation with minimum temperature. Morning and afternoon relative humidity showed a significant positive association with the activity of mites. Regression analysis explained 78.85 per cent variability due to meteorological parameters in the population of red spider mite.

Sudhirkumar and Shelke (2008a) reported that the population of *T. urticae* on rose increased from May. The first peak occurred in June when average maximum temperature was 34.24<sup>0</sup>C, minimum temperature was 22.25<sup>0</sup>C and morning and evening relative humidity was 80.12 and 42.11 per cent, respectively. The population then declined gradually and reached a very low level during the month of January due to adverse effect of low temperature.

Roopa and Nandihalli (2009) reported that in summer *T. macfarlanei* on brinjal appeared at 45 days after transplanting and attained its peak in 28<sup>th</sup> standard week with 14.2 individuals per 4 cm<sup>2</sup> leaf area. The activity of phytoseiids started from 23<sup>rd</sup> standard week with 0.07 mites per leaf and reached peak of 1.20 mite per leaf on 28<sup>th</sup>

standard week coinciding with peak population of prey mite (1.42/4 cm<sup>2</sup> leaf area). On *kharif* crop, spider mites appeared much later than summer crop *i.e.*, at 90 days after transplanting (1<sup>st</sup> week of November). During *rabi*, spider mites population attained two peaks on brinjal. The first peak incidence occurred in 46<sup>th</sup> standard week (November 12-18) with 28.73 individuals per 4 cm<sup>2</sup> leaf area and the second peak, 23.8 individuals per 4 cm<sup>2</sup> leaf area was attained during January 2005 at Dharwad.

Studies carried out by Toke (2010) on population dynamics of *T. urticae* on rose revealed that incidence of spider mite was commenced from the first week of February and increased gradually to reach its peak during first week of July. The maximum and minimum temperature showed significantly positive correlation and morning relative humidity and evening relative humidity were negatively correlated with *T. urticae* population.

Kachhawa and Rahman (2013) reported that the *Oligonychus coffeae* on tea leaves was maximum during the month of April to May-June and September-October, 2011. The minimum number of mites was recorded from July-August and November to February 2011-13. The data taken from 1<sup>st</sup> week of April, 2011 to last week of March 2012. In case of egg population, there was a gradual increasing trend in egg number to reach the peak population in the month of April. From April to June overall higher population of eggs/leaf was noticed. Afterwards sharp decline in number of eggs was noticed during July and August. Again population of

eggs was increased during September and October. Very minimum population of eggs was observed from November to January. Population of eggs was started increasing again from 1<sup>st</sup> week of February to March. Results of the present studies showed that the buildup of the red spider mite, *O. coffeae* population, as well as the number of eggs had a significantly positive correlation with the maximum temperature ( $r=0.320$  and  $r=0.286$  for the mites and eggs, respectively) and minimum temperature ( $r=0.268$  and  $r=0.279$  for mites and eggs, respectively). Whereas the motile stage of red spider mite, *O. coffeae* and eggs had a negative and significant correlation with average relative humidity ( $r = -0.357$  and  $r = -0.282$  for mites and eggs, respectively).

Ghosh (2013) found that the *T. urticae* was active throughout the growing period of okra with a peak population (6.18 mites/leaf) during 23<sup>rd</sup> SMW (last week of May) in the *pre-kharif* crop. Highest population (7.56/leaf) was recorded during 42<sup>nd</sup> SMW (first week of October) in the *post kharif* crop. Sudden fall of population was found in last week of June because of heavy rains. The incidence of mite population always remained higher on the upper canopy of the plant. Weekly population counts on mites showed non-significant positive correlation with temperature, maximum relative humidity, total rainfall and significant positive correlation with minimum and average relative humidity.

Ghoshal (2013) recorded maximum population of *T. neocaledonichus* on tulsi was during May, when the average temperature, average relative humidity and average rainfall

were 32.07°C, 73.75% and 0.95 mm, respectively. The minimum population density was found during September, when the average temperature, average relative humidity and average rainfall were reported to be 28.55°C, 84.76% and 12.64 mm, respectively. The correlation coefficient of the mite population density was found to be positive with temperature while it is negative with relative humidity and rainfall.

Monica *et al.* (2014) conducted study to determine the population dynamics of two spotted spider mite, *T. urticae* on brinjal under north Bihar condition from March to August, 2012. The mite population appeared initially at lower level with an average of 0.57 mites per cm<sup>2</sup> leaf area. Population gradually increased from April to June and recorded maximum 6.91 mites per cm<sup>2</sup> leaf area in the first week of June and then sharply declined from 4<sup>th</sup> week of June onward. The relationship between the population of *T. urticae* and the weather parameters showed significant positive correlation with maximum temperature and significant negative correlation with the relative humidity at 0700 hrs, when the temperature increased the mite population also increased and with increasing relative humidity at 0700 hrs, the mite population decreased.

Tripathi *et al.* (2014) recorded the maximum population of *T. urticae* in the I<sup>st</sup> fortnight of June (352.50 mites/leaf) on okra and *T. ludeni* (308.60mites/leaf) on brinjal when average atmospheric temperature was 35.53, relative humidity was 33.0% and rainfall was nil while minimum population of *T. urticae* (7.20 mites/leaf) on okra and *T.*

*ludeni* (4.20 mites/leaf) on brinjal was recorded in I<sup>st</sup> fortnight of March when average atmospheric temperature was 21.7, relative humidity was 61.7% and rainfall was 6.40mm. A positive correlation was found between temperature and mite population and negative with relative humidity and rainfall.

Shah and Shukla (2014) studied the seasonal activities of *T. urticae* on gerbera under polyhouse conditions from January to December 2013. The spider mite population remained active round the year under polyhouse condition with peak population during July (12.86 mites/ 2cm<sup>2</sup>leaf). The correlation between polyhouse maximum, minimum and average temperature of polyhouse with mite population was non-significantly negative, while average relative humidity of polyhouse had significant positive correlation with mite population. The *T.urticae* population was maximum on top leaf strata as compared to middle and bottom strata under polyhouse on gerbera.

Mazid *et al.* (2015) carried out study on seasonal incidence of red spider mite, *Oligonychus coffeae* Nietner in Tongani tea estate of Mangaldai, Assam. The red spider mites were found to be active in the summer season. Highest population of the mite was recorded in 2nd fortnight of June and whereas in December least number of mites were recorded. Mite numbers were considerably low in the winter months. Sudden decline in mite population was observed in July and August with the onset of heavy rainfall. Correlation studies of pest population with weather parameters revealed that there was a significant positive correlation of the

population of mites with the increasing temperature and rainfall whereas moderate positive correlation was observed with relative humidity.

### **2.2.2 *Aceria lycopersici* and other eriophyid mites:**

Doreste (1968) as well as Mariau (1970 and 1977) reported that there was no clear relationship between mite population and wet or dry weather that in Venezuela and Mexico.

Zuluaga and Sanchez (1971) and Griffith (1984) reported that although the coconut perianth mite was present in the gardens of Columbia and Trinidad throughout the year, the infestation was more severe in relatively dry climates or during the dry periods of wetter climates.

Zalon *et al.* (1986) from California carried out survey and found that 60 per cent of the tomato field were showing damage symptoms of *A. lycopersici* with no significant difference between year, location or irrigation type. Significantly greater frequency plantings compared with late planting. No consistent relationship was found between heat unit accumulations from seedling emergence to first detected damage symptoms for years or for category of seedling emergence date. A significant relationship was found for most years or for category of seedling emergence date between expression of damage symptoms and stage of plant growth. The most likely stages of plant growth at which damage symptoms would be expressed are when most plants have pink fruit or mature green tomatoes >2.5cm.

Howard *et al.* (1990) found that though the coconut mite was more predominant in tropical and sub-tropical regions, it was able to survive both short periods of the frost and some prolonged periods of temperature just above zero, than those normally encountered where coconut palms were grown.

Haq (1999) observed that the population density of *A. guerreronis* at Puthukkod in Trichur district of Kerala increased slightly from July to August and then declined up to October, a slow increase in population occurred from October to December which accelerated from December to March-April then the population declined from May to July. A positive correlation between mite population and dry climate during summer months and negative relationship with rainfall during the monsoon was observed.

Kannaiyan *et al.* (2000) studied the population dynamics of coconut perianth mite from September 1998 to November 1999 at Agriculture Research Station, Aliyanagar, Tamil Nadu which revealed that the population of eriophyid mite was maximum during May (86/4 mm<sup>2</sup>) followed by April (73/4mm<sup>2</sup>) and March (70/4 mm<sup>2</sup>). Fairly high mite populations were recorded even during the rainy months.

In *L. esculentum*, attack by *A. lycopersici* was concentrated on both surfaces of the leaves and in the proximal area of the basal leaflet in the medium-third canopy level. In contrast, the number of *A. lycopersici* was similar at both canopy heights and leaflet position of *L. hirsutum*. (Leite *et al.*, 2000)

Vidyasagar (2000) noticed the incidence of the coconut perianth mite *A. guerreronis* in the gardens throughout the year with a peak population during summer or dry periods in Kerala and similar observations were reported from Chittoor district of Andhra Pradesh (Reddy and Naik, 2000).

Varadarajan and David (2000) found that the densities of active and egg stage of *A. guerreronis* were not significantly correlated with weather parameters, further they also found that the population of *A. guerreronis* had no significant relationship with any of the weather factors.

Srikanth (2001) reported that the coconut eriophyid mite *A. guererronis* population was high during April and first fortnight of May 2000 and a steep decline was observed from June 2000 which reached the minimum during first week of August.

Arthanari *et al.* (2002) studied the relationship between weather parameters and nuts affected with eriophyid mite which indicated that temperature had both positive and negative correlation with respect to cultivars and wind speed had higher effect on the nuts affected with eriophyid mite irrespective of cultivars except in tall x dwarf cultivar.

Haque and Kawai (2002) studied the population growth of the tomato russet mite, *Aculops lycopersici* (Masse), and its effect on tomato plants in glasshouses. The population increased exponentially for six weeks after infestation. The intrinsic rate of natural increase was estimated to be 0.175 per day. At seven weeks after

infestation, the predator, *Homeopronematus anconai* (Baker) (Acari: Tydeidae), appeared on several plants. The population of *A. lycopersici* decreased rapidly on plants where the predator appeared, due to predation. But it decreased gradually on plants where the predator did not appear, because of the damage to the host plant caused by the mites. More than 70% of the population infested the leaves. *A. lycopersici* first reproduced on the released leaves then moved upward. The infestation caused great injury to the plants, with a large number of leaves turning brown and then drying up. The number of leaves, the plant height and the diameter of the main stem of the plants all decreased.

Kannaiyan *et al.* (2002) reported that the population trend of coconut eriophyid mite was almost constant throughout the year. The population was higher during the second fortnight of May (32.88/4 mm<sup>2</sup>) and November 2000 (34.26/4 mm<sup>2</sup>) and declined during the second fortnight of December 2000 and February 2001 (0.80 to 3.60/4 mm<sup>2</sup>).

Celar and Valic (2003) observed tomato russet mite (*A. lycopersici*) in a number of experimental greenhouses in Slovenia. The mite is most often reported as a pest of tomato, although it can attack plants from other genera from Solanaceae besides *Solanum* (*Ipomoea*, *Nicotiana* and *Capsicum*). Infestation by the mites occurs soon after the plants are transplanted. Mite populations increase significantly in a short time. As a consequence, the plants die.

Ramaraju *et al.* (2003) conducted correlation study and revealed that there was no significant relationship between eriophyid mites with any of the weather parameters. However, eriophyid mite population on four month old buttons had positive correlation with predatory mites.

Nair *et al.* (2003) reported the consistent persistence of the eriophyid mite *A. guerreronis*, with highest population during April (2439 mites/4 mm<sup>2</sup>) and the lowest in June (1128 mites/4 mm<sup>2</sup>).

Kawai and Haque (2004) from Japan studied the distribution pattern of adult and nymphs of russet mite, *A. lycopersici* on tomato. About half number of russet mite population infested leaflets and the other half petioles. Most of the mites infested the upper surface of the leaves. On petioles, the density of the mites was high at the posterior part while the numbers were large on leaflets near the stem. On leaflets, the mite density was higher in the middle than periphery and also higher at the bottom than the top, however the density become uniform in the leaf;let when the density become high.

The population of eriophyid mite, *A. guerreronis* remains active was found throughout the year with peak population during January and May 2003. Decline in the eriophyid mite population occurred with the onset of rains during second fortnight of June 2003 at Dharwad. (Raghavendra, 2004).

Abou-Awad (2005) observed mites from an abandoned olive nursery in Egypt for two years, during which

species diversity, seasonal fluctuations and biological aspects of specific eriophyid species were studied. Two eriophyid species – the olive bud mite *Aceria oleae* Nalepa and the olive rust mite *Tegolophus hassani* (Keifer), representing a basic trophic level – were fed upon by two predacious mites – *Neoseiulus cydnodactylon* (Shehata and Zaher) and *Agistemus olivi* Romeih. Population abundance of the eriophyid mites was affected by climatic conditions, predation, shady and sunny zones, leaf age and vertical distribution. About 12, 5, 15 and 4 generations were recorded for both eriophyid species during the two successive years, respectively. Life table parameters showed that the population of *T. hassani* multiplied 9.92 times in a generation time of 14.42 days at 31 °C and 80 % r. H., while the *A. oleae* population increased 16.70 times in a generation time of 13.50 days at the same conditions. Field and laboratory studies indicated that the olive bud mite is considered to be a disastrous mite on shrub and young olive trees.

The mite population of eriophyid mite, *A. guerreronis* occurred throughout the year at Dharwad with variation during different seasons of the year. The eriophyid mite population was high during April to May, 2005 (67.64 to 75.11 mites/4 mm<sup>2</sup>). It started declining with the onset of rains during first fortnight of July, 2005 (39.28 mites/4 mm<sup>2</sup>). (Girisha, 2005).

Pushpa (2006) found that the mobile and egg stages of coconut eriophyid mite *A. guerreronis* were positively

correlated with temperature and negatively correlated with relative humidity.

An experiment was conducted on population dynamics of coconut eriophyid mite *A. guerreronis* in Tamil Nadu from May 2000 to April 2002 revealed that the population fluctuated drastically throughout the course of study. The mite population reached maximum in the second fortnight of November 2001 (48.3 mites/4 sq. mm) and was least during the first fortnight of March 2001 (0.8/4 sq.mm) (Bhaskaran and Ramaraju, 2007).

Nandihalli (2007) reported that the infestation of eriophyid mite *A. guerreronis* was observed throughout the year on coconut at Dharwad, Karnataka with less activity in the month of August and increased infestation in the dry month of April.

Badawia *et al.* (2011) studied the mango bud *Aceria mangiferae* and the mango rust mite *Metaculus mangiferae* (Attiah) for two years in an abandoned mango orchard in Egypt. The eriophyid mites were fed upon by two predatory phytoseiid mites *Typhlodromus mangiferus* Zaher and El-Borolossy and *Typhlodromips swirskii* (Athias-Henriot). Population abundance of the eriophyid mango prey were affected by climatic conditions, predation, shady and sunny zones and vertical distribution. Higher temperature enhanced development of *A. mangiferae* and *M. mangiferae*. Some of the life table parameters varied greatly, especially at 25 °C and 60 % RH and 35 °C and 50 % RH. Field and laboratory studies

indicated that viviparity is a typical character in the reproduction of *M. mangiferae*.

Kaushik (2013) studied the effect of abiotic factors like temperature, relative humidity and rainfall on pigeon pea eriophyid mite, *A. cajani* mite population. Out of these abiotic factors strong significant correlation was observed with relative humidity. Average temperature of about 20-30°C was found to be congenial for the multiplication of eriophyid mite. But very high temperature is not suitable for the growth of eriophyid mite. Heavy rainfall is also not suitable for the growth of eriophyid mite.

Nasareen and Ramani (2014) studied the seasonal impact on the population density of the gall mite, *A. pongamiae* within the leaf galls of *P. pinnata*. The impact of temperature and humidity could be positively correlated with population density of the gall mite within the leaf galls whereas the rainfall exerted a negative correlation.

## **2.3 Chemical control:**

### **2.3.1 *T. urticae* and other spider mites:**

Srinivasan *et al.* (1975) revealed that the oxythioquinox and omite effectively reduced the spider mite population while, carbophenothion and dioxathion were found to be less effective than oxythioquinox and omite which caused up to 75 per cent reduction of *T. telarius* on *bhendi*

Nair *et al.* (1990) studied the efficacy of various insecticides against mite, *T. neocaledonicus* infesting rose in pot culture experiment and reported that plants that were

treated with dimethoate (0.1%) had the less population of mites (2.1 per leaf) after 14 days after treatment.

Mohite *et al.* (1992) reported that fluvalinate 0.02 per cent was the most effective in reducing *T. urticae* on rose under field conditions. However, it was on par with treatment fluvalinate 0.0125 per cent, fenpropethrin 0.01 per cent and sulphur 0.02 per cent.

Aguiar *et al.* (1995) studied the different concentrations of clofentazine and abamectin against *T. urticae* on roses under greenhouse conditions and they reported that clofentazine at 25 g and abamectin at 3.6 g a.i./100 liters of water were the most effective treatments in reducing the mite population.

Hole and Salunkhe (1997) tested nine pesticides belonging to organophosphate, synthetic pyrethroids and cyclodine groups against rose mite, *T. urticae* under field condition during November 1991 to April 1992. Among these pesticides, fluvalinate 0.02 per cent found most effective up to three weeks followed by fenpropathrin 0.02 per cent, whereas malathion 0.1 per cent was least effective in controlling the mite.

Dhooria (1999) studied the efficacy of four insecticides, abamectin, dimethoate, ethion and oxydemeton methyl against *T. urticae* infesting roses under polyhouse condition and reported that abamectin, oxydemeton methyl and ethion (each at 2.0 ml/l) had quick knock-down effect on spider mites and effective upto 3 weeks after spray.

Valunj *et al.* (1999) studied the efficacy of chlorfenapyr 10 EC, fluvalinate 25 EC, dicofol 18.5 EC and flufenoxuron 10 EC against carnation mite, *T. cinnabarinus* under polyhouse conditions and reported that chlorfenapyr at 500 ml/ha was the more effective treatment, suppressing the pest for 3 weeks with 90-95 per cent efficacy.

Gangopadhyay and Sarkar (2001) tested four pesticides (3 doses for each) against adult stages of *T. cinnabarinus* on *bhendi* and found that the dicofol (0.06% *a.i.*), ethion (0.05% *a.i.*), and sulphur (0.6% *a.i.*) gave better control than their other two doses, *i.e.*, dicofol at 0.04 and 0.05% *a.i.*, ethion at 0.03 and 0.04% *a.i.* moreover, sulphur at 0.2 and 0.4% *a.i.* monocrotophos, for all the three doses (0.03, 0.04 and 0.05% *a.i.*) showed lowest efficacy.

Patra *et al.* (2001) studied the efficacy of fenpropathrin, deltamethrin, ethion, dicofol and monocrotophos against mite (*T. urticae*) infesting rose under field condition and reported that fenpropathrin gave best result followed by dicofol and ethion.

Abhyankar (2003) reported that the treatment abamectin 0.005 per cent found promising in reducing mite population followed by treatment fenazaquin 0.02 per cent as against rose mite, *T. urticae* under polyhouse condition.

Akashe *et al.* (2003) tested abamectin 1.8 EC with its lowest  $LC_{50}$  value (0.00006) and recorded highest mortality ranging from 92.85 to 100.00 per cent followed by clofentezine 50 SC (0.0017), amitraz 20 EC (0.0072),

triazophos 40 EC (0.0123) and diafenthiuron 50 WP (0.0295) against *T. urticae* on rose under laboratory conditions.

Akashe *et al.* (2003) studied six miticides for their efficacy against rose mite, *T. urticae* under laboratory conditions and reported that vertimec 1.8 EC at 0.00045%, 0.00022% and 0.00011% concentrations were more toxic to *T. urticae* followed by clofentazine 50 SC and amitraz 20 EC.

Jayachandran (2003) proved that the Vertimec 0.25 ml/lit was very effective in controlling the population of *T. urticae* up to three weeks, whereas dicofol 2.5 ml/lit and ethion 2 ml/lit gave moderate control and monocrotophos 2.5 ml/lit was less effective against rose mite, *T. urticae* under field condition.

The result of polyhouse experiment revealed that, lowest population (20.90 mites/leaflet) was observed in treatment profenofos (0.02%) at seven days after first spray while, other treatment *viz.*, flufenoxuron (0.001, 0.0025, 0.004, 0.005, 0.0075, 0.01, 0.015 and 0.02%) was not effective even after two sprays against *T. urticae* on rose (Rudramuni *et al.*, 2003).

Venugopal *et al.* (2003) revealed that, treatments of abamectin 0.05 per cent and dicofol 0.1 per cent were found to be significantly superior over all other treatments *viz.*, flufenoxuron 0.01 per cent, profenofos 0.1 per cent, ethion 0.05 per cent, sulfur 0.2 per cent against *T. cinnabarinus* on okra. However, Ramaraju (2004) proved that dicofol 0.05 per cent was most effective with 70.56 to 91.85 per cent reduction

of spider mites in okra and 66.99 to 99.20 per cent reduction in brinjal both under field and pot culture conditions.

Ahn *et al.* (2004) studied the toxicity of 42 pesticides (13 acaricides, 13 insecticides, 13 fungicides and 3 adjuvants) against spider mite, *T. urticae* and its predator, *Phytoseiulus persimilis* on rose under greenhouse conditions and they reported that among 13 acaricides tested acequinocyl, bifentazate, fenbutatin oxide and spiroticlofen showed much less toxicity to *P. persimilis* than to *T. urticae*. Among the insecticides, acetamiprid, imidacloprid, spinosad, thiamethoxam and acetamiprid + etofenprox showed less toxicity to *P. persimilis* and *T. urticae*.

According to Akashe (2004a) abamectin 1.8 EC recorded the lowest LC<sub>50</sub> value (0.000041%), followed by clofentezien 50 SC (0.00095%) indicating more toxicity of these compounds to *T. urticae*.

Akashe (2004b) tested 12 new miticides for their efficacy against *T. urticae* infesting rose under field conditions and reported that higher mortality of 87.43 and 86.35 per cent was recorded with abamectin at 0.00045 per cent and clofentazine at 0.006 per cent, respectively. However, dicofol at 0.05 per cent, amitraz of 0.026 per cent and novaluron at 0.01 per cent also recorded significantly higher mortality of 82.63, 80.41 and 80.08 percent, respectively.

Chavan *et al.* (2004) revealed that the treatment avermectin 0.00045 per cent was found to be most promising, which gave 94.71 per cent mortality at 72 hrs after treatment followed by fluvalinate 0.02 per cent, flufenoxuron 0.012 per

cent and methyl-o-demeton 0.05 per cent with mortality of 91.21, 90.40 and 88.95 per cent, respectively against *T. cinnabarinus* on okra.

Nakat and Chede (2004) found that the spraying of abamectin 0.036 per cent recorded maximum mortality of spider mite followed by diafenthiuron 0.05 per cent and dicofol 0.05 per cent. While, sulphur 0.3 per cent, leufenuron + profenofos 0.05 per cent and fluvalinate 0.05 per cent found relatively less effective in descending order against *T. neocaledonicus* on french bean.

Sridhar and Jhansi (2004) stated that, milbemectin 1 % EC @ 4.5 g *a.i.* per ha found effective against spider mite up to three weeks without any phytotoxic effect on rose plants. Moreover, milbemectin found less toxic to beneficial organisms and quickly degrade in the environment.

Jhansi and Sridhar (2005) evaluated bifenazate against rose mite, *T. urticae* at three doses (0.12, 0.18 and 0.24g/lit) and revealed that the highest dose of 0.24 g/lit gave significantly lowest (3.56 per cent) mite survival at two seasons (March-April and September-October, 2003). Moreover, the bifenazate was found safe to predatory mite and non phytotoxic to rose plant under polyhouse conditions.

Jana and Somchoudhury (2005) studied relative efficacy of a synthetic pyrethroid, fenpropathrin 30 EC along with two acaricides *i.e.* dicofol (18.5 EC), ethion (50 EC) and one broad spectrum acaroinsecticide profenofos (50 EC) was evaluated at 0.5, 0.75, 1.0, 2.5, 2.0 and 1.0 ml of water dosages respectively on a tea plantation at Motidhar Tea

Estate, Terai, Darjeeling, West Bengal. Fenpropathrin 30 E.C. exhibited excellent control of tea red spider mite @ 0.75 and 1.0 ml per litre of water than conventional acaricides at recommended doses.

Kumar and Singh (2005) revealed that omite 57 EC @ 1 ml/lit alone provided significantly best control of *T. urticae* and *T. neocaledonicus* on okra and brinjal, but addition of dhanuvit @ 1 ml/l enhanced the efficacy of omite, culminating in the mortality of mites was 94.88, 98.77, 90.99 and 71.20 per cent on Okra and 86.77, 95.44, 88.66 and 67.13 per cent on brinjal, after 1, 3, 7 and 14 days after spraying, respectively.

Naik *et al.* (2005) reported that, dicofol showed fair efficacy as standard check exhibiting good and moderate mode of action *viz.*, ovicidal, nymphicidal and adulticidal. Moreover, the treatment of fenpyroximate showed quick knockdown effect on spider mite of brinjal in glasshouse.

Rajkumar *et al.* (2005c) revealed that, the treatment methoxy fenoizide (0.1%) found most effective with 81.56 per cent reduction of mite population followed by ethion (0.05%) which imparted 54.03 per cent reduction in mite, *T. urticae* on rose.

Naik *et al.* (2006) carried out an experiment on field-bioefficacy of flufenzin, fenpyroximate and dicofol @ 60, 80 and 100, 15, 20 and 25 and 250 g a.i./ha, respectively was evaluated against red spider mite (*T. cinnabarinus*) on brinjal. Fenpyroximate was more effective than flufenzin in protecting the crop against the mite. Relationship of profit

margins-contributed by the acaricides suggested that all the three dosages of fenpyroximate and the higher dosage of flufenzin effectively controlled the mite and extended better monetary returns.

According to Akashe *et al.* (2006) abamectin 0.0005 per cent, amitraz 0.07 per cent, demeton-methyl 0.893 per cent, profenofos 2.09 per cent and novaluron 0.112 per cent showed higher persistency and controlled spider mite effectively than other miticides.

Ashley *et al.* (2006) revealed that, all the acaricidal treatments *viz.*, fenpropathrin, etaxazole and propargite caused significantly highest mortality to mixed stage population of spider mite *T. urticae*. While, the etaxazole and propargite imparted cent per cent eggs mortality of *T. urticae* on peanut.

Singh *et al.* (2006) evaluated the efficacy of five pesticides *viz.*, dicofol 0.04 per cent, imidacloprid 0.04 per cent, propargite 0.1 per cent, oxydemeton methyl 0.05 per cent and dimethoate 0.06 per cent against eggs and active stages of *T. urticae* on rose in glasshouse. The effectiveness of the insecticides in descending order was propargite 0.1 per cent, dicofol 0.04 per cent, dimethoate 0.06 per cent and oxydemeton methyl 0.05 per cent, respectively.

Villanueva and Walgenbach (2006) studied the effect of spinosad against two spotted spider mite, *T. urticae* and european red mite, *Panonychus ulmi* (Koch) on bean under laboratory condition and recorded significantly higher mortality and lower oviposition rate of adult female, *T. urticae*

when placed on spinosad treated disk as compared to control (water).

Bhaskaran *et al.* (2007) evaluated four new acaricides against red spider mite, *T. urticae* on *bhendi* and concluded that, the diafenthiuron 50 SC and 50 WP at 450 g *a.i./ha.* gave highest mean reduction of 87.95 to 96.08 and 89.38 to 93.79 per cent in spider mite population after first and second sprayings, respectively.

Choudhary *et al.* (2007) tested the milbemectin 1.0 per cent at three doses *viz.*, 3.5, 4.5 and 5.0 g *a.i. /ha* against two spotted spider mite, *T. urticae* on rose in polyhouse condition and the results indicated that milbemectin @ 5 g *a.i./ha* recorded the maximum per cent reduction in spider mite population.

Duchovskiene (2007) tested the abamectin at three concentration (0.12, 0.1 and 0.08%) against rose mite, *T. urticae* during 2005-2006. Among these three concentrations abamectin 0.12 per cent @ 18 g/lit established its superiority by causing 63.5 to 100, 97 to 100, 97.9 to 100 and 79 to 100 per cent mortality at 2 to 3, 5 to 6, 7 to 8 and 12 to 14 days after treatment, respectively.

Singh and Choudhary (2008) revealed that, the treatment of abamectin 1.9 EC @ 400 ml/ha was found most effective with 86.42 per cent reduction of spider mite population and maximum fruit yield (72.12 q/ha). However, it was at par with propargite 57 EC @ 1500 ml/ha, which gave 84.67 per cent reduction of mite population and (72.42q/ha.) okra fruit yield.

Sarkar *et al.* (2009) evaluated two different dosages (0.125 g/l and 0.25g/l) of diafenthiuron (50 WP), alone and with adjuvants i.e. karanj oil (1%) and citronella oil (1%) in presence of surfactant (APSA 80% a. i.) for their efficacy against adult females and eggs of tea red spider mite, *Oligonychus coffeae* (Nietner) under laboratory condition. The best efficacy was registered with the application of diafenthiuron alone (0.5gm/l). Karanj oil and citronella oil in solo application were not effective. Half and half of half of the recommended dose (0.25 g and 0.125 g) of the test chemical in combination with adjuvants showed promising result up to five days after treatment. Adjuvant combinations were also moderately effective against egg stages (33.91% and 43.19% mortality).

Sudhirkumar and Shelke (2008b) obtained best results in the field by spraying abamectin (0.004%) with 89.77 per cent reduction of *T. urticae*, followed by clofentazine (0.006%) with 87.13 per cent on rose under polyhouse conditions.

Patel *et al.* (2009) revealed that diafenthiuron at lower dose (0.125%) was found effective in reducing phytophagous mite, *T. urticae* population and it was safer to predatory mite and also observed non phytotoxic to rose plants in field condition.

Toke (2010) tested the efficacy of different pesticides under polyhouse conditions against *T. urticae* infesting rose and found that the abamectin 0.0025 per cent proved most effective pesticide in per cent reduction of *T.*

*urticae*. It was followed by propargite 0.05 per cent while dimethoate 0.03 per cent found moderately effective against the spider mite.

Deka *et al.* (2011) conducted experiments in laboratory and greenhouse on relative efficacy of agricultural spray oil and azadirachtin for the management of two-spotted spider mite (*T. urticae* on cucumber (*Cucumis sativus* L.). The treatments included the spray of agricultural spray oil, azadirachtin and combination of both at 0.1, 0.5, 1 and 2 per cent under laboratory conditions and 0.1 and 0.5 per cent under greenhouse conditions, replicated thrice. The laboratory experiment results indicated highest mortality of the spider mite after 24, 48 and 72 hr of spray in agricultural spray oil + azadirachtin (at 1 and 2%), followed by 2 per cent agricultural spray oil alone in both the seasons. Greenhouse experiment results also indicated highest mortality of the spider mite on spraying agricultural spray oil + azadirachtin (0.5%) throughout the period, however, agricultural spray oil (0.5%) resulted in highest mortality only a day after spraying during the first season.

Misra (2011) conducted a field trial at Central Research Station Farm, Orissa University of Agriculture and Technology, Bhubaneswar during winter seasons of 2008-09 and 2009-10, using tomato variety Arka Vikas to test the bio-efficacy of fenazaquin 10 EC against two spotted spider mite, *T. urticae*. The results revealed that fenazaquin at 125 and 150 g *a.i./ha* registered significantly lowest mite population (3.5-4.8/4 cm<sup>2</sup> leaf area) followed by dicofol at 250 g *a.i./ha* at 10

days after spraying during both the years of study. The highest population reduction was achieved (90.27-92.13%) with fenazaquin at 125-150 g *a.i./ha* followed by dicofol at 250 g *a.i./ha* and fenazaquin at 100 g *a.i./ha* (76.40-76.81 %) compared to control. Plots receiving fenazaquin at 125 and 150 g *a.i./ha* treatments recorded significantly highest fruit yield (18.9-19.2 t/ha) which was 30.0-32.1 per cent more than control (14.5 t/ha).

Tomar and Singh (2011) at Gurgaon evaluated the efficacy of two new acaricides *viz.*, propargite 57EC (omite) @ 750, 1000 and 2000 ml/ha, fenpyroximate 5 EC @ 100, 200 and 500 ml/ha against red spider mite, *T. urticae* and found that propargite 57EC (omite) @ 1000 ml/ha and Fenpyroximate 5 EC @ 500 ml/ha was significantly at par in reducing mite population and remained effective till 15 days after sprays on brinjal crop.

Ghosh (2013) evaluated microbial insecticide (toxin), avermectin (Vertimec 1.9 EC) @ 1.0 ml/l, botanical insecticide azadirachtin (neemactin 0.15 EC) @ 2.5 ml/l, botanical extracts of *Spilanthes paniculata* flower extracted in methanol @ 1.0% and 5.0% and mixed formulation like neem and floral extract of *Spilanthes* 5% (@ 2.5 ml and 50 ml/l were evaluated and compared with the ability of Sulphur (Sulfex 80 WP) @ 5g/ l and Fenazaquin (Magister 10 EC) @ 2ml/l for the management of the spider mite pest. Fenazaquin resulted in the best suppression of spider mite population (79.24 % suppression), closely followed by avermectin (76.40 % suppression). Among bio-pesticides avermectin and

combination of neem with *Spilanthes* gave better results recording more than 70 per cent suppression. Neem and *Spilanthes* individually did not produce good results but when used as a mixture they recorded better results (70.66 % suppression).

Patel *et al.* (2013) at Sardarkrushinagar tested the efficacy of some pesticides against *T. urticae* on brinjal and found that abamectin 0.001 per cent recorded the highest brinjal fruit yield. Two neem based formulations *i.e.* NSKS 5 per cent as well as azadirachtin 0.0075 per cent have also recorded significantly superior yield over untreated control.

Reddy and Pushpalatha (2013) conducted experiments in farmers field in Kadapa district of Andhra Pradesh during summer seasons of 2011 and 2012 using ridge gourd variety Ranjit to test the bio-efficacy of new acaricides (Fenazaquin, Spiromesifen, Hexythaizox and Fenpyroximate) against two spotted spider mite, *T. urticae*. The results revealed all the new acaricides tested were effective against two spotted spider mite and recorded 55.55-99.66 per cent mortality up to 14 days after spray as compared to standard acaricide, dicofol during I season (2011) and 66.50-100 per cent mortality in II season (2012). Fenazaquin and spiromesifen offered superior control over all other acaricides.

Alam *et al.* (2014) revealed that spiromesifen 240 SC @ 150 g *a.i.* /ha significantly reduced the red spider mite infestation with highest yield of tomato. Further, spiromesifen showed excellent residual activity over three weeks whereas standards failed to provide such long residual action in spite

of three or four applications. Observations also indicated that the spiromesifen was very safe to *Stethorus* sp. and *Amblyseius* sp.

Abou El-Ela (2014) evaluated five acaricides, Challenger, Ortus, Vertimec, Delmite and Bioca for controlling phytophagous mite, *T. urticae* and their side effects on the predatory insects, mites and spiders at El-Fayoum Governorate on cotton seedlings during the late season of 2007 and 2008. At the early seedling time, the application of the five tested compounds induced an average of 81.55, 80.62, 75.94, 65.35 and 54.57 per cent reduction in the population of spider mite during the 2007 season, and then changed to 79.72, 77.92, 72.54, 60.05 and 47.97 per cent reduction during the 2008 season. However, at the late season (fruiting time), the application of these compounds induced 83.24, 84.11, 76.34, 56.29 and 59.57 per cent reduction during the 2007 season changed to 84.78, 84.94, 77.31, 55.58 and 58.68 per cent reduction during 2008, respectively. As to the natural enemies, the highest reduction in the population after using the tested compounds was noticed for effect of Delmite during 2007 (33.79%), while the lowest ratio recorded when Ortus was used in the second season 2008 (18.53%). The side effect of the most important tested compounds (Challenger) was investigated in the laboratory against the predatory phytoseiid mite, *Euseius scutalis*.

Shah and Shukla (2014) studied the efficacy of different pesticides against *T. urticae* infesting gerbera under polyhouse conditions and revealed that all the pesticidal

treatments were significantly superior over untreated control in checking the eggs and mobile stages of mite. Diafenthiuron 50 WP was most effective (68.79% reduction) and was at par with other treatments *viz.*, fenpyroximate 5% EC, buprofenzin 25% EC, abamectin 1.9% EC and fenazaquin 10%. The treatment comprising dimethoate 30% EC was less effective in reducing spider mites under polyhouse conditions. On the basis of net CBR, fenpyroximate (1:28:78) stood first among all treatments.

### **2.3.2 *A. lycopersici* and other spider mites**

Mariau and Julia (1970) observed that lowest number of damaged nuts by eriophyid mites was obtained with application of quinomethionate @ 0.05 per cent at three weeks intervals.

Hernandez (1977) found reduction of eriophyid mite damage significantly with spraying of 2 ml dicrotophos, 2 ml monocrotophos, 2 ml quinomethionate and 1.5 ml cyhexaltin per litre of water to the inflorescence and nuts less than three months old at the interval of 20 or 30 days.

Mariau (1977) showed that monocrotophos (0.014%) and dimethoate (0.03%) spraying at an interval of two months reduced the nut loss by 90 per cent as well as population of *A. guerreronis*.

Cermeliz *et al.* (1982) in a preliminary trial on control of *A. lycopersici* recorded the best results by applying dicofol, chlorobenzilate, endosulfan, propargite, cyhexatin and wettable sulfur.

Muthiah and Bhaskaran (1999) found that the spraying of methyl demeton at 4 ml per litre or triazophos 5 ml per litre of water at 7 to 10 days interval helps to reduce the eriophyid mite infestation on coconut.

Ramaraju *et al.* (2000) reported that triazophos 40 EC @ 5 ml or methyl demeton 25 EC @ 4 ml per litre of water or root feeding of monocrotophos 25 EC @ 15 ml + 15 ml of water per tree gave reasonable control of eriophyid mite infestation on coconut. But the mite population started increasing again 23 days after treatment.

An experiment was conducted at Krishnapuram, Kerala and it was found that the application of 0.4 per cent wettable sulfur, 0.004 per cent azadirachtin and 0.05 per cent endosulfan was effective in the management eriophyid mite. (Chandrika Mohan and Nair, 2000).

Kannaiyan *et al.* (2000) reported that spraying of triazophos 40 EC, monocrotophos 36 SL and carbosulfan 25 EC @ 5 ml per litre were found to be highly effective in reducing eriophyid mite population and recorded higher undamaged buttons of 100, 100 and 73.61 per cent, respectively, four months after the first spray. Another experiment conducted by them at Veppankulam revealed that spraying of either methyl demeton @ 4 ml or monocrotophos @ 1.5 ml per litre at 10 days interval significantly reduced nut damage to 25 per cent as compared to 53 per cent in untreated control.

The root feeding of carbosulfan @ 15 ml + 15 ml of water resulted in the highest reduction of 79.09 to 89.87 per

cent in mite population followed by profenophos @ 15 ml + 15 ml of water (75.82%) and triazophos @ 15 ml + 15 water (74.13%). (Ramaraju *et al.*, 2000).

The spraying of chemicals *viz.*, dicofol @ 6ml per litre of water or 0.03 per cent monocrotophos or 0.03 per cent dimethoate twice at monthly interval was effective in reducing damage. Spraying with wettable sulphur 4 g/l twice is also recommended against coconut eriophyid mite. (Reddy and Naik, 2000).

Saradamma *et al.* (2000) reported that spraying of micronized wettable powder formulation of sulfur 0.4 per cent at 5 g per litre of water was effective against coconut eriophyid mite.

The application of fenazaquin 10 EC administered through roots @ 10 ml per palm reduced the eriophyid mite population by 83 per cent, whereas spraying the same chemical @ 200 to 250 ml/litre of water gave 92 per cent reduction in the mite population. (Dey *et al.*, 2001).

Dey and Somchoudhary (2001) reported that root feeding of fenpyroximate 5 EC at 10 ml per palm reduced population by 90.24 per cent while spraying palm with same chemical at 1.0 ml/litre of water gave 80 per cent reduction in eriophyid mite population.

A field trails was conducted during August-November 1999, with Hexythiazox alone and in combinations with abamectin, fenbutatin, carbosulfon, sulfur, bromopropylate and fenpyroximate revealed that the highest

eriophyid mite control was obtained with hexythiazox, in combination with fenpyroximate, sulfur and abamectin when applied starting from the time of flower opening (Anonymous, 2002).

Nair *et al.* (2002) studied the seasonal abundance, extent of damage and management of eriophyid mite and reported that the eriophyid mite can be best managed by spraying of pesticides like monocrotophos, dicofol and methyl demeton and the botanical pesticide (2% neem oil garlic mixture).

The spraying of triazophos 40 EC 5 ml/l, methyl demeton 25 EC 4ml/l or monocrotophos 36 SL 1.5 ml/l significantly reduced mite population and also suggested root feeding of monocrotophos 15 ml with 15 ml of water per tree with repeated application at short interval. (Natarajan *et al.*, 2002).

Sujata *et al.* (2004) conducted field trial at ARS, Ambajipeta through root feeding using monocrotophos, fenobucarb and fipronil @ 20 ml + 20 ml water respectively, fenazaquin @ 1 ml + 10 ml water and acetamiprid @ 0.5 + 10 ml water. Results revealed that monocrotophos was the most effective treatment with 89 per cent decrease in mite population followed by fenazaquin with 78 per cent decrease in mite population.

Mallik *et al.* (2005) conducted experiment and found that among the different pesticides studied *i.e.* monocrotophos @ 0.2 ml + 2 ml water/bunch, azadirachtin @ 1 ml + 1 ml water/bunch, azadirachtin @ 1 ml + 1

ml/water/bunch, NSKE @ 2 ml/bunch, abamectin @ 0.1 ml + 2 ml water/bunch and milbemectin @ 0.1 ml + 2 ml water/bunch, only monocrotophos could cause upto 100 per cent mortality of the coconut eriophyid mite. Though some of the other pesticides studied are very effective acaricides (e.g. abamectin and milbemectin), none could cause more than 5 per cent mortality.

Murthy and Bhushan (2010) conducted a trial during *Rabi* 2006-07 (summer) to evaluate the bioefficacy of fenpyroximate 5% EC for effective control of important mite pests on tomato including *A. lycopersici* and bottle gourd. The efficacy of this new acaricide *i.e.*, fenpyroximate 5% EC was tested at 500 ml/ha, 625 ml/ha and 750 ml/ha and the efficacy was compared with a standard miticide dicofol 18.5 EC @ 1375 ml/ha. The results indicated that fenpyroximate 5% EC @ 500 to 625 ml/ha found to be more effective in controlling tomato and bottle gourd eriophyid mite incidence and recorded highest cost benefit ratio compared to dicofol 18.5% EC @ 1375ml/ha.

#### **2. 4. Biodiversity of phytophagous mites:**

Lahiri *et al.* (2005) carried out survey of .phytophagous and predatory mites occurring on medicinal and aromatic plants in Kolkata, West Bengal, India. A total of 48 species of mites, collected from 35 species of medicinal plants were recorded. The 17 species of phytophagous mites belonged to 4 families (Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae). Among these, *T. urticae*, *Schizotetranychus cajani*, *Panonychus citri* and

*Polyphagotarsonemus latus* were important pest species, causing substantial damage to respective host plants.

Kumral and Kovanci (2007) carried out survey in Turkey to study the impact of conventional growing on the mite diversity and abundance in 6 deciduous fruit trees. Among the total species recorded in conventional sites, *Panonychus ulmi* and *T. urticae* and in agrochemical free sites *Bryobia rubrioculus* and *Amphitetranychus viennensis* were predominant species and formed more than 66 per cent of the mite species collected. They further reported that mite diversity in conventional sites was decreased by agricultural practices as the high number of unique species was found in agrochemical free sites.

Moraes and Castro (2007) studied the number of specimens and morphospecies and the respective proportions (%) of the different families and the genera collected in Brazil. Out of the mites with varied feeding habitats, Tetranychidae was the most predominant family with 61 per cent of collected specimens and 31 percent of morphospecies were recorded from this family as compared to other.

Sidumo *et al.* (2007) studied the diversity of spider mites on tomato crop in 5 provinces and 10 districts of Mozambique and recorded three species of spider mites on tomato crop in different seasons. Among these the *T. evansi* was the most dominant species infesting tomato crop in all provinces of Mozambique as compared to other species i.e. *T. urticae* and *T. ludeni*.

Prassanna and Kumar (2008) carried out survey of Tetranychid mites on brinjal in Northern Karnataka and reported different species such as *T. macfarlanei*, *T. urticae* and *Tetranychus* sp. from two districts of Northern Karnataka.

Al-Atawi (2011) investigated phytophagous and predatory mites associated with vegetable plants in Riyadh, Saudi Arabia. Eight phytophagous and 10 predacious mites were collected from 14 species of vegetable crops covering five major production localities. Out of these 18 mite species, 13 species are new to the mite fauna of Saudi Arabia. In addition, the two species, *Tenuipalpus punicae* and *Agistemus exsertus*, are reported for the first time on vegetable crops in Saudi Arabia. For each mite species found, notes on host plant association and occurrence period are given. An illustrated key for the identification of the 18 mite species reported in this study.

Gupta and Karmakar (2011) carried out survey in different parts of India between 2002 and 2009 as well as information reported in previous works conducted in the country reported that 267 mite species of 93 genera and 18 families were found. Most of these species (208) belong to families constituted mostly by phytophagous, but quite a large number of species (56) belong to families constituted predominantly by predators. Despite the wide array of phytophagous species, relatively few have behaved as major pests, which may be at least in part due to the effect of the predatory mites with which they have been found. They

consider 17 species as major pests of medicinal and aromatic plants and 11 species as main predators.

Rai and Indrajeet (2011) recorded 10 species on 15 commonly grown vegetables in Varanasi and Azamgarh districts of eastern Uttar Pradesh. Out of these, six species belonged to Tetranychidae (spider mite), two to Tenuipalpidae (false spider mite) and one species each to Eriophyidae (erineum or gall mite) and Tarsonemidae (yellow mite).

Singh (2011) carried out survey and reported that the following species are considered major pests in North Indian region: Tetranychidae *Eutetranychus orientalis* (Klein), *Oligonychus coffeae* (Nietner), *T. ludeni*, *T. neocaledonicus* and *T. urticae*. Other 16 species in those families are also considered important as plant pests in this area of India. Among the tetranychids, *T. ludeni* was identified as an alarming problem in 1987. Many outbreaks of this pest were recorded from 1988 to 1990 on cowpea [*Vigna unguiculata* (L.)Walp], an important summer vegetable of eastern Uttar Pradesh. Okra (*Abelmoschus esculentus* Moench) and eggplant (*Solanum melongena* L.), particularly when grown in the summer, have serious problems with *T. urticae* and *T. macfarlanei*. Further *Panonychus ulmi* (Koch) has emerged as a serious problem on the expanding cultivation of apple in Himachal Pradesh, whereas *Petrobia latens* (Muller) populations are increasing in dryland cultivation of Rajasthan, attaining serious pest status mainly on wheat and coriander.

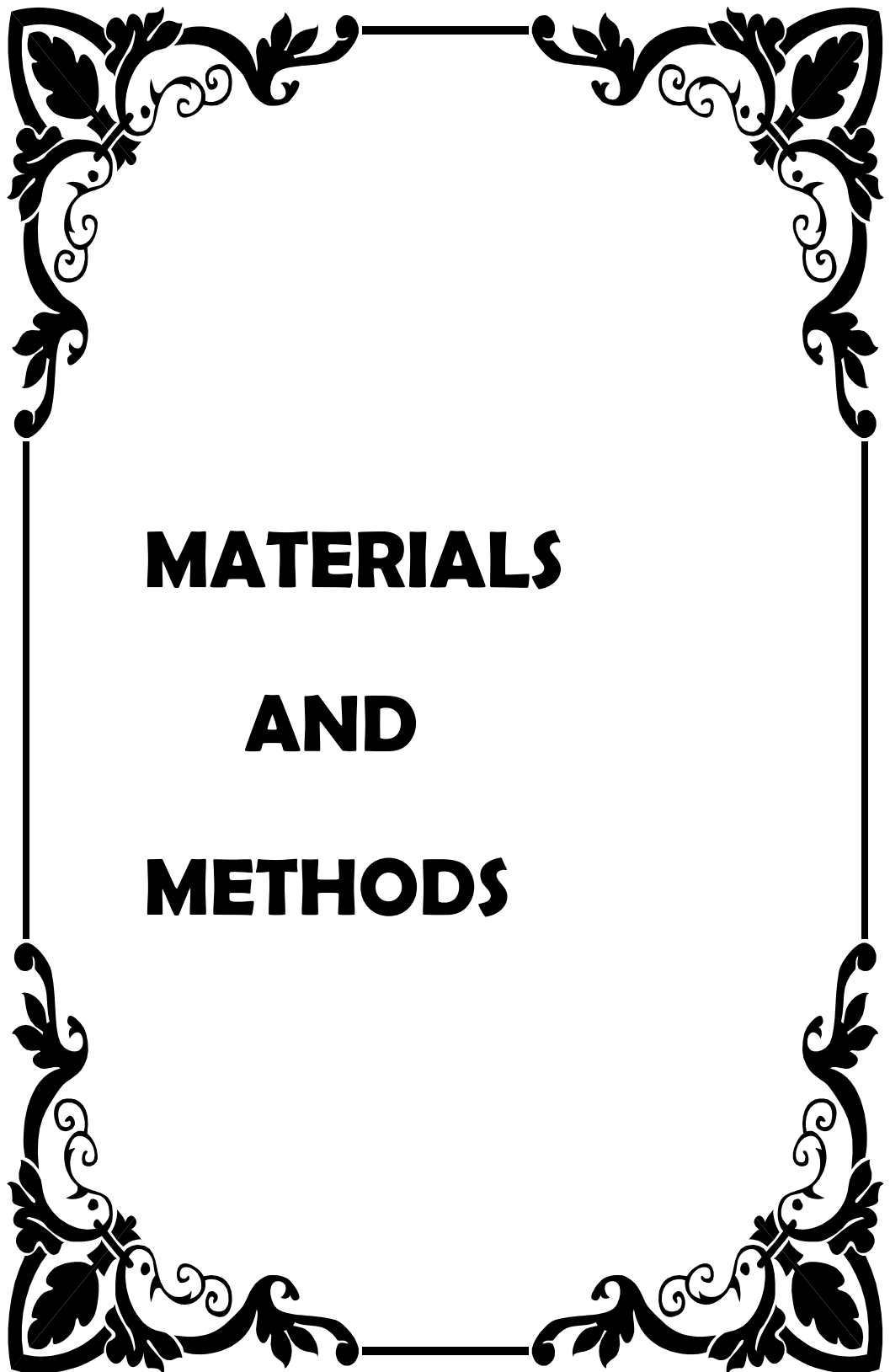
Forghani and Honarparvar (2012) in a survey in Golestan Province of Iran to determine major species of spider

mites in cotton. From 2008 to 2009, 50 cotton leaves were sampled from fields with different topography ranging from low-land, to foot-hill fortnightly. About 1000 slides were randomly prepared for microscopic identifications. Data indicated that *T. turkestani*, *T. urticae* and *Schizotetranychus* sp. included 52.27%, 40.80%, 6.91% of the spider mite populations, respectively. Thus, they could be the dominant pests in cotton fields. This finding is considered as a first step of the integrated pest management program in the target areas.

Haghghadam and Arbabi (2012) reported that some plant mites are considered as important pests of ornamental plants in greenhouse environments that sometimes bring irreversible damage to ornamental plants. Damaging species of plant mites have been collected and reported from most parts of Iran and the world. In order to study the fauna of mites and their natural enemies on ornamental plants, during years 2003-2006, sampled from different parts of plants and identify different species of mites from greenhouses of different parts of Guilan and West of Mazandaran was carried out. During this period, 40 species of ornamental plants in greenhouses of above regions were identified that thereby the organs of infected and suspicious to mites were collected and transfer to laboratory. Of these, over 28 species of ornamental plants and weeds infected to damaging mites. Mites and their natural enemies after collecting were transferred to the laboratory and were kept separately in 70% alcohol solution and based on the family were identified using identification keys. In this study, 6 damaging plant mite species belonging to families

Tenuipalpidae, Tetranychidae, one genus and 4 species of predatory mites of the family Phytoseiidae, Trombidiidae, Tydeidae were identified totally. Also in this research, predatory ladybird beetle, belonging to the family Coccinellidae with the scientific name of *Stethotus gilvifrons* Mulsant were collected and identified.

Mohammed M. E. and Elmoghazy (2014) studied the abundance and diversity of mites associated with date palm, olive and citrus trees in Sakaka, Kingdom of Saudi Arabia during winter and spring seasons (December 2013 to May 2014). The recorded species associated with date palm, olive and citrus trees are classified according to the type of nutrition into three trophic groups: phytophagous, predaceous and miscellaneous mites. In total, 12 families, 13 genera and 13 mite species belonging to the four sub-orders Actinedida, Acaridida, Oribatida and Gamasida were recorded. The phytophagous mites were numerically dominant of three species belonging to two families. Whereas five species are predaceous mites belonging to five families. Moreover, the miscellaneous five species belonging to five families. Results obtained from this study revealed data about species recorded for the first time in Sakaka, Kingdom of Saudi Arabia where there is a need for such information to support future environmental programs in integrated pest management to attain good and healthy agricultural product.



**MATERIALS**  
**AND**  
**METHODS**

### 3. MATERIALS AND METHODS

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Studies on various aspects of the Acari associated with tomato, with special reference to two phytophagous mites viz., *Tetranychus urticae* Koch and *Aceria lycopersici* Wolffenstein were undertaken between January 2014 to December, 2014 in laboratory and polyhouse. Details of the materials used and techniques employed for different aspects of studies during the course of investigation are as under:

#### 3.1 Description of study area:

The experimental site, N. M. College of Agriculture, Navsari Agricultural University, Navsari is situated 13 kilometers away in the East from the great historical place, Dandi on the Arabian sea shore at an elevation of 10 meter above the mean sea level and at 27°57'E latitude 72°54'E longitude.

The climate is typically tropical in nature exhibiting fairly hot summer, mild cold winter and more humid and warm monsoon. Monsoon in general commences from the second week of June and ends in the last week of September with an annual average rainfall of about 1500 mm. Winter season starts from November and lasts up to February. The lowest minimum temperature of season is recorded either in the ends of December or in the first fortnight of January. Usually "Summer" starts from March and lasts up to May. April and May remain the hottest months of summer.

Soils are classified under the group of ustohrepts and order inceptisols with Jalalpore series characterized by deep, moderately drained clayey soils which are classified as

'red soils' predominating with montmorillonite clay mineral by its origin. It is rich in organic matter and potash having good water holding capacity.

### **3.2 Biology of the two spotted red spider mite, *Tetranychus urticae* (Koch) on tomato**

Studies on the biology of *T. urticae* on tomato was carried out in the Acarology laboratory of Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during three seasons viz., Summer (June-August), Monsoon (August-September) and winter (November-December) of 2014. Room temperature (°C) and relative humidity (%) were recorded during the course of study.

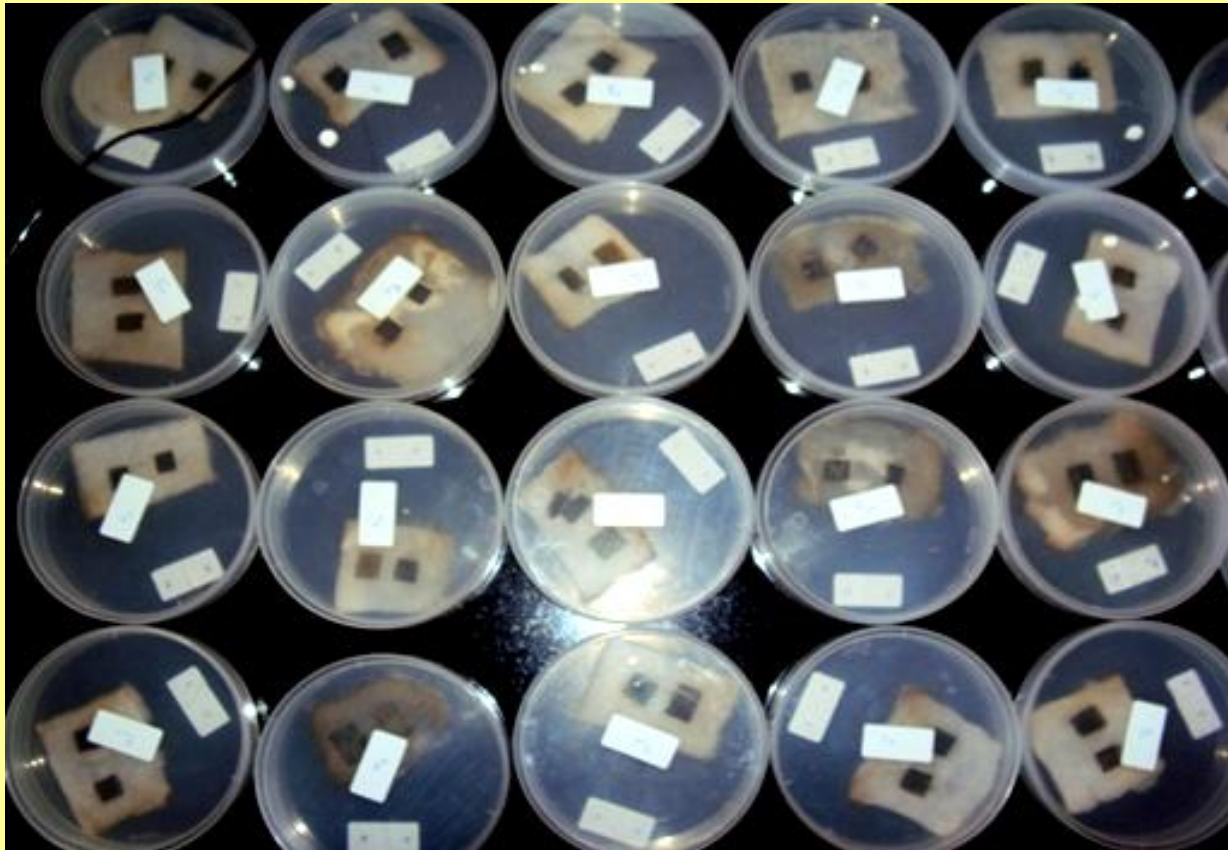
#### **3.2.1 Rearing technique:**

Stock cultures of *T. urticae* were raised and maintained in petri-dishes under laboratory conditions. For the purpose, spider mites were collected during December 2013 from the brinjal and french bean crops grown at Horticulture farm and polyhouses. Fifteen pairs of a male and a female of *T. urticae* were released on tomato leaf kept on wet filter paper overlying a wad of wet cotton in petri dish (9 cm in diameter and 2 cm in height). The adults were removed after three days when sufficient number of eggs was laid. Beginning with these eggs, further rearing was continued in laboratory. This was done so as to have a pure mass culture and constant supply of spider mites for the investigations. The spider mites were transferred to fresh leaf periodically by placing cut pieces of old leaf with *T. urticae* on them. Those pieces were

allowed to remain on the fresh leaf for a few days (3-4 days) so as to ensure that all the postembryogenic stages have been crawled to fresh leaf.

### **3.2.2 Method of rearing individuals:**

For studying the life cycle of the two spotted red spider mite, *T. urticae* using tomato as host, it was reared individually on leaf bits (2 cm x 2 cm) of tomato from egg to death of adult. For this purpose the leaf bits were prepared by cutting the leaf of tomato into a size of 2 cm x 2 cm. These leaf bits were placed upside down on wet filter paper overlying a wad of wet cotton in petri dish (9 cm in diameter and 2 cm in height). To obtain fresh eggs for the study, 30 females were released on a fresh leaf in a petri dish in the evening and they were removed from the leaf next day in the morning. The eggs laid by them on the leaf were left as such on the leaf for further observation for hatching. After hatching, the newly emerged hexapod larvae were lifted carefully with the help of zero number fine camel hair brush and placed on the previously prepared leaf bits, one each per bit. The water was added in petri dish periodically so as to keep the cotton wad saturated and to maintain the leaf bits in turgid condition. The leaf bits were replaced with the fresh bits every alternate day. Thus, after the hatching of eggs, the further rearing of individual mite was made on leaf bits throughout the study period. The observations were made twice a day (8.30 a.m. and 4.30 p.m.) with the help stereo binocular microscope. The size of all the stages were measured with the help of SCAPE software already installed



**Plate 1- : Technique used for rearing *T. urticae* on tomato leaves**

and attached to stereo binocular microscope. The mean and standard deviation were calculated for all the cases of study.

### **3.2.3 Egg:**

The fresh eggs laid on the leaf were examined under microscope twice a day till hatching to study the shape and colour of the eggs. The diameter of the eggs was measured and noticed for their size. Counted number of eggs were observed till hatching for studying incubation period.

### **3.2.4 Larva:**

The period of time from newly hatched larva to initiation of nymphochrysalis form was considered as the larval period. The shape, size and colour of the larva were recorded by observing the larva under microscope.

### **3.2.5 Nymphochrysalis:**

The quiescent period in larval stage till the initiation of protonymphal stage was considered as nymphochrysalis period. The shape, size and colour of nymphochrysalis were studied under microscope.

### **3.2.6 Protonymph:**

When the nymphochrysalis stage was over there was a moulting. The period between the first moult and initiation of deutochrysalis stage was marked as the protonymphal period. The shape, size and colour of this stage were studied under microscope. The exuviae was taken as the criterion for determination of moulting.

### **3.2.7 Deutochrysalis:**

The quiescent period in protonymph till second moult to enter in deutonymph was considered as deutochrysalis period. Observations on deutochrysalis was made for colour, shape and quiescent period.

### **3.2.8 Deutonymph:**

Second moult taken place after breaking a deutochrysalis period in protonymph. The period between second moult and initiation of teleochrysalis, a quiescent stage in deutonymph was considered as deutonymph stage. The exuviae left behind after moulting was the criterion for determining this stage. The shape, length, breadth, colour and deutonymphal periods were recorded.

### **3.2.9 Teleochrysalis:**

The quiescent period in deutonymph till third moult to emerge as adult was described as teleochrysalis period. The observations on shape, size, colour and teleochrysalis periods were noted.

### **3.1.10 Developmental period:**

The period taken for development from egg to emergence of adult was considered as total developmental period.

### **3.2.11 Adult:**

The adults emerged after completion of teleochrysalis period in deutonymph was studied for different aspects. The colour, shape and size were studied in the case of

other stages. Mating behaviour of both the sexes were studied and described.

### **3.2.11.1 Preoviposition, oviposition and Post-oviposition periods, fecundity and longevity:**

The preoviposition, oviposition and post-oviposition period were studied for mated and unmated females. At teleochrysalis stage, two different sets were prepared. The one set, a pairs of a male and a female were kept whereas in another set female without male were kept individually.

A portion between the emergence of female adult and commencing the egg laying was considered as preoviposition period. Period between starting of egg laying and stopping of egg laying by individual female was noted as oviposition period, while period between stopping of egg laying to death of female was considered as post-oviposition period. The number of eggs laid by each female was recorded daily till the death of the female and total fecundity per individual was calculated. The longevity of mated and unmated individuals of both the sexes was calculated separately from the date of emergence and the date of death.

### **3.2.12 Impact of some factors influencing on oviposition of *T. urticae*:**

Impact of some factors *viz.*, mated and unmated conditions, webbing and without webbing conditions as well as photoperiodism on oviposition period, fecundity and rate of fecundity was studied in the laboratory.

### **3.2.12.1 Impact of mating:**

The oviposition period, total fecundity and rate of fecundity per female for mated and unmated conditions were recorded and compared with each mated and unmated conditions to study the impact of mating.

### **3.2.12.2 Impact of webbing:**

To study the impact of webbing, the mites were reared in two sets, from one of which the webs spin by mites (adult female) were removed twice a day ( 8.00 a.m. and 4.00 p.m.) with the help of zero number camel hair brush. Whereas, in another set, webbing was not removed. The observations on oviposition period, total fecundity and the rate of fecundity per day per female were recorded. The data so obtained for both the sets were compared with each other to study the impact of webbing.

### **3.2.12.3 Impact of photoperiodism:**

The impact of light on total fecundity and rate of fecundity per day per female of *T. urticae* was studied in laboratory at temperature 30 °C to 32 °C (Av. 30.7 °C) and 51 to 75 per cent (Av. 65.8%) relative humidity during April 2014. Experiment was conducted under three different light conditions throughout the study period. The conditions were continuous darkness (provided by covering thick black paper), continuous light (day light during day time and light with 60 w bulb at night and natural laboratory condition (day light during day time and darkness during night). The observations were recorded twice a day (8.00 a.m. and 5.00 p.m.) for egg

laying in all three different conditions separately for severe consecutive days only, commencing from first day and oviposition.

### **3.3 Biology of the tomato russet mite *Aceria lycopersici* Wolffenstein on tomato**

Studies on the biology of *A. lycopersici* on tomato was carried out in the Acarology laboratory of Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during October to November 2014. Temperature (°C) and relative humidity (%) were recorded during the course of study.

#### **3.3.1 Rearing technique:**

Stock cultures of tomato russet mite, *A. lycopersici* were raised and maintained in petri-dishes under laboratory conditions. For the purpose, russet mites were collected during from the brinjal and tomato crops grown at Horticulture farm of ASPEE college of Horticulture and Forestry, Navsari. Approximately fifteen pairs of a male and females of *A. lycopersici* were released on tomato leaf kept on wet filter paper overlying a wad of wet cotton in petri dish (9 cm in diameter and 2 cm in height). The adults were removed after three days when sufficient number of eggs were laid. Beginning with these eggs, further rearing was continued in laboratory. This was done so as to have a pure mass culture and constant supply of tomato russet mites for the investigations. The russet mites were transferred to fresh tomato leaf periodically by placing cut pieces of old leaf with *A. lycopersici* on them. Those pieces were allowed to remain

on the fresh leaf for a few days (3-4 days) so as to ensure that all the postembryogenic stages have been crawled to fresh leaf.

### **3.3.2 Method of rearing individuals:**

For studying the life cycle of the tomato russet mite, *A. lycopersici* using tomato as host, it was reared individually on leaf bits (2 cm x 2 cm) of tomato from egg to death of adult. For this purpose the leaf bits were prepared by cutting the leaf of tomato into a size of 2 cm x 2 cm. These leaf bits were placed upside down on wet filter paper overlying a wad of wet cotton in petri dish (9 cm in diameter and 2 cm in height). To obtain fresh eggs for the study, 30 females were released on a fresh leaf in a petri dish in the evening and they were removed from the leaf next day in the morning. The eggs laid by them on the leaf were left as such on the leaf for further observation for hatching. After hatching, the newly emerged hexapod larvae were lifted carefully with the help of zero number fine camel hair brush and placed on the previously prepared leaf bits, one each per bit. The water was added in petri dish periodically so as to keep the cotton wad saturated and to maintain the leaf bits in turgid condition. The leaf bits were replaced with the fresh bits every alternate day. Thus, after the hatching of eggs, the further rearing of individual russet mite was made on leaf bits throughout the study period. The observations were made twice a day (8.30 a.m. and 4.30 p.m.) with the help of stereo binocular microscope. The size of adult stage was measured with the help of the software SCAPE attached to binocular

microscope. The mean and standard deviation were calculated for all the cases of study.

### **3.3.3 Egg:**

The fresh eggs laid on the leaf were examined under microscope twice a day till hatching to study the shape and colour of the eggs. Counted number of eggs were observed till hatching for studying incubation period.

### **3.3.4 Larva:**

The period of time from newly hatched larva to initiation of nymphochrysalis form was considered as the larval period. The shape, size and colour of the larva were recorded by observing the larva under microscope.

### **3.3.5 Quiescent stage-1 (Q-1):**

The quiescent period in larval stage till the initiation of protonymphal stage was considered as quiescent period (Q-1). The shape and colour of Q-1 were studied under microscope.

### **3.3.6 Nymph:**

When the quiescent stage (Q-1) was over when there was a moulting. The period between the first moult and initiation of quiescent stage-2 (Q-2) was marked as the protonymphal period. The shape, size and colour of this stage were studied under microscope. The exuviae was taken as the criterion for determination of moulting.

### **3.3.7 Quiescent stage-2 (Q-2):**

The quiescent period in protonymph till second moult to enter in deutonymph was considered as quiescent period-2. Observations on quiescent stage-2 was made for colour, shape and quiescent period.

### **3.3.8 Developmental period:**

The period taken for development from egg to emergence of adult was considered as total developmental period.

### **3.3.9. Adult:**

The adults emerged after completion of the period of quiescent stage-2 was studied for different aspects. The colour, shape and size were studied.

### **3.3.10 Preoviposition, oviposition and Post oviposition periods, fecundity and longevity:**

The preoviposition, oviposition and post-oviposition period were studied for mated and unmated females. At quiescent stage-2, two different sets were prepared. The one set, a pairs of a male and a female were kept whereas in another set female without male were kept individually.

A portion between the emergence of female adult and commencing the egg laying was considered as preoviposition period. Period between starting of egg laying and stopping of egg laying by individual female was noted as oviposition period, while period between stopping of egg laying to death of female was considered as post-oviposition period. The number of eggs laid by each female was recorded

daily till the death of the female and total fecundity per individual was calculated. The longevity of mated and unmated individuals of both the sexes was calculated separately from the date of emergence and the date of death.

### **3.3.11 Impact of some factors influencing on oviposition of *A. lycopersici*:**

Impact of some factors *viz.*, mated and unmated conditions, as well as photoperiodism on oviposition period, fecundity and fecundity was studied in the laboratory.

#### **3.3.11.1 Impact of mating:**

The oviposition period, total fecundity and rate of fecundity per female for mated and unmated conditions were recorded and compared with each mated and unmated conditions to study the impact of mating.

#### **3.3.11.2 Impact of photoperiodism:**

The impact of light on total fecundity and rate of fecundity per day per female of *A. lycopersici* was studied in laboratory at temperature 30°C to 32°C (Av. 30.7°C) and 47 to 70 per cent (Av. 63.3%) relative humidity during October 2014. Experiment was conducted under three different light conditions throughout the study period. The conditions were continuous darkness (provided by covering thick black paper), continuous light (day light during day time and light with 60 w bulb at night and natural laboratory condition (day light during day time and darkness during night). The observations were recorded twice a day (7.30 a.m. and 5.30 p.m.) for egg laying in all three different conditions separately for severe

consecutive days only, commencing from first day and oviposition.

### **3.4 Seasonal activity of phytophagous mites and their natural enemies:**

#### **3.4.1 Layout of the experiment**

1. Location : AINP on Agril. Acarology, Department of Entomology, N.M. College of Agriculture, NAU, Navsari
2. (a) Spacing : 60 x 60 cm  
(b) Bed size : 17.0 m x 1.0 m
3. Season and year : January 2014 to July 2014
4. Crop : Tomato
5. Variety : Heemsohna
6. Fertilizer : As per recommendation

#### **3.4.2 Sampling and method of observation**

The observations on the incidence of phytophagous mite, *T. urticae* and *A. lycopersici* and their predators viz., phytoseiid mite, *A. longispinosus* and predatory thrips, *S. indicus* were recorded at weekly interval, beginning from January 2014 and continued up to July 2014. For sampling, three random leaf representing top, middle and bottom canopy were plucked from each of twenty five randomly selected plants per bed. These samples were held in separate properly labeled polyethylene bags and brought to the laboratory for numerical count of phytophagous mites and their predators. For phytophagous mites viz., *T. urticae* and *A. lycopersici* the

counts (eggs and mobile stages) were made from the leaf bit of 2 cm x 2 cm whereas in case of predators the count were made from the whole leaf under stereo binocular microscope. The data were recorded separately considering canopy for standing tomato plants. The observation on mite counts was recorded for a period of crop season under polyhouse condition. The data so obtained were summed up and converted to total population per leaf (irrespective of plant canopy). To understand the pattern of distribution of phytophagous mites on the plant, the data recorded on mite counts were summed up separately considering plant canopy. The mite species encountered on tomato were collected and got identification by using standard keys (Gupta, 1985).

The impact of biotic and abiotic factors on population build-up of phytophagous mites as well as on predatory mite and predatory thrips was also studied through correlation studies between biotic and abiotic factors (average temperature and relative humidity of polyhouse) by using the simple correlation formula.

### **3.5 Chemical control:**

Various acaricides were evaluated for their bioefficacy against phytophagous mites as well as toxic effect of the acaricides to predatory mites were evaluated under laboratory as well as polyhouse conditions. The acaricides were compared on the basis of per cent mortality of mites and ovicidal effect in the laboratory and per cent reduction of phytophagous mites (egg and mobile stages) in polyhouse conditions

### **3.5.1 Laboratory trials:**

#### **Acaricidal effect against *T. urticae* and *A. lycopersici*:**

The experiment was conducted at room temperature, 28°C to 33°C (Av. 30.4°C) and relative humidity 53 to 71 per cent (Av. 61.4%) during April 2014 adopting Completely Randomized Block Design (CRD) with three repetitions. The details of the treatments and source of acaricides are given in Table 1.

Twenty adult mites of both the species released on leaf bits (Size 4.0 x 4.0 cm) keeping on a wad of wet cotton in petri dish of the size 9 cm diameter. In each petridish three leaf bits were accommodated as three repetitions. The treatment of acaricides was given to both the mite species kept on the leaf bits with the help of hand sprayer.

The mortality counts were made at 24, 48 and 72 hours after acaricidal treatment with the help of stereo binocular microscope. The data converted to per cent mortality of mites were statistically analysed using C.R.D after arcsin transformation.

### **3.5.2 Ovicidal effect of acaricides against *T. urticae* and *A. lycopersici*:**

To test the ovicidal effect of various acaricides, a trial was conducted in Acarology laboratory at temperature 28°C to 33°C (Av. 30.8°C) and relative humidity, 55 to 77 per cent (59.8%). In order to collect eggs for the study, ten adult females of mites of both the species were released on a tomato

**Table 1:- Details of the acaricidal treatments:**

| Treatment      | Technical Name   | Trade Name | Formulation | Concentration (%) | Dose (ml/g) in 10 lit of water | Chemical Name   | Manufactures/source   |
|----------------|------------------|------------|-------------|-------------------|--------------------------------|---|---|
| T <sub>1</sub> | Wettable sulphur | Sultaf     | 80% WP      | 0.20              | 25                             | Sulphur   | Rallis India Pvt Ltd. Vachha road, churchgate, Mumbai-400-020.                                  |
| T <sub>2</sub> | Fenazaquin       | Magister   | 10% EC      | 0.01              | 10                             | 4-tert-butylphenethyl quin azolin-4-yl-ether (IUPAC) 3-[2-[4-(1,1-dimethylethyl)phenyl] ethoxy] quinazoline (CAS) | Syngenta India Ltd. (pesticidal division), Royal Estate, Tata Road, Churchgate, Mumbai, 400071. |
| T <sub>3</sub> | Propargite       | Omite      | 57% EC      | 0.05              | 8.7                            | 2-(4-tert-butylphenoxy)cyclohexyl prop-2-yne-1-sulfonate  | DhanukaAgritech Limited, Daulatabad Road, Gurgaon,Haryana.                                      |
| T <sub>4</sub> | Chlorfenapyr     | Lepido     | 10SC        | 0.01              | 10                             | 4-Bromo-2-(p-chloropenyl)-1-(ethoxymethyl-5-(trifluoromethyl)pyrrole-3-carbonitrile                               | Rallis India Pvt Ltd. GIDC Industrial area, Ankleshwar, Bharuch-Gujarat                         |
| T <sub>5</sub> | Diafenthiuron    | Polo       | 50% WP      | 0.055             | 11                             | 1-tert-butyl-3-(2,6-diisopropyl-4-phenoxyphenyl)thiourea  | Syngenta India Ltd. (pesticidal division) Royal estate, Tata Road, Churchgate, Mumbai, 400071.  |
| T <sub>6</sub> | Triazophos       | Wilpho     | 40EC        | 0.1               | 25                             | O, O-diethyl O-(1- Phenyl -1 H -1,2,4-triazol -3 yl) phosphorothioate   | Gharda Chemicals Ltd  |
| T <sub>7</sub> | Fenpyroximate    | Sedna      | 5% EC       | 0.0025            | 5                              | tert-butyl (E)-á-(1,3-dimethyl-5-phenoxy-pyrazol-4-ylmethyleneamino-oxy)- p-toluate                               | Rallis India Pvt Ltd. GIDC Industrial Area, Ankleshwar, Bharuch-Gujarat                         |
| T <sub>8</sub> | Control          | --         | --          | --                | --                             | -----   | -----   |

leaf bits (4 cm x 4 cm) kept on a wad of wet cotton in petri dish of the size of 10 cm diameter. The number of eggs were counted in the following day and the mites were removed from the leaf bits. There were three repetitions for each treatment. The treatment of acaricides was given to eggs kept on the leaf bits with the help of a hand sprayer. The eggs were observed daily under stereo binocular microscope upto 7 days for their hatching (the maximum hatching period being 4 to 5 days, observations were continued upto 7 days). The percentage hatching of eggs was calculated. The data were statistically analysed using C.R.D. after arcsin transformation.

### **3.5.3 Studies on effect of acaricides against *T. urticae* when released 72 hrs after spraying:**

The effect of the acaricides was also determined after spraying on leaves and then releasing mites after 72 hours of the spraying, in Acarology laboratory at temperature 30 to 32°C (Av. 31.40°C) and relative humidity 55 to 70 per cent (61.2%) during April 2014. The spraying of acaricides was done on leaf bits of tomato (size 4 cm x 4 cm) kept on a wad of wet cotton petridish with the help of hand sprayer (capacity 1 liter). There were three repetitions for each treatment. Twenty mites were released per leaf bit after 72 hours of the spraying. The mortality of the mites was determined after 72 hours of the release and per cent mortality was worked out. The data were analysed statistically using C.R.D. after arcsin transformation.

### **3.5.4 Toxicity of acaricides to predatory mite *Amblyseius longispinosus* (Evans):**

The experiment was undertaken in Acarology laboratory at room temperature (Av. 33.4°C) and relative humidity (Av. 70.5%) during May 2014. Adults of phytoseiid predators, *A. longispinosus* reared in the laboratory on *T. urticae* and on castor pollens and honey were used for testing toxicity of different acaricides. The slide dip method was adopted for testing toxicity of acaricides (Anonymous, 1968). For the purpose, a strip of adhesive tap was fastened across slide in such a way as to keep sticky surface facing upward. Thirty adults female mites taken from stock culture were stuck on their back on sticky surface of adhesive tap with the help of fine zero number camel hair brush in three rows each having 10 mites. Each row of 10 mites was considered as a repetition. Such slides were dipped separately in different freshly prepared solution of acaricides for 5 to 10 seconds and agitated to ensure complete wetting. Excess solution after the treatment on the slide was removed by placing the slide slanting on its edge on absorbent paper for 15 minutes. Observations on the mortality of the predatory mites were made under stereo binocular microscope at regular interval of 1 hour after application of acaricides and continued upto 7 hours. The survival of the phytoseiid predatory mites was determined by prodding them with a fine brush. The mites those showed movement of legs were considered as alive. The data thus obtained were converted to per cent mortality as

affected by different acaricidal treatments and analysed statistically using C.R.D. after arcsin transformation.

### **3.5.5 Polyhouse trial:**

Studies on the bioefficacy of different acaricides against the phytophagous mites viz., *T. urticae* and *A. lycopersici* as well as the toxic effect of the acaricides to predatory mites, *A. longispinosus* were carried out in the polyhouse of AINP on Agricultural Acarology during April 2014. The acaricidal treatments were applied at the time of heavy incidence of the mites during April 2014. The details of the acaricidal treatment and source of acaricides is given in Table 1.

#### **3.5.5.1 Details of the experiment:**

The details of the layout of the experiment are as under:

- |    |                       |  |
|----|-----------------------|--|
| 1. | Soil type             | :Red lateritic                         |
| 2. | Statistical design    | :Completely Randomized Design (C.R.D.) |
| 3. | No. of treatments     | :8                                     |
| 4. | No. of repetitions    | :3                                     |
| 5. | Bed size              | :17.0 m x 1.0 m                        |
| 6. | Spacing               | :60 cm x 60 cm                         |
| 7. | Variety               | :Heemsohna                             |
| 8. | Date of sowing        | :10-11-2013                            |
| 9. | Date of transplanting | :03-01-2014                            |

#### **3.5.5.2 Application of the acaricidal treatments:**

The plants of tomato (c.v Heemsohna) were treated at the time of heavy incidence of both the phytophagous mites

*i.e.* *T. urticae* and *A. lycopersici*. The spraying was done on the crop with knapsack sprayer (15 liter capacity) to the extent of slight run off. The sprayer was washed thoroughly prior to the application of each acaricidal treatment.

### 3.5.5.3 Sampling and method of observation:

Five plants were randomly selected from each bed of each acaricidal treatment, repetition wise and from each plant three leaves were selected representing top, middle and bottom canopy of the plant. The leaves were plucked and packed in polythene bags which were properly labeled. The leaves were observed under stereo binocular microscope and number of eggs and moving stages (nymphs and adults) of phytophagous mites (*T. urticae* and *A. lycopersici*) as well as predatory mites (*A. longispinosus*) were counted from a leaf bit of 2 cm x 2 cm and whole leaf, respectively. The pre-treatment counts of all the phytophagous mites and predatory mite were made just before the application of acaricidal treatments. The post treatment counts were made 1, 3, 7 and 14 days after acaricidal treatment. The data so obtained were summed up and converted to average count per leaf. The correlated per cent mortality was calculated by the following formula as described by Henderson and Tilton (1955).

$$\text{Per cent correlated mortality} = 100 \left[ 1 - \frac{T_a \times C_b}{T_b \times C_a} \right]$$

**Where,**

**T<sub>b</sub>** = Number of eggs and mobile stages observed before treatment

**Ta** = Number of eggs and mobile stages observed after treatment

**Cb** = Number of eggs and mobile stages observed from untreated control plot before treatment

**Ca** = Number of eggs and mobile stages observed from untreated control plot after treatment

The data thus obtained were statistically analysed by using C.R.D. after arcsin transformation to calculate the bioefficacy of various acaricidal treatments.

### **3.6. Biodiversity of plant mites associated with vegetables:**

A survey on the phytophagous mite fauna associated with various vegetables grown in polyhouse/greenhouse and open field conditions were made in an around the University farm of Navsari for the period of one year *i.e.* January-December 2014. The observations were recorded at monthly interval in fixed plots till the availability of the host. Twenty five leaves of each host plants were plucked randomly placed in labeled polythene bags and brought to the laboratory for assessing the presence of plant mites fauna, after examining the whole leaf with the help of stereo binocular microscope. The presence or absence of various plant mites on their vegetable host plants were recorded and presented in tabular form.



**RESULTS  
AND  
DISCUSSION**

## 4. RESULTS AND DISCUSSION

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The results of different experiments were presented and discussed with the following headings and subheadings:

### 4.1 **Biology of *T. urticae* on tomato under laboratory condition.**

The biology of *T. urticae* was studied during summer, monsoon and winter seasons of 2014 under laboratory conditions at different room temperatures and relative humidity. Different stages of life cycle viz., egg, larva, protonymph, deutonymph and adults were described for their shape, size, duration etc.

#### 4.1.1 **Egg:**

Freshly laid eggs were smooth, soft, spherical and translucent white in colour. Then it turned to dirty white as it was about to hatch. Two red eye spots (simple eyes) of the developing larva were clearly visible through chorion, just prior to hatching (Plate 2).

Data on measurement of eggs revealed that the diameter of eggs varied from 0.10 to 0.13 mm (Av.  $0.11 \pm 0.01$  mm) (Table 2). The findings on colour, shape and size are in conformity with the report of Jose (1983), Jose and Shah (1989), Sejalina (1983) and Sejalina *et al.* (1993).

The incubation period of male ranged from 2.00 to 4.00 days (Av.  $2.45 \pm 0.60$  days), 2.00 to 6.00 days (Av.  $4.05 \pm 0.99$  days) and 3.00 to 7.00 days (Av.  $4.65 \pm 0.98$  days) during summer, monsoon and winter season while the yearly average of all these three seasons were ranged from 2.67 to 4.67 days (Av.  $3.71 \pm 0.54$  days) (Table 3). The present

**Table 2:- Measurement of various stages of *T. urticae* reared on tomato (Cv. Heemsohna)**

| Sr. No. | Stage           | No. observed | Length (mm) |         |                 | Width (mm) |         |                 |
|---------|-----------------|--------------|-------------|---------|-----------------|------------|---------|-----------------|
|         |                 |              | Minimum     | Maximum | AV. $\pm$ SD    | Minimum    | Maximum | AV. $\pm$ SD    |
| 1.      | Eggs            | 20           | 0.10        | 0.13    | 0.11 $\pm$ 0.01 | 0.12       | 0.14    | 0.13 $\pm$ 0.01 |
| 2.      | Larvae          | 20           | 0.12        | 0.15    | 0.13 $\pm$ 0.01 | 0.07       | 0.1     | 0.08 $\pm$ 0.01 |
| 3.      | Nymphochrysalis | 20           | 0.16        | 0.19    | 0.17 $\pm$ 0.01 | 0.09       | 0.11    | 0.10 $\pm$ 0.01 |
| 4.      | Protonymph      | 20           | 0.16        | 0.2     | 0.18 $\pm$ 0.01 | 0.10       | 0.12    | 0.11 $\pm$ 0.01 |
| 5.      | Deutochrysalis  | 20           | 0.17        | 0.22    | 0.19 $\pm$ 0.01 | 0.11       | 0.13    | 0.12 $\pm$ 0.01 |
| 6.      | Deutonymph      | 20           | 0.26        | 0.35    | 0.31 $\pm$ 0.02 | 0.12       | 0.17    | 0.15 $\pm$ 0.01 |
| 7.      | Teleochrysalis  | 20           | 0.25        | 0.36    | 0.30 $\pm$ 0.03 | 0.16       | 0.19    | 0.17 $\pm$ 0.01 |
| 8.      | Adult           |              |             |         |                 |            |         |                 |
|         | Male            | 20           | 0.34        | 0.46    | 0.39 $\pm$ 0.03 | 0.16       | 0.18    | 0.16 $\pm$ 0.01 |
|         | Female          | 20           | 0.44        | 0.48    | 0.46 $\pm$ 0.01 | 0.18       | 0.22    | 0.20 $\pm$ 0.01 |

findings of incubation period of *T.urticae* was more or less similar to those, reported by Jose (1983) on cotton and Sejalina *et al.* (1993) on okra and Shah (2014) on gerbera.

The incubation period of female ranged from 2.00 to 4.00 days (Av.  $2.45 \pm 0.60$  days), 3.00 to 4.00 days (Av.  $3.80 \pm 0.41$  days) and 4.00 to 8.00 days (Av.  $5.25 \pm 1.18$  days) during summer, monsoon and winter season while the average of all these three seasons were ranged between 3.33 to 5.00 days (Av.  $3.83 \pm 0.42$  days) (Table 4). The present findings of incubation period of female *T.urticae* was more or less similar to those reported by Jose (1983) on cotton and Sejalina *et al.* (1993) on okra and Shah (2014) on gerbera.

Incubation period in present study carried out during different seasons of the year was longer during winter where temperature becomes lower and *vice versa*. Jose (1983) on cotton and Sejalina *et al.* (1993) on okra had also reported similar effect of temperature on incubation period. Further, Shah (2014) in the laboratory trial on biology of *T.urticae* on gerbera also found that the incubation of *T.urticae*, both male and female were more during winter as compared to summer and monsoon, thus confirmed the present findings.

#### **4.1.2 Larva:**

The newly emerged larva of *T.urticae* was hexapodus, spherical in shape and creamy white in colour (Plate 2). Two bright prominent red simple spots were present on the side of the dorsal propodosomal region. The colour slightly turned to green as it entered the quiescent stage.

Data on the measurement of larvae revealed that, the length varied from 0.12 to 0.15 mm (Av.  $0.13 \pm 0.01$  mm)

**Table 3:-Incubation period of eggs of male *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 2.00             | 3.00             | 4.00             | 3.00             |
| 2.                  | 3.00             | 2.00             | 4.00             | 3.00             |
| 3.                  | 2.00             | 3.00             | 3.00             | 2.67             |
| 4.                  | 3.00             | 5.00             | 4.00             | 4.00             |
| 5.                  | 2.00             | 3.00             | 6.00             | 3.67             |
| 6.                  | 3.00             | 4.00             | 7.00             | 4.67             |
| 7.                  | 3.00             | 4.00             | 4.00             | 3.67             |
| 8.                  | 4.00             | 3.00             | 4.00             | 3.67             |
| 9.                  | 2.00             | 4.00             | 4.00             | 3.33             |
| 10.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| 11.                 | 2.00             | 5.00             | 4.00             | 3.67             |
| 12.                 | 2.00             | 6.00             | 5.00             | 4.33             |
| 13.                 | 3.00             | 5.00             | 5.00             | 4.33             |
| 14.                 | 2.00             | 5.00             | 6.00             | 4.33             |
| 15.                 | 2.00             | 4.00             | 6.00             | 4.00             |
| 16.                 | 2.00             | 3.00             | 4.00             | 3.00             |
| 17.                 | 3.00             | 4.00             | 4.00             | 3.67             |
| 18.                 | 2.00             | 4.00             | 4.00             | 3.33             |
| 19.                 | 3.00             | 5.00             | 5.00             | 4.33             |
| 20.                 | 2.00             | 5.00             | 5.00             | 4.00             |
| <b>Minimum</b>      | <b>2.00</b>      | <b>2.00</b>      | <b>3.00</b>      | <b>2.67</b>      |
| <b>Maximum</b>      | <b>4.00</b>      | <b>6.00</b>      | <b>7.00</b>      | <b>4.67</b>      |
| <b>Mean ± S. D.</b> | <b>2.45±0.60</b> | <b>4.05±0.99</b> | <b>4.65±0.98</b> | <b>3.71±0.54</b> |

Summer- June-August; Monsoon- August-September; Winter- November-December

**Table 4:-Incubation period of eggs of female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 3.00             | 5.00             | 3.67             |
| 2.                  | 2.00             | 4.00             | 6.00             | 4.00             |
| 3.                  | 2.00             | 4.00             | 6.00             | 4.00             |
| 4.                  | 4.00             | 4.00             | 7.00             | 5.00             |
| 5.                  | 2.00             | 3.00             | 6.00             | 3.67             |
| 6.                  | 3.00             | 4.00             | 5.00             | 4.00             |
| 7.                  | 2.00             | 4.00             | 7.00             | 4.33             |
| 8.                  | 2.00             | 4.00             | 8.00             | 4.67             |
| 9.                  | 2.00             | 4.00             | 5.00             | 3.67             |
| 10.                 | 3.00             | 3.00             | 5.00             | 3.67             |
| 11.                 | 3.00             | 4.00             | 4.00             | 3.67             |
| 12.                 | 2.00             | 4.00             | 4.00             | 3.33             |
| 13.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| 14.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| 15.                 | 2.00             | 4.00             | 4.00             | 3.33             |
| 16.                 | 3.00             | 4.00             | 4.00             | 3.67             |
| 17.                 | 3.00             | 3.00             | 5.00             | 3.67             |
| 18.                 | 2.00             | 4.00             | 4.00             | 3.33             |
| 19.                 | 3.00             | 4.00             | 5.00             | 4.00             |
| 20.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| <b>Minimum</b>      | <b>2.00</b>      | <b>3.00</b>      | <b>4.00</b>      | <b>3.33</b>      |
| <b>Maximum</b>      | <b>4.00</b>      | <b>4.00</b>      | <b>8.00</b>      | <b>5.00</b>      |
| <b>Mean ± S. D.</b> | <b>2.45±0.60</b> | <b>3.80±0.41</b> | <b>5.25±1.11</b> | <b>3.83±0.42</b> |

and the breadth varied from 0.07 to 0.10 mm (Av.  $0.08\pm 0.01$  mm) (Table- 2).

It can be seen from Table 5 that larval period lasted for 3.00 to 5.00 days ( $4.05\pm 0.51$  days) for male and 3.00 to 5.00 days ( $4.25\pm 0.63$  days) for female during summer, 2.00 to 3.00 days ( $2.60\pm 0.50$  days) for male and 2.00 to 4.00 days ( $3.00\pm 0.56$  days) for female in monsoon and 4.00 to 7.00 days ( $5.40\pm 0.75$  days) for male and 4.00 to 8.00 days ( $6.30\pm 1.21$  days) for female in winter with the average larval period ranging between 3.33 to 4.67 days (Av.  $4.01\pm 0.35$  days) for male and 3.67 to 5.33 days (Av.  $4.51\pm 0.52$  days) for females (Table 6).

Thus, the larval period during winter season was longer due to low temperature and *vice versa*. The present findings are in confirmation with the earlier reports of Jose and Shah (1989) on cotton and Sejalina *et al.* (1993) on okra who also reported lower larval period of *T. macfarlanei* with lower temperature. Further, Shah (2014) also recorded the longer larval period for both the sexes during winter season when reared on gerbera under laboratory. Thus, the present findings are more or less matches with the earlier work.

#### **4.1.3 Nymphochrysalis:**

Quiescent period in larval stage is called nymphochrysalis in which the larva found anchoring itself to the leaf surface with their front two pairs of legs projecting forward and a hind pair projecting backwards. During this period, the mite suspended all its activities like feeding and

movement. The colour of nymphochrysalis stage was light green initially which later on turns dark green (Plate 2).

The body of mite in this stage varied between 0.16 to 0.19 mm (Av.  $0.17 \pm 0.01$  mm) in length and 0.09 to 0.11 mm (Av.  $0.10 \pm 0.01$  mm) in breadth (Table 2).

The nymphochrysalis period for male was 0.25 to 2.25 days (Av.  $0.65 \pm 0.45$  days), 0.25 to 1.00 days (Av.  $0.66 \pm 0.23$  days) and 0.50 to 1.50 days (Av.  $0.91 \pm 0.31$  days) during summer, monsoon and winter seasons (Table 7), whereas in case of females it was 1.00 to 4.00 days (Av.  $2.40 \pm 0.82$  days), 3.00 to 4.00 days (Av.  $3.50 \pm 0.51$  days) and 3.00 to 5.00 days (Av.  $3.85 \pm 0.58$  days) during summer, monsoon and winter seasons (Table 8). The average nymphochrysalis period for male and female was 0.33 to 1.42 days (Av.  $0.74 \pm 0.23$  days) and 2.67 to 4.00 days (Av.  $3.25 \pm 0.40$  days). The average temperature during this period were 30.00 °C, 31.00 °C and 23.00 °C and an average relative humidity was 60.00, 90.00 and 78.00 per cent, respectively.

After completion of nymphochrysalis period, moulting takes place. During moulting, integument splits transversely at mid line of body and the mite removes posterior half of the exuviae with the help of hind legs and escape from anterior half of the exuviae by walking backwardly.

In past, Jose and Shah (1989) reported nymphochrysalis period of male on cotton to be 0.53 and 0.60 days at varying room temperature 28-32°C and 22-29°C, respectively and for female it was recorded to be 0.67, 0.50 and 0.75 days at varying room temperature 30-35°C, 28-32°C

**Table 5:-Larval period of male *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 2.00             | 5.00             | 3.33             |
| 2.                  | 4.00             | 3.00             | 6.00             | 4.33             |
| 3.                  | 4.00             | 2.00             | 4.00             | 3.33             |
| 4.                  | 4.00             | 3.00             | 6.00             | 4.33             |
| 5.                  | 4.00             | 3.00             | 7.00             | 4.67             |
| 6.                  | 4.00             | 3.00             | 5.00             | 4.00             |
| 7.                  | 5.00             | 2.00             | 5.00             | 4.00             |
| 8.                  | 3.00             | 3.00             | 6.00             | 4.00             |
| 9.                  | 4.00             | 3.00             | 5.00             | 4.00             |
| 10.                 | 4.00             | 2.00             | 5.00             | 3.67             |
| 11.                 | 5.00             | 2.00             | 6.00             | 4.33             |
| 12.                 | 4.00             | 2.00             | 5.00             | 3.67             |
| 13.                 | 4.00             | 3.00             | 6.00             | 4.33             |
| 14.                 | 4.00             | 3.00             | 5.00             | 4.00             |
| 15.                 | 4.00             | 2.00             | 6.00             | 4.00             |
| 16.                 | 4.00             | 3.00             | 5.00             | 4.00             |
| 17.                 | 4.00             | 3.00             | 6.00             | 4.33             |
| 18.                 | 4.00             | 3.00             | 5.00             | 4.00             |
| 19.                 | 5.00             | 2.00             | 6.00             | 4.33             |
| 20.                 | 4.00             | 3.00             | 4.00             | 3.67             |
| <b>Minimum</b>      | <b>3.00</b>      | <b>2.00</b>      | <b>4.00</b>      | <b>3.33</b>      |
| <b>Maximum</b>      | <b>5.00</b>      | <b>3.00</b>      | <b>7.00</b>      | <b>4.67</b>      |
| <b>Mean ± S. D.</b> | <b>4.05±0.51</b> | <b>2.60±0.50</b> | <b>5.40±0.75</b> | <b>4.01±0.35</b> |

**Table 6:-Larval period of female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 2.00             | 6.00             | 3.67             |
| 2.                  | 4.00             | 3.00             | 4.00             | 3.67             |
| 3.                  | 4.00             | 2.00             | 6.00             | 4.00             |
| 4.                  | 4.00             | 3.00             | 5.00             | 4.00             |
| 5.                  | 3.00             | 3.00             | 5.00             | 3.67             |
| 6.                  | 4.00             | 3.00             | 7.00             | 4.67             |
| 7.                  | 4.00             | 4.00             | 4.00             | 4.00             |
| 8.                  | 5.00             | 3.00             | 5.00             | 4.33             |
| 9.                  | 4.00             | 3.00             | 6.00             | 4.33             |
| 10.                 | 4.00             | 4.00             | 7.00             | 5.00             |
| 11.                 | 4.00             | 4.00             | 7.00             | 5.00             |
| 12.                 | 4.00             | 3.00             | 8.00             | 5.00             |
| 13.                 | 5.00             | 3.00             | 7.00             | 5.00             |
| 14.                 | 5.00             | 3.00             | 7.00             | 5.00             |
| 15.                 | 5.00             | 3.00             | 8.00             | 5.33             |
| 16.                 | 4.00             | 3.00             | 7.00             | 4.67             |
| 17.                 | 4.00             | 2.00             | 8.00             | 4.67             |
| 18.                 | 5.00             | 3.00             | 7.00             | 5.00             |
| 19.                 | 5.00             | 3.00             | 6.00             | 4.67             |
| 20.                 | 5.00             | 3.00             | 6.00             | 4.67             |
| <b>Minimum</b>      | <b>3.00</b>      | <b>2.00</b>      | <b>4.00</b>      | <b>3.67</b>      |
| <b>Maximum</b>      | <b>5.00</b>      | <b>4.00</b>      | <b>8.00</b>      | <b>5.33</b>      |
| <b>Mean ± S. D.</b> | <b>4.25±0.63</b> | <b>3.00±0.56</b> | <b>6.30±1.21</b> | <b>4.51±0.52</b> |

and 22-29°C, respectively. Sejalía *et al.* (1993) found nymphochrysalis period to be 0.65 and 0.54 days for male, while for female, it was 0.66 and 0.70 days when reared on okra at varying room temperature 23-32°C and 27.5-31.5°C, respectively. Furthermore, Shah (2014) also reported the average nymphochrysalis period of males as 0.20 to 1.20 days (Av.  $0.69 \pm 0.32$  days), 0.20 to 1.40 days ( $0.74 \pm 0.36$  days) and 0.40 to 1.40 days (Av.  $1.02 \pm 0.27$  days) during summer, monsoon and winter seasons, whereas for females it was 0.50 to 3.20 days (Av.  $1.47 \pm 0.82$  days), 0.20 to 1.50 days (Av.  $0.62 \pm 0.36$  days) and 1.20 to 6.00 days (Av.  $3.19 \pm 1.11$  days) during summer, monsoon and winter seasons days respectively when reared on gerbera. Thus, nymphochrysalis period on tomato under the present study was more or less matches with the findings of these workers on other host plants.

#### **4.1.4 Protonymph:**

The protonymph differed from the larva because of the presence of four pairs of legs and bigger in size. The body of this stage was found oval, more pigmented and having dark green colour in the beginning which turned to amber colour in the later period (Plate 2). These findings are in close confirmity with the report of Jose and Shah (1989) on cotton, Sejalía (1989) on okra and Shah (2014) on gerbera.

The length and breadth of the body of protonymph varied from 0.16 to 0.21 mm (Av.  $0.18 \pm 0.01$  mm) and 0.10 to 0.12 mm (Av.  $0.11 \pm 0.01$  mm), respectively. Sejalía *et al.* (1993) reported this stage to be 0.250 mm in length and 0.156

**Table 7:-Duration of Nymphochrysalis period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 0.25             | 0.25             | 0.50             | 0.33             |
| 2.                  | 0.25             | 0.50             | 0.50             | 0.42             |
| 3.                  | 0.50             | 0.50             | 0.50             | 0.50             |
| 4.                  | 0.50             | 0.50             | 0.50             | 0.50             |
| 5.                  | 1.00             | 0.50             | 0.75             | 0.75             |
| 6.                  | 0.50             | 1.00             | 0.50             | 0.67             |
| 7.                  | 0.50             | 0.75             | 1.25             | 0.83             |
| 8.                  | 0.75             | 0.75             | 1.00             | 0.83             |
| 9.                  | 0.75             | 0.75             | 1.00             | 0.83             |
| 10.                 | 0.75             | 0.50             | 1.00             | 0.75             |
| 11.                 | 0.25             | 0.50             | 1.25             | 0.67             |
| 12.                 | 0.25             | 1.00             | 1.00             | 0.75             |
| 13.                 | 1.00             | 1.00             | 0.75             | 0.92             |
| 14.                 | 1.00             | 1.00             | 0.75             | 0.92             |
| 15.                 | 2.25             | 0.50             | 1.50             | 1.42             |
| 16.                 | 0.50             | 0.50             | 1.50             | 0.83             |
| 17.                 | 0.25             | 0.50             | 1.00             | 0.58             |
| 18.                 | 0.50             | 0.50             | 1.00             | 0.67             |
| 19.                 | 0.50             | 1.00             | 1.00             | 0.83             |
| 20.                 | 0.75             | 0.75             | 1.00             | 0.83             |
| <b>Minimum</b>      | <b>0.25</b>      | <b>0.25</b>      | <b>0.50</b>      | <b>0.33</b>      |
| <b>Maximum</b>      | <b>2.25</b>      | <b>1.00</b>      | <b>1.50</b>      | <b>1.42</b>      |
| <b>Mean ± S. D.</b> | <b>0.65±0.45</b> | <b>0.66±0.23</b> | <b>0.91±0.31</b> | <b>0.74±0.23</b> |

**Table 8:-Duration of Nymphochrysalis female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>                     | <b>Summer</b>                   | <b>Monsoon</b>                  | <b>Winter</b>                   | <b>Average</b>                  |
|------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1.                                 | 1.00                            | 3.00                            | 4.00                            | 2.67                            |
| 2.                                 | 3.00                            | 4.00                            | 3.00                            | 3.33                            |
| 3.                                 | 4.00                            | 4.00                            | 4.00                            | 4.00                            |
| 4.                                 | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| 5.                                 | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| 6.                                 | 1.00                            | 3.00                            | 4.00                            | 2.67                            |
| 7.                                 | 2.00                            | 4.00                            | 5.00                            | 3.67                            |
| 8.                                 | 3.00                            | 3.00                            | 4.00                            | 3.33                            |
| 9.                                 | 4.00                            | 3.00                            | 3.00                            | 3.33                            |
| 10.                                | 2.00                            | 4.00                            | 4.00                            | 3.33                            |
| 11.                                | 2.00                            | 4.00                            | 4.00                            | 3.33                            |
| 12.                                | 2.00                            | 3.00                            | 3.00                            | 2.67                            |
| 13.                                | 3.00                            | 4.00                            | 4.00                            | 3.67                            |
| 14.                                | 3.00                            | 4.00                            | 4.00                            | 3.67                            |
| 15.                                | 2.00                            | 4.00                            | 5.00                            | 3.67                            |
| 16.                                | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| 17.                                | 3.00                            | 4.00                            | 3.00                            | 3.33                            |
| 18.                                | 3.00                            | 4.00                            | 4.00                            | 3.67                            |
| 19.                                | 2.00                            | 3.00                            | 3.00                            | 2.67                            |
| 20.                                | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| <b>Minimum</b>                     | <b>1.00</b>                     | <b>3.00</b>                     | <b>3.00</b>                     | <b>2.67</b>                     |
| <b>Maximum</b>                     | <b>4.00</b>                     | <b>4.00</b>                     | <b>5.00</b>                     | <b>4.00</b>                     |
| <b>Mean <math>\pm</math> S. D.</b> | <b>2.40<math>\pm</math>0.82</b> | <b>3.50<math>\pm</math>0.51</b> | <b>3.85<math>\pm</math>0.58</b> | <b>3.25<math>\pm</math>0.40</b> |

mm in breadth on okra. This slight difference in size may be due to the food plant.

The protonymphal period of the male of *T. urticae* during the different periods of study are presented in Table 9. The protonymph period of male was lasted from 2.00 to 4.00 days (Av.  $3.15 \pm 0.81$  days), 3.00 to 5.00 days (Av.  $4.40 \pm 0.68$  days) and 4.00 to 6.00 days (Av.  $5.00 \pm 0.64$  days) during summer, monsoon and winter seasons, respectively. While female took 3.00 to 6.00 days (Av.  $4.10 \pm 0.71$  days), 3.00 to 7.00 days (Av.  $4.50 \pm 0.88$  days) and 5.00 to 7.00 days (Av.  $6.20 \pm 0.69$  days) during summer, monsoon and winter seasons (Table 10).

Jose and Shah (1989) reported that the protonymphal period on cotton was 0.94 and 1.60 days at varying room temperature 28-32°C and 22-29°C, respectively for male, while it was 2.27, 0.96, 1.06 and 1.67 days at temperature ranging from 30-34°C, 30-35°C, 28-32 °C and 22-29°C, respectively for female. Whereas, Sejalina *et al.* (1993) found this period on okra to be 1.16 and 0.86 days for male and 1.18 and 0.86 days for female at varying room temperature 23-32 °C and 27.5-31.5 °C, respectively. Shah (2014) also reported the protonymphal period of *T. urticae* for male to be  $2.73 \pm 0.45$  days,  $3.60 \pm 0.52$  days and  $4.46 \pm 1.06$  days and for female  $3.26 \pm 0.66$  days,  $3.00 \pm 0.257$  days and  $6.24 \pm 0.83$  days during summer, winter and monsoon when reared on gerbera. Thus, more or less confirms the present findings on tomato.

**Table9:-Protonymphal period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 3.00             | 4.00             | 3.33             |
| 2.                  | 2.00             | 5.00             | 6.00             | 4.33             |
| 3.                  | 3.00             | 5.00             | 6.00             | 4.67             |
| 4.                  | 4.00             | 5.00             | 4.00             | 4.33             |
| 5.                  | 3.00             | 5.00             | 5.00             | 4.33             |
| 6.                  | 3.00             | 4.00             | 5.00             | 4.00             |
| 7.                  | 2.00             | 4.00             | 6.00             | 4.00             |
| 8.                  | 4.00             | 4.00             | 5.00             | 4.33             |
| 9.                  | 3.00             | 4.00             | 4.00             | 3.67             |
| 10.                 | 4.00             | 5.00             | 5.00             | 4.67             |
| 11.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| 12.                 | 4.00             | 5.00             | 6.00             | 5.00             |
| 13.                 | 4.00             | 3.00             | 5.00             | 4.00             |
| 14.                 | 3.00             | 4.00             | 5.00             | 4.00             |
| 15.                 | 4.00             | 5.00             | 5.00             | 4.67             |
| 16.                 | 4.00             | 5.00             | 5.00             | 4.67             |
| 17.                 | 4.00             | 5.00             | 4.00             | 4.33             |
| 18.                 | 3.00             | 5.00             | 5.00             | 4.33             |
| 19.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| 20.                 | 2.00             | 4.00             | 5.00             | 3.67             |
| <b>Minimum</b>      | <b>2.00</b>      | <b>3.00</b>      | <b>4.00</b>      | <b>3.33</b>      |
| <b>Maximum</b>      | <b>4.00</b>      | <b>5.00</b>      | <b>6.00</b>      | <b>5.00</b>      |
| <b>Mean ± S. D.</b> | <b>3.15±0.81</b> | <b>4.40±0.68</b> | <b>5.00±0.64</b> | <b>4.18±0.43</b> |

**Table 10:- Protonymphal period of female *T.urticae* under laboratory conditions (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 4.00             | 4.00             | 6.00             | 4.67             |
| 2.                  | 4.00             | 5.00             | 5.00             | 4.67             |
| 3.                  | 3.00             | 4.00             | 6.00             | 4.33             |
| 4.                  | 4.00             | 5.00             | 6.00             | 5.00             |
| 5.                  | 5.00             | 4.00             | 7.00             | 5.33             |
| 6.                  | 4.00             | 4.00             | 5.00             | 4.33             |
| 7.                  | 4.00             | 5.00             | 5.00             | 4.67             |
| 8.                  | 6.00             | 4.00             | 6.00             | 5.33             |
| 9.                  | 4.00             | 5.00             | 7.00             | 5.33             |
| 10.                 | 3.00             | 4.00             | 6.00             | 4.33             |
| 11.                 | 4.00             | 6.00             | 6.00             | 5.33             |
| 12.                 | 3.00             | 7.00             | 6.00             | 5.33             |
| 13.                 | 4.00             | 5.00             | 7.00             | 5.33             |
| 14.                 | 5.00             | 4.00             | 7.00             | 5.33             |
| 15.                 | 4.00             | 4.00             | 6.00             | 4.67             |
| 16.                 | 4.00             | 3.00             | 7.00             | 4.67             |
| 17.                 | 4.00             | 4.00             | 7.00             | 5.00             |
| 18.                 | 4.00             | 4.00             | 7.00             | 5.00             |
| 19.                 | 5.00             | 4.00             | 6.00             | 5.00             |
| 20.                 | 4.00             | 5.00             | 6.00             | 5.00             |
| <b>Minimum</b>      | <b>3.00</b>      | <b>3.00</b>      | <b>5.00</b>      | <b>4.33</b>      |
| <b>Maximum</b>      | <b>6.00</b>      | <b>7.00</b>      | <b>7.00</b>      | <b>5.33</b>      |
| <b>Mean ± S. D.</b> | <b>4.10±0.71</b> | <b>4.50±0.88</b> | <b>6.20±0.69</b> | <b>4.93±0.36</b> |

#### **4.1.5 Deutochrysalis:**

Deutochrysalis is quiescent period in protonymphal stage in which the protonymph suspended all its activities and remained anchored to the leaf surface. The body also shrunk and decreased in its size. The colour becomes dark green (Plate 2).

The length in this stage varied from 0.17 to 0.22 mm (Av.  $0.19 \pm 0.01$  mm), while the breadth varied from 0.11 to 0.13 mm (Av.  $0.12 \pm 0.01$  mm) (Table 2).

The deutochrysalis period of male varied from 0.25 to 0.75 days (Av.  $0.41 \pm 0.16$  days), 0.50 to 1.00 days (Av.  $0.78 \pm 0.20$  day) and 0.75 to 1.50 days (Av.  $1.11 \pm 0.23$  days), respectively during summer, monsoon and winter seasons with an average of 0.50 to 1.00 days (Av.  $0.77 \pm 0.13$  days) (Table 11). The same period for female lasted for 0.75 to 1.25 days (Av.  $1.01 \pm 0.12$  days), 0.75 to 2.00 days ( $1.20 \pm 0.36$  day) and 1.00 to 3.00 days ( $1.56 \pm 0.49$  days) during summer, monsoon and winter while the average period ranging between 1.00 to 2.03 days (Av.  $1.25 \pm 0.23$  days) (Table 12). These findings are more or less in agreement with those of Jose and Shah (1989). The deutochrysalis period on an average ranged between  $0.92 \pm 0.15$  for male and  $2.04 \pm 0.50$  days when reared on gerbera (Shah, 2014). Thus closely support the present findings.

#### **4.1.6 Deutonymph:**

The protonymph moulted in to the deutonymph. The body of deutonymph was carmine in colour but was larger and broader than protonymph and thus distinguishable from other stages (Plate 2). The body of deutonymph was oval with

**Table 11:-Duration of male deutochrysalis *T. urticae* under laboratory condition (Days)**

| Sr. No.                            | Summer                          | Monsoon                         | Winter                          | Average                         |
|------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1.                                 | 0.25                            | 0.50                            | 1.00                            | 0.59                            |
| 2.                                 | 0.25                            | 0.50                            | 0.75                            | 0.50                            |
| 3.                                 | 0.75                            | 1.00                            | 1.25                            | 1.00                            |
| 4.                                 | 0.50                            | 0.75                            | 1.00                            | 0.75                            |
| 5.                                 | 0.50                            | 0.50                            | 1.00                            | 0.67                            |
| 6.                                 | 0.50                            | 1.00                            | 1.00                            | 0.83                            |
| 7.                                 | 0.25                            | 1.00                            | 1.00                            | 0.75                            |
| 8.                                 | 0.25                            | 1.00                            | 1.25                            | 0.83                            |
| 9.                                 | 0.50                            | 0.50                            | 1.00                            | 0.67                            |
| 10.                                | 0.50                            | 0.75                            | 1.50                            | 0.92                            |
| 11.                                | 0.25                            | 0.75                            | 1.50                            | 0.83                            |
| 12.                                | 0.75                            | 0.75                            | 1.50                            | 1.00                            |
| 13.                                | 0.25                            | 1.00                            | 1.50                            | 0.92                            |
| 14.                                | 0.25                            | 1.00                            | 1.25                            | 0.83                            |
| 15.                                | 0.50                            | 1.00                            | 1.00                            | 0.83                            |
| 16.                                | 0.25                            | 0.50                            | 1.00                            | 0.58                            |
| 17.                                | 0.50                            | 0.75                            | 0.75                            | 0.67                            |
| 18.                                | 0.50                            | 0.75                            | 1.00                            | 0.75                            |
| 19.                                | 0.50                            | 0.75                            | 1.00                            | 0.75                            |
| 20.                                | 0.25                            | 1.00                            | 1.00                            | 0.75                            |
| <b>Minimum</b>                     | <b>0.25</b>                     | <b>0.50</b>                     | <b>0.75</b>                     | <b>0.50</b>                     |
| <b>Maximum</b>                     | <b>0.75</b>                     | <b>1.00</b>                     | <b>1.50</b>                     | <b>1.00</b>                     |
| <b>Mean <math>\pm</math> S. D.</b> | <b>0.41<math>\pm</math>0.16</b> | <b>0.78<math>\pm</math>0.20</b> | <b>1.11<math>\pm</math>0.23</b> | <b>0.77<math>\pm</math>0.13</b> |

**Table 12:-Duration duetochrysalis of female *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 1.00             | 1.00             | 1.25             | 1.08             |
| 2.                  | 1.00             | 1.00             | 1.50             | 1.17             |
| 3.                  | 1.00             | 1.50             | 1.50             | 1.33             |
| 4.                  | 1.00             | 1.00             | 1.50             | 1.17             |
| 5.                  | 1.25             | 2.00             | 3.00             | 2.03             |
| 6.                  | 1.00             | 1.50             | 2.00             | 1.50             |
| 7.                  | 1.25             | 1.00             | 1.50             | 1.25             |
| 8.                  | 1.00             | 1.00             | 2.00             | 1.33             |
| 9.                  | 0.75             | 0.75             | 2.00             | 1.17             |
| 10.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 11.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 12.                 | 1.00             | 1.00             | 2.00             | 1.33             |
| 13.                 | 1.00             | 1.00             | 1.50             | 1.17             |
| 14.                 | 0.75             | 2.00             | 1.50             | 1.47             |
| 15.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 16.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 17.                 | 1.00             | 1.00             | 2.00             | 1.33             |
| 18.                 | 1.25             | 1.50             | 1.50             | 1.42             |
| 19.                 | 1.00             | 1.00             | 1.50             | 1.17             |
| 20.                 | 1.00             | 1.75             | 1.00             | 1.25             |
| <b>Minimum</b>      | <b>0.75</b>      | <b>0.75</b>      | <b>1.00</b>      | <b>1.00</b>      |
| <b>Maximum</b>      | <b>1.25</b>      | <b>2.00</b>      | <b>3.00</b>      | <b>2.03</b>      |
| <b>Mean ± S. D.</b> | <b>1.01±0.12</b> | <b>1.20±0.36</b> | <b>1.56±0.49</b> | <b>1.25±0.23</b> |

the abdominal region rounded in case of males. The colour of male was light carmine and not as deep as in the case of females.

The length of this stage varied from 0.26 to 0.35 mm (Av.  $0.31 \pm 0.02$  mm), while the breadth varied from 0.12 to 0.17 (Av.  $0.15 \pm 0.01$  mm) (Table 2).

The period of deutonymphal stage lasted between 2.00 to 3.00 days (Av.  $2.40 \pm 0.50$  days), 3.00 to 5.00 days (Av.  $4.20 \pm 0.69$  days) and 4.00 to 6.00 days (Av.  $4.80 \pm 0.52$  days) in case of male (Table 13) and 3.00 to 6.00 days (Av.  $4.90 \pm 0.78$  days), 2.00 to 4.00 days (Av.  $3.25 \pm 0.85$  days) and 4.00 to 8.00 days (Av.  $5.65 \pm 0.87$  days) for female during summer, monsoon and winter season (Table 14). The average deutonymphal period of male and females lasted 3.00 to 4.33 days (Av.  $3.80 \pm 0.38$  days) for male and 3.33 to 6.00 days ( $4.60 \pm 0.61$  days) for females.

Jose and Shah (1989) reported that the deutonymphal period of male mite on cotton was 0.80 and 1.00 day at varying room temperature 28-32 °C and 22-29 °C, respectively and that of for female mite was 1.33, 0.84, 0.78 and 1.00 days at temperature varying from 30-34 °C, 30-35 °C, 28-32 °C and 22-29 °C, respectively. Further, Sejalina *et al.* (1993) also recorded this period in okra for *T. macfarlanei* as 1.06 and 0.66 days in case of male, while in case of female, it was 0.69 and 1.27 days at varying room temperature 23-32 °C and 27.5 to 31.5 °C, respectively. Shah (2014) also recorded this period for *T. urticae* when reared on gerbera as  $3.26 \pm 0.38$  days for male and  $4.19 \pm 0.37$  days for female, thus more or less in close agreement of present work.

**Table 13:-Deutonymphal Period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.                            | Summer                          | Monsoon                         | Winter                          | Average                         |
|------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1.                                 | 2.00                            | 4.00                            | 4.00                            | 3.33                            |
| 2.                                 | 3.00                            | 4.00                            | 4.00                            | 3.67                            |
| 3.                                 | 3.00                            | 5.00                            | 5.00                            | 4.33                            |
| 4.                                 | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| 5.                                 | 2.00                            | 3.00                            | 4.00                            | 3.00                            |
| 6.                                 | 3.00                            | 5.00                            | 5.00                            | 4.33                            |
| 7.                                 | 2.00                            | 5.00                            | 5.00                            | 4.00                            |
| 8.                                 | 2.00                            | 4.00                            | 5.00                            | 3.67                            |
| 9.                                 | 3.00                            | 4.00                            | 5.00                            | 4.00                            |
| 10.                                | 2.00                            | 5.00                            | 5.00                            | 4.00                            |
| 11.                                | 2.00                            | 4.00                            | 5.00                            | 3.67                            |
| 12.                                | 3.00                            | 5.00                            | 4.00                            | 4.00                            |
| 13.                                | 3.00                            | 4.00                            | 5.00                            | 4.00                            |
| 14.                                | 2.00                            | 4.00                            | 5.00                            | 3.67                            |
| 15.                                | 2.00                            | 5.00                            | 5.00                            | 4.00                            |
| 16.                                | 2.00                            | 5.00                            | 5.00                            | 4.00                            |
| 17.                                | 3.00                            | 4.00                            | 5.00                            | 4.00                            |
| 18.                                | 2.00                            | 3.00                            | 5.00                            | 3.33                            |
| 19.                                | 2.00                            | 4.00                            | 6.00                            | 4.00                            |
| 20.                                | 3.00                            | 4.00                            | 5.00                            | 4.00                            |
| <b>Minimum</b>                     | <b>2.00</b>                     | <b>3.00</b>                     | <b>4.00</b>                     | <b>3.00</b>                     |
| <b>Maximum</b>                     | <b>3.00</b>                     | <b>5.00</b>                     | <b>6.00</b>                     | <b>4.33</b>                     |
| <b>Mean <math>\pm</math> S. D.</b> | <b>2.40<math>\pm</math>0.50</b> | <b>4.20<math>\pm</math>0.69</b> | <b>4.80<math>\pm</math>0.52</b> | <b>3.80<math>\pm</math>0.38</b> |

**Table 14:-Deutonymphal period of female *T. urticae* under laboratory condition (Days)**

| Sr. No.                            | Summer                          | Monsoon                         | Winter                          | Average                         |
|------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1.                                 | 6.00                            | 2.00                            | 6.00                            | 4.67                            |
| 2.                                 | 5.00                            | 4.00                            | 5.00                            | 4.67                            |
| 3.                                 | 4.00                            | 2.00                            | 4.00                            | 3.33                            |
| 4.                                 | 4.00                            | 3.00                            | 6.00                            | 4.33                            |
| 5.                                 | 3.00                            | 3.00                            | 6.00                            | 4.00                            |
| 6.                                 | 4.00                            | 4.00                            | 5.00                            | 4.33                            |
| 7.                                 | 5.00                            | 2.00                            | 5.00                            | 4.00                            |
| 8.                                 | 5.00                            | 4.00                            | 7.00                            | 5.33                            |
| 9.                                 | 5.00                            | 3.00                            | 6.00                            | 4.67                            |
| 10.                                | 6.00                            | 4.00                            | 8.00                            | 6.00                            |
| 11.                                | 6.00                            | 4.00                            | 6.00                            | 5.33                            |
| 12.                                | 5.00                            | 4.00                            | 6.00                            | 5.00                            |
| 13.                                | 5.00                            | 2.00                            | 5.00                            | 4.00                            |
| 14.                                | 4.00                            | 4.00                            | 5.00                            | 4.33                            |
| 15.                                | 5.00                            | 4.00                            | 6.00                            | 5.00                            |
| 16.                                | 5.00                            | 2.00                            | 5.00                            | 4.00                            |
| 17.                                | 5.00                            | 4.00                            | 5.00                            | 4.67                            |
| 18.                                | 6.00                            | 4.00                            | 6.00                            | 5.33                            |
| 19.                                | 5.00                            | 3.00                            | 6.00                            | 4.67                            |
| 20.                                | 5.00                            | 3.00                            | 5.00                            | 4.33                            |
| <b>Minimum</b>                     | <b>3.00</b>                     | <b>2.00</b>                     | <b>4.00</b>                     | <b>3.33</b>                     |
| <b>Maximum</b>                     | <b>6.00</b>                     | <b>4.00</b>                     | <b>8.00</b>                     | <b>6.00</b>                     |
| <b>Mean <math>\pm</math> S. D.</b> | <b>4.90<math>\pm</math>0.78</b> | <b>3.25<math>\pm</math>0.85</b> | <b>5.65<math>\pm</math>0.87</b> | <b>4.60<math>\pm</math>0.61</b> |



Eggs



Larvae



Nymphochrysalis



Protonymph



Deutochrysalis



Deutonymph



Teleiochrysalis

**Plate 2 : Life stages of *T. urticae* on tomato**

#### 4.1.7 Teleochrysalis:

Quiescent period in deutonymphal stage is called teleochrysalis. During this period, the mite suspended all its activities and its body was shranked and decreased in its size. The colour was light caramine and creamy (Plate 2). These findings are in close confirmity with report of Jose and Shah (1989) and Sejalina (1989) as well as with Shah (2014) on different spider mites when reared on cotton, okra and gerbera respectively.

The size of teleochrysalis varied from 0.25 to 0.36 mm (Av.  $0.30\pm 0.03$  mm) in length and 0.16 to 0.19 mm (Av.  $0.17\pm 0.01$  mm) in breadth (Table 2).

The teleochrysalis period of the spider mite, *T. urticae* during the different seasons are presented in Table 15 and 16. This period varied from 0.25 to 1.00 day (Av.  $0.61\pm 0.30$  day), 0.50 to 1.00 day (Av.  $0.83\pm 0.20$  day) and 1.00 to 2.00 day (Av.  $1.32\pm 0.38$  day) in case of male, while in case of female, it was varied from 1.00 to 3.00 days (Av.  $1.50\pm 0.60$  days), 0.50 to 1.50 days (Av.  $0.80\pm 0.28$  days) and 1.00 to 2.00 days (Av.  $1.55\pm 0.31$  days) and average teleochrysalis period for male and female was 0.58 to 1.25 days (Av.  $0.92\pm 0.18$  days) and 0.83 to 1.92 days (Av.  $1.28\pm 0.24$  days) in different seasons *i.e.* summer, monsoon and winter, respectively with different temperature and relative humidity. In past, Jose and Shah (1989) reported this period on cotton to be lasting for 0.33 and 0.40 days at varying room temperature 28-32 °C and 22-29 °C, respectively for male as 0.50, 0.57 and 0.50 day at varying room temperature 30-35 °C, 28-32 °C and 22-29 °C,

**Table 15:-Duration of teleochrysalis period of male *T.urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 0.25             | 0.50             | 1.00             | 0.58             |
| 2.                  | 0.25             | 0.50             | 1.00             | 0.58             |
| 3.                  | 1.00             | 0.75             | 1.00             | 0.92             |
| 4.                  | 0.50             | 1.00             | 1.00             | 0.83             |
| 5.                  | 0.25             | 1.00             | 1.00             | 0.75             |
| 6.                  | 0.50             | 0.50             | 1.25             | 0.75             |
| 7.                  | 0.50             | 0.50             | 1.50             | 0.83             |
| 8.                  | 1.00             | 0.75             | 2.00             | 1.25             |
| 9.                  | 0.75             | 0.75             | 1.00             | 0.83             |
| 10.                 | 0.50             | 1.00             | 1.00             | 0.83             |
| 11.                 | 0.50             | 1.00             | 2.00             | 1.17             |
| 12.                 | 0.25             | 1.00             | 1.50             | 0.92             |
| 13.                 | 0.75             | 1.00             | 1.00             | 0.92             |
| 14.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 15.                 | 1.00             | 1.00             | 1.00             | 1.00             |
| 16.                 | 0.25             | 1.00             | 2.00             | 1.08             |
| 17.                 | 0.75             | 0.75             | 1.50             | 1.00             |
| 18.                 | 0.25             | 1.00             | 1.50             | 0.92             |
| 19.                 | 1.00             | 0.75             | 1.50             | 1.08             |
| 20.                 | 1.00             | 1.00             | 1.75             | 1.25             |
| <b>Minimum</b>      | <b>0.25</b>      | <b>0.50</b>      | <b>1.00</b>      | <b>0.58</b>      |
| <b>Maximum</b>      | <b>1.00</b>      | <b>1.00</b>      | <b>2.00</b>      | <b>1.25</b>      |
| <b>Mean ± S. D.</b> | <b>0.61±0.30</b> | <b>0.83±0.20</b> | <b>1.32±0.38</b> | <b>0.92±0.18</b> |

**Table 16:-Duration of teleochrysalis period of female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 1.00             | 0.50             | 1.00             | 0.83             |
| 2.                  | 1.00             | 0.50             | 1.00             | 0.83             |
| 3.                  | 2.00             | 1.00             | 1.50             | 1.50             |
| 4.                  | 1.00             | 1.00             | 1.50             | 1.17             |
| 5.                  | 2.00             | 0.50             | 1.75             | 1.42             |
| 6.                  | 1.00             | 1.00             | 1.50             | 1.17             |
| 7.                  | 1.00             | 0.50             | 2.00             | 1.17             |
| 8.                  | 1.00             | 0.75             | 2.00             | 1.25             |
| 9.                  | 2.00             | 0.50             | 1.00             | 1.17             |
| 10.                 | 2.00             | 0.50             | 1.50             | 1.33             |
| 11.                 | 1.00             | 1.00             | 1.50             | 1.17             |
| 12.                 | 3.00             | 1.00             | 1.75             | 1.92             |
| 13.                 | 2.00             | 0.50             | 1.50             | 1.33             |
| 14.                 | 1.00             | 1.00             | 2.00             | 1.33             |
| 15.                 | 1.00             | 1.00             | 1.50             | 1.17             |
| 16.                 | 1.00             | 1.00             | 1.50             | 1.17             |
| 17.                 | 2.00             | 0.50             | 1.50             | 1.30             |
| 18.                 | 2.00             | 0.75             | 1.50             | 1.42             |
| 19.                 | 2.00             | 1.00             | 2.00             | 1.67             |
| 20.                 | 1.00             | 1.50             | 1.50             | 1.33             |
| <b>Minimum</b>      | <b>1.00</b>      | <b>0.50</b>      | <b>1.00</b>      | <b>0.83</b>      |
| <b>Maximum</b>      | <b>3.00</b>      | <b>1.50</b>      | <b>2.00</b>      | <b>1.92</b>      |
| <b>Mean ± S. D.</b> | <b>1.50±0.60</b> | <b>0.80±0.28</b> | <b>1.55±0.31</b> | <b>1.28±0.24</b> |

respectively for female while Sejalina *et. al.*(1993) found this period for male *T. macfarlanei* on okra to be 0.56 and 0.66 day and for female to be 0.57 and 0.50 day at varying room temperature *i.e.*, 23-32 °C and 27.5-31.5 °C, respectively. Shah (2014) also reported this period as  $0.76\pm 0.12$  days for male and  $2.01\pm 0.34$  days for female when reared on gerbera, thus more or less in agreement with present work.

#### 4.1.8 Developmental period:

Developmental period is the period taken for development from egg to emergence of adult. From Table 17 it can be seen that the developmental period of male, *T. urticae* varied from 10.75 to 17.00 days (Av.  $13.65\pm 1.51$  days) during summer, 13.25 to 20.00 days (Av.  $17.71\pm 1.69$  days) during monsoon and 19.50 to 25.50 days (Av.  $23.18\pm 1.70$  days) in winter season. The average total developmental period of *T. urticae* on tomato during three different seasons varied between 14.50 to 20.42 days (Av.  $18.18\pm 1.27$  days). The developmental period for female ranged from 18.00 to 25.00 days (Av.  $20.85\pm 1.80$  days) in summer, 15.50 to 25.50 days (Av.  $20.02\pm 2.09$  days) in monsoon and 25.50 to 33.00 days (Av.  $30.41\pm 1.88$  days) during winter season and the average developmental period for female ranged between 21.25 to 26.58 days (Av.  $23.76\pm 1.30$  days) when reared on tomato under laboratory conditions. Thus, the male adults emerged earlier than the female. It can also be seen from the Table 18 that the time required for the development during winter (lower temperature) was longer as compared to summer and monsoon.

The present findings are in close agreement with earlier work carried out by Jose and Shah (1989) who reported the developmental period (egg to adult emergence) on cotton to be 6.12, 7.67 and 10.90 days at varying room temperature 30-35°C, 28-32°C and 22-29 °C, respectively for male, while it was 7.73, 7.43, 7.42 and 11.81 days at varying room temperature 30-34°C, 30-3°C, 28-32°C and 22-29 °C, respectively for female. Shah (2014) also recorded the total development period of *T. urticae*. In male it varied from 6.90 to 15.60 days (Av. 9.28± 0.73 days) during summer, 9.60 to 14.20 days (Av. 11.61± 1.34 days) during monsoon and 11.40 to 15.80 days (Av. 13.89 days) in winter season and for female ranged from 11.15 to 21.10 days (Av. 14.81± 2.37 days) in summer, 8.49 to 14.14 days (Av. 10.29± 1.19 days) in monsoon and 26.00 to 45.20 days (Av. 32.13±4.40 days) during winter season when reared on gerbera at room temperature. Thus, present finding are in close agreement with earlier reports.

#### **4.1.9 Adult period:**

The newly emerged male was light green in colour which later on turned to pinkish. Whereas the newly emerged female was bright red in colour which later changed to dark red. Thus, the male and female could be easily distinguish from each other on the basis of the body colour. The female was oblong with rounded abdomen (Plate 3), whereas the male was oval with distinctly pointed abdomen (Plate 3).

Data on measurement of adult clearly indicated that the length of the male varied from 0.34 to 0.46 mm (Av. 0.39± 0.03 mm), while the breadth varied from 0.16 to 0.18 mm (Av.

**Table 17:-Developmental period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer            | Monsoon           | Winter            | Average           |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 10.75             | 13.25             | 19.50             | 14.50             |
| 2.                  | 12.75             | 15.50             | 22.25             | 16.83             |
| 3.                  | 13.25             | 17.25             | 20.75             | 17.08             |
| 4.                  | 14.50             | 18.25             | 20.50             | 17.75             |
| 5.                  | 12.75             | 15.00             | 24.75             | 17.50             |
| 6.                  | 15.50             | 18.50             | 24.75             | 19.58             |
| 7.                  | 13.25             | 17.25             | 23.75             | 18.08             |
| 8.                  | 15.25             | 18.00             | 24.25             | 19.17             |
| 9.                  | 14.00             | 17.25             | 21.00             | 17.42             |
| 10.                 | 13.75             | 18.25             | 23.50             | 18.50             |
| 11.                 | 11.00             | 18.75             | 24.45             | 18.07             |
| 12.                 | 14.75             | 19.00             | 24.00             | 19.25             |
| 13.                 | 17.00             | 20.00             | 24.25             | 20.42             |
| 14.                 | 13.00             | 20.00             | 24.00             | 19.00             |
| 15.                 | 13.75             | 18.50             | 25.50             | 19.25             |
| 16.                 | 13.00             | 18.00             | 23.50             | 18.17             |
| 17.                 | 15.50             | 18.00             | 22.25             | 18.58             |
| 18.                 | 12.25             | 16.25             | 22.50             | 17.00             |
| 19.                 | 13.00             | 17.50             | 25.50             | 18.67             |
| 20.                 | 14.00             | 19.75             | 22.75             | 18.83             |
| <b>Minimum</b>      | <b>10.75</b>      | <b>13.25</b>      | <b>19.50</b>      | <b>14.50</b>      |
| <b>Maximum</b>      | <b>17.00</b>      | <b>20.00</b>      | <b>25.50</b>      | <b>20.42</b>      |
| <b>Mean ± S. D.</b> | <b>13.65±1.51</b> | <b>17.71±1.69</b> | <b>23.18±1.70</b> | <b>18.18±1.27</b> |

**Table 18:-Total developmental period of female *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer            | Monsoon           | Winter            | Average           |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 19.00             | 15.50             | 29.25             | 21.25             |
| 2.                  | 20.00             | 21.50             | 25.50             | 22.33             |
| 3.                  | 20.00             | 18.00             | 29.00             | 22.33             |
| 4.                  | 20.00             | 20.00             | 31.00             | 23.67             |
| 5.                  | 18.25             | 18.50             | 32.75             | 23.17             |
| 6.                  | 18.00             | 20.50             | 30.50             | 23.00             |
| 7.                  | 19.00             | 20.50             | 28.50             | 22.67             |
| 8.                  | 23.00             | 19.75             | 33.00             | 25.25             |
| 9.                  | 21.75             | 19.25             | 31.00             | 24.00             |
| 10.                 | 21.00             | 20.50             | 32.50             | 24.67             |
| 11.                 | 21.00             | 25.00             | 28.50             | 24.83             |
| 12.                 | 25.00             | 23.00             | 31.75             | 26.58             |
| 13.                 | 22.00             | 19.50             | 31.00             | 24.17             |
| 14.                 | 20.75             | 22.00             | 32.50             | 25.08             |
| 15.                 | 20.00             | 21.00             | 30.50             | 23.83             |
| 16.                 | 20.00             | 17.00             | 28.50             | 21.83             |
| 17.                 | 22.00             | 18.50             | 32.50             | 24.33             |
| 18.                 | 23.25             | 21.25             | 30.00             | 24.83             |
| 19.                 | 23.00             | 19.00             | 30.50             | 24.17             |
| 20.                 | 20.00             | 20.25             | 29.50             | 23.25             |
| <b>Minimum</b>      | <b>18.00</b>      | <b>15.50</b>      | <b>25.50</b>      | <b>21.25</b>      |
| <b>Maximum</b>      | <b>25.00</b>      | <b>25.00</b>      | <b>33.00</b>      | <b>26.58</b>      |
| <b>Mean ± S. D.</b> | <b>20.85±1.80</b> | <b>20.02±2.09</b> | <b>30.41±1.88</b> | <b>23.76±1.30</b> |

0.16± 0.01 mm) (Table 2). The length of female varied from 0.44 to 0.48 mm (Av. 0.46±0.01), while the breadth varied from 0.18 to 0.22 mm (Av. 0.20±0.01 mm). Thus, female was bigger than male. The present findings are tally with the reports of Jose and Shah (1989) and Sejalina *et al.* (1993), who reported that the male of spider mite was slightly smaller than the female.

The adult period of male varied from 10.00 to 13.00 days (Av. 11.05±0.94 days), 9.00 to 14.00 days (Av. 12.10±1.41 days) and 10.00 to 15.00 days (Av. 12.75±1.77 days). The average adult period of three seasons for male varied from 10.00 to 13.67 days (Av. 11.96±0.97) (Table 19). The adult period for unmated females varied from 11.00 to 17.00 days (Av. 14.50±1.50 days) during summer, 14.00 to 21.00 days (Av. 16.60±1.66 days) during monsoon, 14.00 to 21.00 days (Av. 17.20±1.93 days) during winter and with an average period ranged between 14.00 to 19.33 days (Av. 16.09±1.15 days) (Table 20). The same period for mated female varied from 9.00 to 22.00 days (Av. 17.50±3.13 days), 14.00 to 24.00 days (Av. 21.05± 2.50 days) and 18.00 to 26.00 days (Av. 22.20±1.96) during summer, monsoon and winter season with an average of 13.67 to 22.67 days (Av. 20.24±2.11 days) (Table 21). Thus, in both the cases, *i.e.* unmated or mated, the female lived longer than the male. Further, it can also be seen from data that the unmated females lived longer than the mated ones.

The present findings on longevity of adult were more or less close to the findings of Jose and Shah (1989) who reported longer longevity of female than the male on

**Table 19:-Total adult period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer            | Monsoon           | Winter            | Average           |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 11.00             | 9.00              | 10.00             | 10.00             |
| 2.                  | 10.00             | 12.00             | 11.00             | 11.00             |
| 3.                  | 11.00             | 12.00             | 11.00             | 11.33             |
| 4.                  | 10.00             | 13.00             | 14.00             | 12.33             |
| 5.                  | 10.00             | 13.00             | 12.00             | 11.67             |
| 6.                  | 13.00             | 9.00              | 11.00             | 11.00             |
| 7.                  | 10.00             | 11.00             | 10.00             | 10.33             |
| 8.                  | 11.00             | 11.00             | 11.00             | 11.00             |
| 9.                  | 11.00             | 11.00             | 12.00             | 11.33             |
| 10.                 | 13.00             | 12.00             | 13.00             | 12.67             |
| 11.                 | 12.00             | 14.00             | 11.00             | 12.33             |
| 12.                 | 11.00             | 14.00             | 13.00             | 12.67             |
| 13.                 | 11.00             | 13.00             | 14.00             | 12.67             |
| 14.                 | 10.00             | 12.00             | 15.00             | 12.33             |
| 15.                 | 10.00             | 12.00             | 14.00             | 12.00             |
| 16.                 | 11.00             | 12.00             | 14.00             | 12.33             |
| 17.                 | 12.00             | 13.00             | 15.00             | 13.33             |
| 18.                 | 11.00             | 12.00             | 15.00             | 12.67             |
| 19.                 | 11.00             | 13.00             | 14.00             | 12.67             |
| 20.                 | 12.00             | 14.00             | 15.00             | 13.67             |
| <b>Minimum</b>      | <b>10.00</b>      | <b>9.00</b>       | <b>10.00</b>      | <b>10.00</b>      |
| <b>Maximum</b>      | <b>13.00</b>      | <b>14.00</b>      | <b>15.00</b>      | <b>13.67</b>      |
| <b>Mean ± S. D.</b> | <b>11.05±0.94</b> | <b>12.10±1.41</b> | <b>12.75±1.77</b> | <b>11.96±0.97</b> |

**Table 20:-Adult period of unmated female *T. urticae* under laboratory condition (Days)**

| Sr. No.                           | Summer                           | Monsoon                          | Winter                           | Average                          |
|-----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 1.                                | 15.00                            | 16.00                            | 15.00                            | 13.67                            |
| 2.                                | 11.00                            | 16.00                            | 16.00                            | 18.00                            |
| 3.                                | 14.00                            | 19.00                            | 16.00                            | 16.33                            |
| 4.                                | 16.00                            | 21.00                            | 21.00                            | 19.33                            |
| 5.                                | 16.00                            | 16.00                            | 17.00                            | 20.33                            |
| 6.                                | 15.00                            | 15.00                            | 19.00                            | 20.33                            |
| 7.                                | 15.00                            | 14.00                            | 19.00                            | 20.33                            |
| 8.                                | 13.00                            | 16.00                            | 20.00                            | 20.33                            |
| 9.                                | 15.00                            | 16.00                            | 15.00                            | 21.00                            |
| 10.                               | 12.00                            | 17.00                            | 16.00                            | 21.00                            |
| 11.                               | 14.00                            | 17.00                            | 16.00                            | 20.33                            |
| 12.                               | 15.00                            | 19.00                            | 19.00                            | 20.67                            |
| 13.                               | 14.00                            | 16.00                            | 19.00                            | 21.00                            |
| 14.                               | 15.00                            | 17.00                            | 17.00                            | 21.00                            |
| 15.                               | 14.00                            | 15.00                            | 19.00                            | 22.33                            |
| 16.                               | 14.00                            | 15.00                            | 18.00                            | 21.33                            |
| 17.                               | 17.00                            | 17.00                            | 17.00                            | 21.67                            |
| 18.                               | 17.00                            | 18.00                            | 16.00                            | 22.33                            |
| 19.                               | 13.00                            | 15.00                            | 14.00                            | 21.00                            |
| 20.                               | 15.00                            | 17.00                            | 15.00                            | 22.67                            |
| <b>Minimum</b>                    | <b>11.00</b>                     | <b>14.00</b>                     | <b>14.00</b>                     | <b>14.00</b>                     |
| <b>Maximum</b>                    | <b>17.00</b>                     | <b>21.00</b>                     | <b>21.00</b>                     | <b>19.33</b>                     |
| <b>Mean <math>\pm</math> S.D.</b> | <b>14.50<math>\pm</math>1.50</b> | <b>16.60<math>\pm</math>1.66</b> | <b>17.20<math>\pm</math>1.93</b> | <b>16.09<math>\pm</math>1.15</b> |

**Table 21:-Adult period of mated female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>     | <b>Monsoon</b>    | <b>Winter</b>     | <b>Average</b>    |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 9.00              | 14.00             | 18.00             | 15.33             |
| 2.                  | 12.00             | 21.00             | 21.00             | 14.33             |
| 3.                  | 12.00             | 18.00             | 19.00             | 16.33             |
| 4.                  | 17.00             | 19.00             | 22.00             | 19.33             |
| 5.                  | 18.00             | 22.00             | 21.00             | 16.33             |
| 6.                  | 18.00             | 21.00             | 22.00             | 16.33             |
| 7.                  | 18.00             | 21.00             | 22.00             | 16.00             |
| 8.                  | 17.00             | 21.00             | 23.00             | 16.33             |
| 9.                  | 17.00             | 21.00             | 25.00             | 15.33             |
| 10.                 | 19.00             | 19.00             | 25.00             | 15.00             |
| 11.                 | 19.00             | 18.00             | 24.00             | 15.67             |
| 12.                 | 19.00             | 22.00             | 21.00             | 17.67             |
| 13.                 | 20.00             | 21.00             | 22.00             | 16.33             |
| 14.                 | 20.00             | 22.00             | 21.00             | 16.33             |
| 15.                 | 22.00             | 24.00             | 21.00             | 16.00             |
| 16.                 | 18.00             | 24.00             | 22.00             | 15.67             |
| 17.                 | 18.00             | 23.00             | 24.00             | 17.00             |
| 18.                 | 21.00             | 24.00             | 22.00             | 17.00             |
| 19.                 | 18.00             | 22.00             | 23.00             | 14.00             |
| 20.                 | 18.00             | 24.00             | 26.00             | 15.67             |
| <b>Minimum</b>      | <b>9.00</b>       | <b>14.00</b>      | <b>18.00</b>      | <b>13.67</b>      |
| <b>Maximum</b>      | <b>22.00</b>      | <b>24.00</b>      | <b>26.00</b>      | <b>22.67</b>      |
| <b>Mean ± S. D.</b> | <b>17.50±3.13</b> | <b>21.05±2.50</b> | <b>22.20±1.96</b> | <b>20.24±2.11</b> |



**Plate 3 : Adult two spotted spider mite, *T. urticae***

cotton. Sejalina *et al.* (1993) also reported longer longevity of female than the male when reared on okra. Likewise Shah (2014) also recorded that the female live longer than males when reared on gerbera under laboratory conditions. Thus, more or less similar to the present findings.

#### **4.1.10 Sexual behaviour:**

Mating between male and female usually took place soon after emergence from last moult. Males usually emerged a little earlier than the females and were observed to move and waiting nearby quiescent deutonymph from which females were emerged. Sometimes three or four females were observed waiting nearby one female deutonymph. The males were often observed assisting the female in making itself free from the exuvium. To copulate with the female, the male crawled underneath the female from behind and joined its aedeagus to genital opening of the female by bending its opisthosoma upward, remaining underneath the female with two pairs of extended forelegs raised interiorly upward. Mating lasted from 1 to 5 minutes. The same type of mating behaviour and mating time were reported in past by Jose and Shah (1989), Sejalina *et al.* and Shah (2014).

#### **4.1.11 Oviposition:**

The adult period of female *T.urticae* when reared on tomato comprises of three demarkable periods *viz.*, preoviposition, oviposition and post oviposition period.

The female laid eggs after a lapse of certain time was mentioned as preoviposition period. This period was 3.00 to 7.00 days (Av.  $4.90 \pm 1.07$  days), 5.00 to 7.00 days (Av.  $5.65 \pm 0.74$  days) and 4.00 to 8.00 days (Av.  $5.70 \pm 0.97$  days)

with a yearly average of 4.00 to 6.67 days (Av.  $5.41 \pm 0.63$  days) for unmated female, while in case of mated female, this period varied from 2.00 to 5.00 days (Av.  $3.85 \pm 1.08$  days), 2.00 to 6.00 days (Av.  $4.45 \pm 0.82$  days), and 4.00 to 7.00 days (Av.  $5.50 \pm 0.88$  days) during summer, monsoon and winter, respectively with an average preoviposition period ranged between 2.67 to 5.33 days (Av.  $4.60 \pm 0.67$  days). Thus, the preoviposition period was shorter when the females were not mated with the males. Under the present study it was also found that the preoviposition period was longer in winter (low temperature) as compared to summer and monsoon seasons with higher temperature.

Jose and Shah (1989) reported preoviposition period of *T. macfarlanei* on cotton to be  $1.20 \pm 0.62$ ,  $0.24 \pm 0.44$ ,  $0.93 \pm 0.13$  and  $1.51 \pm 0.45$  days at temperature ranging from 30-32°C, 30-35°C, 28-32°C and 22-29°C, respectively. Further, Sejalina *et al.* (1993) reported that this period on okra was  $1.24 \pm 0.39$  and  $0.71 \pm 0.15$  days for unmated female of *T. macfarlanei* at temperature ranging from 23-32°C and 27.5-31.5°C, respectively and in case of mated female, it was  $1.83 \pm 0.75$  days at varying room temperature 27.5 to 31.5°C. Recently, Shah (2014) recorded that the preoviposition period for unmated female was 5.86 days while for mated female it was 3.15 days, respectively when *T. urticae* reared on gerbera under laboratory. Thus, these reports are more or less in concurrence with present findings.

The period of egg laying *i.e.* after the preoviposition till the termination of egg laying was considered as oviposition period. It can be seen from the

Table 24 that the oviposition period lasted for 5.00 to 8.00 days (Av.  $6.30 \pm 1.03$  days), 5.00 to 10.00 days (Av.  $6.65 \pm 1.34$  days) and 5.00 to 10.00 days (Av.  $7.30 \pm 1.52$  days) during summer, monsoon and winter season, respectively for virgin female, with the average oviposition period ranged between 5.33 to 9.00 days (Av.  $6.75 \pm 0.87$  days), while in case of mated female, it was 4.00 to 11.00 days (Av.  $8.65 \pm 2.34$  days), 7.00 to 12.00 days (Av.  $10.40 \pm 1.63$  days) and 8.00 to 12.00 days (Av.  $10.70 \pm 1.12$  days) in summer, monsoon and winter season respectively with the yearly average oviposition period of the ranged between 6.33 to 11.33 days (Av.  $9.91 \pm 1.29$  days). Similar oviposition period were recorded by Shah (2014) in case of *T. urticae* when reared on gerbera as well as in past by Sejalina *et al.* (1993) on okra for *T. macfarlanei*.

The period between last egg laid and death of the female adult was considered as post oviposition period. The post oviposition period for virgin female varied from 2.00 to 4.00 days (Av.  $3.30 \pm 0.86$  days), 3.00 to 5.00 days (Av.  $4.30 \pm 0.57$  days) and 3.00 to 5.00 days (Av.  $4.15 \pm 0.67$  days) during summer, monsoon and winter season, respectively (Table 26). The average post oviposition period for unmated female was ranged between 3.33 to 4.67 days (Av.  $3.91 \pm 0.45$  days). In case of mated female, it was varied from 3.00 to 6.00 days (Av.  $5.00 \pm 0.85$  days) in summer, 5.00 to 8.00 days (Av.  $6.20 \pm 1.05$  days) in monsoon and 5.00 to 8.00 days (Av.  $6.00 \pm 0.97$  days) in winter under laboratory condition on tomato. The average post oviposition period for mated female ranged between 4.67 to 7.00 days (Av.  $5.73 \pm 0.64$  days) (Table 27). The present findings are in accordance with the earlier work

**Table 22:-Pre-oviposition period of unmated female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 5.00             | 4.00             | 2.67             |
| 2.                  | 4.00             | 6.00             | 6.00             | 4.00             |
| 3.                  | 4.00             | 5.00             | 5.00             | 4.00             |
| 4.                  | 6.00             | 7.00             | 6.00             | 5.00             |
| 5.                  | 7.00             | 6.00             | 7.00             | 3.67             |
| 6.                  | 4.00             | 5.00             | 7.00             | 4.00             |
| 7.                  | 5.00             | 5.00             | 6.00             | 5.33             |
| 8.                  | 4.00             | 5.00             | 8.00             | 5.33             |
| 9.                  | 5.00             | 6.00             | 4.00             | 5.00             |
| 10.                 | 4.00             | 7.00             | 6.00             | 5.00             |
| 11.                 | 4.00             | 5.00             | 5.00             | 5.33             |
| 12.                 | 5.00             | 6.00             | 6.00             | 5.00             |
| 13.                 | 6.00             | 6.00             | 6.00             | 4.33             |
| 14.                 | 6.00             | 6.00             | 5.00             | 4.67             |
| 15.                 | 4.00             | 5.00             | 5.00             | 5.33             |
| 16.                 | 4.00             | 5.00             | 6.00             | 4.67             |
| 17.                 | 6.00             | 6.00             | 6.00             | 5.00             |
| 18.                 | 6.00             | 7.00             | 5.00             | 4.67             |
| 19.                 | 6.00             | 5.00             | 5.00             | 4.33             |
| 20.                 | 5.00             | 5.00             | 6.00             | 4.67             |
| <b>Minimum</b>      | <b>3.00</b>      | <b>5.00</b>      | <b>4.00</b>      | <b>4.00</b>      |
| <b>Maximum</b>      | <b>7.00</b>      | <b>7.00</b>      | <b>8.00</b>      | <b>6.67</b>      |
| <b>Mean ± S. D.</b> | <b>4.90±1.07</b> | <b>5.65±0.74</b> | <b>5.70±0.97</b> | <b>5.41±0.63</b> |

**Table 23:-Pre oviposition Period of mated female *T.urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 2.00             | 2.00             | 4.00             | 4.00             |
| 2.                  | 2.00             | 4.00             | 6.00             | 5.33             |
| 3.                  | 4.00             | 4.00             | 4.00             | 4.67             |
| 4.                  | 5.00             | 5.00             | 5.00             | 6.33             |
| 5.                  | 2.00             | 4.00             | 5.00             | 6.67             |
| 6.                  | 2.00             | 4.00             | 6.00             | 5.33             |
| 7.                  | 4.00             | 5.00             | 7.00             | 5.33             |
| 8.                  | 5.00             | 5.00             | 6.00             | 5.67             |
| 9.                  | 5.00             | 4.00             | 6.00             | 5.00             |
| 10.                 | 4.00             | 5.00             | 6.00             | 5.67             |
| 11.                 | 4.00             | 5.00             | 7.00             | 4.67             |
| 12.                 | 4.00             | 6.00             | 5.00             | 5.67             |
| 13.                 | 5.00             | 4.00             | 4.00             | 6.00             |
| 14.                 | 5.00             | 4.00             | 5.00             | 5.67             |
| 15.                 | 5.00             | 5.00             | 6.00             | 4.67             |
| 16.                 | 4.00             | 5.00             | 5.00             | 5.00             |
| 17.                 | 4.00             | 5.00             | 6.00             | 6.00             |
| 18.                 | 4.00             | 5.00             | 5.00             | 6.00             |
| 19.                 | 3.00             | 4.00             | 6.00             | 5.33             |
| 20.                 | 4.00             | 4.00             | 6.00             | 5.33             |
| <b>Minimum</b>      | <b>2.00</b>      | <b>2.00</b>      | <b>4.00</b>      | <b>2.67</b>      |
| <b>Maximum</b>      | <b>5.00</b>      | <b>6.00</b>      | <b>7.00</b>      | <b>5.33</b>      |
| <b>Mean ± S. D.</b> | <b>3.85±1.08</b> | <b>4.45±0.82</b> | <b>5.50±0.88</b> | <b>4.60±0.67</b> |

**Table 24:-Oviposition period of unmated female *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 8.00             | 8.00             | 7.00             | 6.33             |
| 2.                  | 5.00             | 6.00             | 6.00             | 9.00             |
| 3.                  | 7.00             | 9.00             | 7.00             | 7.33             |
| 4.                  | 7.00             | 10.00            | 10.00            | 9.00             |
| 5.                  | 6.00             | 6.00             | 6.00             | 10.00            |
| 6.                  | 7.00             | 6.00             | 9.00             | 11.33            |
| 7.                  | 8.00             | 5.00             | 9.00             | 9.33             |
| 8.                  | 5.00             | 6.00             | 8.00             | 9.67             |
| 9.                  | 6.00             | 6.00             | 6.00             | 9.67             |
| 10.                 | 6.00             | 6.00             | 6.00             | 9.67             |
| 11.                 | 6.00             | 8.00             | 8.00             | 9.67             |
| 12.                 | 6.00             | 8.00             | 9.00             | 10.33            |
| 13.                 | 5.00             | 6.00             | 9.00             | 11.00            |
| 14.                 | 5.00             | 6.00             | 8.00             | 11.00            |
| 15.                 | 6.00             | 6.00             | 9.00             | 10.67            |
| 16.                 | 8.00             | 5.00             | 7.00             | 10.33            |
| 17.                 | 7.00             | 6.00             | 6.00             | 10.67            |
| 18.                 | 7.00             | 6.00             | 6.00             | 11.33            |
| 19.                 | 5.00             | 6.00             | 5.00             | 11.00            |
| 20.                 | 6.00             | 8.00             | 5.00             | 11.00            |
| <b>Minimum</b>      | <b>5.00</b>      | <b>5.00</b>      | <b>5.00</b>      | <b>5.33</b>      |
| <b>Maximum</b>      | <b>8.00</b>      | <b>10.00</b>     | <b>10.00</b>     | <b>9.00</b>      |
| <b>Mean ± S. D.</b> | <b>6.30±1.03</b> | <b>6.65±1.34</b> | <b>7.30±1.52</b> | <b>6.75±0.87</b> |

**Table 25:-Oviposition Period of mated female *T.urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>    | <b>Winter</b>     | <b>Average</b>   |
|---------------------|------------------|-------------------|-------------------|------------------|
| 1.                  | 4.00             | 7.00              | 8.00              | 7.67             |
| 2.                  | 5.00             | 12.00             | 10.00             | 5.67             |
| 3.                  | 4.00             | 8.00              | 10.00             | 7.67             |
| 4.                  | 8.00             | 8.00              | 11.00             | 9.00             |
| 5.                  | 10.00            | 11.00             | 9.00              | 6.00             |
| 6.                  | 11.00            | 12.00             | 11.00             | 7.33             |
| 7.                  | 8.00             | 11.00             | 9.00              | 7.33             |
| 8.                  | 7.00             | 11.00             | 11.00             | 6.33             |
| 9.                  | 6.00             | 11.00             | 12.00             | 6.00             |
| 10.                 | 10.00            | 8.00              | 11.00             | 6.00             |
| 11.                 | 11.00            | 8.00              | 10.00             | 7.33             |
| 12.                 | 10.00            | 10.00             | 11.00             | 7.67             |
| 13.                 | 10.00            | 11.00             | 12.00             | 6.67             |
| 14.                 | 10.00            | 12.00             | 11.00             | 6.33             |
| 15.                 | 11.00            | 11.00             | 10.00             | 7.00             |
| 16.                 | 8.00             | 12.00             | 11.00             | 6.67             |
| 17.                 | 9.00             | 11.00             | 12.00             | 6.33             |
| 18.                 | 11.00            | 11.00             | 12.00             | 6.33             |
| 19.                 | 11.00            | 11.00             | 11.00             | 5.33             |
| 20.                 | 9.00             | 12.00             | 12.00             | 6.33             |
| <b>Minimum</b>      | <b>4.00</b>      | <b>7.00</b>       | <b>8.00</b>       | <b>6.33</b>      |
| <b>Maximum</b>      | <b>11.00</b>     | <b>12.00</b>      | <b>12.00</b>      | <b>11.33</b>     |
| <b>Mean ± S. D.</b> | <b>8.65±2.34</b> | <b>10.40±1.63</b> | <b>10.70±1.12</b> | <b>9.91±1.29</b> |

**Table 26:-Post oviposition period of unmated female *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer           | Monsoon          | Winter           | Average          |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 4.00             | 3.00             | 3.00             | 4.67             |
| 2.                  | 2.00             | 4.00             | 4.00             | 5.00             |
| 3.                  | 3.00             | 5.00             | 4.00             | 5.00             |
| 4.                  | 3.00             | 4.00             | 5.00             | 5.33             |
| 5.                  | 3.00             | 4.00             | 4.00             | 6.67             |
| 6.                  | 4.00             | 4.00             | 3.00             | 5.00             |
| 7.                  | 2.00             | 4.00             | 4.00             | 5.67             |
| 8.                  | 4.00             | 5.00             | 4.00             | 5.33             |
| 9.                  | 4.00             | 4.00             | 5.00             | 6.33             |
| 10.                 | 2.00             | 4.00             | 4.00             | 6.33             |
| 11.                 | 4.00             | 4.00             | 3.00             | 5.33             |
| 12.                 | 4.00             | 5.00             | 4.00             | 5.33             |
| 13.                 | 3.00             | 4.00             | 4.00             | 5.67             |
| 14.                 | 4.00             | 5.00             | 4.00             | 5.33             |
| 15.                 | 4.00             | 4.00             | 5.00             | 6.33             |
| 16.                 | 2.00             | 5.00             | 5.00             | 6.33             |
| 17.                 | 4.00             | 5.00             | 5.00             | 6.00             |
| 18.                 | 4.00             | 5.00             | 5.00             | 6.33             |
| 19.                 | 2.00             | 4.00             | 4.00             | 5.67             |
| 20.                 | 4.00             | 4.00             | 4.00             | 7.00             |
| <b>Minimum</b>      | <b>2.00</b>      | <b>3.00</b>      | <b>3.00</b>      | <b>3.33</b>      |
| <b>Maximum</b>      | <b>4.00</b>      | <b>5.00</b>      | <b>5.00</b>      | <b>4.67</b>      |
| <b>Mean ± S. D.</b> | <b>3.30±0.86</b> | <b>4.30±0.57</b> | <b>4.15±0.67</b> | <b>3.91±0.45</b> |

**Table 27:-Post oviposition period of mated female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>    | <b>Monsoon</b>   | <b>Winter</b>    | <b>Average</b>   |
|---------------------|------------------|------------------|------------------|------------------|
| 1.                  | 3.00             | 5.00             | 6.00             | 3.33             |
| 2.                  | 5.00             | 5.00             | 5.00             | 3.33             |
| 3.                  | 4.00             | 6.00             | 5.00             | 4.00             |
| 4.                  | 4.00             | 6.00             | 6.00             | 4.00             |
| 5.                  | 6.00             | 7.00             | 7.00             | 3.67             |
| 6.                  | 5.00             | 5.00             | 5.00             | 3.67             |
| 7.                  | 6.00             | 5.00             | 6.00             | 3.33             |
| 8.                  | 5.00             | 5.00             | 6.00             | 4.33             |
| 9.                  | 6.00             | 6.00             | 7.00             | 4.33             |
| 10.                 | 5.00             | 6.00             | 8.00             | 3.33             |
| 11.                 | 4.00             | 5.00             | 7.00             | 3.67             |
| 12.                 | 5.00             | 6.00             | 5.00             | 4.33             |
| 13.                 | 5.00             | 6.00             | 6.00             | 3.67             |
| 14.                 | 5.00             | 6.00             | 5.00             | 4.33             |
| 15.                 | 6.00             | 8.00             | 5.00             | 4.33             |
| 16.                 | 6.00             | 7.00             | 6.00             | 4.00             |
| 17.                 | 5.00             | 7.00             | 6.00             | 4.67             |
| 18.                 | 6.00             | 8.00             | 5.00             | 4.67             |
| 19.                 | 4.00             | 7.00             | 6.00             | 3.33             |
| 20.                 | 5.00             | 8.00             | 8.00             | 4.00             |
| <b>Minimum</b>      | <b>3.00</b>      | <b>5.00</b>      | <b>5.00</b>      | <b>4.67</b>      |
| <b>Maximum</b>      | <b>6.00</b>      | <b>8.00</b>      | <b>8.00</b>      | <b>7.00</b>      |
| <b>Mean ± S. D.</b> | <b>5.00±0.85</b> | <b>6.20±1.05</b> | <b>6.00±0.97</b> | <b>5.73±0.64</b> |



Plate 4 : Tomato leaves affected by *T. urticae*

of Shah (2014) who found post oviposition period of unmated *T. urticae* as 6.02 days and 6.81 days for mated females when reared on gerbera, thus more or less similar to the present findings. Further, Sejalina *et al.* (1993) and Bhanderi (1991) also reported similar trends in case of *T. macfarlanei* on okra under laboratory conditions.

#### **4.1.12 Fecundity:**

Data presented in Table 28 indicated the rate of egg laying per female per day. For unmated female it varied from 17.00 to 42.00 eggs (Av.  $33.40 \pm 7.98$  eggs) during summer, 20.00 to 46.00 eggs (Av.  $32.90 \pm 7.88$  eggs) during monsoon and 11.00 to 38.00 eggs (Av.  $26.00 \pm 6.66$  eggs) during winter season with an annual average varied from 19.00 to 39.67 eggs (Av.  $30.76 \pm 5.56$  eggs). In case of mated females, it was varied from 53.00 to 89.00 eggs (Av.  $66.40 \pm 10.47$  eggs), 87.00 to 128.00 eggs (Av.  $105.90 \pm 11.79$  eggs), 74.00 to 104.00 eggs (Av.  $89.65 \pm 9.99$  eggs) during summer, monsoon and winter, respectively. The average fecundity per female varied between 77.67 to 96.67 (Av.  $87.31 \pm 4.96$  eggs) (Table 29). Thus, higher fecundity was observed in case of mated females as compared to unmated females. Fecundity was also higher during summer season having higher temperature, while lower during winter and monsoon. The present findings more or less similar with those of Shah (2014) who recorded fecundity of *T. urticae* as 25.77 for unmated females and 64.50 for mated females on gerbera. Thus, more or less similar to the present findings.

#### **4.1.13 Sex ratio:**

Mated female produced progeny consisting of both the sexes, whereas unmated females invariably gave rise to

**Table 28:-Fecundity of unmated female *T. urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>     | <b>Monsoon</b>    | <b>Winter</b>     | <b>Average</b>    |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 17.00             | 20.00             | 20.00             | 19.00             |
| 2.                  | 20.00             | 20.00             | 22.00             | 20.67             |
| 3.                  | 18.00             | 22.00             | 18.00             | 19.33             |
| 4.                  | 24.00             | 46.00             | 11.00             | 27.00             |
| 5.                  | 30.00             | 41.00             | 19.00             | 30.00             |
| 6.                  | 34.00             | 42.00             | 22.00             | 32.67             |
| 7.                  | 36.00             | 40.00             | 24.00             | 33.33             |
| 8.                  | 35.00             | 40.00             | 20.00             | 31.67             |
| 9.                  | 41.00             | 40.00             | 24.00             | 35.00             |
| 10.                 | 41.00             | 22.00             | 26.00             | 29.67             |
| 11.                 | 36.00             | 25.00             | 30.00             | 30.33             |
| 12.                 | 30.00             | 27.00             | 32.00             | 29.67             |
| 13.                 | 32.00             | 30.00             | 30.00             | 30.67             |
| 14.                 | 33.00             | 33.00             | 28.00             | 31.33             |
| 15.                 | 40.00             | 35.00             | 26.00             | 33.67             |
| 16.                 | 39.00             | 35.00             | 33.00             | 35.67             |
| 17.                 | 41.00             | 37.00             | 38.00             | 38.67             |
| 18.                 | 39.00             | 35.00             | 34.00             | 36.00             |
| 19.                 | 42.00             | 35.00             | 33.00             | 36.67             |
| 20.                 | 40.00             | 33.00             | 30.00             | 34.33             |
| <b>Minimum</b>      | <b>17.00</b>      | <b>20.00</b>      | <b>11.00</b>      | <b>19.00</b>      |
| <b>Maximum</b>      | <b>42.00</b>      | <b>46.00</b>      | <b>38.00</b>      | <b>39.67</b>      |
| <b>Mean ± S. D.</b> | <b>33.40±7.98</b> | <b>32.90±7.88</b> | <b>26.00±6.66</b> | <b>30.76±5.56</b> |

**Table 29:-Fecundity of mated female *T. urticae* under laboratory condition (Days)**

| Sr. No.             | Summer             | Monsoon             | Winter            | Average           |
|---------------------|--------------------|---------------------|-------------------|-------------------|
| 1.                  | 89.00              | 92.00               | 100.00            | 19.00             |
| 2.                  | 80.00              | 90.00               | 78.00             | 20.67             |
| 3.                  | 53.00              | 87.00               | 93.00             | 19.33             |
| 4.                  | 58.00              | 120.00              | 93.00             | 27.00             |
| 5.                  | 54.00              | 111.00              | 79.00             | 30.00             |
| 6.                  | 56.00              | 121.00              | 83.00             | 32.67             |
| 7.                  | 78.00              | 102.00              | 74.00             | 33.33             |
| 8.                  | 70.00              | 100.00              | 101.00            | 31.67             |
| 9.                  | 73.00              | 98.00               | 104.00            | 35.00             |
| 10.                 | 78.00              | 90.00               | 84.00             | 29.67             |
| 11.                 | 68.00              | 113.00              | 80.00             | 30.33             |
| 12.                 | 63.00              | 110.00              | 93.00             | 29.67             |
| 13.                 | 60.00              | 105.00              | 90.00             | 30.67             |
| 14.                 | 53.00              | 105.00              | 79.00             | 31.33             |
| 15.                 | 68.00              | 110.00              | 100.00            | 33.67             |
| 16.                 | 66.00              | 100.00              | 104.00            | 35.67             |
| 17.                 | 57.00              | 128.00              | 90.00             | 38.67             |
| 18.                 | 61.00              | 121.00              | 75.00             | 36.00             |
| 19.                 | 63.00              | 98.00               | 100.00            | 36.67             |
| 20.                 | 80.00              | 117.00              | 93.00             | 34.33             |
| <b>Minimum</b>      | <b>53.00</b>       | <b>87.00</b>        | <b>74.00</b>      | <b>77.67</b>      |
| <b>Maximum</b>      | <b>89.00</b>       | <b>128.00</b>       | <b>104.00</b>     | <b>96.67</b>      |
| <b>Mean ± S. D.</b> | <b>66.40±10.47</b> | <b>105.90±11.79</b> | <b>89.65±9.99</b> | <b>87.31±4.96</b> |

male progeny. Thus, the spider mite reproduce bisexually and parthenogenetically.

#### **4.1.13.1 Bisexual reproduction:**

The male to female ratio of bisexual reproduction of *T. urticae* was worked out as 1: 2.33 (70 per cent females), 1: 2.57 (72 per cent females) and 1: 2.57 (72.00 per cent females) during summer, monsoon and winter season, respectively. The average sex ratio of these three seasons *T. urticae* was 1: 2.48 (71.32 per cent females) was recorded during the period of investigations (Table-30).

#### **4.1.13.2 Parthenogenetical reproduction:**

The sex ratio of parthenogenetically reproduced population was found to be 100 per cent male (Table-30). Thus, in bisexual reproduction, the females outnumbered the males without any marked effect of season (temperature and relative humidity) on sex ratio. According to Jose (1983), the male to female ratio of bisexual reproduction of *T. macfarlanei* on cotton was 1: 2.75(73.33 per cent females). Jose (1983) and Sejalina *et al.* (1993) found cent percent male in case of parthenogenetically reproduced population. Thus, present findings are closely agreed with the reports of above workers.

#### **4.1.14 Total life cycle:**

The total life period occupied by unmated female *T. urticae* varied from 21.75 to 29.00 (Av. 25.07±2.12 days) during summer, 22.25 to 33.75 days (Av. 30.01±2.65 days) during monsoon and 29.50 to 39.50 days (35.93± 2.66 days) during winter with overall average ranged between 24.50 to 33.08 days (Av. 30.34± 1.99 days) when reared on tomato

Table 30:- Sex ratio of *T. urticae* reared on tomato under laboratory**Summer**

| Sr. No. | Spider mite        | Total Observed | Male  | Female | Ratio (M:F) | Percentage  |
|---------|--------------------|----------------|-------|--------|-------------|-------------|
| 1       | Bi-sexual          | 50.00          | 14.00 | 36.00  | 1.00:2.57   | 38.00:72.00 |
| 2       | Partheno-genetical | 50.00          | 50.00 | -      | -           | 100:00      |

**Monsoon**

| Sr. No. | Spider mite        | Total Observed | Male  | Female | Ratio (M:F) | Percentage  |
|---------|--------------------|----------------|-------|--------|-------------|-------------|
| 1       | Bi-sexual          | 50.00          | 12.00 | 38.00  | 1.00:3.16   | 24.00:76.00 |
| 2       | Partheno-genetical | 50.00          | 50.00 | -      | -           | 100:00      |

**Winter**

| Sr. No. | Spider mite        | Total Observed | Male  | Female | Ratio (M:F) | Percentage  |
|---------|--------------------|----------------|-------|--------|-------------|-------------|
| 1       | Bi-sexual          | 50.00          | 13.00 | 37.00  | 1.00:2.84   | 26.00:74.00 |
| 2       | Partheno-genetical | 50.00          | 50.00 | -      | -           | 100:00      |

**Average**

| Sr. No. | Spider mite        | Total Observed | Male  | Female | Ratio (M:F) | Percentage   |
|---------|--------------------|----------------|-------|--------|-------------|--------------|
| 1       | Bi-sexual          | 50.00          | 13.00 | 37.00  | 1.00: 2.85  | 26.00: 74.00 |
| 2       | Partheno-genetical | 50.00          | 50.00 | -      | -           | 100.00       |

under laboratory conditions (Table 31). The total life cycle of mated female ranged between 31.00 to 40.25 days (Av.  $35.35 \pm 2.33$  days) in summer, 31.00 to 42.00 days (Av.  $36.60 \pm 2.96$  days) in monsoon and 41.50 to 53.00 days (Av.  $47.61 \pm 3.03$  days) in winter under laboratory conditions with an overall average of 36.42 to 44.25 days (Av.  $39.85 \pm 2.00$  days) (Table 32). While, the total life cycle for male completed in 28.00 to 44.00 days (Av.  $38.33 \pm 4.07$  days) in summer, 29.50 to 45.25 days (Av.  $41.07 \pm 3.56$  days) in monsoon and 46.50 to 57.50 days (Av.  $52.61 \pm 3.00$  days) during winter season with an average of 34.92 to 47.25 days (Av.  $44.00 \pm 3.03$  days) (Table 33). In past, Shah (2014) also reported more or less similar life cycle and periods of *T. urticae* reared on gerbera under laboratory in different seasons viz., summer, winter and monsoon. More or less support present research work.

#### **4.1.15 Impact of webbing:**

Impact of webbing on oviposition of *T. urticae* was studied in laboratory at an average temperature  $31.6^{\circ}\text{C}$  and average relative humidity 78 per cent during 2014. From the Table 34, it can be seen that the rate of egg laying was less in the beginning which increased gradually and reached to its peak on 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> days of oviposition with webbing (Avg. 4.0 eggs), while in without webbing (removal of webs), it reached to its peak on 9<sup>th</sup> day of oviposition (Av. 2.0 eggs). The fecundity and fecundity rate were higher with webbing as compared to those of without webbing. The oviposition period with webbing of *T. urticae* was higher (15.0 days) than that of without webbing (8.0 days)

**Table 31:-Total life period of male *T. urticae* under laboratory condition (Days)**

| Sr. No.            | Summer            | Monsoon           | Winter            | Average           |
|--------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                 | 21.75             | 22.25             | 29.50             | 24.50             |
| 2.                 | 22.75             | 27.50             | 33.25             | 27.83             |
| 3.                 | 24.25             | 29.25             | 31.75             | 28.42             |
| 4.                 | 29.00             | 31.25             | 34.50             | 31.58             |
| 5.                 | 22.75             | 28.00             | 36.75             | 29.17             |
| 6.                 | 28.50             | 27.50             | 35.75             | 30.58             |
| 7.                 | 23.25             | 28.25             | 33.75             | 28.42             |
| 8.                 | 26.25             | 29.00             | 35.25             | 30.17             |
| 9.                 | 25.00             | 29.25             | 33.00             | 29.08             |
| 10.                | 26.75             | 32.25             | 36.50             | 31.83             |
| 11.                | 24.00             | 32.75             | 35.45             | 30.73             |
| 12.                | 26.75             | 33.00             | 37.00             | 32.25             |
| 13.                | 28.00             | 33.00             | 38.25             | 33.08             |
| 14.                | 23.00             | 32.00             | 39.00             | 31.33             |
| 15.                | 23.75             | 30.50             | 39.50             | 31.25             |
| 16.                | 24.00             | 30.00             | 37.50             | 30.50             |
| 17.                | 27.50             | 31.00             | 37.25             | 31.92             |
| 18.                | 24.25             | 29.25             | 37.50             | 30.33             |
| 19.                | 24.00             | 30.50             | 39.50             | 31.33             |
| 20.                | 26.00             | 33.75             | 37.75             | 32.50             |
| <b>Minimum</b>     | <b>21.75</b>      | <b>22.25</b>      | <b>29.50</b>      | <b>24.50</b>      |
| <b>Maximum</b>     | <b>29.00</b>      | <b>33.75</b>      | <b>39.50</b>      | <b>33.08</b>      |
| <b>Mean± S. D.</b> | <b>25.07±2.12</b> | <b>30.01±2.65</b> | <b>35.93±2.66</b> | <b>30.34±1.99</b> |

**Table 32:-Total life period of unmated female *T. urticae* under laboratory condition (Days)**

| Sr. No.            | Summer            | Monsoon           | Winter            | Average           |
|--------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                 | 34.00             | 31.00             | 44.25             | 36.42             |
| 2.                 | 31.00             | 37.50             | 41.50             | 36.67             |
| 3.                 | 34.00             | 37.00             | 45.00             | 38.67             |
| 4.                 | 36.00             | 41.00             | 52.00             | 43.00             |
| 5.                 | 34.25             | 34.50             | 49.75             | 39.50             |
| 6.                 | 33.00             | 35.50             | 49.50             | 39.33             |
| 7.                 | 34.00             | 34.50             | 47.50             | 38.67             |
| 8.                 | 36.00             | 35.75             | 53.00             | 41.58             |
| 9.                 | 36.75             | 35.25             | 46.00             | 39.33             |
| 10.                | 33.00             | 37.50             | 48.50             | 39.67             |
| 11.                | 35.00             | 42.00             | 44.50             | 40.50             |
| 12.                | 40.00             | 42.00             | 50.75             | 44.25             |
| 13.                | 36.00             | 35.50             | 50.00             | 40.50             |
| 14.                | 35.75             | 39.00             | 49.50             | 41.42             |
| 15.                | 34.00             | 36.00             | 49.50             | 39.83             |
| 16.                | 34.00             | 32.00             | 46.50             | 37.50             |
| 17.                | 39.00             | 35.50             | 49.50             | 41.33             |
| 18.                | 40.25             | 39.25             | 46.00             | 41.83             |
| 19.                | 36.00             | 34.00             | 44.50             | 38.17             |
| 20.                | 35.00             | 37.25             | 44.50             | 38.92             |
| <b>Minimum</b>     | <b>31.00</b>      | <b>31.00</b>      | <b>41.50</b>      | <b>36.42</b>      |
| <b>Maximum</b>     | <b>40.25</b>      | <b>42.00</b>      | <b>53.00</b>      | <b>44.25</b>      |
| <b>Mean± S. D.</b> | <b>35.35±4.07</b> | <b>36.60±2.96</b> | <b>47.61±3.03</b> | <b>39.85±2.00</b> |

**Table 33:-Total life period of mated female *T.urticae* under laboratory condition (Days)**

| <b>Sr. No.</b>      | <b>Summer</b>     | <b>Monsoon</b>    | <b>Winter</b>     | <b>Average</b>    |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| 1.                  | 28.00             | 29.50             | 47.25             | 34.92             |
| 2.                  | 32.00             | 42.50             | 46.50             | 40.33             |
| 3.                  | 32.00             | 36.00             | 48.00             | 38.67             |
| 4.                  | 37.00             | 39.00             | 53.00             | 43.00             |
| 5.                  | 36.25             | 40.50             | 53.75             | 43.50             |
| 6.                  | 36.00             | 41.50             | 52.50             | 43.33             |
| 7.                  | 37.00             | 41.50             | 50.50             | 43.00             |
| 8.                  | 40.00             | 40.75             | 56.00             | 45.58             |
| 9.                  | 38.75             | 40.25             | 56.00             | 45.00             |
| 10.                 | 40.00             | 39.50             | 57.50             | 45.67             |
| 11.                 | 40.00             | 43.00             | 52.50             | 45.17             |
| 12.                 | 44.00             | 45.00             | 52.75             | 47.25             |
| 13.                 | 42.00             | 40.50             | 53.00             | 45.17             |
| 14.                 | 40.75             | 44.00             | 53.50             | 46.08             |
| 15.                 | 42.00             | 45.00             | 51.50             | 46.17             |
| 16.                 | 38.00             | 41.00             | 50.50             | 43.17             |
| 17.                 | 40.00             | 41.50             | 56.50             | 46.00             |
| 18.                 | 44.00             | 45.25             | 52.00             | 47.08             |
| 19.                 | 41.00             | 41.00             | 53.50             | 45.17             |
| 20.                 | 38.00             | 44.25             | 55.50             | 45.92             |
| <b>Minimum</b>      | <b>28.00</b>      | <b>29.50</b>      | <b>46.50</b>      | <b>34.92</b>      |
| <b>Maximum</b>      | <b>44.00</b>      | <b>45.25</b>      | <b>57.50</b>      | <b>47.25</b>      |
| <b>Mean ± S. D.</b> | <b>38.33±4.07</b> | <b>41.07±3.56</b> | <b>52.61±3.00</b> | <b>44.00±3.03</b> |

Thus, the present investigation indicated that the daily removal of webs (twice day) had an adverse effect on rate of egg laying and fecundity with shorter oviposition period. Satio (1977) and Gerson and Aronowitz (1981) found positive correlation between amount of webbing produced and number of egg laid. Bhanderi (1991) reported that the daily removal of webs of *T. macfarlanei* on okra had adversely affected egg laying but it does not affected oviposition period. These reports are more or less in concurrence with the present findings.

#### **4.1.16 Impact of photoperiodism:**

The impact of photoperiodism on oviposition of *T. urticae* was studied in laboratory at an average temperature and relative humidity per cent during April 2014. It can be seen from the Table 35 that the individuals kept under continuous darkness laid less number of eggs (Av. 3.67 eggs) as compared to that of individual kept under continuous light (Av. 3.86 eggs) and natural condition (Av. 6.41 eggs). This indicated the individuals expose to natural condition laid comparatively more number of eggs than that of other two conditions. Similar findings were reported in past by Kamburov (1971) for *T. cinnabarinus* and *B.phoenicis*. Jose (1983) for *T. macfarlanei* and Malaviya (1994) for *T. ludeni*.

#### **4.2. Biology of *A. lycopersici* on tomato under laboratory conditions:**

The biology of *A. lycopersici* was studied during May-June 2014 under the laboratory conditions at room temperature and relative humidity. The following life stages of the russet mite, *A. lycopersici* were observed: egg, larva,

**Table 35:- Oviposition by *T. urticae* with and without webbing**

| Ovipositional days                | Average number of eggs/female |             |
|-----------------------------------|-------------------------------|-------------|
|                                   | With web                      | Without web |
| 1.                                | 1.0                           | 0.0         |
| 2.                                | 3.0                           | 0.0         |
| 3.                                | 3.0                           | 1.0         |
| 4.                                | 4.0                           | 1.0         |
| 5.                                | 2.0                           | 1.0         |
| 6.                                | 2.0                           | 1.0         |
| 7.                                | 4.0                           | 1.0         |
| 8.                                | 4.0                           | 1.0         |
| 9.                                | 4.0                           | 2.0         |
| 10.                               | 2.0                           | 1.0         |
| 11.                               | 3.0                           | 0.0         |
| 12.                               | 0.0                           | 0.0         |
| 13.                               | 0.0                           | 0.0         |
| 14.                               | 0.0                           | 0.0         |
| 15.                               | 0.0                           | 0.0         |
| <b>Fecundity</b>                  | <b>32.00</b>                  | <b>9.00</b> |
| <b>Fecundity rate</b>             | <b>2.13</b>                   | <b>1.12</b> |
| <b>Oviposition period in days</b> | <b>15.00</b>                  | <b>8.00</b> |

**Table 34:- Impact of photoperiodism on oviposition of *T. urticae***

| Sr. No.                | Date of observation | Oviposition period | Average number of eggs/female |                 |                   |
|------------------------|---------------------|--------------------|-------------------------------|-----------------|-------------------|
|                        |                     |                    | Continous dark                | Continous light | Natural condition |
| 1.                     | 08.04.14            | 1                  | 1.80                          | 1.00            | 2.00              |
| 2.                     | 09.04.14            | 2                  | 4.60                          | 4.00            | 6.00              |
| 3.                     | 10.04.14            | 3                  | 8.00                          | 7.00            | 9.67              |
| 4.                     | 11.04.14            | 4                  | 7.50                          | 6.50            | 8.25              |
| 5.                     | 12.04.14            | 5                  | 4.25                          | 4.65            | 7.50              |
| 6.                     | 13.04.14            | 6                  | 3.17                          | 4.00            | 7.15              |
| 7.                     | 14.04.14            | 7                  | 2.33                          | 2.00            | 6.10              |
| 8.                     | 15.04.14            | 8                  | 3.00                          | 2.00            | 6.00              |
| 9.                     | 16.04.14            | 9                  | 2.00                          | 2.00            | 6.25              |
| 10.                    | 17.04.14            | 10                 | 2.00                          | 1.60            | 5.25              |
| <b>Overall average</b> |                     |                    | <b>3.86</b>                   | <b>3.67</b>     | <b>6.41</b>       |

**Table 2 : Duration of various stages of *T. urticae* on tomato**

| Sr. No. | Stage  |                | No. of obs. | Summer |       |             | Monsoon |        |              | Winter |        |             | Yearly Av. ± S.D. |
|---------|--|----------------|-------------|--------|-------|-------------|---------|--------|--------------|--------|--------|-------------|-------------------|
|         |  |                |             | Min.   | Max.  | Ave. ± S.D. | Min.    | Max.   | Ave. ± S.D.  | Min.   | Max.   | Ave. ± S.D. |                   |
| 1.      | Incubation period  | Male           | 20          | 2.00   | 4.00  | 2.45±0.60   | 2.00    | 6.00   | 4.05±0.99    | 3.00   | 7.00   | 4.65±0.98   | 3.71±0.54         |
|         |  | Mated female   | 20          | 2.00   | 4.00  | 2.45±0.60   | 3.00    | 4.00   | 3.80±0.41    | 4.00   | 8.00   | 5.25±1.11   | 3.83±0.42         |
| 2.      | Larval period  | Male           | 20          | 3.00   | 5.00  | 4.05±0.51   | 2.00    | 3.00   | 2.60±0.50    | 4.00   | 7.00   | 5.40±0.75   | 4.01±0.35         |
|         |  | Female         | 20          | 3.00   | 5.00  | 4.25±0.63   | 2.00    | 4.00   | 3.00±0.56    | 4.00   | 8.00   | 6.30±1.21   | 4.51±0.52         |
| 3.      | Nymphochrysalis period   | Male           | 20          | 0.25   | 2.25  | 0.65±0.45   | 0.25    | 1.00   | 0.66±0.23    | 0.50   | 1.50   | 0.91±0.31   | 0.74±0.23         |
|         |  | Female         | 20          | 1.00   | 4.00  | 2.40±0.82   | 3.00    | 4.00   | 3.50±0.51    | 3.00   | 5.00   | 3.85±0.58   | 3.25±0.40         |
| 4.      | Protonymphalperiod   | Male           | 20          | 2.00   | 4.00  | 3.15±0.81   | 3.00    | 5.00   | 4.40±0.68    | 4.00   | 6.00   | 5.00±0.64   | 4.18±0.43         |
|         |  | Female         | 20          | 3.00   | 6.00  | 4.10±0.71   | 3.00    | 7.00   | 4.50±0.88    | 5.00   | 7.00   | 6.20±0.69   | 4.93±0.36         |
| 5.      | Deutochrysalisperiod   | Male           | 20          | 0.25   | 0.75  | 0.41±0.16   | 0.50    | 1.00   | 0.78±0.20    | 0.75   | 1.50   | 1.11±0.23   | 0.77±0.13         |
|         |  | Female         | 20          | 0.75   | 1.25  | 1.01±0.12   | 0.75    | 2.00   | 1.20±0.36    | 1.00   | 3.00   | 1.56±0.49   | 1.25±0.23         |
| 6.      | Deutonymphal period  | Male           | 20          | 2.00   | 3.00  | 2.40±0.50   | 3.00    | 5.00   | 4.20±0.69    | 4.00   | 6.00   | 4.80±0.52   | 3.80±0.38         |
|         |  | Female         | 2           | 3.00   | 6.00  | 4.90±0.78   | 2.00    | 4.00   | 3.25±0.85    | 4.00   | 8.00   | 5.65±0.87   | 4.60±0.61         |
| 7.      | Teleochrysalisperiod   | Male           | 20          | 0.25   | 1.00  | 0.61±0.30   | 0.50    | 1.00   | 0.83±0.20    | 1.00   | 2.00   | 1.32±0.38   | 0.92±0.18         |
|         |  | Female         | 20          | 1.00   | 3.00  | 1.50±0.60   | 0.50    | 1.50   | 0.80±0.28    | 1.00   | 2.00   | 1.55±0.31   | 1.28±0.24         |
| 8.      | Total developmental period<br>(combined larval, nymphal and quiescent period ) | Male           | 20          | 10.75  | 17.00 | 13.65±1.51  | 13.25   | 20.00  | 17.71±1.69   | 19.50  | 25.50  | 23.18±1.70  | 18.18±1.27        |
|         |  | Female         | 20          | 18.00  | 25.00 | 20.85±1.80  | 15.50   | 25.00  | 20.02±2.09   | 25.50  | 33.00  | 30.41±1.88  | 23.76±1.30        |
| 9.      | Adult period   | Male           | 20          | 10.00  | 13.00 | 11.05±0.94  | 9.00    | 14.00  | 12.10±1.41   | 10.00  | 15.00  | 12.75±1.77  | 11.96±0.97        |
|         |  | Unmated female | 20          | 11.00  | 17.00 | 14.50±1.50  | 14.00   | 21.00  | 16.60±1.66   | 14.00  | 21.00  | 17.20±1.93  | 16.09±1.15        |
|         |  | Mated female   | 20          | 9.00   | 22.00 | 17.50±3.13  | 14.00   | 24.00  | 21.05±2.50   | 18.00  | 26.00  | 22.20±1.96  | 20.24±2.11        |
| 10.     | Pre- oviposition period  | Unmated        | 20          | 3.00   | 7.00  | 4.90±1.07   | 5.00    | 7.00   | 5.65±0.74    | 4.00   | 8.00   | 5.70±0.97   | 5.41±0.63         |
|         |  | Mated          | 20          | 2.00   | 5.00  | 3.85±1.08   | 2.00    | 6.00   | 4.45±0.82    | 4.00   | 7.00   | 5.50±0.88   | 4.60±0.67         |
| 11.     | Oviposition period   | Unmated        | 20          | 5.00   | 8.00  | 6.30±1.03   | 5.00    | 10.00  | 6.65±1.34    | 5.00   | 10.00  | 7.30±1.52   | 6.75±0.87         |
|         |  | Mated          | 20          | 4.00   | 11.00 | 8.65±2.34   | 7.00    | 12.00  | 10.40±1.63   | 8.00   | 12.00  | 10.70±1.12  | 9.91±1.29         |
| 12.     | Post- oviposition period   | Unmated        | 20          | 2.00   | 4.00  | 3.30±0.86   | 3.00    | 5.00   | 4.30±0.57    | 3.00   | 5.00   | 4.15±0.67   | 3.91±0.45         |
|         |  | Mated          | 20          | 3.00   | 6.00  | 5.00±0.85   | 5.00    | 8.00   | 6.20±1.05    | 5.00   | 8.00   | 6.00±0.97   | 5.73±0.64         |
| 13.     | Fecundity  | Unmated        | 20          | 17.00  | 42.00 | 33.40±7.98  | 20.00   | 46.00  | 32.90±7.88   | 11.00  | 38.00  | 26.00±6.66  | 30.76±5.56        |
|         |  | Mated          | 20          | 53.00  | 89.00 | 66.40±10.45 | 87.00   | 128.00 | 105.90±11.79 | 74.00  | 104.00 | 89.65±9.99  | 87.31±4.96        |
| 14.     | Total life period  | Male           | 20          | 21.75  | 29.00 | 25.07±2.12  | 22.25   | 33.75  | 30.01±2.65   | 29.50  | 39.50  | 35.93±2.66  | 30.34±1.99        |
|         |  | Unmated        | 20          | 31.00  | 40.25 | 35.35±2.33  | 31.00   | 42.00  | 36.60±2.96   | 41.50  | 53.00  | 47.61±3.03  | 39.85±2.00        |
|         |  | Mated          | 20          | 28.00  | 44.00 | 38.33±4.07  | 29.50   | 45.25  | 41.07±3.56   | 46.50  | 57.50  | 52.61±3.00  | 44.00±3.03        |

nymph and adult along with two resting stages. The shape, size and duration of each stage were described under:

#### **4.2.1 Egg:**

Eggs were usually round to oval, almost transparent and glittering which later on turned to white. They were laid solitary all over the leaves and stem of tomato plants. A few hours before hatching, they become milky white. Immediately before hatching, a small projection appeared at the anal pole of the egg. Subsequently, this region extended into a longitudinal slit which slowly increased in length. Thrashing movement of the emerging larva against the longitudinal slit helped to widen the gap. After some time, the anterior region of the larva slowly wriggled out half way. With further wriggling, the remaining part of the body emerged. The hatching was accomplished in about 25 to 30 minutes. The incubation period in case of males ranged between 1.50 to 3.0 days with an average of  $2.08 \pm 0.49$  days, while in case of female the incubation varied between 2.50 to 3.0 days with an average of  $2.86 \pm 0.22$  days under laboratory conditions at room temperature. Kay (1986) also described that the eggs of *A. lycopersici* are round and colourless to white, thus more or less similar to the present findings, while Bailey and Keifer (1943) observed that at 21°C the eggs hatched in 2 days also support the present findings.

#### **4.2.2 larva:**

The newly emerged larvae were very small, vermiform and almost transparent. The larvae started feeding soon after emergence. The active period of this stage in case

of males varied between 0.50 to 1.50 days with an average of  $1.00\pm 0.32$  days, while in case of females, it varied between 1.0 to 2.0 days with an average of  $1.56\pm 0.36$  days when reared on tomato under the laboratory conditions at room temperature. The larvae stopped feeding and entered into a resting stage known as quiescent stage. The quiescent period varied from 0.25 to 1.0 days with an average of  $0.49\pm 0.19$  days in males, while in case of females the quiescent period lasted between 0.50 to 1.0 days with an average of  $0.85\pm 0.14$  days. The quiescent form was turgid and milky. At the end of the quiescent period, a dorsolongitudinal slit appeared at the anterior end of the body. Subsequently, gnathosoma and legs protrude. With the constant movements of the legs the slit widened up and the nymph emerged. This process takes 15 to 20 minutes in both the sexes. The present morphological descriptions are more or less similar to that described by Kay (1986), while Bailey and Keifer (1943) observed the larval period as one day, which is slightly different from present one, it may be due to the change in the agroclimatic conditions, different tomato variety and method of handling however it partially support the present findings.

#### **4.2.3 Nymph:**

The nymph was pale whitish. It actively feed for about 1.50 to 2.50 days with an average of  $1.76\pm 0.29$  days in case of males, while in case of females it feed on tomato leaves for 2.0 to 3.0 days with an average of  $2.60\pm 0.38$  days. The full grown nymph then become quiescent for 0.75 to 1.00 days with an average of  $0.90\pm 0.12$  day in case of males and 1.0 to 2.50 days with an average of  $1.96\pm 0.45$  days in case of

females. The quiescent form was also turgid and milky. The moulting process of adult stage was similar to those as earlier described for the previous moulting. The present findings are more or less similar to those of Bailey and Keifer (1943).

#### **4.2.4 Developmental period:**

The total development period of *A. lycopersici* were given in the Table 37 and 38. The data showed that in case of male the developmental period ranged between 5.25 to 8.0 days with an average of  $6.23 \pm 0.70$  days, while in case of females the total developmental period ranging between 8.0 to 11.50 days with an average of  $9.87 \pm 0.88$  days under laboratory conditions. The present findings are more or less similar to the Rice and Strong (1962) who also reported the development period as 11.0 to 12.0 days. The slight difference in development period may be due to different agroclimatic conditions and crop variety.

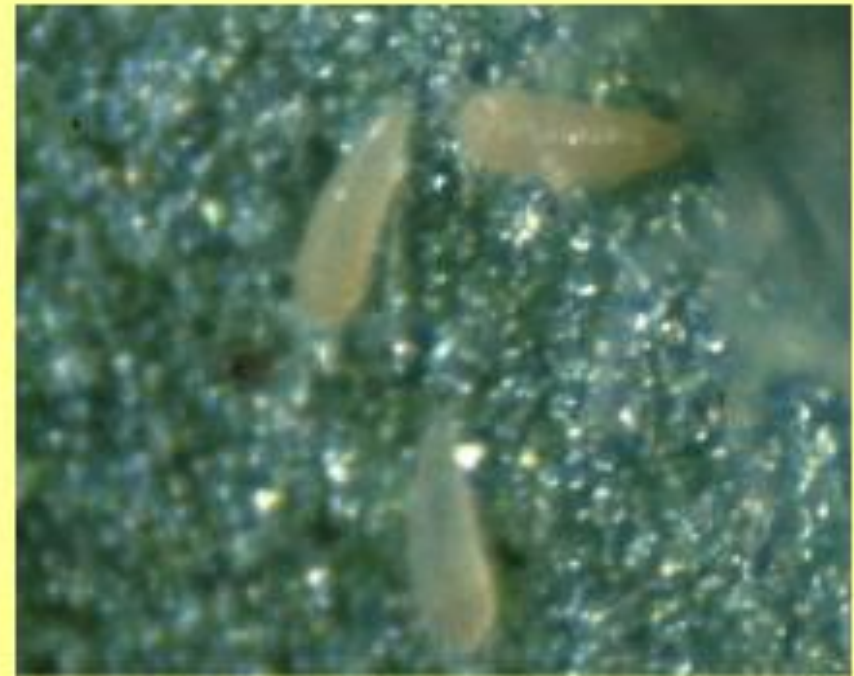
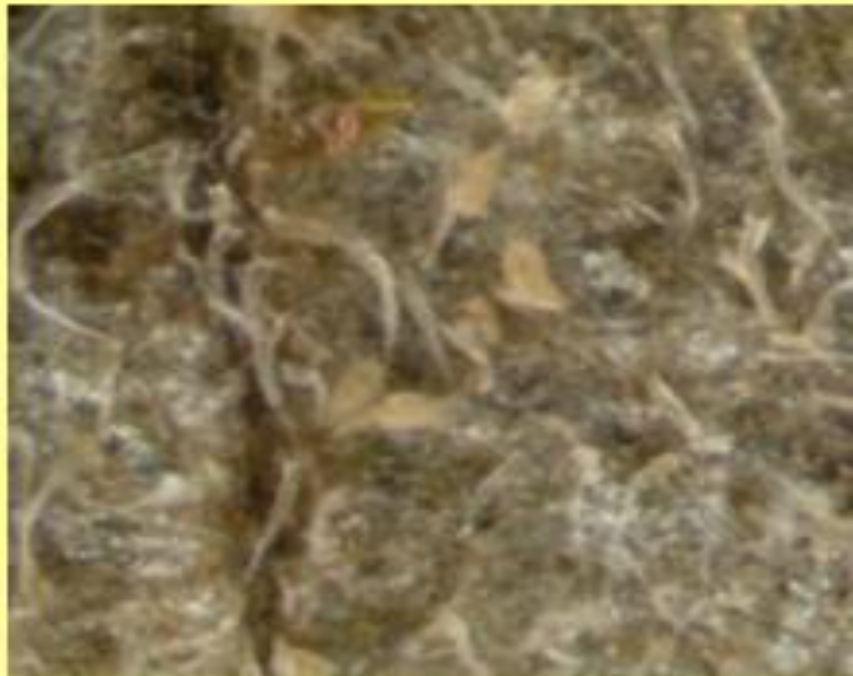
#### **4.2.5 Preoviposition, oviposition and post oviposition period:**

The preoviposition period of both mated and unmated females of *A. lycopersici* were also recorded and presented in Table 39. The preoviposition period of mated females ranged between 4.0 to 7.0 days with an average of  $5.32 \pm 0.90$  days, while in case of unmated females it varied between 2.00 to 4.00 days with an average of  $2.76 \pm 0.72$  days. The oviposition period of mated females were presented in Table 38. The oviposition period of mated females varied between 12.0 to 17.0 days with an average of  $14.44 \pm 1.38$  days under laboratory conditions whereas, for the unmated females this period varied between 4.0 to 8.0 days (Av.  $5.72 \pm 0.93$

days). The post oviposition period of mated females of *A. lycopersici* were ranged between 3.0 to 6.0 days (Av.  $4.96 \pm 0.79$  days) while, in case of unmated females the post oviposition period varied from 1.0 to 3.0 days (Av.  $2.32 \pm 0.55$  days). Thus, from the above results it can be concluded that preoviposition, oviposition and post oviposition period of mated females were more or just double than the unmated females. In past, Baradaran and Daneshwar (1992) also reported that the *A. lycopersici* female had three well developed stages just like in the present experiment and in case of unmated female this period becomes shorter as compared to mated females thus more or less support the present findings. Further, Kay (1986) also reported preoviposition and oviposition period as 2.0 and 19.0 days, respectively. Thus, confirms the present findings.

#### **4.2.6 Adult longevity:**

The adult longevity period of males and females, both mated and unmated were presented in Table 39. The adult period for male varied between 18.25 to 24.00 days with an average adult period of  $20.63 \pm 1.70$  days. The longevity of mated females varied between 20.0 to 28.0 days, (Av.  $24.76 \pm 1.79$  days) while in case of unmated females the longevity varies from 8.00 to 13.00 days (Av.  $10.80 \pm 1.38$  days). From the above observation on adult longevity it was found that the longevity of mated females were more in comparison to males and unmated females. In past, Kay (1986) also reported the adult period of male as 16 days and for female about 22 days, more or less in accordance with the present findings, however the slight difference in the adult



**Plate 5: Adults russet mite *Aceria lycopersici* on tomato leaf**

periods may be due to the different agroclimatic conditions and host plant.

#### 4.2.7 Fecundity:

The rate of egg laying by female per day is called as fecundity. Data presented in Table 38, indicated that the rate of egg laying per female per day for unmated female was varied from 11.0 to 21.0 eggs (Av.  $15.52 \pm 2.78$  eggs) while for mated female it was varied from 34.0 to 57.0 eggs (Av.  $42.52 \pm 5.90$  eggs).

#### 4.2.8 Sex ratio:

The mated female produced progeny having both males and females, where as unmated females produced only males. Under the present study the male to female ratio of bisexual reproduction of *A. lycopersici* was worked out as 1:3.45 (77.55 per cent females) (Table ), while the sex ratio

**Table 40: Sex ratio of *A. lycopersici* on tomato under laboratory conditions**

| Sr. No. | Russet mite       | Total Observed | Male | Female | Ratio (M:F) | Percentage  |
|---------|-------------------|----------------|------|--------|-------------|-------------|
| 1       | Bi-sexual         | 47             | 3.00 | 114    | 1.00:3.45   | 22.45:77.55 |
| 2       | Parthenogenetical | 103            | 103  | -      | -           | 100:00      |

of parthenogenetically reproduced population was found to be 100 per cent male. (Table 40). The present work was closely supported by Jose (1983) and Shah and Shukla (2014) on various species of spider mites infesting different crops.

#### 4.2.9 Total life period:

The total life period of male and females were also recorded and the data were presented in Table 37 and 38. The life period of male varied between 18.25 to 24.0 days with an

**Table 37:- Biology and morphometrics of male of *A. lycopersici* under laboratory conditions (Days)**

| Sr. No             | Incubation period | Larval period    | Q1               | Nymphal period   | Q2               | Adult period      | Total development period | Total life period  | Length             | Width              |
|--------------------|-------------------|------------------|------------------|------------------|------------------|-------------------|--------------------------|--------------------|--------------------|--------------------|
| 1                  | 2.00              | 1.00             | 0.50             | 2.00             | 0.75             | 12.00             | 6.25                     | 18.25              | 0.10               | 0.03               |
| 2                  | 3.00              | 1.00             | 1.00             | 2.00             | 1.00             | 16.00             | 8.00                     | 24.00              | 0.10               | 0.03               |
| 3                  | 2.00              | 0.50             | 0.50             | 1.50             | 0.75             | 13.00             | 5.25                     | 18.25              | 0.13               | 0.04               |
| 4                  | 2.00              | 1.00             | 0.50             | 2.00             | 1.00             | 12.00             | 6.50                     | 18.50              | 0.17               | 0.03               |
| 5                  | 2.00              | 1.50             | 0.50             | 2.00             | 1.00             | 12.00             | 7.00                     | 19.00              | 0.14               | 0.04               |
| 6                  | 2.00              | 1.00             | 0.25             | 2.00             | 1.00             | 16.00             | 6.25                     | 22.25              | 0.13               | 0.04               |
| 7                  | 1.50              | 1.50             | 0.25             | 1.50             | 0.75             | 17.00             | 5.50                     | 22.50              | 0.10               | 0.04               |
| 8                  | 2.00              | 1.00             | 0.50             | 1.50             | 1.00             | 16.00             | 6.00                     | 22.00              | 0.19               | 0.03               |
| 9                  | 1.50              | 1.00             | 0.50             | 1.50             | 1.00             | 14.00             | 5.50                     | 19.50              | 0.17               | 0.04               |
| 10                 | 2.50              | 1.00             | 0.75             | 1.50             | 0.75             | 13.00             | 6.50                     | 19.50              | 0.18               | 0.03               |
| 11                 | 2.00              | 1.50             | 0.25             | 2.00             | 0.75             | 14.00             | 6.50                     | 20.50              | 0.14               | 0.03               |
| 12                 | 2.00              | 1.00             | 0.25             | 1.50             | 1.00             | 16.00             | 5.75                     | 21.75              | 0.14               | 0.04               |
| 13                 | 1.50              | 0.50             | 0.75             | 1.50             | 1.00             | 15.00             | 5.25                     | 20.25              | 0.15               | 0.03               |
| 14                 | 2.50              | 0.50             | 0.50             | 2.00             | 1.00             | 16.00             | 6.50                     | 22.50              | 0.14               | 0.03               |
| 15                 | 3.00              | 0.50             | 0.25             | 1.50             | 0.75             | 16.00             | 6.00                     | 22.00              | 0.13               | 0.03               |
| 16                 | 2.00              | 1.00             | 0.50             | 1.50             | 1.00             | 15.00             | 6.00                     | 21.00              | 0.13               | 0.03               |
| 17                 | 2.00              | 1.00             | 0.50             | 2.00             | 0.75             | 14.00             | 6.25                     | 20.25              | 0.14               | 0.03               |
| 18                 | 3.00              | 1.00             | 0.75             | 2.00             | 0.75             | 15.00             | 7.50                     | 22.50              | 0.15               | 0.04               |
| 19                 | 1.50              | 1.50             | 0.50             | 2.50             | 1.00             | 16.00             | 7.00                     | 23.00              | 0.19               | 0.03               |
| 20                 | 2.00              | 1.00             | 0.50             | 2.00             | 1.00             | 13.00             | 6.5                      | 19.50              | 0.12               | 0.03               |
| 21                 | 1.50              | 1.00             | 0.50             | 1.50             | 0.75             | 14.00             | 5.25                     | 19.25              | 0.13               | 0.04               |
| 22                 | 2.00              | 1.50             | 0.50             | 1.50             | 1.00             | 13.00             | 6.50                     | 19.50              | 0.12               | 0.04               |
| 23                 | 1.50              | 1.00             | 0.75             | 2.00             | 0.75             | 16.00             | 6.00                     | 22.00              | 0.18               | 0.03               |
| 24                 | 3.00              | 1.00             | 0.25             | 1.50             | 1.00             | 13.00             | 6.75                     | 19.75              | 0.13               | 0.03               |
| 25                 | 2.00              | 0.50             | 0.25             | 1.50             | 1.00             | 13.00             | 5.25                     | 18.25              | 0.15               | 0.04               |
| <b>Minimum</b>     | <b>1.50</b>       | <b>0.50</b>      | <b>0.25</b>      | <b>1.50</b>      | <b>0.75</b>      | <b>12.00</b>      | <b>5.25</b>              | <b>18.25</b>       | <b>0.10</b>        | <b>0.03</b>        |
| <b>Maximum</b>     | <b>3.00</b>       | <b>1.50</b>      | <b>1.00</b>      | <b>2.50</b>      | <b>1.00</b>      | <b>17.00</b>      | <b>8.00</b>              | <b>24.00</b>       | <b>0.19</b>        | <b>0.04</b>        |
| <b>Avg. ± S.D.</b> | <b>2.08±0.49</b>  | <b>1.00±0.32</b> | <b>0.49±0.19</b> | <b>1.76±0.29</b> | <b>0.90±0.12</b> | <b>14.40±1.55</b> | <b>6.23 ± 0.70</b>       | <b>20.63 ±1.70</b> | <b>0.14 ± 0.02</b> | <b>0.03 ±0.005</b> |



Plate 6: Tomato russet mite *Aceria lycopersici* (Slide)

average total life period  $20.63 \pm 1.70$  days, while the total life period for mated females ranged between 28.0 to 39.0 days (Av.  $34.59 \pm 2.23$  days) while for the unmated females the period varied between 17.0 to 23.50 days with an average of  $20.67 \pm 1.60$  days. From the present investigation it is found that the total life period of females (both mated and unmated) was more than male russet mites. The life period of female mite is more as compared to males. In contrary, Baradaran and Daneshwar (1992) from Varamin reported that the life cycle of *A. lycopersici* from egg to adult took 8 days at  $25 \pm 1^\circ\text{C}$  and 50+5 per cent RH which is quite different from the present findings. It may be due to the change in the agroclimate, variety of tomato. Kamau (1977) from Kenya also reported that the life cycle from egg to adult took 7 days at  $26-28^\circ\text{C}$ . The life cycle of *A. lycopersici* in laboratory takes 21 days for female and 17 days for male in Egypt, more or less similar to the present findings.

#### **4.2.10 Behaviour:**

The tomato russet mite can kill tomato plants by feeding and reproducing rapidly on tomato plants. This phenomenon is known as “solanum stimulation”. The tomato russet mite also exhibits “solanum stimulation” in tomato. Injury to tomato plants is caused by feeding. The tomato russet mite usually begins at the base of the tomato plant, and eventually works its way up the plant. The tomato russet mite feeds on all green surfaces of the host plant. They puncture the plant epidermal cells to feed on the plant cell contents. The greatest concentration of mites is normally the area just ahead of the damaged area. The tomato russet mite population

**Table 38:- Biology and morphometrics of female of *A. lycopersici* under laboratory conditions (Days)**

| Sr. No             | Incubation Females | Larval period    | Q1               | Nymphal period   | Q2               | Total development period | Adult period      |                   | Total life period  |                     | Fecundity         |                   |
|--------------------|--------------------|------------------|------------------|------------------|------------------|--------------------------|-------------------|-------------------|--------------------|---------------------|-------------------|-------------------|
|                    |                    |                  |                  |                  |                  |                          | Mated Female      | Unmated Female    | Mated Female       | Unmated Female      | Mated Female      | Unmated Female    |
| 1                  | 3.00               | 1.00             | 1.00             | 2.00             | 1.00             | 8.00                     | 20.00             | 9.00              | 28.00              | 17.00               | 41.00             | 11.00             |
| 2                  | 3.00               | 1.50             | 0.75             | 2.00             | 1.50             | 8.75                     | 25.00             | 12.00             | 33.75              | 20.75               | 34.00             | 16.00             |
| 3                  | 2.50               | 1.00             | 0.50             | 2.50             | 1.50             | 8.00                     | 23.00             | 12.00             | 31.00              | 20.00               | 36.00             | 13.00             |
| 4                  | 3.00               | 2.00             | 1.00             | 2.00             | 1.50             | 9.50                     | 25.00             | 9.00              | 34.50              | 18.50               | 41.00             | 19.00             |
| 5                  | 2.50               | 1.00             | 1.00             | 2.50             | 2.00             | 9.00                     | 25.00             | 10.00             | 34.00              | 19.00               | 39.00             | 14.00             |
| 6                  | 3.00               | 1.00             | 1.00             | 3.00             | 2.50             | 10.50                    | 24.00             | 11.00             | 34.50              | 21.50               | 36.00             | 16.00             |
| 7                  | 3.00               | 1.50             | 0.75             | 2.50             | 2.50             | 10.25                    | 24.00             | 13.00             | 34.25              | 23.25               | 39.00             | 14.00             |
| 8                  | 2.50               | 1.50             | 0.75             | 2.50             | 1.50             | 8.75                     | 26.00             | 13.00             | 34.75              | 21.75               | 57.00             | 11.00             |
| 9                  | 2.50               | 1.50             | 1.00             | 3.00             | 2.50             | 10.50                    | 23.00             | 13.00             | 33.50              | 23.50               | 40.00             | 13.00             |
| 10                 | 3.00               | 1.00             | 1.00             | 3.00             | 1.50             | 9.50                     | 27.00             | 10.00             | 36.50              | 19.50               | 43.00             | 14.00             |
| 11                 | 3.00               | 1.50             | 1.00             | 2.50             | 2.00             | 10.00                    | 24.00             | 10.00             | 34.00              | 20.00               | 47.00             | 13.00             |
| 12                 | 2.50               | 2.00             | 0.75             | 2.50             | 2.00             | 9.75                     | 25.00             | 11.00             | 34.75              | 20.75               | 39.00             | 17.00             |
| 13                 | 3.00               | 2.00             | 0.75             | 3.00             | 1.50             | 10.25                    | 25.00             | 11.00             | 35.25              | 21.25               | 40.00             | 21.00             |
| 14                 | 3.00               | 2.00             | 1.00             | 2.00             | 2.00             | 10.00                    | 24.00             | 11.00             | 34.00              | 21.00               | 40.00             | 18.00             |
| 15                 | 3.00               | 1.50             | 1.00             | 3.00             | 2.50             | 11.00                    | 28.00             | 10.00             | 39.00              | 21.00               | 43.00             | 17.00             |
| 16                 | 3.00               | 1.50             | 1.00             | 3.00             | 2.50             | 11.00                    | 23.00             | 11.00             | 34.00              | 22.00               | 40.00             | 17.00             |
| 17                 | 3.00               | 2.00             | 0.75             | 2.50             | 2.50             | 10.75                    | 26.00             | 11.00             | 36.75              | 21.75               | 38.00             | 21.00             |
| 18                 | 3.00               | 1.50             | 0.75             | 2.50             | 2.00             | 9.75                     | 24.00             | 12.00             | 33.75              | 21.75               | 39.00             | 20.00             |
| 19                 | 2.50               | 1.50             | 0.75             | 3.00             | 2.00             | 9.75                     | 25.00             | 13.00             | 34.75              | 22.75               | 47.00             | 15.00             |
| 20                 | 3.00               | 2.00             | 1.00             | 3.00             | 1.50             | 10.50                    | 27.00             | 8.00              | 37.50              | 18.50               | 51.00             | 16.00             |
| 21                 | 3.00               | 1.50             | 1.00             | 2.50             | 2.00             | 10.00                    | 25.00             | 10.00             | 35.00              | 20.00               | 50.00             | 15.00             |
| 22                 | 3.00               | 1.50             | 1.00             | 2.50             | 2.00             | 10.00                    | 26.00             | 10.00             | 36.00              | 20.00               | 55.00             | 15.00             |
| 23                 | 2.50               | 1.50             | 0.75             | 3.00             | 1.50             | 9.25                     | 23.00             | 9.00              | 32.25              | 18.25               | 41.00             | 16.00             |
| 24                 | 3.00               | 2.00             | 1.00             | 2.00             | 2.50             | 10.50                    | 28.00             | 11.00             | 38.50              | 21.50               | 39.00             | 13.00             |
| 25                 | 3.00               | 2.00             | 1.00             | 3.00             | 2.50             | 11.50                    | 23.00             | 10.00             | 34.50              | 21.50               | 48.00             | 13.00             |
| <b>Min.</b>        | <b>2.50</b>        | <b>1.00</b>      | <b>0.50</b>      | <b>2.00</b>      | <b>1.00</b>      | <b>8.00</b>              | <b>20.00</b>      | <b>8.00</b>       | <b>28.00</b>       | <b>17.00</b>        | <b>34.00</b>      | <b>11.00</b>      |
| <b>Max.</b>        | <b>3.00</b>        | <b>2.00</b>      | <b>1.00</b>      | <b>3.00</b>      | <b>2.50</b>      | <b>11.50</b>             | <b>28.00</b>      | <b>13.00</b>      | <b>39.00</b>       | <b>23.50</b>        | <b>57.00</b>      | <b>21.00</b>      |
| <b>Avg. ± S.D.</b> | <b>2.86±0.22</b>   | <b>1.56±0.36</b> | <b>0.89±0.14</b> | <b>2.60±0.38</b> | <b>1.96±0.45</b> | <b>9.87 ± 0.88</b>       | <b>24.72±1.79</b> | <b>10.80±1.38</b> | <b>34.59 ±2.23</b> | <b>20.67 ± 1.60</b> | <b>42.52±5.90</b> | <b>15.52±2.78</b> |

density increases, feeding activity of each individual mite accelerates.

#### **4.2.11 Impact of photoperiodism:**

The impact of photoperiodism on oviposition of *A. lycopersici* was studied in the laboratory at room temperature and 31.6 °C relative humidity 78 per cent during 2014. It can be seen from the Table 41, that the individuals kept under continuous darkness laid less number of egg (Av. 0.52 eggs) as compared to that of individuals kept under continuous light (0.72 eggs) and natural condition (Av. 1.11 eggs). The present finding indicated that the individuals exposed to natural condition laid comparatively more number of eggs than that of other two conditions. The present findings are more or less similar to the earlier work done by Kumbarov (1971), Jose (1983) and Malaviya (1994) on different species of spider mite.

#### **4.3 Seasonal incidence of phytophagous mites and their natural enemies on tomato under polyhouse condition:-**

Under the present study which was carried out during January to July, 2014 to investigate the seasonal incidence of phytophagous mites and their natural enemies on tomato cv. Heemsohna under the polyhouse conditions. In present investigation two spotted red spider mite, *T. urticae* and tomato russet mite, *A. lycopersici* were observed throughout the crop season, while two potential predators of these mites viz., phytoseiid mite, *Amblyseius longispinosus* and predatory thrips *Scolothrips indicus* were also closely associated with the colonies of both the phytophagous mite

**Table 39:- Oviposition period of *A. lycopersici* under laboratory conditions(Days)**

| Sr.No.             | Unmated               |                    |                         | Mated                 |                    |                         | Adult longevity (mated) | Adult longevity (unmated) |
|--------------------|-----------------------|--------------------|-------------------------|-----------------------|--------------------|-------------------------|-------------------------|---------------------------|
|                    | Preoviposition Period | Oviposition period | Post oviposition period | Preoviposition Period | Oviposition period | Post oviposition period |                         |                           |
| 1                  | 2.00                  | 5.00               | 2.00                    | 4.00                  | 12.00              | 4.00                    | 20.00                   | 9.00                      |
| 2                  | 3.00                  | 6.00               | 3.00                    | 6.00                  | 16.00              | 3.00                    | 25.00                   | 12.00                     |
| 3                  | 4.00                  | 6.00               | 2.00                    | 6.00                  | 13.00              | 4.00                    | 23.00                   | 12.00                     |
| 4                  | 2.00                  | 5.00               | 2.00                    | 6.00                  | 14.00              | 5.00                    | 25.00                   | 9.00                      |
| 5                  | 2.00                  | 5.00               | 3.00                    | 4.00                  | 16.00              | 5.00                    | 25.00                   | 10.00                     |
| 6                  | 3.00                  | 6.00               | 2.00                    | 6.00                  | 14.00              | 4.00                    | 24.00                   | 11.00                     |
| 7                  | 4.00                  | 7.00               | 2.00                    | 4.00                  | 14.00              | 6.00                    | 24.00                   | 13.00                     |
| 8                  | 3.00                  | 7.00               | 3.00                    | 6.00                  | 16.00              | 4.00                    | 26.00                   | 13.00                     |
| 9                  | 3.00                  | 8.00               | 2.00                    | 5.00                  | 13.00              | 5.00                    | 23.00                   | 13.00                     |
| 10                 | 2.00                  | 5.00               | 3.00                    | 6.00                  | 16.00              | 5.00                    | 27.00                   | 10.00                     |
| 11                 | 2.00                  | 5.00               | 3.00                    | 5.00                  | 14.00              | 5.00                    | 24.00                   | 10.00                     |
| 12                 | 2.00                  | 7.00               | 2.00                    | 4.00                  | 16.00              | 5.00                    | 25.00                   | 11.00                     |
| 13                 | 3.00                  | 6.00               | 2.00                    | 6.00                  | 13.00              | 6.00                    | 25.00                   | 11.00                     |
| 14                 | 3.00                  | 5.00               | 3.00                    | 5.00                  | 14.00              | 5.00                    | 24.00                   | 11.00                     |
| 15                 | 3.00                  | 5.00               | 2.00                    | 7.00                  | 16.00              | 5.00                    | 28.00                   | 10.00                     |
| 16                 | 4.00                  | 5.00               | 2.00                    | 4.00                  | 14.00              | 5.00                    | 23.00                   | 11.00                     |
| 17                 | 2.00                  | 6.00               | 3.00                    | 6.00                  | 16.00              | 4.00                    | 26.00                   | 11.00                     |
| 18                 | 3.00                  | 6.00               | 3.00                    | 5.00                  | 13.00              | 6.00                    | 24.00                   | 12.00                     |
| 19                 | 4.00                  | 7.00               | 2.00                    | 6.00                  | 14.00              | 5.00                    | 25.00                   | 13.00                     |
| 20                 | 2.00                  | 4.00               | 2.00                    | 6.00                  | 16.00              | 5.00                    | 27.00                   | 8.00                      |
| 21                 | 2.00                  | 6.00               | 2.00                    | 5.00                  | 14.00              | 6.00                    | 25.00                   | 10.00                     |
| 22                 | 2.00                  | 5.00               | 3.00                    | 6.00                  | 14.00              | 6.00                    | 26.00                   | 10.00                     |
| 23                 | 3.00                  | 5.00               | 1.00                    | 4.00                  | 13.00              | 6.00                    | 23.00                   | 9.00                      |
| 24                 | 3.00                  | 6.00               | 2.00                    | 6.00                  | 17.00              | 5.00                    | 28.00                   | 11.00                     |
| 25                 | 3.00                  | 5.00               | 2.00                    | 5.00                  | 13.00              | 5.00                    | 23.00                   | 10.00                     |
| <b>Minimum</b>     | <b>2.00</b>           | <b>4.00</b>        | <b>1.00</b>             | <b>4.00</b>           | <b>12.00</b>       | <b>3.00</b>             | <b>20.00</b>            | <b>8.00</b>               |
| <b>Maximum</b>     | <b>4.00</b>           | <b>8.00</b>        | <b>3.00</b>             | <b>7.00</b>           | <b>17.00</b>       | <b>6.00</b>             | <b>28.00</b>            | <b>13.00</b>              |
| <b>Avg. ± S.D.</b> | <b>2.76±0.72</b>      | <b>5.72±0.93</b>   | <b>2.32±0.55</b>        | <b>5.32±0.90</b>      | <b>14.44±1.38</b>  | <b>4.96±0.79</b>        | <b>24.76±1.79</b>       | <b>10.80±1.38</b>         |

**Table 41:- Impact of photoperiodism on oviposition of *A. lycopersici***

| Sr. No.                | Date of observation | Oviposition period | Average number of eggs/female |                 |                   |
|------------------------|---------------------|--------------------|-------------------------------|-----------------|-------------------|
|                        |                     |                    | Continous dark                | Continous light | Natural condition |
| 1.                     | 08.04.14            | 1                  | 0.80                          | 0.20            | 1.00              |
| 2.                     | 09.04.14            | 2                  | 0.80                          | 0.50            | 1.00              |
| 3.                     | 10.04.14            | 3                  | 1.00                          | 0.50            | 1.00              |
| 4.                     | 11.04.14            | 4                  | 1.00                          | 0.50            | 1.00              |
| 5.                     | 12.04.14            | 5                  | 1.00                          | 1.00            | 1.00              |
| 6.                     | 13.04.14            | 6                  | 1.00                          | 0.50            | 1.50              |
| 7.                     | 14.04.14            | 7                  | 0.50                          | 0.50            | 1.50              |
| 8.                     | 15.04.14            | 8                  | 0.20                          | 0.50            | 1.00              |
| 9.                     | 16.04.14            | 9                  | 0.20                          | 0.50            | 1.00              |
| 10.                    | 17.04.14            | 10                 | 0.00                          | 0.00            | 0.00              |
| <b>Overall average</b> |                     |                    | <b>0.72</b>                   | <b>0.52</b>     | <b>1.11</b>       |

**Table 42:- Duration of various stages of *A. lycopersici* reared on Tomato under laboratory condition**

| Sr. No. | Stage                    | No. observed | Min. | Max.  | Avg. $\pm$ S.D. |                  |
|---------|--------------------------|--------------|------|-------|-----------------|------------------|
| 1.      | Incubation period        | Male         | 25   | 1.50  | 3.00            | 2.08 $\pm$ 0.49  |
|         |                          | female       | 25   | 2.50  | 3.00            | 2.86 $\pm$ 0.22  |
| 2.      | Larval                   | Male         | 25   | 0.50  | 1.50            | 1.00 $\pm$ 0.32  |
|         |                          | Female       | 25   | 1.00  | 2.00            | 1.56 $\pm$ 0.36  |
| 3.      | Q 1                      | Male         | 25   | 0.25  | 2.50            | 1.48 $\pm$ 4.90  |
|         |                          | Female       | 25   | 0.50  | 1.00            | 0.89 $\pm$ 0.14  |
| 4.      | Nymph                    | Male         | 25   | 1.50  | 2.50            | 1.76 $\pm$ 0.29  |
|         |                          | Female       | 25   | 2.00  | 3.00            | 2.60 $\pm$ 0.38  |
| 5.      | Q2                       | Male         | 25   | 0.75  | 1.00            | 0.90 $\pm$ 0.12  |
|         |                          | Female       | 25   | 1.00  | 2.50            | 1.96 $\pm$ 0.45  |
| 6.      | Adult males              | Male         | 25   | 12.00 | 17.00           | 14.40 $\pm$ 1.55 |
|         |                          | Length       | 25   | 0.10  | 0.19            | 0.14 $\pm$ 0.02  |
|         |                          | width        | 25   | 0.03  | 0.04            | 0.03 $\pm$ 0.005 |
|         |                          | Mated        | 25   | 20.00 | 28.00           | 24.72 $\pm$ 1.79 |
|         |                          | Unmated      | 25   | 8.00  | 13.00           | 10.80 $\pm$ 1.38 |
| 7.      | Total development period | Male         | 25   | 5.25  | 8.00            | 6.23 $\pm$ 0.70  |
|         |                          | Female       | 25   | 11.50 | 16.00           | 13.89 $\pm$ 1.02 |
| 8.      | Total life period        | Male         | 25   | 18.25 | 24.00           | 20.63 $\pm$ 1.70 |
|         |                          | Mated        | 25   | 28.00 | 39.00           | 34.59 $\pm$ 2.23 |
|         |                          | Unmated      | 25   | 17.00 | 23.50           | 20.67 $\pm$ 1.60 |
| 9.      | Pre oviposition period   | Unmated      | 25   | 2.00  | 4.00            | 2.76 $\pm$ 0.72  |
|         |                          | Mated        | 25   | 4.00  | 7.00            | 5.32 $\pm$ 0.90  |
| 10.     | Oviposition period       | Unmated      | 25   | 4.00  | 8.00            | 5.72 $\pm$ 0.93  |
|         |                          | Mated        | 25   | 12.00 | 17.00           | 14.44 $\pm$ 1.38 |
| 11.     | Post ovipostion period   | Unmated      | 25   | 1.00  | 3.00            | 2.32 $\pm$ 0.55  |
|         |                          | Mated        | 25   | 3.00  | 6.00            | 4.96 $\pm$ 0.79  |
| 12.     | Fecundity period         | Mated        | 25   | 34.00 | 57.00           | 42.52 $\pm$ 5.90 |
|         |                          | Unmated      | 25   | 11.00 | 21.00           | 15.52 $\pm$ 2.78 |
| 13.     | Adult longevity period   | Mated        | 25   | 20.00 | 28.00           | 24.76 $\pm$ 1.79 |
|         |                          | Unmated      | 25   | 8.00  | 13.00           | 10.80 $\pm$ 1.38 |

#### **4.3.1 Seasonal incidence of two spotted red spider mite, *T. urticae*:**

The seasonal activities of *T. urticae* on tomato were recorded by numerically counting the number of eggs and mobile stages (nymphs and adults) on 2 cm x 2 cm leaf bits at weekly intervals. The data presented in Table 43 showed the number of eggs laid by *T. urticae* at weekly interval under the polyhouse conditions. The initial egg laying on leaves during 2<sup>nd</sup> standard meteorological week (SMW) (second week of January) was 0.33 eggs per leaf. The average temperature and relative humidity of polyhouse during this period were 31.90°C and 73.30 per cent, respectively. The number of eggs per leaf fluctuated at different time intervals and three distinct peaks were observed during the crop season. The first peak was recorded during the 12<sup>th</sup> SMW (3<sup>rd</sup> week of March) with 2.80 eggs per leaf. The average temperature and relative humidity of polyhouse were 34.50°C and 75.70 per cent, respectively. The number of eggs per leaf gradually fluctuated and again reaching to its peak with 4.93 eggs per leaf during 18<sup>th</sup> SMW (1<sup>st</sup> week of May) with average temperature and relative humidity 33.90°C and 77.20 per cent, respectively. The third distinct peak in the number of eggs were recorded during 24<sup>th</sup> SMW (2<sup>nd</sup> week of June) where 5.33 eggs of *T. urticae* were recorded from a leaf. The average temperature and relative humidity of polyhouse were 37.70°C and 78.20 per cent, respectively. The number of eggs then gradually decreased and at the time of crop harvest the number of eggs were least

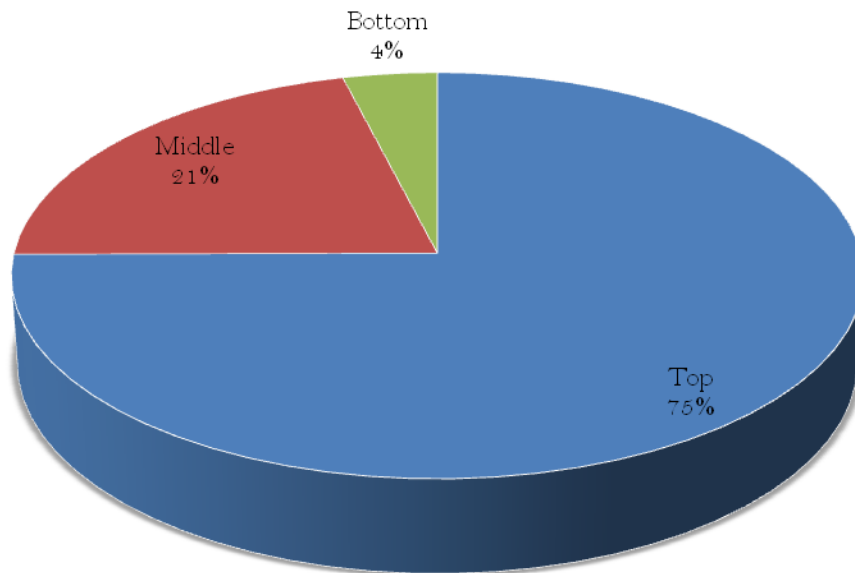
*i.e.* 0.46 per leaf. The average of eggs per leaf was 2.69. The distribution of *T. urticae* eggs were also recorded on top, middle and bottom canopy of the plant and it was found that throughout the crops period the highest number of eggs were recorded from the top canopy of the plant (6.05 eggs per leaf) and were followed by middle leaves (1.71 eggs per leaf) and bottom leaves (0.32 eggs per leaf) (Figure 1).

The correlation coefficient between the number of eggs and the average temperature and relative humidity of polyhouse were also worked out and presented in Table 49. The number of eggs of *T. urticae* showed a significant positive correlation with average temperature ( $r=0.690$ ) and average relative humidity ( $r=0.671$ ) of the polyhouse. Thus, it can be concluded from the present investigation that average temperature and average relative humidity of the polyhouse favoured the egg laying of *T. urticae*. Under the present study the average temperature and relative humidity of polyhouse varied between 30.10 to 38.30°C and 72.30 to 78.70 per cent, respectively.

The population of mobile stages of two spotted red spider mite, *T. urticae* were also recorded throughout the crop season. The initial population of mobile stages was 0.07 per leaf during 1<sup>st</sup> SMW (first week of January). The average temperature and relative humidity during this period were 30.10°C and 74.30 per cent, respectively. The population of *T. urticae* were gradually fluctuated at different time intervals and reached to the first peak *i.e.* 6.06 per leaf during 15<sup>th</sup> SMW (second week of April). The average temperature and relative humidity during this period were 34.30°C and 76.40

**Table43:-Seasonal activity of egg stage of two spotted red spider mite, *T. urticae* eggs on Tomato (cv. Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of eggs on plant canopy (No. of eggs/2cm <sup>2</sup> leaf surface) |             |             | No. of eggs per leaf (2 cm <sup>2</sup> ) | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|--|-------------|-------------|---|--------------------------|-------------------------------|
|                                    |                     | Top  | Middle      | Bottom      |   |                          |                               |
| 01                                 | 03-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                      | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 1.00   | 0.00        | 0.00        | 0.33                                      | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 2.00   | 0.60        | 0.00        | 0.87                                      | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 1.40   | 0.20        | 0.00        | 0.53                                      | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 2.80   | 0.60        | 0.00        | 1.33                                      | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 2.60   | 1.40        | 0.00        | 1.33                                      | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 2.40   | 0.80        | 0.20        | 1.13                                      | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 2.80   | 1.20        | 0.20        | 1.40                                      | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 2.80   | 2.00        | 0.20        | 1.66                                      | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 2.40   | 1.40        | 0.20        | 1.33                                      | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 3.00   | 1.80        | 0.20        | 1.66                                      | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 5.80   | 2.20        | 0.40        | 2.80                                      | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 5.40   | 2.20        | 0.40        | 2.66                                      | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 6.60   | 3.20        | 0.20        | 2.00                                      | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 8.00   | 2.60        | 0.40        | 2.20                                      | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 6.60   | 2.40        | 0.40        | 3.14                                      | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 10.60  | 3.60        | 0.40        | 4.67                                      | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 11.40  | 2.80        | 0.60        | 4.93                                      | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 9.00   | 2.40        | 0.40        | 3.94                                      | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 11.20  | 3.20        | 0.60        | 5.00                                      | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 11.40  | 3.20        | 0.60        | 5.06                                      | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 12.20  | 2.40        | 0.20        | 4.80                                      | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 12.00  | 2.20        | 1.00        | 5.06                                      | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 12.60  | 2.80        | 0.60        | 5.33                                      | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 11.60  | 2.20        | 0.60        | 4.80                                      | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 10.40  | 1.60        | 0.80        | 4.26                                      | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 5.80   | 1.20        | 0.40        | 2.46                                      | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 4.00   | 0.60        | 0.40        | 1.00                                      | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 2.60   | 0.20        | 0.20        | 1.00                                      | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 1.20   | 0.20        | 0.00        | 0.46                                      | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>6.05</b>  | <b>1.71</b> | <b>0.32</b> | <b>2.69</b>                               | <b>34.14</b>             | <b>75.60</b>                  |



**Figure 1: Distribution of eggs of *T. urticae* on tomato plant**

per cent, respectively. The population of *T. urticae* again fluctuated and gradually increased again and reached to the second peak during 24<sup>th</sup> SMW (second week of June). The mean population of mobile stages of *T. urticae* were 7.33 per leaf while, the average temperature and relative humidity during this period were 37.70°C and 78.20 per cent, respectively. The average of the mobile stages was 4.54 per leaf. The distribution of mobile stages of *T. urticae* on tomato grown under polyhouse condition was also presented in the Table 43. Throughout the crop season the population of mobile stages remains higher on the top leaves (9.74 per leaf), followed by middle leaves (3.16 per leaf) and lowest population were recorded on bottom leaf canopy (0.71 per leaf).

The correlation between mobile stages of *T. urticae* and average temperature and relative humidity of polyhouse were also worked out. The data on correlation studies were presented in Table 47, showed that the mobile stages had a significant positive correlation ( $r=0.678$ ). Similarly, it had also significantly positively correlated with average relative humidity ( $r=0.574$ ). Thus, from the present studies it was concluded that the average temperature and relative humidity of polyhouse favoured the spider mite growth and development. The seasonal average temperature and relative humidity ranged between 30.40 to 38.30°C and 72.30 to 78.70 per cent, respectively.

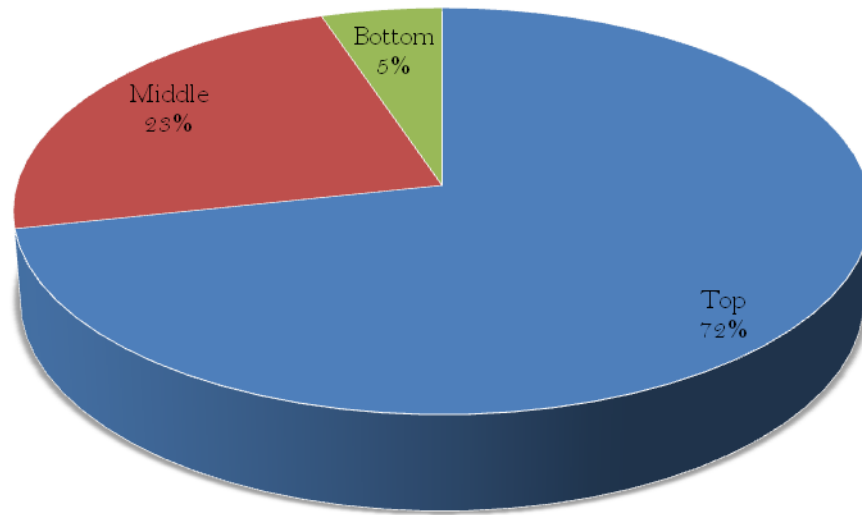
Sudhirkumar and Shelke (2008a) reported that the spider mite population started from 35<sup>th</sup> SMW with 1<sup>st</sup> peak at 42<sup>nd</sup> SMW and reached up to lowest population during 1<sup>st</sup>

SMW. Whereas, pest population also started from 2<sup>nd</sup> SMW and reached its 2<sup>nd</sup> peak at 11<sup>th</sup> SMW. Dhar *et al.* (2000) found 30 °C temperature and 78.5 per cent relative humidity to be optimum for highest incidence of *T. urticae* (both eggs and mobile stages) on okra. Recently, Shah (2014) from Navsari also studied the seasonal activities of *T. urticae* on polyhouse gerbera and found that the eggs and mobile stages of *T. urticae* showed a non-significant negative correlation with temperature whereas, it had a significant positive correlation with relative humidity. It was also found that on gerbera the spider mite remains active throughout the crop season with a peak during 31<sup>st</sup> SMW (last week of July), thus more or less in support of the present findings. Further, Mazid *et al.* (2015) from their studies on *Oligonychus coffeae* Nietner concluded that there was a significant positive correlation of the population of spider mites with the increasing temperature whereas moderate positive correlation existed between relative humidity.

Further, the distribution of spider mite on the plant canopy was also recorded and it was found that the spider mite lays eggs on top canopy as well as maximum activities of mobile stages were also recorded on top canopy followed by middle and bottom canopy. It was due to the continuous supply of vital nutrients which are nutritive for spider mite. In past, Shah (2014) also reported that the spider mite, *T. urticae* lays maximum eggs on top canopy of gerbera with maximum mobile stages. Gulati (2004) on okra and Gupta (1991) also reported similar results on brinjal. However, Onkarappa *et al.* (1999) as well as Mondal and Ara (2006)

**Table 44:- Seasonal activity of mobile stages of two spotted red spider mite, *T. urticae* on Tomato (cv. Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of mobile stages on plant canopy (No. of eggs/2cm <sup>2</sup> leaf surface) |             |             | No. of mobile stages per leaf (2 cm <sup>2</sup> ) | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|---|-------------|-------------|--|--------------------------|-------------------------------|
|                                    |                     | Top   | Middle      | Bottom      |  |                          |                               |
| 01                                 | 03-01-2014          | 0.20  | 0.00        | 0.00        | 0.07   | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 2.00  | 0.60        | 0.60        | 1.06   | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 4.20  | 2.00        | 0.40        | 2.20   | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 4.20  | 2.20        | 0.80        | 2.40   | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 5.00  | 2.80        | 0.20        | 2.66   | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 6.20  | 2.80        | 0.40        | 3.13   | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 6.80  | 3.60        | 1.20        | 3.86   | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 7.20  | 3.40        | 1.00        | 3.73   | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 7.40  | 4.00        | 0.80        | 4.06   | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 6.00  | 4.60        | 0.60        | 3.73   | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 6.60  | 4.80        | 0.40        | 3.40   | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 9.20  | 3.80        | 0.20        | 4.40   | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 11.00   | 4.00        | 0.80        | 5.26   | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 13.00   | 4.40        | 0.60        | 6.00   | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 13.20   | 4.00        | 1.00        | 6.06   | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 13.20   | 3.40        | 0.60        | 5.73   | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 14.00   | 5.00        | 1.00        | 4.00   | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 15.00   | 3.80        | 0.60        | 6.46   | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 14.00   | 3.60        | 0.80        | 6.13   | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 14.80   | 4.20        | 1.20        | 6.73   | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 15.20   | 4.20        | 1.00        | 6.80   | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 16.60   | 3.80        | 1.00        | 7.13   | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 15.60   | 4.20        | 1.40        | 7.06   | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 15.80   | 4.80        | 1.40        | 7.33   | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 14.60   | 3.60        | 1.00        | 6.40   | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 13.00   | 2.60        | 0.80        | 5.46   | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 10.20   | 2.00        | 0.40        | 4.20   | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 8.00  | 1.20        | 0.40        | 3.20   | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 6.00  | 0.80        | 0.40        | 2.40   | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 4.00  | 0.60        | 0.20        | 1.60   | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>9.74</b>   | <b>3.16</b> | <b>0.71</b> | <b>4.54</b>  | <b>34.14</b>             | <b>75.60</b>                  |



**Figure 2: Distribution of mobile stages of *T. urticae* on tomato plant**

observed the abundance of mite population on bottom strata than on middle and top strata on open cultivated rose. This may be due to different crop and the crop growing situations.

#### **4.3.2 Seasonal incidence of tomato russet mite, *A. lycopersici*:**

Studies were undertaken during January to July 2014 to investigate the seasonal incidence of tomato russet mite, *A. lycopersici* under polyhouse conditions. The observations were recorded on the eggs and mobile stages of *A. lycopersici* and data on the population were presented in the Table 45 and 46 and Figure 3 and 4.

The data presented in Table 45 showed the number of eggs laid by *A. lycopersici* on tomato under polyhouse. The russet mite starts egg laying during 4<sup>th</sup> SMW (3<sup>rd</sup> week of January) (0.12 per leaf). The average temperature and relative humidity of polyhouse were 31.60 °C and 72.30 per cent, respectively. The number of eggs gradually increased at various intervals and the maximum eggs were recorded during 21<sup>st</sup> SMW (4<sup>th</sup> week of May) *i.e.* 9.20 eggs per leaf. The average temperature and relative humidity during this period were 36.20°C and 75.90 per cent, respectively. The eggs then declined gradually in numbers and at the time of crop maturity the number of eggs per leaf was 0.40. The average temperature and relative humidity were 34.60°C and 76.70 per cent, respectively.

The distribution of eggs of *A. lycopersici* was also studied on plant canopy and it was found that the maximum number of eggs were laid on the top leaves (4.28 eggs per leaf) which was followed by middle leaves (2.41 eggs per leaf) and

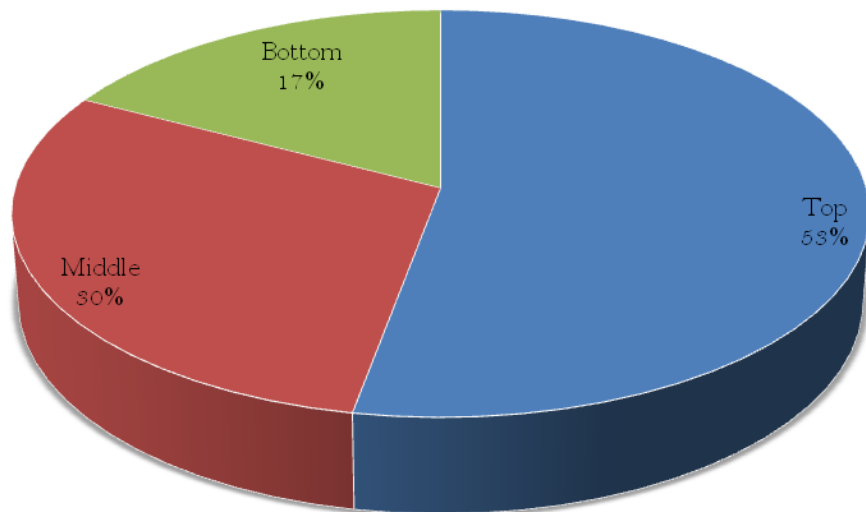
the bottom leaves (0.39 eggs per leaf). Thus, it was found from the present investigation that maximum number of eggs were laid on top leaves.

The results of correlation studies between number of eggs laid by *A. lycopersici* and average temperature as well as relative humidity were presented in Table 50. The number of eggs have a significant positive correlation with average temperature ( $r=0.508$ ) and similarly a significant positive correlation exists between number of eggs and average relative humidity ( $r=0.499$ ) under polyhouse conditions on tomato. Thus, it was found in the present investigation that the average temperature and relative humidity ranging between 30.40 to 38.30°C and 72.30 to 78.70 per cent had positive effect on egg laying of *A. lycopersici*.

The seasonal incidence of mobile stages of *A. lycopersici* on tomato under polyhouse condition were also recorded during the crop season and presented in the Table 46. The initial population of mobile stage during 1<sup>st</sup> SMW (1<sup>st</sup> week of January) was 0.20 per plant. The average temperature and relative humidity during this period was 30.10°C and 74.30 per cent, respectively. The mite population gradually increased and reached to its peak i.e. 9.00 per leaf during 21<sup>st</sup> SMW (4<sup>th</sup> week of May). The average temperature and relative humidity of polyhouse during this period were 36.20°C and 75.90 per cent, respectively. The population then gradually decreased and at the time of maturity the mite population was 0.93 per leaf with the average temperature and relative humidity of 34.60°C and 76.70 per cent, respectively

**Table45:- Seasonal activity of egg stage of tomato russet mite *A.lycopersici* on Tomato (cv. Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of eggs on plant canopy (No. of eggs/2cm <sup>2</sup> leaf surface) |             |             | No. of eggs per leaf (2 cm <sup>2</sup> ) | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|--|-------------|-------------|---|--------------------------|-------------------------------|
|                                    |                     | Top  | Middle      | Bottom      |   |                          |                               |
| 01                                 | 03-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                      | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                      | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                      | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 0.40   | 0.20        | 0.00        | 0.12                                      | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 0.80   | 0.20        | 0.00        | 0.33                                      | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 1.00   | 0.60        | 0.00        | 0.53                                      | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 1.40   | 0.60        | 0.20        | 0.73                                      | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 1.60   | 1.00        | 0.40        | 1.00                                      | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 2.80   | 1.00        | 0.20        | 1.33                                      | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 3.40   | 1.40        | 0.40        | 1.73                                      | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 3.60   | 1.20        | 0.40        | 1.73                                      | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 4.00   | 1.20        | 0.20        | 1.80                                      | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 3.20   | 1.40        | 0.40        | 1.00                                      | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 4.40   | 2.60        | 0.20        | 2.40                                      | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 4.40   | 2.40        | 0.20        | 2.33                                      | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 6.20   | 2.80        | 0.40        | 3.13                                      | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 6.80   | 3.20        | 0.60        | 3.53                                      | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 9.20   | 5.60        | 1.00        | 5.26                                      | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 10.20  | 8.60        | 1.40        | 6.73                                      | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 13.20  | 8.80        | 1.40        | 7.80                                      | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 16.20  | 9.80        | 1.60        | 9.20                                      | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 9.60   | 6.60        | 1.20        | 5.80                                      | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 8.00   | 5.20        | 0.60        | 4.60                                      | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 5.60   | 2.00        | 0.40        | 2.66                                      | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 2.20   | 0.80        | 0.20        | 1.06                                      | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 2.60   | 1.40        | 0.20        | 1.40                                      | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 2.60   | 1.20        | 0.20        | 1.33                                      | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 2.60   | 1.00        | 0.00        | 1.20                                      | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 1.80   | 1.00        | 0.00        | 0.93                                      | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 0.80   | 0.40        | 0.00        | 0.40                                      | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>4.29</b>  | <b>2.41</b> | <b>0.39</b> | <b>2.36</b>                               | <b>34.14</b>             | <b>75.60</b>                  |



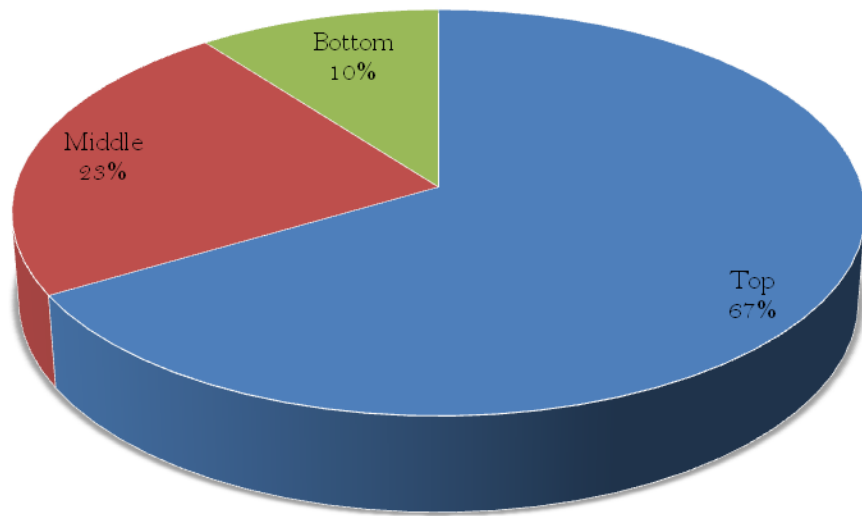
**Figure 3: Distribution of eggs of *A. lycopersici* on tomato plant**

The distribution of tomato russet mite, *A. lycopersici* was also presented in Table 44 showed that the maximum number of mobile stages was recorded from the top leaves of tomato followed by middle and bottom leaves. The number of mites was 8.98, 3.13 and 0.95 per leaves on three canopy of tomato plant.

A simple correlation coefficient was also worked out between the mobile stages and the abiotic factors of the polyhouse and the results are presented in Table 50. The data showed that there was a significantly positive correlation exists between the mobile stages of *A. lycopersici* and average temperature ( $r=0.441$ ). Likewise, the mobile stages of *A. lycopersici* also showed significantly positive correlation with average relative humidity ( $r=0.406$ ). Thus, from the present study it was found that the tomato russet mite *A. lycopersici* population flourished on tomato plants when the average temperature of polyhouse ranged between 30.10 to 38.30°C and the average relative humidity ranged between 72.30 to 78.70 per cent. The present findings are in accordance with the earlier work of Rice and Strong (1962) who reported that the temperature 32-35 °C and high humidity 70-80 per cent were necessary for the survival of *A. lycopersici*. Further, Baradaran and Daneshwar (1992) from Varami reported that *A. lycopersici* appeared in July and a population buildup was observed in September and October. Under the present studies the *A. lycopersici* reached to peak in May does not match with the earlier work. This may be due to difference in climatic condition, crop varieties and growing

**Table 46:- Seasonal activity of mobile stages of tomato russet mite *A.lycopersici* on Tomato (cv. Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of mobile stages on plant canopy (No. of eggs/2cm <sup>2</sup> leaf surface) |             |             | No. of mobile stages per leaf (2 cm <sup>2</sup> ) | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|---|-------------|-------------|--|--------------------------|-------------------------------|
|                                    |                     | Top   | Middle      | Bottom      |  |                          |                               |
| 01                                 | 03-01-2014          | 0.40  | 0.20        | 0.00        | 0.20   | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 0.60  | 0.40        | 0.20        | 0.40   | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 2.00  | 1.00        | 0.40        | 1.13   | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 2.40  | 1.20        | 0.40        | 1.33   | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 3.00  | 1.20        | 0.80        | 1.00   | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 3.80  | 0.80        | 0.60        | 1.04   | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 4.60  | 2.40        | 0.80        | 2.60   | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 6.80  | 3.60        | 0.80        | 3.73   | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 7.80  | 4.60        | 1.60        | 4.67   | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 8.40  | 5.00        | 1.60        | 5.00   | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 9.80  | 5.20        | 1.60        | 5.53   | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 10.40   | 5.40        | 1.40        | 5.73   | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 12.00   | 4.40        | 1.40        | 5.93   | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 12.60   | 4.00        | 1.20        | 6.93   | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 13.20   | 3.60        | 1.40        | 6.06   | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 14.00   | 4.20        | 1.20        | 6.46   | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 15.60   | 4.80        | 1.40        | 7.26   | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 16.00   | 6.20        | 2.00        | 8.06   | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 18.80   | 4.80        | 1.80        | 8.46   | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 19.00   | 5.20        | 1.80        | 8.66   | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 20.00   | 5.80        | 1.20        | 9.00   | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 14.20   | 3.40        | 1.00        | 6.20   | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 10.60   | 2.60        | 0.60        | 4.60   | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 9.60  | 2.60        | 0.60        | 4.26   | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 8.60  | 3.00        | 0.80        | 4.13   | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 7.00  | 2.20        | 0.60        | 3.26   | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 6.60  | 2.40        | 0.60        | 3.06   | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 5.40  | 2.20        | 0.40        | 2.66   | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 4.20  | 0.80        | 0.20        | 1.73   | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 2.00  | 0.60        | 0.20        | 0.93   | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>8.98</b>   | <b>3.13</b> | <b>0.95</b> | <b>4.35</b>  | <b>34.14</b>             | <b>75.60</b>                  |



**Figure 4: Distribution of mobile stages of *A. lycopersici* on tomato plant**



**Plate 7: Tomato leaves affected by *Aceria lycopersici***



Tomato leaves affected by *Aceria lycopersici*



Tomato fruits affected by *Aceria lycopersici*



*Aceria lycopersici* colony on tomato fruit

**Plate 8: Damage of *Aceria lycopersici* on tomato**

practices. Celar and Valic (2003) also reported the activities of *A. lycopersici* on tomato soon after the plants are transplanted.

### **4.3.3 Seasonal incidence of Predatory mite, *A. longispinosus*:**

Under the present investigation the activities of predatory mite, *A. longispinosus* was also observed and the data on the activities of *A. longispinosus* were presented in Table 47. The activities of predatory mite, *A. longispinosus* starts during 1<sup>st</sup> SMW (1<sup>st</sup> week of January) with the mean population of 0.66 mites per leaf. The average temperature and relative humidity were 30.10°C and 74.30 per cent, respectively. The activities of *A. longispinosus* gradually fluctuated and two distinct peaks were observed during the crop season. The first peak was observed during 13<sup>th</sup> SMW (4<sup>th</sup> week of March) where the mean population of predatory mite *A. longispinosus* was 2.67 mites per leaf. The mean number of eggs and mobile stages of both the prey species *i.e.* *T. urticae* and *A. lycopersici* were 2.66, 5.26, 1.00 and 5.93 per leaf, respectively. The average temperature and relative humidity during this period were 33.30°C and 75.20 per cent, respectively. The population of *A. longispinosus* then gradually fluctuated and reaching to second peak during 25<sup>th</sup> SMW (3<sup>rd</sup> week of June) with the mean population of 2.67 per leaf. The prey population *i.e.* eggs and mobile stages of both the prey species *i.e.* *T. urticae* and *A. lycopersici* were 4.80, 6.40, 1.06 and 4.13 per leaf, respectively. The average temperature was 35.80°C and the average relative humidity was 76.30 per cent. The population of predatory mite, *A.*

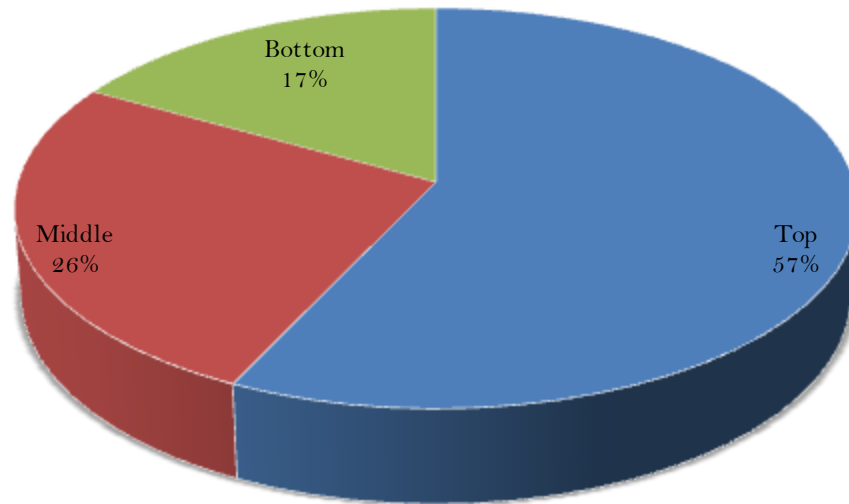
*longispinosus* then gradually declined towards the crop maturity. The mean population was 0.67 per leaf. The yearly average of predatory mite was 1.45 mites per leaf. The data presented in Table 45 also showed the distribution of predatory mite *A. longispinosus* on tomato plant and it was observed that the maximum mean number of predatory mites were found on top leaves (2.47 mites per leaf) followed by middle leaves (1.13 mites per leaf) and bottom leaves (0.73 per leaf). This may be due to the eggs and mobile stages of its prey *i.e.*, *T. urticae* and *A. lycopersici* was also highest on top leaves throughout the crop season.

The correlation coefficient was also worked out between incidence of predatory mite, *A. longispinosus* and abiotic factors (average temperature and relative humidity) of polyhouse and its prey (Table 51). The correlation studies showed significant positive correlation with the eggs and mobile stages of *T. urticae* ( $r=0.758$  and  $r=0.799$ ) on tomato, similarly the predatory mite *A. longispinosus* showed significant positive correlation with eggs and mobile stages of *A. lycopersici* ( $r=0.563$  and  $r=0.727$ , respectively). The activities of predatory mite *A. longispinosus* were significantly positive with average temperature ( $r=0.515$ ) and relative humidity ( $r=0.401$ ) of the polyhouse. Therefore predatory mite *A. longispinosus* were active when average temperature and relative humidity ranged between 30.40 to 38.30°C and 72.30 to 78.70 per cent, respectively.

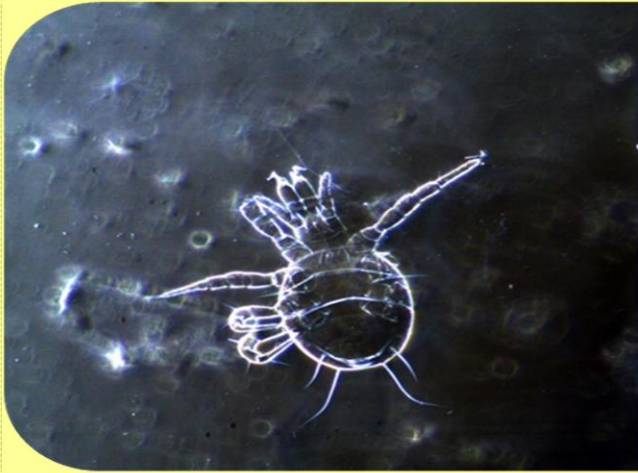
In past similar reports were done by Naik (2000) who suggested that the predatory mite, *A. longispinosus* had positive correlation with its prey both eggs and mobile stage

**Table47:-Seasonal activity of Predatory mites *Amblyseius longispinosus* (Evans) on Tomato (cv. Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of Predatory mites on plant canopy |             |             | Number of predatory mites per leaf | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|---|-------------|-------------|------------------------------------|--------------------------|-------------------------------|
|                                    |                     | Top   | Middle      | Bottom      |                                    |                          |                               |
| 01                                 | 03-01-2014          | 2.00  | 0.00        | 0.00        | 0.66                               | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 3.00  | 0.00        | 0.00        | 1.00                               | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 2.00  | 1.00        | 0.00        | 1.00                               | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 2.00  | 0.00        | 0.00        | 0.66                               | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 2.00  | 0.00        | 0.00        | 0.66                               | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 2.00  | 0.00        | 0.00        | 0.66                               | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 2.00  | 0.00        | 0.00        | 0.66                               | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 2.00  | 1.00        | 0.00        | 1.00                               | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 1.00  | 2.00        | 0.00        | 1.00                               | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 3.00  | 1.00        | 0.00        | 1.34                               | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 3.00  | 2.00        | 1.00        | 2.00                               | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 3.00  | 1.00        | 1.00        | 1.66                               | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 4.00  | 2.00        | 2.00        | 2.67                               | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 3.00  | 2.00        | 2.00        | 2.34                               | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 2.00  | 2.00        | 1.00        | 1.66                               | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 3.00  | 1.00        | 1.00        | 1.66                               | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 3.00  | 1.00        | 1.00        | 1.66                               | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 4.00  | 0.00        | 1.00        | 1.66                               | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 2.00  | 2.00        | 1.00        | 1.66                               | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 3.00  | 2.00        | 1.00        | 2.00                               | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 3.00  | 2.00        | 2.00        | 2.34                               | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 2.00  | 2.00        | 2.00        | 2.00                               | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 4.00  | 2.00        | 1.00        | 2.33                               | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 3.00  | 2.00        | 2.00        | 2.33                               | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 4.00  | 2.00        | 2.00        | 2.67                               | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 2.00  | 1.00        | 1.00        | 1.33                               | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 2.00  | 1.00        | 0.00        | 1.00                               | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 1.00  | 1.00        | 0.00        | 0.67                               | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 1.00  | 1.00        | 0.00        | 0.67                               | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 1.00  | 1.00        | 0.00        | 0.67                               | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>2.47</b>                                     | <b>1.13</b> | <b>0.73</b> | <b>1.45</b>                        | <b>34.14</b>             | <b>75.60</b>                  |



**Figure 5: Distribution of *A. longispinosus* on tomato plant**



**Plate 9: Predatory Mite**  
*Amblyseius longispinosus*

of its prey *O. indicus* as well as with average temperature and average relative humidity.

#### **4.3.4 Seasonal incidence of predatory thrips *S. indicus*:**

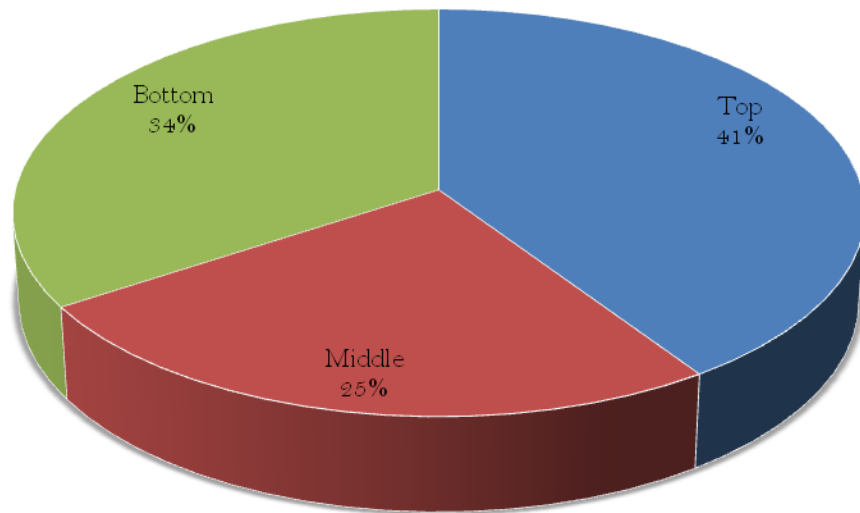
In present investigation the predatory thrips *S. indicus* was also recorded as one of the potential predator inhabiting near the colonies of both phytophagous mites. The predatory thrips, *S. indicus* starts its activity during 6<sup>th</sup> SMW (1<sup>st</sup> week of February) with an average population of 0.33 per leaf. The average temperature and relative humidity during this period were 32.10°C and 73.50 per cent, respectively. The population of predatory thrips, *S. indicus* gradually fluctuated and reaching to its peak during 26<sup>th</sup> SMW (4<sup>th</sup> week of June) with the average population of 3.00 thrips per leaf. The average population of the eggs and mobile stages of its prey *i.e.* *T. urticae* and *A. lycopersici* during the peak activities period of predatory thrips were 4.26, 5.46, 1.40 and 3.26 per leaf, respectively. The average temperature and relative humidity during peak activity period were 35.30°C and 76.00 per cent, respectively. The population of predatory thrips, *S. indicus* then gradually decreased and at the time of crop maturity the mean population was 0.33 predatory thrips per leaf. The yearly mean of predatory thrips *S. indicus* was 0.96 thrips per plant. The distribution of the predatory thrips were also observed and presented in the Table 46. It was found that the highest predatory thrips population was recorded on top leaves of tomato plants (1.66 per leaf), followed by middle leaves (1.03 per leaf) and least on bottom

leaves (0.37 per leaf). It was found in the present investigation that most of the activities of its prey mites *i.e.T. urticae* and *A. lycopersici* were also on top canopy of the tomato crop, therefore the predatory thrips, *S. indicus* were found more on top leaves as compared to middle and bottom canopy.

The correlation studies were also worked out between predatory thrips, *S. indicus* and its prey mites as well as with abiotic factors of polyhouse. It was found that the predatory thrips, *S. indicus* showed a significant positive correlation with the eggs and mobile stages of prey mites *i.e.T. urticae* and *A. lycopersici* ( $r=0.851$ ,  $0.802$ ,  $0.551$  and  $0.461$ , respectively). The predatory thrips, *S.indicus* also showed a significant positive correlation with the average temperature ( $r=0.822$ ) and average relative humidity ( $r=0.663$ ) of polyhouse. Thus, from the present study it can be concluded that the predatory thrips, *S. indicus* remains active in polyhouse when the average temperature was ranging between  $30.10$  to  $38.30^{\circ}\text{C}$  and relative humidity ranging between  $72.30$  to  $78.70$  per cent respectively. Pakyari (2011) also reported that predatory thrips, *S. longicornis* remains active throughout the year under Mediterranean region in high temperature and relative humidity. The *S. longicornis* lays eggs at higher temperature and relative humidity (Pakyari *et al.*, 2012). The present findings are more or less similar to the earlier one as temperature and relative humidity had also positive effect on predatory thrips, *S. indicus* population

**Table48:-Seasonal activity of Predatory thrips *Scolothrips indicuson* Tomato (cv.Heemsohna) under polyhouse condition**

| Standard meteorological week (SMW) | Date of Observation | Distribution of Predatory thrips on plant canopy |             |             | Number of predatory thrips per leaf | Average Temperature (°C) | Average relative humidity (%) |
|------------------------------------|---------------------|--|-------------|-------------|-------------------------------------|--------------------------|-------------------------------|
|                                    |                     | Top  | Middle      | Bottom      |                                     |                          |                               |
| 01                                 | 03-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                | 30.10                    | 74.30                         |
| 02                                 | 07-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                | 31.90                    | 73.30                         |
| 03                                 | 13-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                | 30.40                    | 74.10                         |
| 04                                 | 20-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                | 31.60                    | 72.30                         |
| 05                                 | 30-01-2014          | 0.00   | 0.00        | 0.00        | 0.00                                | 32.30                    | 74.40                         |
| 06                                 | 05-02-2014          | 1.00   | 0.00        | 0.00        | 0.33                                | 32.10                    | 73.50                         |
| 07                                 | 10-02-2014          | 1.00   | 0.00        | 0.00        | 0.33                                | 33.00                    | 75.00                         |
| 08                                 | 19-02-2014          | 0.00   | 1.00        | 0.00        | 0.33                                | 33.40                    | 72.30                         |
| 09                                 | 25-02-2014          | 1.00   | 0.00        | 0.00        | 0.33                                | 32.70                    | 74.00                         |
| 10                                 | 03-03-2014          | 1.00   | 0.00        | 0.00        | 0.33                                | 33.40                    | 73.60                         |
| 11                                 | 12-03-2014          | 2.00   | 0.00        | 0.00        | 0.66                                | 33.90                    | 74.70                         |
| 12                                 | 20-03-2014          | 1.00   | 2.00        | 0.00        | 1.00                                | 34.50                    | 75.70                         |
| 13                                 | 24-03-2014          | 1.00   | 1.00        | 0.00        | 0.66                                | 33.30                    | 75.20                         |
| 14                                 | 02-04-2014          | 2.00   | 1.00        | 0.00        | 1.00                                | 33.90                    | 73.50                         |
| 15                                 | 07-04-2014          | 2.00   | 1.00        | 0.00        | 1.00                                | 34.30                    | 76.40                         |
| 16                                 | 17-04-2014          | 1.00   | 2.00        | 0.00        | 1.00                                | 33.80                    | 78.70                         |
| 17                                 | 22-04-2014          | 1.00   | 1.00        | 0.00        | 0.67                                | 34.60                    | 76.70                         |
| 18                                 | 01-05-2014          | 2.00   | 1.00        | 1.00        | 1.33                                | 33.90                    | 77.20                         |
| 19                                 | 06-05-2014          | 2.00   | 1.00        | 1.00        | 1.33                                | 34.70                    | 76.30                         |
| 20                                 | 16-05-2014          | 3.00   | 2.00        | 1.00        | 2.00                                | 35.80                    | 77.20                         |
| 21                                 | 20-05-2014          | 3.00   | 2.00        | 1.00        | 2.00                                | 36.20                    | 75.90                         |
| 22                                 | 28-05-2014          | 2.00   | 2.00        | 1.00        | 2.00                                | 34.70                    | 78.20                         |
| 23                                 | 03-06-2014          | 4.00   | 3.00        | 1.00        | 2.66                                | 38.30                    | 77.80                         |
| 24                                 | 10-06-2014          | 4.00   | 3.00        | 1.00        | 2.66                                | 37.70                    | 78.20                         |
| 25                                 | 17-06-2014          | 3.00   | 4.00        | 1.00        | 2.66                                | 35.80                    | 76.30                         |
| 26                                 | 23-06-2014          | 4.00   | 3.00        | 2.00        | 3.00                                | 35.30                    | 76.00                         |
| 27                                 | 03-07-2014          | 3.00   | 1.00        | 1.00        | 1.67                                | 36.80                    | 78.20                         |
| 28                                 | 07-07-2014          | 3.00   | 0.00        | 0.00        | 1.00                                | 36.00                    | 75.20                         |
| 29                                 | 16-07-2014          | 2.00   | 0.00        | 0.00        | 0.67                                | 35.30                    | 77.10                         |
| 30                                 | 23-07-2014          | 1.00   | 0.00        | 0.00        | 0.33                                | 34.60                    | 76.70                         |
| <b>Mean</b>                        |                     | <b>1.66</b>                                      | <b>1.03</b> | <b>0.37</b> | <b>0.96</b>                         | <b>34.14</b>             | <b>75.60</b>                  |



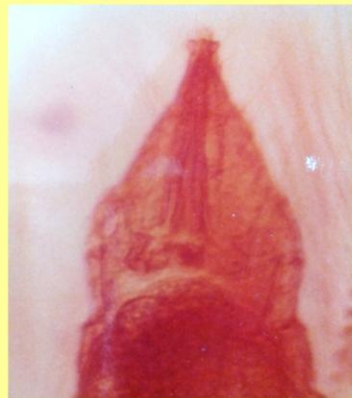
**Figure 6: Distribution of *S. indicus* on tomato plant**



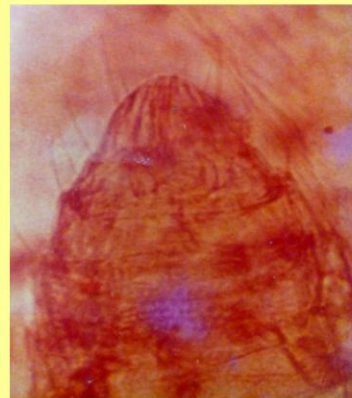
Adult male



Adult female



Abdominal tip of male



Abdominal tip of female

**Plate 10: Predatory thrips**  
*Scolothrips indicus*

**Table 49:-Correlation between the population of two spotted red spider mite, *T. urticae* and abiotic factors**

|                            | Stages        | Average Temperature (°C) | Relative Humidity (%) | Critical value at 5% level of significance |
|----------------------------|---------------|--------------------------|-----------------------|--|
| <i>Tetranychus urticae</i> | Eggs          | *0.690                   | *0.671                | 0.360                                      |
|                            | Mobile stages | *0.678                   | *0.574                |  |

\*Significant at 5% level of significance

**Table 50:-Correlation between the population of tomato russet mite, *A. lycopersici* and abiotic factors**

|                           | Stages        | Average Temperature (°C) | Relative Humidity (%) | Critical value at 5% level of significance |
|---------------------------|---------------|--------------------------|-----------------------|--|
| <i>Aceria lycopersici</i> | Eggs          | *0.508                   | *0.499                | 0.360                                      |
|                           | Mobile stages | *0.441                   | *0.406                |  |

\*Significant at 5% level of significance

**Table 51:-Correlation of Predatory mite *A. longipsinosus* with biotic and abiotic factors.**

|                 | <i>T. urticae</i> |               | <i>A. lycopersici</i> |               | Average Temperature (°C) | Relative Humidity (%) | Critical value at 5% level of significance |
|-----------------|-------------------|---------------|-----------------------|---------------|--------------------------|-----------------------|--|
|                 | Egg Stages        | Mobile stages | Egg stages            | Mobile stages |                          |                       |  |
| Predatory mites | *0.758            | *0.799        | *0.563                | *0.727        | *0.515                   | *0.401                | 0.360                                      |

\*Significant at 5% level of significance

**Table 52:- Correlation of Predatory thrips *S. indicus* with biotic and abiotic factors.**

|                  | <i>T. urticae</i> |               | <i>A. lycopersici</i> |               | Average Temperature (°C) | Relative Humidity (%) | Critical value at 5% level of significance |
|------------------|-------------------|---------------|-----------------------|---------------|--------------------------|-----------------------|--|
|                  | Egg stages        | Mobile stages | Egg stages            | Mobile stages |                          |                       |  |
| Predatory thrips | *0.851            | *0.802        | *0.551                | *0.461        | *0.822                   | *0.663                | 0.360                                      |

\*Significant at 5% level of significance

#### **4.4. Chemical control of phytophagous mites and adverse effect of acaricides on predatory mites:**

The various acaricides were evaluated for the control of phytophagous mites *viz.*, *T. urticae* and *A. lycopersici* and their adverse effect on predatory mite, *A. longispinosus* under laboratory as well as field conditions were also observed.

##### **4.4.1 Laboratory trials:**

There were eight treatments including control (Table 1). The treatments were evaluated on the basis of per cent mortality of both the phytophagous mites and per cent hatching of eggs of mites.

##### **4.4.1.1 Spray applied on spider mites *T. urticae* and eggs on the leaf:**

###### **Evaluation on mortality basis:**

Per cent mortality of *T.urticae* in different treatments were recorded and presented in Table 53.

The data presented in Table 53 showed that 24 hours after spraying, all the acaricidal treatments were significantly superior over control. The treatment diafenthiuron and chlorfenapyr provided maximum mortality of mite *i.e.* 50.60 and 45.33 per cent kill and they are significantly superior over rest of the acaricidal treatments. Next in order of effectiveness was fenazaquin (38.67% mortality) and it was at par with chlorfenapyr. Among the various acaricides tested wettable sulphur was the least effective showing 21.33 per cent mortality. The order of effectiveness of various treatments based on per cent mortality was: diafenthiuron (50.60%)> chlorfenapyr

(45.33%)> fenazaquin (38.67%)> propargite (36.00%)> fenpyroximate (34.67%)> triazophos (33.33%)> wettable sulphur (31.33%)> control (0.00%).

Similarly, 48 hours after spraying all the treatments were significantly superior over the control (Table 53). Diafenthiuron, fenazaquin and chlorfenapyr provided highest per cent mortality *i.e.* 57.54, 50.00 and 48.16 per cent and they were significantly superior than rest of the treatments. They all were at par with each other. Triazophos showed 38.44 per cent mortality and was found at par with fenpyroximate (42.74% mortality). The order of effectiveness of various treatments on the basis of per cent mortality was: Diafenthiuron (57.54%)> chlorfenapyr (48.16%)> fenpyroximate (42.74%)> triazophos (38.44%)> propargite (31.20%)> wettable sulphur (28.72%)> control (0.00%).

From the Table 53 it can be seen that 72 hours after spraying, all the acaricidal treatments were significantly superior over the control. Diafenthiuron (61.27%) gives the highest mortality of mites and was followed by chlorfenapyr(49.09%)> fenazaquin (48.14%)> propargite (39.89%)> fenpyroximate (39.63%)> triazophos (35.04%)> wettable sulphur (23.80%)> control (0.00%).

Thus it can be stated that diafenthiuron 50 WP (0.055%) was the effective treatment for the control of *T. urticae* on tomato followed by chlorfenapyr 10 SC (0.01%) and fenazaquin 10 EC (0.01%). While wettable sulphur 80 WP (0.20%) proved to be least effective acaricidal treatment under laboratory conditions. In past, Shah and Shukla (2014)

**Table 53:- Mortality of *T. urticae* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent mortality             |                                |                                |
|---------|------------------------|-------------------|--------------------------------|--------------------------------|--------------------------------|
|         |                        |                   | 24 hrs                         | 48 hrs                         | 72 hrs                         |
| 1.      | Wettable sulphur 80 WP | 0.20              | 27.48 <sup>d</sup><br>(31.33)  | 32.42 <sup>d</sup><br>(28.72)  | 29.15 <sup>d</sup><br>(23.80)  |
| 2.      | Fenazaquin 10 EC       | 0.01              | 38.48 <sup>bc</sup><br>(38.67) | 45.00 <sup>a</sup><br>(50.00)  | 43.93 <sup>b</sup><br>(48.14)  |
| 3.      | Propargite 57 EC       | 0.05              | 36.85 <sup>c</sup><br>(36.00)  | 33.90 <sup>cd</sup><br>(31.20) | 39.11 <sup>bc</sup><br>(39.89) |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 42.31 <sup>ab</sup><br>(45.33) | 43.94 <sup>a</sup><br>(48.16)  | 44.48 <sup>b</sup><br>(49.09)  |
| 5.      | Diafenthurion 50 WP    | 0.055             | 45.38 <sup>a</sup><br>(50.60)  | 45.86 <sup>a</sup><br>(57.54)  | 51.53 <sup>a</sup><br>(61.27)  |
| 6.      | Triazophos 40 EC       | 0.1               | 35.45 <sup>c</sup><br>(33.33)  | 38.27 <sup>bc</sup><br>(38.44) | 36.28 <sup>c</sup><br>(35.04)  |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 36.04 <sup>c</sup><br>(34.67)  | 40.81 <sup>bc</sup><br>(42.74) | 38.94 <sup>bc</sup><br>(39.63) |
| 8.      | Control (Water spray)  | -                 | 0.58 <sup>e</sup><br>(0.00)    | 0.58 <sup>e</sup><br>(0.00)    | 0.58 <sup>e</sup><br>(0.00)    |
|         | S. Em. Period (P)      |                   | 1.57                           | 1.65                           | 2.07                           |
|         | C. D at 5% Period (P)  |                   | 5.09                           | 5.34                           | 6.71                           |
|         | C.V. %                 |                   | 8.98                           | 8.79                           | 10.93                          |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

also reported diafenthiuron as best treatment against *T. urticae* under laboratory conditions on gerbera.

#### **4.4.1.2 Evaluation on the basis of ovicidal effect against *T. urticae*:**

The treatments were evaluated for their ovicidal effect against eggs of *T. urticae*. The eggs hatching as affected by different acaricidal treatments was significantly low in comparison to control (Table 54). The percentage of hatching in control was maximum *i.e.* 96.66 per cent.

It can be seen from the Table 54, that the treatment comprising diafenthiuron was the best ovicide as it recorded the lowest egg hatching (32.22%) off all the treatments and proved significantly superior over other acaricidal treatments. The treatments propargite, fenazaquin and chlorfenapyr were at par with each other with egg hatching of 54.43, 51.11 and 47.77 per cent, respectively. While wettable sulphur and triazophos were least effective having higher per cent hatching *i.e.* 67.33 and 64.44 per cent.

So, from the present results it can be concluded that diafenthiuron 50 WP (0.055%) had showed the best ovicidal action. The treatments of propargite 57 EC (0.05%), fenazaquin 10 EC (0.01%) and chlorfenapyr 10 SC (0.01%) had also showed better results. Whereas wettable sulphur and triazophos had showed poor ovicidal action against the eggs of *T. urticae* under the laboratory conditions.

The present findings was closely supported by Shah and Shukla (2014) who also reported the ovicidal properties of diafenthiuron against *T. Urticae* on gerbera leaves under laboratory conditions.

**Table54:- Hatching of eggs of *T. urticae* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent hatching             |
|---------|------------------------|-------------------|-------------------------------|
| 1.      | Wettable sulphur 80 WP | 0.20              | 55.41 <sup>b</sup><br>(67.33) |
| 2.      | Fenazaquin 10 EC       | 0.01              | 45.64 <sup>c</sup><br>(51.11) |
| 3.      | Propargite 57 EC       | 0.05              | 47.55 <sup>c</sup><br>(54.43) |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 43.72 <sup>c</sup><br>(47.77) |
| 5.      | Diafenthurion 50 WP    | 0.055             | 34.53 <sup>d</sup><br>(32.22) |
| 6.      | Triazophos 40 EC       | 0.1               | 53.39 <sup>b</sup><br>(64.44) |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 36.54 <sup>d</sup><br>(35.55) |
| 8.      | Control (Water spray)  | -                 | 79.47 <sup>a</sup><br>(96.66) |
|         | S. Em. Period (P)      |                   | 1.59                          |
|         | C. D at 5% Period (P)  |                   | 5.13                          |
|         | C.V. %                 |                   | 5.98                          |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

#### **4.4.1.3 Spider mite released on the leaf after 72 hours of spraying:**

The experiment was conducted in the laboratory and data on mortality of *T. urticae* are given in Table 55. The data indicated that all the acaricidal treatments were significantly superior over the control. Among the different acaricidal treatments diafenthiuron recorded maximum kill of spider mites, *T. urticae* (68.33%) and significantly superior over all the other treatments. The next in order of effectiveness was fenpyroximate (50.00%) and chlorfenapyr (48.33%). These two treatments were significantly superior over the rest of the treatments. The descending order of effectiveness was: diafenthiuron (68.33%)> fenpyroximate (50.00%)> chlorfenapyr (48.33%)> fenazaquin (38.33%)> triazophos (33.33%)> propargite (30.00%)> wettable sulphur (16.67%)> control (0.00%). The present findings are more or less in accordance with the earlier work done by Shah and Shukla (2014) on gerbera and found diafenthiuron as most effective treatment against *T. urticae* under laboratory conditions.

#### **4.4.2.1 Spray applied on spider mites *A. lycopersici* and eggs on the leaf:**

##### **Evaluation on mortality basis:**

The results were recorded as per cent mortality of *A. lycopersici* in different acaricidal treatments and presented in Table 56.

From the Table 56, it can be seen that 24 hours after spraying all the acaricidal treatments were significantly superior over the control. The treatment diafenthiuron was

**Table55:- Mortality of *T. urticae* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent hatching              |
|---------|------------------------|-------------------|--------------------------------|
| 1.      | Wettable sulphur 80 WP | 0.20              | 24.04 <sup>e</sup><br>(16.67)  |
| 2.      | Fenazaquin 10 EC       | 0.01              | 38.22 <sup>d</sup><br>(38.33)  |
| 3.      | Propargite 57 EC       | 0.05              | 33.16 <sup>d</sup><br>(30.00)  |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 44.04 <sup>bc</sup><br>(48.33) |
| 5.      | Diafenthurion 50 WP    | 0.055             | 55.76 <sup>a</sup><br>(68.33)  |
| 6.      | Triazophos 40 EC       | 0.1               | 35.25 <sup>d</sup><br>(33.33)  |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 45.00 <sup>b</sup><br>(50.00)  |
| 8.      | Control (Water spray)  | -                 | 4.69 <sup>f</sup><br>(1.67)    |
|         | S. Em. Period (P)      |                   | 1.84                           |
|         | C. D at 5% Period (P)  |                   | 5.94                           |
|         | C.V. %                 |                   | 9.79                           |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

proved most effective in terms of highest per cent mortality of russet mite, *A. lycopersici* (62.67%), whereas the second most effective treatments in terms of per cent mortality were chlorfenapyr (52.00%) and fenpyroximate (50.67%) and both the treatments were at par with each other. The next effective treatments in terms of per cent mortality were fenazaquin (37.85%), propargite (33.33%), wettable sulphur (36.00%) and triazophos (33.33%) and all of these were at par with each other. The descending order of effectiveness of different acaricidal treatments in terms of mortality against *A. lycopersici* were: diafenthiuron (62.67%)> chlorfenapyr (52.00%)> fenpyroximate (50.67%)> fenazaquin (37.85%)> propargite (33.33%)> wettable sulphur (36.00%)> triazophos (33.33%) > control (0.00%).

Similarly, 48 hours after spraying (Table 56) all the treatments were significantly superior over the control. Among all the acaricidal treatments diafenthiuron provided 78.51 per cent mortality and was significantly superior than rest of the treatments. There was no significant difference among fenpyroximate and chlorfenapyr, but they were significantly superior to fenazaquin (52.08%) and triazophos (51.82%). The order of effectiveness of various treatments on the basis of per cent mortality against *A. lycopersici* were: diafenthiuron (78.51%)> fenpyroximate (62.47%)> chlorfenapyr (61.10%)> fenazaquin (52.08%)> triazophos (51.82%)> propargite (49.26%)> wettable sulphur (43.74%)> control (4.00%).

From the Table 56, it can be seen that 72 hours after spraying, all the acaricidal treatments were

**Table56:- Mortality of *A. lycopersici* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent mortality            |                               |                               |
|---------|------------------------|-------------------|-------------------------------|-------------------------------|-------------------------------|
|         |                        |                   | 24 hrs                        | 48 hrs                        | 72 hrs                        |
| 1.      | Wettable sulphur 80 WP | 0.20              | 36.80 <sup>c</sup><br>(36.00) | 41.38 <sup>d</sup><br>(43.74) | 46.34 <sup>a</sup><br>(33.65) |
| 2.      | Fenazaquin 10 EC       | 0.01              | 37.67 <sup>c</sup><br>(37.85) | 46.19 <sup>c</sup><br>(52.08) | 44.99 <sup>a</sup><br>(49.99) |
| 3.      | Propargite 57 EC       | 0.05              | 37.33 <sup>c</sup><br>(33.33) | 44.57 <sup>d</sup><br>(49.26) | 44.99 <sup>a</sup><br>(49.99) |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 46.15 <sup>b</sup><br>(52.00) | 51.44 <sup>b</sup><br>(61.10) | 45.00 <sup>a</sup><br>(50.00) |
| 5.      | Diafenthurion 50 WP    | 0.055             | 52.34 <sup>a</sup><br>(62.67) | 62.39 <sup>a</sup><br>(78.51) | 45.00 <sup>a</sup><br>(50.04) |
| 6.      | Triazophos 40 EC       | 0.1               | 37.25 <sup>c</sup><br>(33.33) | 46.05 <sup>c</sup><br>(51.82) | 40.15 <sup>a</sup><br>(41.59) |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 43.38 <sup>b</sup><br>(50.67) | 52.25 <sup>b</sup><br>(62.47) | 40.00 <sup>a</sup><br>(41.67) |
| 8.      | Control (Water spray)  | -                 | 0.58 <sup>d</sup><br>(0.00)   | 11.53 <sup>e</sup><br>(4.00)  | 11.76 <sup>b</sup><br>(4.16)  |
|         | S. Em. Period (P)      |                   | 1.39                          | 1.36                          | 2.50                          |
|         | C. D at 5% Period (P)  |                   | 4.50                          | 4.37                          | 8.09                          |
|         | C.V. %                 |                   | 7.07                          | 5.68                          | 11.76                         |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

significantly superior over the control. All the acaricidal treatments were found at par to each other in terms of per cent mortality of mobile stages of *A. lycopersici*. The order of effectiveness of treatments were: diafenthiuron (50.00%)> chlorfenapyr (50.00%)> fenazaquin (49.99%), propargite (49.99%)> fenpyroximate (41.67%)> triazophos (41.59%)> wettable sulphur (33.65%)> control (4.16%).

Thus, it can be stated that diafenthiuron 50 WP (0.055%) was the most effective acaricidal treatment for the control of *A. lycopersici* on tomato. Earlier, Haji *et al.* (1988) tested different chemical pesticides against *A. lycopersici* on tomato and found flubenzimine, abamectin, dicofol, dicofol plus tetradifon, sulphur, methamidophos and clofentezine as effective against the eriophyid mite. The present findings also suggests that chemical pesticides were effective against *A. lycopersici* on tomato. Further, Kay and Shepherd (1988) found sulphur as ineffective against *A. lycopersici* on tomato, under the present study sulphur was found inferior as compared to other acaricidal treatments thus supports the present findings. In general, diafenthiuron was found most effective against various phytophagous mites like *T. Urticae* on gerbera (Shah and Shukla, 2014).

#### **4.4.2.2 Evaluation on the basis of ovicidal effect against *A. lycopersici*:**

The acaricidal treatments were evaluated for their ovicidal effect against eggs of *A. lycopersici*. The egg hatching as affected by different acaricidal treatments were significantly lower in comparison to untreated control

**Table57:- Hatching of eggs of *A. lycopersici* in different acaricidal treatments**

| <b>Sr. No.</b> | <b>Treatment</b>       | <b>Concentration (%)</b> | <b>Per cent hatching</b>      |
|----------------|------------------------|--------------------------|-------------------------------|
| 1.             | Wettable sulphur 80 WP | 0.20                     | 62.24 <sup>b</sup><br>(77.77) |
| 2.             | Fenazaquin 10 EC       | 0.01                     | 46.28 <sup>d</sup><br>(52.22) |
| 3.             | Propargite 57 EC       | 0.05                     | 54.06 <sup>c</sup><br>(65.55) |
| 4.             | Chlorfenpyr 10 SC      | 0.01                     | 42.31 <sup>d</sup><br>(45.33) |
| 5.             | Diafenthurion 50 WP    | 0.055                    | 32.50 <sup>e</sup><br>(19.89) |
| 6.             | Triazophos 40 EC       | 0.1                      | 45.01 <sup>d</sup><br>(49.99) |
| 7.             | Fenpyroximate 5 EC     | 0.0025                   | 40.50 <sup>d</sup><br>(42.21) |
| 8.             | Control (Water spray)  | -                        | 82.78 <sup>a</sup><br>(97.77) |
|                | S. Em. Period (P)      |                          | 2.20                          |
|                | C. D at 5% Period (P)  |                          | 7.14                          |
|                | C.V. %                 |                          | 8.14                          |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

Table 57). The percentage of hatching in control was significantly higher in control (97.77%).

It can also be seen from the Table 57 that the acaricidal treatment diafenthiuron was the best ovicide as it recorded the lowest egg hatching (19.89%) among all the acaricidal treatments and proved significantly superior over all the acaricidal treatments. The treatment fenpyroximate (42.21%) was at par with chlorfenapyr (45.33%), triazophos (49.99%) and fenazaquin (52.22%). The acaricidal treatment propargite gave 65.55 per cent ovicidal effect while wettable sulphur (77.77%) showed less ovicidal action as compared to rest of the acaricidal treatments. In past, diafenthiuron showed ovicide effect against spider mite *T. urticae* on gerbera (Shah and Shukla, 2014). Therefore supports the present findings. So, from the present findings, it can be concluded that diafenthiuron 50 WP (0.055%) had showed the best ovicidal action. While wettable sulphur 80 WP (0.20%) was less effective in ovicidal action against *A. lycopersici*.

The descending order of ovicidal action of various acaricidal treatments were: diafenthiuron (19.89%)> fenpyroximate (42.21%)> chlorfenapyr (45.33%)> triazophos (49.99%)> fenazaquin (52.22%)> propargite (65.55%)> wettable sulphur (77.77%)> control (97.77%).

#### **4.4.2.3 Russet mite released on the leaf after 72 hours of spraying:**

The experiment was conducted in the Acarology laboratory and the data on mortality of russet mite *A. lycopersici* are given in Table 58. The data indicated that all the acaricidal treatments were significantly superior over the

**Table58:-Mortality of *A. lycopersici* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent hatching             |
|---------|------------------------|-------------------|-------------------------------|
| 1.      | Wettable sulphur 80 WP | 0.20              | 19.30 <sup>e</sup><br>(11.67) |
| 2.      | Fenazaquin 10 EC       | 0.01              | 46.91 <sup>b</sup><br>(53.33) |
| 3.      | Propargite 57 EC       | 0.05              | 29.92 <sup>d</sup><br>(25.00) |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 48.83 <sup>b</sup><br>(56.67) |
| 5.      | Diafenthurion 50 WP    | 0.055             | 61.14 <sup>a</sup><br>(76.61) |
| 6.      | Triazophos 40 EC       | 0.1               | 37.25 <sup>c</sup><br>(36.67) |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 46.91 <sup>b</sup><br>(53.33) |
| 8.      | Control (Water spray)  | -                 | 12.92 <sup>f</sup><br>(5.00)  |
|         | S. Em. Period (P)      |                   | 1.62                          |
|         | C. D at 5% Period (P)  |                   | 5.24                          |
|         | C.V. %                 |                   | 7.99                          |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed value

control. Among the different acaricidal treatments diafenthiuron recorded maximum kill of russet mite (76.61%) and was statistically significant over all other acaricidal treatments. The next in order of effectiveness was chlorfenapyr (56.67%), fenazaquin (53.33%) and fenpyroximate (53.33%), all these three acaricidal treatments were statistically at par with each other in terms of per cent mortality. The acaricidal treatment wettable sulphur (11.67%) was the least effective among all the acaricidal treatments. The descending order of effectiveness of different acaricidal treatments were: diafenthiuron (76.61%)> chlorfenapyr (56.67%)> fenazaquin (53.33%)> fenpyroximate (53.33%)> triazophos (36.67%)> propargite (25.00%)> wettable sulphur (11.67%)> control (5.00%). Very little information is available in regard to the effectiveness of chemicals when russet mites released on the leaf after 72 hours of spraying. But in past, Shah and Shukla (2014) reported diafenthiuron as very effective in reducing spider mite under laboratory conditions, therefore support the present findings.

#### **4.4.3 Toxicity of chemicals to predatory mite (*Amblyseius longispinosus*)**

Acaricidal treatments as mentioned in Table 1 were evaluated for their toxicity to phytoseiid predatory mite, *A. longispinosus* through slide dip technique under laboratory conditions.

From the Table 59, all the acaricidal treatments showed significantly higher mortality of predatory mite as compared to untreated control. One hour after treatment

triazophos, wettable sulphur and propargite gave 21.10, 18.89 and 16.67 per cent mortality which was at par with each others. It was followed by the other treatments *viz.*, chlorfenapyr (6.67%), fenazaquin (6.66%) and fenpyroximate (5.55%), all these treatments were found at par with each others in terms of per cent mortality of predatory mite *A. longispinosus*. Among the all treatments the lowest per cent mortality was recorded in diafenthiuron (1.11%). Two hours after treatment, mortality was highest in wettable sulphur (29.44%), triazaophos (25.29%) and propargite (22.74%). All these were at par with each other. The acaricidal treatments *i.e.* propargite and trizaophos were also found at par with chlorfenapyr (8.37%) and fenpyroximate (7.06%). The treatment comprises diafenthiuron gives less per cent mortality of predatory mite, *A. longispinosus* (3.40%).

Three hours after treatment highest per cent mortality was recorded in the treatment triazophos (32.09%) and it was at par with wettable sulphur (29.50%), propargite (18.91%), fenazaquin (26.40%), while the lowest per cent mortality was recorded in the treatment diafenthiuron (2.38%).

Four hours after treatment propargite, triazophos and wettable sulphur gave maximum per cent mortality and were statistically at par with each other. Mortality in the treatment diafenthiuron was lowest (3.38%) and was at par with chlorfenapyr (8.26%).

Five hours after treatment, the lowest per cent mortality of predatory mite, *A. longispinosus* was recorded in diafenthiuron (3.71%). The highest per cent mortality was recorded in the treatment wettable sulphur (81.54%). Other

treatments also showed varying degree of mortality to the predatory mite.

Six hours after treatment, wettable sulphur and triazophos gave cent per cent mortality of predatory mite, *A. longispinosus*. The treatments diafenthiuron, chlorfenapyr and fenazaquin gave lowest per cent mortality of predatory mite and were also at par with each others. The rest of the treatment also gave varying degree of mortality.

Seven hours after treatment, similar trends were recorded. The treatment diafenthiuron maintains its superiority over all the acaricidal treatments and were at par with rest of treatments. While wettable sulphur and triazophos gave cent per cent mortality and were at par with propargite (66.67%).

Based on mean of all the seven observations, toxicity of the acaricidal treatments to predatory mite *A. longispinosus* in descending order were: propargite (42.37%)> wettable sulphur (41.16%)> triazophos (37.20%)> fenpyroximate (10.38%)> fenazaquin (9.15%)> chlorfenapyr(8.58%)> diafenthiuron (2.72%)> control (2.00%).

Thus, it can be concluded that though not a single acaricidal treatment was non toxic to predatory mite, *A. longispinosus*. Diafenthiuron was comparative less toxic as it showed lower mortality for longer period after treatment, wettable sulphur and traizophos were more toxic as they gave 100 % mortality within six hours after treatments while the remaining treatments were considered moderate in terms of non toxic effect on predatory mite, *A. longispinosus*.

**Table59:- Toxicity of predatory mite *A. longispinosus* in different acaricidal treatments**

| Sr. No. | Treatment              | Concentration (%) | Per cent mortality            |                                |                                 |                               |                               |                                 |                               |                               |
|---------|------------------------|-------------------|-------------------------------|--------------------------------|---------------------------------|-------------------------------|-------------------------------|---------------------------------|-------------------------------|-------------------------------|
|         |                        |                   | One                           | two                            | three                           | Four                          | Five                          | Six                             | Seven                         | Mean                          |
| 1.      | Wettable sulphur 80 WP | 0.20              | 25.74 <sup>a</sup><br>(18.89) | 32.86 <sup>a</sup><br>(29.44)  | 32.77 <sup>a</sup><br>(29.50)   | 32.28 <sup>a</sup><br>(28.78) | 60.38 <sup>a</sup><br>(81.54) | 89.41 <sup>a</sup><br>(100)     | 89.41 <sup>a</sup><br>(100)   | 39.91 <sup>a</sup><br>(41.16) |
| 2.      | Fenazaquin 10 EC       | 0.01              | 14.63 <sup>b</sup><br>(6.66)  | 15.11 <sup>cd</sup><br>(7.06)  | 25.48 <sup>ab</sup><br>(26.40)  | 18.70 <sup>b</sup><br>(10.94) | 17.70 <sup>d</sup><br>(9.26)  | 18.62 <sup>cde</sup><br>(10.21) | 21.00 <sup>b</sup><br>(13.56) | 17.53 <sup>b</sup><br>(9.15)  |
| 3.      | Propargite 57 EC       | 0.05              | 24.03 <sup>a</sup><br>(16.67) | 28.45 <sup>ab</sup><br>(22.74) | 23.05 <sup>abc</sup><br>(18.91) | 35.65 <sup>a</sup><br>(33.98) | 40.43 <sup>b</sup><br>(42.12) | 70.64 <sup>b</sup><br>(84.12)   | 59.80 <sup>a</sup><br>(66.67) | 40.58 <sup>a</sup><br>(42.37) |
| 4.      | Chlorfenpyr 10 SC      | 0.01              | 14.63 <sup>b</sup><br>(6.67)  | 8.92 <sup>bc</sup><br>(8.37)   | 17.38 <sup>bcd</sup><br>(5.29)  | 6.69 <sup>bc</sup><br>(8.26)  | 20.16 <sup>c</sup><br>(12.34) | 19.74 <sup>cd</sup><br>(11.49)  | 15.75 <sup>b</sup><br>(7.68)  | 16.90 <sup>b</sup><br>(8.58)  |
| 5.      | Diafenthurion 50 WP    | 0.055             | 3.89 <sup>c</sup><br>(1.11)   | 8.77 <sup>d</sup><br>(3.40)    | 10.96 <sup>cd</sup><br>(2.38)   | 10.90 <sup>cd</sup><br>(3.38) | 11.10 <sup>e</sup><br>(3.71)  | 11.32 <sup>de</sup><br>(3.85)   | 4.23 <sup>b</sup><br>(1.33)   | 9.40 <sup>c</sup><br>(2.72)   |
| 6.      | Triazophos 40 EC       | 0.1               | 27.24 <sup>a</sup><br>(21.10) | 25.46 <sup>ab</sup><br>(25.29) | 34.43 <sup>a</sup><br>(32.09)   | 33.68 <sup>a</sup><br>(30.92) | 45.55 <sup>b</sup><br>(50.95) | 89.41 <sup>a</sup><br>(100)     | 89.41 <sup>a</sup><br>(100)   | 37.59 <sup>a</sup><br>(37.20) |
| 7.      | Fenpyroximate 5 EC     | 0.0025            | 13.47 <sup>b</sup><br>(5.55)  | 20.01 <sup>bc</sup><br>(7.06)  | 15.99 <sup>bcd</sup><br>(7.59)  | 17.97 <sup>b</sup><br>(9.61)  | 21.67 <sup>c</sup><br>(13.65) | 27.33 <sup>c</sup><br>(21.09)   | 22.59 <sup>b</sup><br>(14.86) | 18.77 <sup>b</sup><br>(10.38) |
| 8.      | Control (Water spray)  | -                 | 3.89 <sup>c</sup><br>(0.00)   | 7.10 <sup>d</sup><br>(1.11)    | 3.89 <sup>d</sup><br>(1.11)     | 10.63 <sup>d</sup><br>(3.40)  | 7.45 <sup>e</sup><br>(2.38)   | 7.58 <sup>e</sup><br>(2.47)     | 11.16 <sup>b</sup><br>(3.75)  | 8.02 <sup>c</sup><br>(2.00)   |
|         | S. Em. Period (P)      |                   | 1.82                          | 3.12                           | 4.39                            | 1.29                          | 2.47                          | 3.53                            | 9.89                          | 1.18                          |
|         | C. D at 5% Period (P)  |                   | 5.88                          | 10.12                          | 14.24                           | 5.94                          | 8.01                          | 11.45                           | 32.04                         | 3.85                          |
|         | C.V. %                 |                   | 21.87                         | 29.86                          | 40.14                           | 15.56                         | 16.48                         | 15.85                           | 18.92                         | 9.43                          |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

Kottalagi and Veerendra (2014) from Dharwad, Karnataka reported diafenthiuron, fenazaquin and spiromesifen as safe for predatory mite on lime and recorded lowest predatory mite population from treatments *viz.*, propargite and sulphur.

#### **4.4.4 Chemical control under polyhouse conditions:**

Various acaricides were tested for their efficacy against two spotted spider mite, *T.urticae* and russet mite, *A.lycopersici* on tomato as well as their toxicity to phytoseiid predator, *A. longispinosus*. There were in all eight treatments including untreated control (Table-1). Based on the live mite (mobile stages and eggs) count, the percentage reduction in the population of both the mite species, as affected by different treatments were calculated.

##### **4.4.4.1 Effectiveness of acaricidal treatments against *T. urticae*:**

The data present in the Table 60 showed the effectiveness of various treatments against eggs and mobile stages of *T. urticae* under polyhouse conditions.

##### **Egg stage:**

##### **First spray:**

The pre treatment population of spider mite eggs varied from 7.33 to 7.89 per leaf in different acaricidal treatments. All the acaricidal treatments provided a significant reduction of spider mite eggs over untreated control.

At 1 day after spray, a significantly most effective treatment was diafenthiuron giving 49.83 per cent reduction in eggs. It was statistically at par with fenpyroximate (33.87% reduction) and chlorfenapyr (32.16% reduction) but

both of these treatments were also found statistically at par with rest of the treatments. So after 1 DAS the descending order of effectiveness of various acaricidal treatments were: diafenthiuron (49.83%)> fenpyroximate (33.87%)> chlorfenapyr (32.16%)> triazophos (30.10%)> fenazaquin (27.32%)> propargite (23.15%)> wettable sulphur (19.63%).

At 3 DAS diafenthiuron gave maximum reduction in eggs (86.08% reduction) and differed significantly with rest of the treatments except fenpyroximate (79.12% reduction) and triazophos (76.77% reduction) and were at par with each others. Both of these treatments were also at par with other treatments which includes fenazaquin (74.06% reduction), chlorfenapyr (71.70% reduction) and propargite (70.44% reduction). Among all the treatments wettable sulphur was found less effective in reducing eggs (66.06% reduction) of *T. urticae*.

At 7 DAS, diafenthiuron gave maximum reduction in eggs (95.73% reduction). However, it was at par with triazophos (89.90% reduction). Rest of the treatments also showed varying degree of reduction in spider mite eggs. On the basis of per cent reduction in eggs the order of effectiveness were: diafenthiuron (95.73%)> triazophos (89.90%)> fenazaquin (88.55%)> fenpyroximate (87.73%)> chlorfenapyr (86.00%)> wettable sulphur (83.93%)> propargite (81.88%).

At 14 DAS, triazophos stood first in effectiveness giving maximum reduction in eggs (98.18% reduction) and was at par with diafenthiuron (98.10% reduction) and fenpyroximate (95.74% reduction). The next treatment in

order of effectiveness was fenazaquin (94.35% reduction). However, it was at par with rest of the vtreatments. On the basis of the effectiveness against egg stage of *T. urticae* the descending order were: triazophos (98.18%)> diafenthiuron (98.10%)> fenpyroximate (95.74%)> fenazaquin (94.35%)> wettable sulphur (91.77%)> chlorfenapyr (91.54%)> propargite (89.95%).

The pooled analysis of all the acaricidal treatments after first spray revealed that there were significant differences among the treatments (Table 60). The treatment diafenthiuron gave maximum reduction in eggs (82.43% reduction). However, it was at par to the triazophos (73.73% reduction) and differed significantly with remaining acaricidal treatments. The descending order of effectiveness of different acaricidal treatments based on per cent reduction in eggs of spider mite were: diafenthiuron (82.43%)> triazophos (73.73%)> fenazaquin (71.07%)> chlorfenapyr (70.35%)> fenpyroximate (66.61%)> propargite (66.35%)> wettable sulphur (65.35%).

#### **Second spray:**

The data present in the Table 60 showed the effectiveness of different acaricidal treatment after second spray. At 1 DAS, a significantly most effective treatment was diafenthiuron giving 71.22 per cent reduction in eggs. Fenpyroximate ranked second in effectiveness (54.93% reduction). However, it was at par with triazophos (41.06% reduction). Among all the treatments chlorfenapyr showed least reduction in eggs (28.82%). The order of effectiveness of various acaricidal treatments after 1 DAS of second spray

were: diafenthiuron (71.22%)> fenpyroximate (54.93%)> triazophos (41.06%)> wettable sulphur (37.39%)> fenazaquin (34.68%)> propargite (32.87%)> chlorfenapyr (28.82%).

At 3 DAS, diafenthiuron gave maximum reduction in the eggs of spider mite (99.75%) and differed significantly with rest of the treatments except fenpyroximate (85.84%). Further, among all the treatments propargite was found least effective in reducing eggs (70.92%). On the basis of effectiveness of different acaricidal treatments 3 DAS after second spray the order of effectiveness were: diafenthiuron (99.75%)> fenpyroximate (85.84%)> chlorfenapyr (79.81%)> fenazaquin (75.20%)> wettable sulphur (73.88%)> propargite (70.92%)> triazophos (59.40%).

At 7 DAS, diafenthiuron gave maximum reduction in spider mite eggs (99.75% reduction). However, it was at par with chlorfenapyr and fenpyroximate *i.e.* 98.92 and 98.76 per cent reduction. Propargite gave 88.80 per cent reduction of eggs while wettable sulphur gave least per cent reduction of eggs (23.70%). On the basis of their effectiveness against eggs of *T. urticae*, the descending order of effectiveness were: diafenthiuron (99.75%)> chlorfenapyr (98.92%)> fenpyroximate (98.76%)> propargite (88.80%)> triazophos (55.34%)> fenazaquin (25.59%)> wettable sulphur (23.70%).

At 14 DAS, diafenthiuron stood first in effectiveness giving maximum reduction in eggs (99.75%). It was followed by fenpyroximate (74.24%) and fenazaquin (62.32%) which were at par with each other. Later four acaricidal treatments *viz.*, chlorfenapyr (53.15%), wettable

sulphur (51.77%), triazophos (48.91%) and propargite (39.40%) were superior over the control.

The pooled analysis of second spray on eggs of *T. urticae* (Table 60 and Figure 7) revealed that among all the acaricidal treatments diafenthiuron gave maximum reduction<sup>194</sup> in eggs of *T. urticae* (92.61%) and it was statistically superior over all other acaricidal treatments and followed by fenpyroximate (78.44% reduction), while the acaricidal treatment wettable sulphur gave lowest reduction (46.68%). The descending order of effectiveness of various acaricidal treatments based on per cent reduction of eggs were: diafenthiuron (92.61%)> fenpyroximate (78.44%)> chlorfenapyr (65.17%)> propargite (57.99%)> triazophos (51.17%)> fenazaquin (49.44%)> wettable sulphur (46.68%).

The descending order of effectiveness of overall pooled data of various acaricidal treatments against the egg stage of *T. urticae* were: diafenthiuron (87.52%)> fenpyroximate (72.52%)> chlorfenapyr (67.76%)> triazophos (62.45%)> propargite (62.17%)> fenazaquin (60.25%)> wettable sulphur (56.01%).

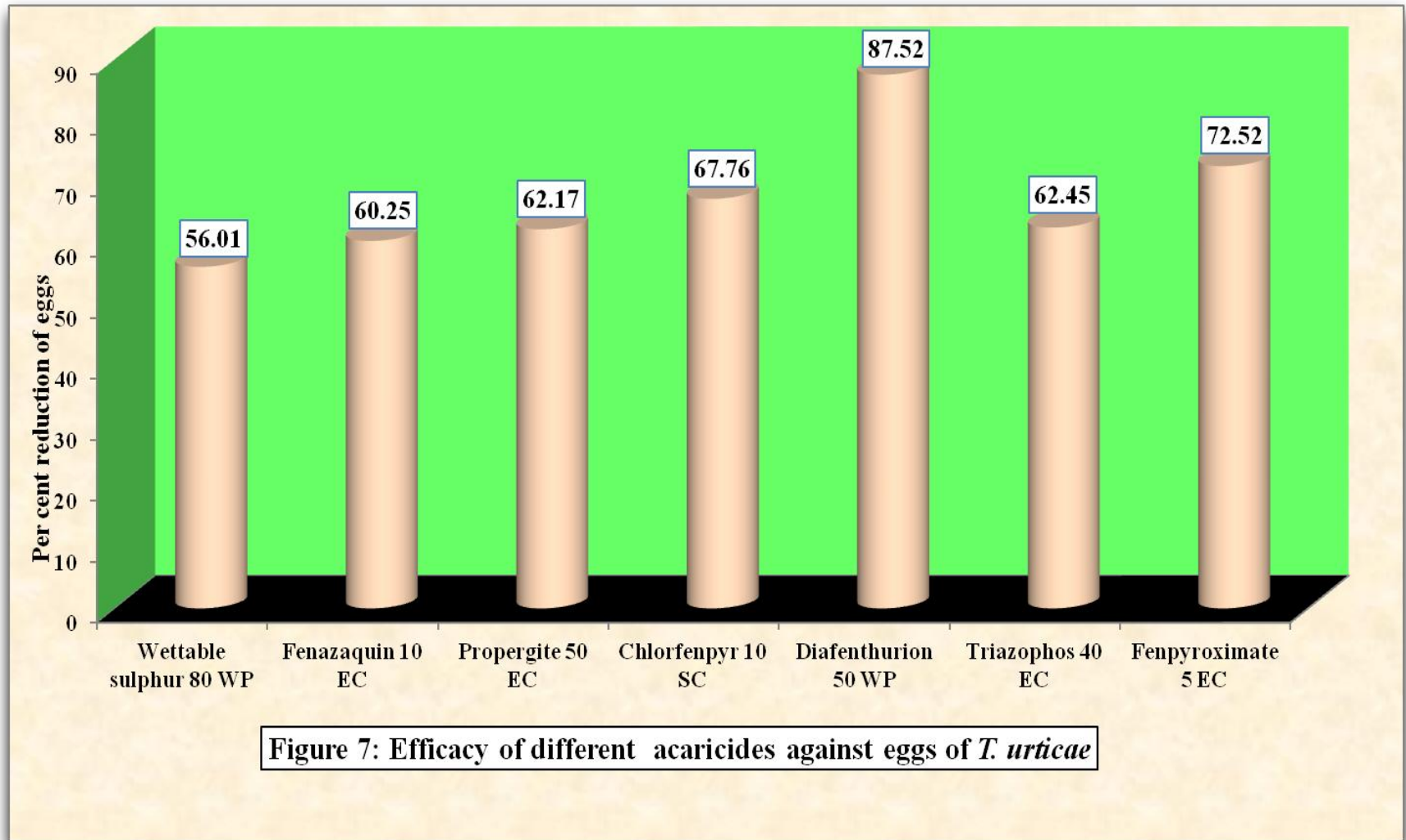
The present findings are more or less similar to the earlier one of Shah and Shukla (2014) who also found the diafenthiuron 50 WP as most effective in reducing the eggs of *T. urticae* on gerbera under polyhouse and was at par with other acaricidal treatments like fenpyroximate 5% EC and fenazaquin 19% EC. Bhaskaran *et al.* (2007) also found diafenthiuron 50 SC and 50 WP both at 450 g a.i./ha as most effective against the egg stage of *T. urticae* after first and second spray on okra. Patel *et al.* (2009) revealed that

**Table 60:- Effectiveness of different acaricidal treatments against eggs of *T. urticae* on tomato under polyhouse**

| Sr. No.               | Treatment              | Concentration (%) | Before Spray | Per cent reduction of eggs at indicated period (First spray) |                                 |                                |                                |                  | Per cent reduction of eggs at indicated period (Second spray) |                                |                               |                                |                  | Overall pooled   |
|-----------------------|------------------------|-------------------|--------------|--|---------------------------------|--------------------------------|--------------------------------|------------------|---|--------------------------------|-------------------------------|--------------------------------|------------------|------------------|
|                       |                        |                   |              | 1 DAS  | 3 DAS                           | 7 DAS                          | 14 DAS                         | Pooled           | 1 DAS   | 3 DAS                          | 7 DAS                         | 14 DAS                         | Pooled           |                  |
| 1.                    | Wettable sulphur 80 WP | 0.20              | 7.33         | 25.56 <sup>b</sup><br>(19.63)                                | 54.57 <sup>c</sup><br>(66.06)   | 66.95 <sup>b</sup><br>(83.93)  | 73.84 <sup>b</sup><br>(91.77)  | 55.23<br>(65.35) | 37.67 <sup>c</sup><br>(37.39)                                 | 59.63 <sup>bc</sup><br>(73.88) | 29.10 <sup>d</sup><br>(23.70) | 46.07 <sup>cd</sup><br>(51.77) | 43.11<br>(46.68) | 49.17<br>(56.01) |
| 2.                    | Fenazaquin 10 EC       | 0.01              | 7.67         | 31.46 <sup>b</sup><br>(27.32)                                | 59.40 <sup>bc</sup><br>(74.06)  | 70.38 <sup>b</sup><br>(88.55)  | 76.45 <sup>ab</sup><br>(94.35) | 59.42<br>(71.07) | 36.05 <sup>c</sup><br>(34.68)                                 | 60.42 <sup>bc</sup><br>(75.20) | 30.36 <sup>d</sup><br>(25.59) | 52.50 <sup>bc</sup><br>(62.32) | 44.83<br>(49.44) | 52.12<br>(60.25) |
| 3.                    | Propargite 57 EC       | 0.05              | 7.89         | 28.46 <sup>b</sup><br>(23.15)                                | 57.16 <sup>bc</sup><br>(70.44)  | 64.96 <sup>b</sup><br>(81.88)  | 71.79 <sup>b</sup><br>(89.95)  | 55.60<br>(66.35) | 34.89 <sup>c</sup><br>(32.87)                                 | 57.52 <sup>bc</sup><br>(70.92) | 73.04 <sup>b</sup><br>(88.80) | 38.75 <sup>d</sup><br>(39.40)  | 51.05<br>(57.99) | 53.32<br>(62.17) |
| 4.                    | Chlorfenpyr 10 SC      | 0.01              | 7.78         | 34.31 <sup>ab</sup><br>(32.16)                               | 57.93 <sup>bc</sup><br>(71.70)  | 68.15 <sup>b</sup><br>(86.00)  | 73.14 <sup>b</sup><br>(91.54)  | 58.38<br>(70.35) | 32.32 <sup>c</sup><br>(28.82)                                 | 66.87 <sup>bc</sup><br>(79.81) | 84.91 <sup>a</sup><br>(98.92) | 46.81 <sup>cd</sup><br>(53.15) | 37.72<br>(65.17) | 48.05<br>(67.76) |
| 5.                    | Diafenthurion 50 WP    | 0.055             | 7.56         | 44.90 <sup>a</sup><br>(49.83)                                | 68.35 <sup>a</sup><br>(86.08)   | 78.11 <sup>a</sup><br>(95.73)  | 83.70 <sup>a</sup><br>(98.10)  | 58.76<br>(82.43) | 58.16 <sup>a</sup><br>(71.22)                                 | 87.13 <sup>a</sup><br>(99.75)  | 87.13 <sup>a</sup><br>(99.75) | 87.13 <sup>a</sup><br>(99.75)  | 79.88<br>(92.61) | 69.32<br>(87.52) |
| 6.                    | Triazophos 40 EC       | 0.1               | 7.67         | 33.23 <sup>b</sup><br>(30.10)                                | 61.22 <sup>abc</sup><br>(76.77) | 71.66 <sup>ab</sup><br>(89.90) | 83.80 <sup>a</sup><br>(98.18)  | 62.47<br>(73.73) | 39.85 <sup>bc</sup><br>(41.06)                                | 51.10 <sup>c</sup><br>(59.40)  | 48.07 <sup>c</sup><br>(55.34) | 44.37 <sup>cd</sup><br>(48.91) | 45.84<br>(51.17) | 54.15<br>(62.45) |
| 7.                    | Fenpyroximate 5 EC     | 0.0025            | 7.67         | 35.35 <sup>ab</sup><br>(33.87)                               | 62.99 <sup>ab</sup><br>(79.12)  | 69.54 <sup>b</sup><br>(87.73)  | 78.14 <sup>ab</sup><br>(95.74) | 61.50<br>(66.61) | 47.84 <sup>b</sup><br>(54.93)                                 | 70.80 <sup>ab</sup><br>(85.84) | 84.64 <sup>a</sup><br>(98.76) | 59.60 <sup>b</sup><br>(74.24)  | 65.72<br>(78.44) | 63.61<br>(72.52) |
| 8.                    | Control (Water spray)  | -                 | 7.89         | -  | -                               | -                              | -                              | -                | -   | -                              | -                             | -                              | -                | -                |
| S. Em. Period (P)     |                        |                   |              | 2.34   | 1.60                            | 1.46                           | 1.61                           | 1.75             | 2.00  | 4.19                           | 2.03                          | 23.0                           | 7.80             | 4.77             |
| C. D at 5% Period (P) |                        |                   |              | 10.87  | 7.466                           | 6.78                           | 7.47                           | 8.14             | 9.29  | 19.46                          | 9.43                          | 10.68                          | 12.21            | 10.17            |
| C.V. %                |                        |                   |              | 18.63  | 7.07                            | 5.53                           | 5.52                           | 9.18             | 12.95   | 17.15                          | 8.62                          | 11.38                          | 12.52            | 10.85            |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

DAS- days after spraying



diafenthiuron at lower dose (0.125%) was found effective against *T. urticae* on rose. Thus, closely support the present findings. Kumari *et al.* (2011) from Punjab reported propargite (Omite 57 EC) @1000ml/ha as one of the best ovicidal treatment against *T. urticae* on okra. Under present investigation propargite also showed its ovicidal effect on *T.urticae* on tomato under polyhouse but as compared to other acaricidal treatments it was less effective. It may be due to different crop, climatic conditions, etc. Valunj *et al.* (1999) recorded chlorfenapyr @ 500ml/ha effective against *T. cinnabarinus* under polyhouse conditions, thus support the present findings. Further, Abhyankar (2003) found fenazaquin, 0.02 per cent effective against rose mite, *T. urticae* under polyhouse. Thus, fully support the present findings.

**Mobile stage:**

**First spray:**

One day after the first spray the treatment diafenthiuron was found effective in reducing the mobile stage of spider mite (40.17% reduction). However, it was stasitically at par with fenpyroximate (32.29% reduction). The lowest per cent reduction was recorded in the treatment wettable sulphur (21.07%). While three days after first spray the highest per cent reduction *i.e.* 79.10 per cent was recorded in diafenthiuron and it was at par with fenpyroximate (66.14% reduction). Where as the lowest per cent reduction were recorded in the wettable sulphur (37.77%).

Seven days after first spray the highest per cent reduction in the spider mite population was recorded in the treatment diafenthiuron (97.13% reduction) and was found

statistically superior over other acaricidal treatment. The second best treatment was fenazaquin (89.37% reduction) and it was at par with some other acaricidal treatments *viz.*, chlorfenapyr (87.68% reduction) and fenpyroximate (86.31% reduction). The treatments wettable sulphur (75.61% reduction) and propargite were found less effective as compared to other acaricidal treatment in reducing mite population.

Fourteen days after first spray, it was observed that diafenthiuron showed its superiority over other acaricidal treatments in terms of per cent reduction of mobile stages of spider mites (95.75% reduction). It was followed by other acaricidal treatments which were statistically at par with each others *viz.*, fenazaquin (95.91%), fenpyroximate (95.36%), chlorfenapyr (94.43%) and propargite (91.89%). The acaricidal treatment wettable sulphur was found least effective in terms of reducing the mite population (80.72% reduction).

The pooled data of first spray also showed the similar trends. The highest per cent reduction in mobile stages of spider mite *T. urticae* was recorded in diafenthiuron (79.03%) and it was followed by fenpyroximate (70.02%) and it was at par with other acaricidal treatments *viz.*, fenazaquin (67.06%), triazophos (63.21%), chlorfenapyr (64.03%) and fenpyroximate (70.02%). However, the acaricidal treatment wettable sulphur was found less effective as compared to other acaricidal treatments (53.79% reduction). On the basis of effectiveness of different acaricidal treatments against mobile stages of *T. urticae* the descending order were:



**Plate 11: Different stages of tomato grown under polyhouse**

diafenthiuron (79.03%)> fenpyroximate (70.02%)> fenazaquin (67.06%)> chlorfenapyr (64.03%)> triazophos (63.21%)> propargite (61.61%)> wettable sulphur (53.79%).

### **Second spray:**

One day after second spray the acaricidal treatment diafenthiuron was most effective in reducing the mobile stages of spider mite (92.15% reduction) and it was followed by fenpyroximate and chlorfenapyr (76.85 and 75.59% reduction). The acaricidal treatment wettable sulphur was found less effective in reducing spider mite population (12.97% reduction). Three days after second spray the acaricidal treatment diafenthiuron maintained its superiority over other acaricidal treatments (99.75% reduction) and it was followed by fenpyroximate (79.19% reduction). The treatment wettable sulphur was less effective in reducing the mobile stage of spider mite (12.43% reduction).

Seven days after second spray diafenthiuron was found most effective in terms of per cent reduction of mobile stage of spider mite (96.37% reduction). It was followed by fenpyroximate (81.50% reduction), while wettable sulphur was found least effective in reducing mobile stage of spider mite (21.95% reduction).

Fourteen days after second spray diafenthiuron was found most effective in reducing mobile stages of spider mite (99.75%) and it was followed by fenpyroximate (85.20% reduction) which were at par with chlorfenapyr (81.63% reduction) and triazophos (71.86% reduction). However the acaricidal treatment wettable sulphur was found least

effective in reducing mobile stages of spider mite (38.16% reduction).

The pooled data of second spray showed that diafenthiuron was most effective in reducing the population of mobile stage of spider mite (97.00% reduction) whereas wettable sulphur was less effective in reducing the mobile stages of spider mite (21.37% reduction). On the basis of effectiveness the descending order were: diafenthiuron (97.00%)> fenpyroximate (80.68%)> chlorfenapyr (74.01%)> fenazaquin (62.38%)> triazophos (58.79%)> propargite (41.42%)> wettable sulphur (21.37%). (Table 61)

The overall efficacy of all the acaricidal treatments also indicated that the treatment diafenthiuron was most effective (88.01% reduction) and was followed by fenpyroximate (75.35% reduction) and chlorfenapyr (66.78% reduction) whereas wettable sulphur was found least effective in reducing mobile stages of spider mite (37.58% reduction). (Table 61 and Figure 8).

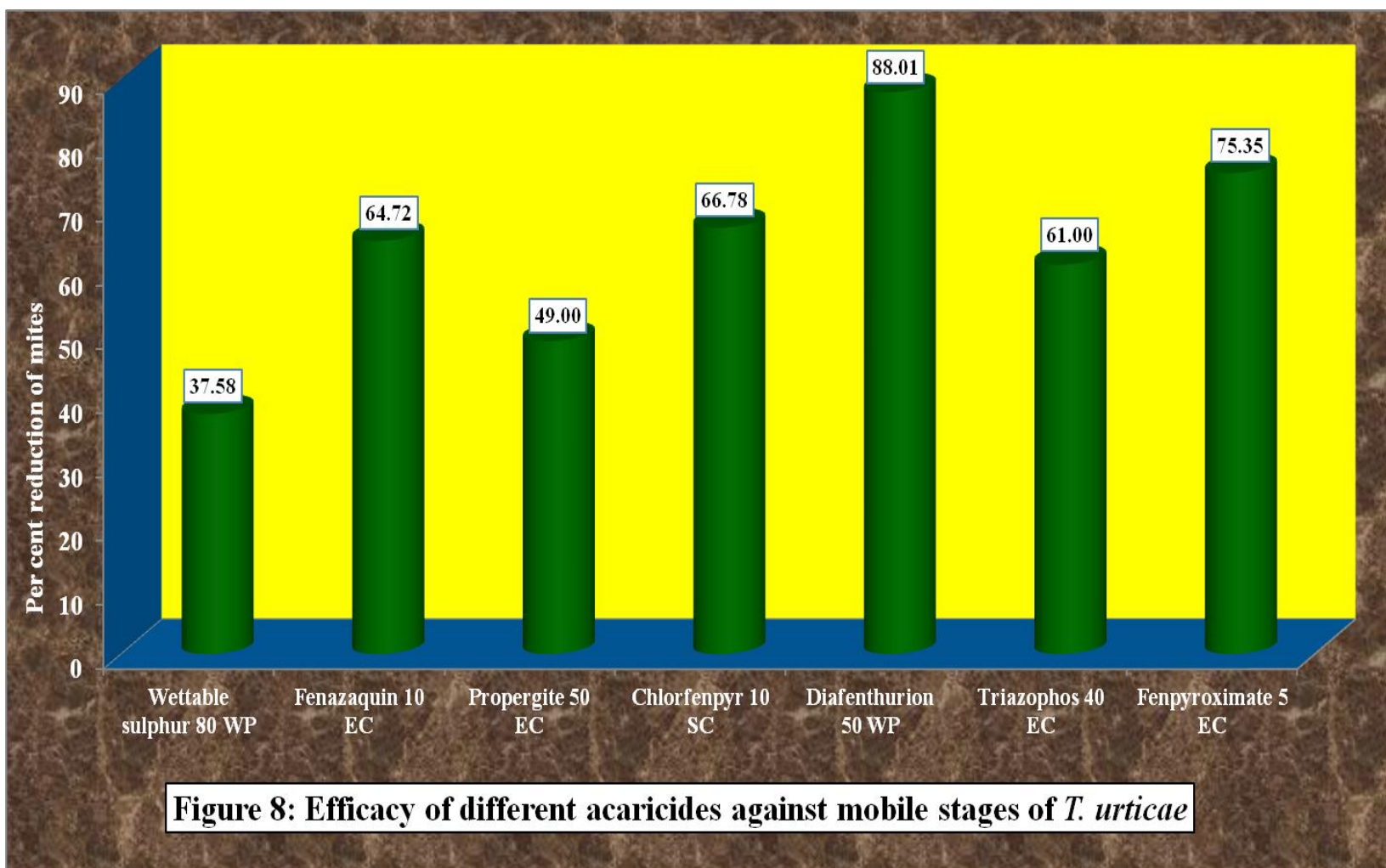
In the present investigation diafenthiuron was found most effective acaricide against mobile stages of *T. urticae* on tomato. Similar results in respect to effectiveness of diafenthiuron 50 SC and 50 WP both at 450 g a.i./ha recorded the highest mean reduction of mite population after two sprays on Okra (Bhaskaran *et.al.*, 2007). Patel *et al.* (2009) revealed that diafenthiuron at lower dose (0.125%) was effective against *T. urticae* on rose. Further Shah and Shukla (2014) also recorded diafenthiuron and fenazaquin very effective against mobile stages of *T. urticae* on gerbera under polyhouse, therefore more or less similar to the present

**Table 61:- Effectiveness of different acaricidal treatments against mobile stages of *T. urticae* on tomato under polyhouse**

| Sr. No.               | Treatment              | Concentration (%) | Before Spray | Per cent reduction of mites at indicated period (First spray) |                                |                                 |                                |                  | Per cent reduction of mites at indicated period (Second spray) |                               |                                |                                 |                  | Overall pooled   |
|-----------------------|------------------------|-------------------|--------------|---|--------------------------------|---------------------------------|--------------------------------|------------------|--|-------------------------------|--------------------------------|---------------------------------|------------------|------------------|
|                       |                        |                   |              | 1 DAS   | 3 DAS                          | 7 DAS                           | 14 DAS                         | Pooled           | 1 DAS  | 3 DAS                         | 7 DAS                          | 14 DAS                          | Pooled           |                  |
| 1.                    | Wettable sulphur 80 WP | 0.20              | 11.22        | 27.24 <sup>cd</sup><br>(21.07)                                | 37.05 <sup>c</sup><br>(37.77)  | 60.95 <sup>d</sup><br>(75.61)   | 64.11 <sup>d</sup><br>(80.72)  | 47.33<br>(53.79) | 21.11 <sup>d</sup><br>(12.97)                                  | 20.56 <sup>e</sup><br>(12.43) | 27.59 <sup>d</sup><br>(21.95)  | 33.84 <sup>d</sup><br>(38.16)   | 25.79<br>(21.37) | 36.56<br>(37.58) |
| 2.                    | Fenazaquin 10 EC       | 0.01              | 11.89        | 28.11 <sup>cd</sup><br>(22.37)                                | 51.14 <sup>b</sup><br>(60.61)  | 71.05 <sup>b</sup><br>(89.37)   | 78.39 <sup>b</sup><br>(95.91)  | 57.17<br>(67.06) | 39.00 <sup>bc</sup><br>(53.00)                                 | 53.59 <sup>c</sup><br>(64.76) | 47.05 <sup>c</sup><br>(53.56)  | 62.29 <sup>abc</sup><br>(78.20) | 50.48<br>(62.38) | 53.82<br>(64.72) |
| 3.                    | Propargite 57 EC       | 0.05              | 9.55         | 27.86 <sup>cd</sup><br>(21.86)                                | 47.48 <sup>bc</sup><br>(54.30) | 62.35 <sup>cd</sup><br>(78.39)  | 74.00 <sup>bc</sup><br>(91.89) | 52.92<br>(61.61) | 35.95 <sup>c</sup><br>(34.48)                                  | 32.77 <sup>d</sup><br>(29.36) | 51.02 <sup>c</sup><br>(60.10)  | 39.32 <sup>cd</sup><br>(41.77)  | 39.76<br>(41.42) | 44.78<br>(49.00) |
| 4.                    | Chlorfenpyr 10 SC      | 0.01              | 12.11        | 31.17 <sup>bc</sup><br>(26.86)                                | (53.79)<br>47.18 <sup>bc</sup> | 69.51 <sup>bc</sup><br>(87.68)  | 76.68 <sup>bc</sup><br>(94.43) | 57.78<br>(64.03) | 60.42 <sup>b</sup><br>(75.59)                                  | 56.63 <sup>c</sup><br>(69.67) | 56.52 <sup>bc</sup><br>(69.51) | 68.22 <sup>ab</sup><br>(81.63)  | 60.47<br>(74.01) | 57.98<br>(66.78) |
| 5.                    | Diafenthurion 50 WP    | 0.055             | 11.11        | 39.33 <sup>a</sup><br>(40.17)                                 | 62.99 <sup>a</sup><br>(79.10)  | 81.26 <sup>a</sup><br>(97.13)   | 87.13 <sup>a</sup><br>(99.75)  | 67.67<br>(79.03) | 76.00 <sup>a</sup><br>(92.15)                                  | 87.13 <sup>a</sup><br>(99.75) | 80.17 <sup>a</sup><br>(96.37)  | 87.13 <sup>a</sup><br>(99.75)   | 82.60<br>(97.00) | 75.13<br>(88.01) |
| 6.                    | Triazophos 40 EC       | 0.1               | 11.00        | 25.30 <sup>d</sup><br>(18.44)                                 | 49.43 <sup>b</sup><br>(57.65)  | 68.92 <sup>bcd</sup><br>(86.82) | 71.55 <sup>c</sup><br>(89.96)  | 53.80<br>(63.21) | 38.96 <sup>c</sup><br>(39.54)                                  | 52.80 <sup>c</sup><br>(63.43) | 51.01 <sup>c</sup><br>(60.36)  | 57.98 <sup>bcd</sup><br>(71.86) | 50.18<br>(58.79) | 51.99<br>(61.00) |
| 7.                    | Fenpyroximate 5 EC     | 0.0025            | 11.89        | 34.62 <sup>ab</sup><br>(32.29)                                | 54.43 <sup>ab</sup><br>(66.14) | 68.44 <sup>bcd</sup><br>(86.31) | 77.98 <sup>b</sup><br>(95.36)  | 58.86<br>(70.02) | 61.33 <sup>b</sup><br>(76.85)                                  | 62.99 <sup>b</sup><br>(79.19) | 65.01 <sup>b</sup><br>(81.50)  | 67.45 <sup>ab</sup><br>(85.20)  | 64.19<br>(80.68) | 61.52<br>(75.35) |
| 8.                    | Control (Water spray)  | -                 | 11.78        | -   | -                              | -                               | -                              | -                | -  | -                             | -                              | -                               | -                | -                |
| S. Em. Period (P)     |                        |                   |              | 1.01  | 2.31                           | 1.80                            | 1.29                           | 1.60             | 1.66   | 0.96                          | 2.32                           | 5.40                            | 2.58             | 2.09             |
| C. D at 5% Period (P) |                        |                   |              | 4.74  | 10.74                          | 8.34                            | 6.00                           | 7.45             | 7.71   | 4.48                          | 10.75                          | 25.04                           | 11.99            | 9.72             |
| C.V. %                |                        |                   |              | 8.87  | 12.28                          | 6.91                            | 4.52                           | 8.14             | 10.36  | 4.88                          | 11.36                          | 24.05                           | 12.66            | 10.40            |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

DAS- days after spraying



findings. Further, under the present investigation fenazaquin also found effective in reducing mobile stages of *T. urticae*. Similarly, Kumari *et.al.* (2011) from Ludhiana also reported fenazaquin @400ml/ha as very effective (85.63% reduction) against mobile stages of *T. urticae* on okra, thus closely support the present findings. Chlorfenapyr and fenpyroximate were also found superior over other treatments including control in the present study. Reddy *et al.* (2014) also found fenpyroximate and chlorfenapyr effective against mobile stages of *T. urticae* on chrysanthemum in polyhouse at Palampur, Himachal Pradesh closely supports the present findings. Pandey (2014) also found fenpyroximate and fenazaquin effective as compared to sulphur against European red mite, *Panonychus ulmi* Koch infesting apple also in support of the present study.

#### **4.4.4.2 Bioefficacy of acaricidal treatments against egg stage of *A. lycopersici***

The various acaricidal treatments were evaluated for their effectiveness against egg and mobile stages of russet mite, *A. lycopersici* infesting tomato under polyhouse conditions.

##### **Egg stage**

##### **First spray:**

One day after the first spray diafenthiuron was found most effective with 58.63 per cent reduction in eggs of *A. lycopersici*. It was followed by another acaricidal treatment fenpyroximate (33.67% reduction) and it was at par with rest of treatments.

Three days after first spray diafenthiuron was found most effective among all the acaricidal treatments in terms of reducing egg population of *A. lycopersici* (74.69% reduction). It was followed by fenpyroximate (64.53% reduction) and were at par with chlorfenapyr (63.61% reduction). Among all the acaricidal treatments wettable sulphur was found least effective in reducing eggs of *A. lycopersici* (50.89%<sup>205</sup> reduction). However, the descending order of effectiveness of different acaricidal treatments three days after first spray were: diafenthiuron (74.69%)> fenpyroximate (64.53%)> chlorfenapyr (63.61%)> triazophos (61.16%)> fenazaquin (56.89%)> propargite (52.56%)> wettable sulphur (50.89%).

Seven days after first spray diafenthiuron was found most effective in reducing eggs of *A. lycopersici* (89.67% reduction) and chlorfenapyr (72.35% reduction). Wettable sulphur was found least effective among all the acaricidal treatments (70.04% reduction). The descending order of various acaricidal treatments were: diafenthiuron (89.67%)> fenpyroximate (87.14%)> chlorfenapyr (81.16%)> fenazaquin (79.29%)> triazophos (77.73%)> propargite (72.35%)> wettable sulphur (70.04%).

Fourteen days after first spray diafenthiuron was very effective in reducing eggs (99.75% reduction). It was followed by other acaricidal treatments and wettable sulphur was least effective (79.46% reduction). The descending order of various acaricidal treatments against egg stages of *A. lycopersici* were: diafenthiuron (99.75%) > fenazaquin (93.96%)> fenpyroximate (93.48%)> chlorfenapyr (91.89%)>

triazophos (88.84%)> propargite (88.24%)> wettable sulphur (79.46%).

On the basis of pooled data of first spray the acaricidal treatment diafenthiuron was found very effective in reducing the eggs (80.68% reduction), while wettable sulphur was found least effective in reducing eggs of *A. lycopersici* (56.28% reduction). The descending order of effectiveness of different acaricidal treatments against egg stage of *A. lycopersici* on tomato were: diafenthiuron (80.68%)> chlorfenapyr (66.96%)> fenazaquin (64.99%)> triazophos (64.94%)> fenpyroximate (62.20%)> propargite (52.83%)> wettable sulphur (56.28%).

#### **Second spray:**

One day after the second spray diafenthiuron was found most effective with 99.75 per cent reduction in egg population of *A. lycopersici*. It was followed by another acaricidal treatment chlorfenapyr (65.07% reduction) which was at par with fenazaquin (53.94% reduction). The lowest per cent reduction in eggs of *A. lycopersici* was recorded in the wettable sulphur (14.65% reduction). The descending order of effectiveness of various acaricidal treatments one day after second spray against egg stage of *A. lycopersici* were: diafenthiuron (99.75%)> chlorfenapyr (65.07%)> fenpyroximate (57.69%)> fenazaquin (53.94%)> propargite (50.04%)> triazophos (47.21%)> wettable sulphur (14.65%).

Three days after second spray diafenthiuron and chlorfenapyr were statistically at par in terms of per cent reduction (96.98 and 92.13%). It was followed by fenazaquin (75.21% reduction) and was at par with propargite (73.64%

reduction). The lowest per cent reduction in egg population of *A. lycopersici* was recorded in the treatment wettable sulphur (51.99% reduction). The descending order of acaricidal treatments were: diafenthiuron (96.98%)> chlorfenapyr (92.13%)> fenazaquin (75.21%)> propargite (73.64%)> triazophos (65.10%)> fenpyroximate (61.25%)> wettable sulphur (51.99%).

Seven days after second spray diafenthiuron maintains its superiority over other treatments in terms of per cent reduction of eggs of *A. lycopersici* (97.27%). However, it was followed by another acaricidal treatment chlorfenapyr (83.75% reduction). Wettable sulphur was least effective among all the acaricidal treatments (66.61% reduction). On the basis of effectiveness of various acaricidal treatments against egg stages of *A. lycopersici*, the descending order were: diafenthiuron (97.27%)> chlorfenapyr (83.75%)> fenazaquin (72.60%)> fenpyroximate (70.16%)> wettable sulphur (66.61%)> propargite (62.82%)> triazophos (61.75%).

Fourteen days after second spray diafenthiuron was found very effective in reducing eggs of *A. lycopersici* (92.40% reduction) and it was at par with chlorfenapyr (92.05% reduction). wettable sulphur was found less effective in reducing eggs of *A. lycopersici* (66.95% reduction). The descending order of various acaricidal treatments 14 DAS were: diafenthiuron (92.40%)> chlorfenapyr (92.05%)> fenazaquin (76.42%)> fenpyroximate (67.54%)> wettable sulphur (66.95%)> triazophos (58.57%)> propargite (56.78%)

On the basis of pooled data of second spray the acaricidal treatment diafenthiuron was proved most effective

in reducing eggs of *A. lycopersici* on tomato while wettable sulphur was least effective. The descending order of effectiveness of various acaricidal treatments were: diafenthiuron (96.60%)> chlorfenapyr (83.25%)> fenazaquin (69.54%)> propargite (60.82%)> triazophos (58.17%)> fenpyroximate (51.32%) > wettable sulphur (50.05%).

On the basis of overall pooled data of both the sprays, the acaricidal treatment diafenthiuron was found most effective (88.64% reduction) where as wettable sulphur was found least effective (53.16% reduction) among all the acaricidal treatments. The descending order of various acaricidal treatments were: diafenthiuron (88.64%)> chlorfenapyr (75.10%)> triazophos (61.55%)> fenazaquin (67.26%)> propargite (56.82%)> fenpyroximate (56.76%)> wettable sulphur (53.16%).

In past no work was carried out on efficacy of acaricides against *A. lycopersici*. However, similar acaricides were evaluated against coconut eriophyid mite *A. guerreronis*. Pushpa (2006) reported diafenthiuron, fenazaquin, triazophos as very effective against egg stage of *A. guerreronis* on coconut. However, among all the treatments she tested wettable sulphur which was found least effective against egg stage of *A. guerreronis*. These partially support the present work. Further these finds are in conformity with Dey *et al.* (2001) and Dey and Somchoudhary (2001) who reported that spraying fenazaquin and fenpyroximate applied directly on crown region significantly reduced egg stage of *A. guerreronis*. Natarajan *et al.* (2002) reported triazophos as effective treatment against egg stage of *A. guerreronis*. All

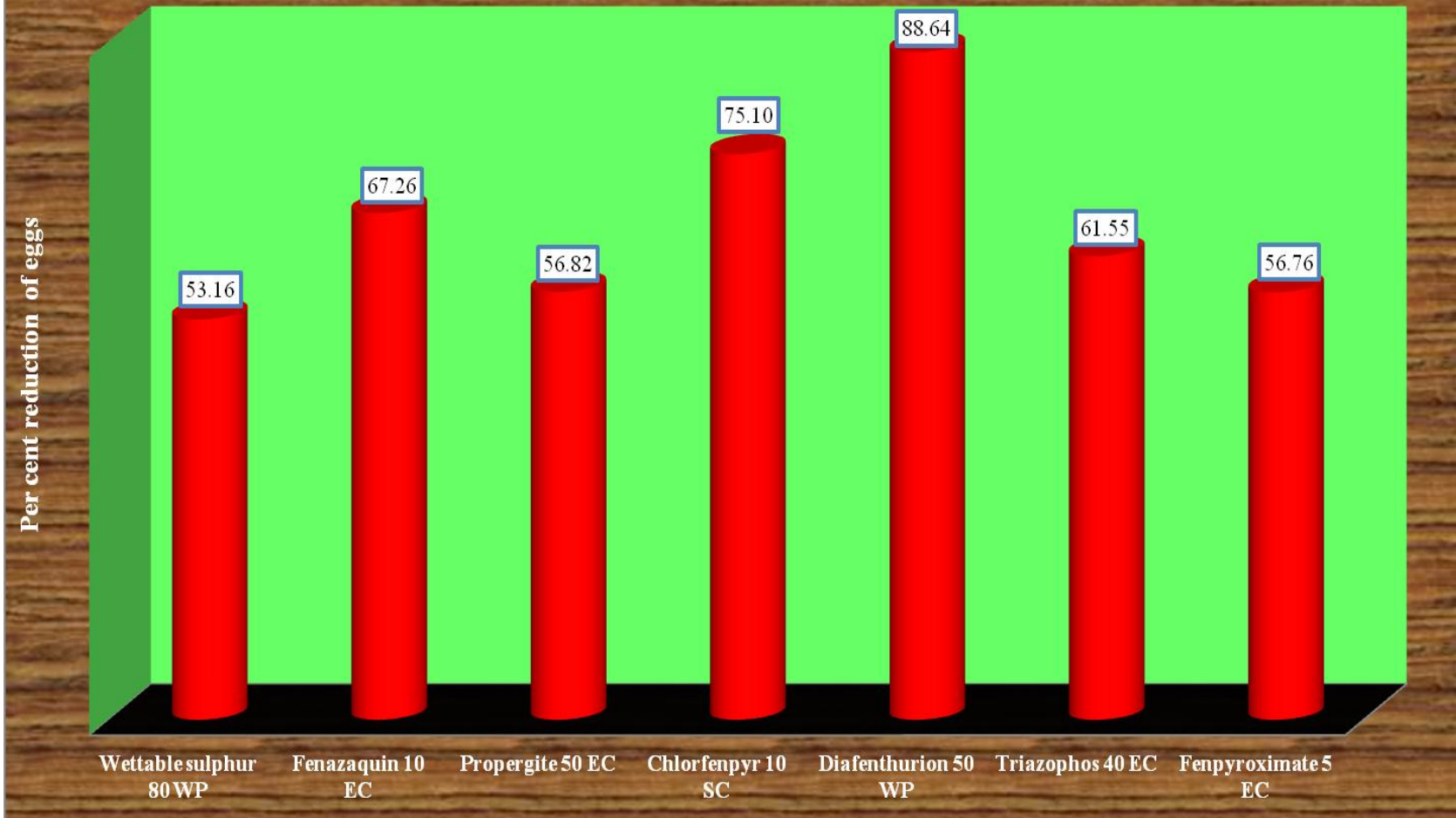
**Table 62:- Effectiveness of different acaricidal treatments against eggs of *A. lycopersici* on tomato under polyhouse**

| Sr. No.               | Treatment              | Concentration (%) | Before Spray | Per cent reduction of eggs at indicated period (First spray) |                                |                                 |                               |                  | Per cent reduction of eggs at indicated period (Second spray) |                                |                                |                                |                  | Overall pooled   |
|-----------------------|------------------------|-------------------|--------------|--|--------------------------------|---------------------------------|-------------------------------|------------------|---|--------------------------------|--------------------------------|--------------------------------|------------------|------------------|
|                       |                        |                   |              | 1 DAS  | 3 DAS                          | 7 DAS                           | 14 DAS                        | Pooled           | 1 DAS   | 3 DAS                          | 7 DAS                          | 14 DAS                         | Pooled           |                  |
| 1.                    | Wettable sulphur 80 WP | 0.20              | 16.67        | 29.63 <sup>b</sup><br>(24.75)                                | 45.52 <sup>c</sup><br>(50.89)  | 56.92 <sup>d</sup><br>(70.04)   | 63.32 <sup>c</sup><br>(79.46) | 48.84<br>(56.28) | 22.49 <sup>d</sup><br>(14.65)                                 | 46.19 <sup>c</sup><br>(51.99)  | 54.79 <sup>cd</sup><br>(66.61) | 54.99 <sup>bc</sup><br>(66.95) | 39.61<br>(50.05) | 44.22<br>(53.16) |
| 2.                    | Fenazaquin 10 EC       | 0.01              | 17.00        | 33.04 <sup>b</sup><br>(29.83)                                | 48.97 <sup>bc</sup><br>(56.89) | 62.98 <sup>bcd</sup><br>(79.29) | 75.94 <sup>b</sup><br>(93.96) | 55.23<br>(64.99) | 47.27 <sup>bc</sup><br>(53.94)                                | 60.59 <sup>b</sup><br>(75.21)  | 58.62 <sup>c</sup><br>(72.60)  | 60.98 <sup>b</sup><br>(76.42)  | 56.86<br>(69.54) | 56.04<br>(67.26) |
| 3.                    | Propargite 57 EC       | 0.05              | 17.22        | 30.07 <sup>b</sup><br>(25.20)                                | 46.48 <sup>c</sup><br>(52.56)  | 58.38 <sup>cd</sup><br>(72.35)  | 70.17 <sup>b</sup><br>(88.24) | 51.27<br>(52.83) | 45.02 <sup>c</sup><br>(50.04)                                 | 59.26 <sup>b</sup><br>(73.64)  | 52.45 <sup>cd</sup><br>(62.82) | 48.92 <sup>c</sup><br>(56.78)  | 51.41<br>(60.82) | 51.34<br>(56.82) |
| 4.                    | Chlorfenpyr 10 SC      | 0.01              | 16.78        | 33.91 <sup>b</sup><br>(31.21)                                | 52.92 <sup>b</sup><br>(63.61)  | 64.35 <sup>abc</sup><br>(81.16) | 73.48 <sup>b</sup><br>(91.89) | 56.16<br>(66.96) | 53.88 <sup>b</sup><br>(65.07)                                 | 75.73 <sup>a</sup><br>(92.13)  | 66.38 <sup>b</sup><br>(83.75)  | 75.66 <sup>a</sup><br>(92.05)  | 67.91<br>(83.25) | 62.03<br>(75.10) |
| 5.                    | Diafenthurion 50 WP    | 0.055             | 17.33        | 50.01 <sup>a</sup><br>(58.63)                                | 59.81 <sup>a</sup><br>(74.69)  | 71.27 <sup>a</sup><br>(89.67)   | 87.13 <sup>a</sup><br>(99.75) | 67.05<br>(80.68) | 87.13 <sup>a</sup><br>(99.75)                                 | 80.97 <sup>a</sup><br>(96.98)  | 80.50 <sup>a</sup><br>(97.27)  | 74.37 <sup>a</sup><br>(92.40)  | 80.75<br>(96.60) | 73.90<br>(88.64) |
| 6.                    | Triazophos 40 EC       | 0.1               | 17.11        | 34.82 <sup>b</sup><br>(32.65)                                | 51.54 <sup>bc</sup><br>(61.16) | 62.12 <sup>cd</sup><br>(77.73)  | 70.66 <sup>b</sup><br>(88.84) | 54.78<br>(64.94) | 43.36 <sup>c</sup><br>(47.21)                                 | 53.82 <sup>bc</sup><br>(65.10) | 51.85 <sup>d</sup><br>(61.75)  | 49.96 <sup>c</sup><br>(58.57)  | 49.74<br>(58.17) | 52.26<br>(61.55) |
| 7.                    | Fenpyroximate 5 EC     | 0.0025            | 17.22        | 35.45 <sup>b</sup><br>(33.67)                                | 53.46 <sup>b</sup><br>(64.53)  | 69.37 <sup>ab</sup><br>(87.14)  | 75.36 <sup>b</sup><br>(93.48) | 58.41<br>(62.20) | 49.48 <sup>b</sup><br>(57.69)                                 | 51.53 <sup>bc</sup><br>(61.25) | 56.90 <sup>cd</sup><br>(70.16) | 55.29 <sup>bc</sup><br>(67.54) | 53.30<br>(51.32) | 55.85<br>(56.76) |
| 8.                    | Control (Water spray)  | -                 | 18.44        | -  | -                              | -                               | -                             | -                | -   | -                              | -                              | -                              | -                | -                |
| S. Em. Period (P)     |                        |                   |              | 1.39   | 1.31                           | 1.53                            | 1.26                          | 1.37             | 1.60  | 2.45                           | 1.41                           | 1.88                           | 1.83             | 1.60             |
| C. D at 5% Period (P) |                        |                   |              | 6.45   | 6.08                           | 7.14                            | 5.85                          | 6.38             | 4.42  | 11.38                          | 6.56                           | 8.75                           | 7.75             | 7.06             |
| C.V. %                |                        |                   |              | 10.44  | 6.78                           | 6.41                            | 6.41                          | 7.51             | 8.50  | 10.63                          | 6.22                           | 8.33                           | 8.42             | 7.96             |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

DAS- days after spraying

**Figure 9: Efficacy of different acaricides against eggs of *A. lycopersici***



these findings more or less support the present findings where eggs of tomato russet mite, which is an eriophyid mite were reduced by application of different acaricidal treatments.

**Mobile stages:**

**First spray:**

One day after the first spray the treatment diafenthiuron was found effective in reducing the mobile stages of russet mite, *A. lycopersici* (45.62% reduction) and was at par with fenazaquin (45.39% reduction), fenpyroximate (43.71% reduction), triazophos (40.06% reduction) and propargite (39.66% reduction). However, the treatment wettable sulphur was found least effective against mobile stages of *A. lycopersici* (19.94% reduction).

Three days after first spray the highest per cent reduction in the mobile stage of *A. lycopersici* was recorded in the acaricidal treatment diafenthiuron (73.25% reduction) and it was at par with fenpyroximate (70.68% reduction) and fenazaquin (69.72% reduction), where as the lowest per cent reduction was recorded in the wettable sulphur (42.55% reduction). the order of effectiveness of various acaricidal treatments three days after spray were: diafenthiuron (73.25%)> fenpyroximate (70.68%)> fenazaquin (69.72%)> propargite (60.47%)> triazophos (60.34%)> chlorfenapyr (55.66%)> wettable sulphur (42.55%).

Seven days after first spray the highest per cent reduction in mobile stage of *A. lycopersici* was recorded in the treatment diafenthiuron (87.04% reduction) where as the lowest per cent reduction was recorded in acaricidal treatment

wettable sulphur (66.59%). The descending order of effectiveness of various acaricidal treatments were: diafenthiuron (87.04%)> fenpyroximate (85.54%)> propargite (84.21%)> fenazaquin (83.15%)> triazophos (79.05%)> chlorfenapyr (76.66%)> wettable sulphur (66.59%).

Fourteen days after first spray it was observed that diafenthiuron maintained its superiority over other acaricidal treatments in terms of per cent reduction (95.25%). It was at par with fenpyroximate (92.87% reduction) however it was at par with chlorfenapyr (90.99% reduction) and fenazaquin (90.02% reduction). The acaricidal treatment wettable sulphur was found least effective in terms of reducing russet mite population (77.88% reduction). However, the descending order of effectiveness at 14 days after spray were: diafenthiuron (95.25%)> fenpyroximate (92.87%)> chlorfenapyr (90.99%)> fenazaquin (90.02%)> propargite (87.43%)> triazophos (87.23%)> wettable sulphur (77.88%).

The pooled data of first spray also showed the similar trends. The highest per cent reduction in mobile stages of russet mite, *A. lycopersici* was recorded in diafenthiuron (75.29% reduction) and was at par with fenpyroximate (73.20% reduction). However, the acaricidal treatment wettable sulphur was less effective in terms of reducing the mobile stage of *A. lycopersici* (51.74% reduction). The order of effectiveness of pooled data of first spray were: diafenthiuron (75.29%)> fenpyroximate (73.20%)> fenazaquin (72.07%)> propargite (67.92%)> triazophos (66.67%)> chlorfenapyr (64.85%)> wettable sulphur (51.74%).

### Second Spray:

One day after second spray the acaricidal treatment chlorfenapyr was most effective in reducing the mobile stages of *A. lycopersici* (55.61% reduction). It was followed by diafenthiuron (46.90% reduction) and fenpyroximate (43.93<sup>213</sup> reduction) and were found at par with other acaricidal treatments. Among the all acaricidal treatments, wettable sulphur was found less effective in reducing mobile stages of *A. lycopersici* (32.05% reduction).

Three days after second spray diafenthiuron was found most effective (87.61% reduction) among all the acaricidal treatments. It was followed by fenpyroximate (68.35% reduction) and was at par with chlorfenapyr (68.78% reduction). However, the treatment wettable sulphur was found least effective in terms of per cent reduction of mobile stages of *A. lycopersici* (57.05% reduction). The descending order of effectiveness of various acaricidal treatments were: diafenthiuron (87.61%)> chlorfenapyr (68.78%)> fenpyroximate (68.35%)> fenazaquin (64.40%)> triazophos (64.26%)> propargite (64.08%)> wettable sulphur (57.05%).

Seven days after second spray diafenthiuron was found most effective in reducing the mobile stages of russet mite, *A. lycopersici* on tomato (99.75%) and was at par with chlorfenapyr (93.36% reduction). The lowest per cent reduction in mobile stage of *A. lycopersici* was recorded in wettable sulphur (66.38%). On the basis of effectiveness of various acaricidal treatments the descending order were: diafenthiuron (99.75%)> chlorfenapyr (93.36%)>

fenpyroximate (91.09%)> triazophos (79.40%)> fenazaquin (76.97%)> propargite (70.74%)> wettable sulphur (66.38%).

Fourteen days after the second spray diafenthiuron maintain its superiority over rest of the acaricidal treatments in terms of per cent reduction of mobile stages of *A. lycopersici* and stood first (99.75%). However, it was at p <sup>214</sup> with chlorfenapyr (93.36%). Among all the acaricidal treatments wettable sulphur was found least effective in reducing population of mobile stage of *A. lycopersici* (66.38%). The descending order of effectiveness of the acaricidal treatments after fourteen days of second spray were: diafenthiuron (99.75%)> chlorfenapyr (93.36%)> fenpyroximate (91.09%)> triazophos (79.40%)> fenazaquin (76.97%)> propargite (70.74%)> wettable sulphur (66.38%).

The pooled data of second spray showed that diafenthiuron was most effective in reducing the russet mite population (83.50% reduction) and was followed by another acaricidal treatment fenpyroximate (73.61% reduction) while wettable sulphur was found least effective (55.46% reduction) among all the acaricidal treatments. The descending order of effectiveness of acaricidal treatments were: diafenthiuron (83.50%)> fenpyroximate (73.61%)> chlorfenapyr (65.27%)> triazophos (64.57%)> fenazaquin (64.34%)> propargite (61.54%)> wettable sulphur (55.46%).

The overall efficacy of all the acaricidal treatments also indicated that the diafenthiuron was most effective (79.39% reduction) and was at par with fenpyroximate (73.40% reduction). However among other treatments wettable sulphur was least effective in reducing the mobile

stage of russet mite, *A. lycopersici* under the polyhouse conditions in tomato. The descending order of effectiveness of various acaricidal treatments were: diafenthiuron (79.39%)> fenpyroximate (73.40%)> fenazaquin (68.20%)> triazophos (65.62%)> chlorfenapyr (65.06%)> propargite (64.73%) > wettable sulphur (53.60%).

In past, no work was done on the tomato eriophyid mite *A. lycopersici* so the work done on similar species *A. guerreronis* were discussed here with the present findings. Pushpa (2006) from Karnataka reported that diafenthiuron, fenazaquin and triazophos were very effective in reducing mobile stages of *A. guerreronis*. More or less same results were also observed in the present experiment likewise Dey *et al.* (2001) and Dey and Somchoudhary (2001) from West Bengal also reported fenazaquin and fenpyroximate as effective against mobile stages of *A. guerreronis* closely support the present findings. Natarajan *et al.* (2002) from Tamil Nadu also reported triazophos as effective pesticide in reducing mobile stage of coconut eriophyid mite whereas found wettable sulphur as least effective among available treatments against mobile stages of *A. guerreronis*. So all these previous work by various scientists are more or less in agreement of the present findings.

#### **4.4.4.3 Toxicity of acaricidal treatments to predatory mite, *A. longispinosus*:**

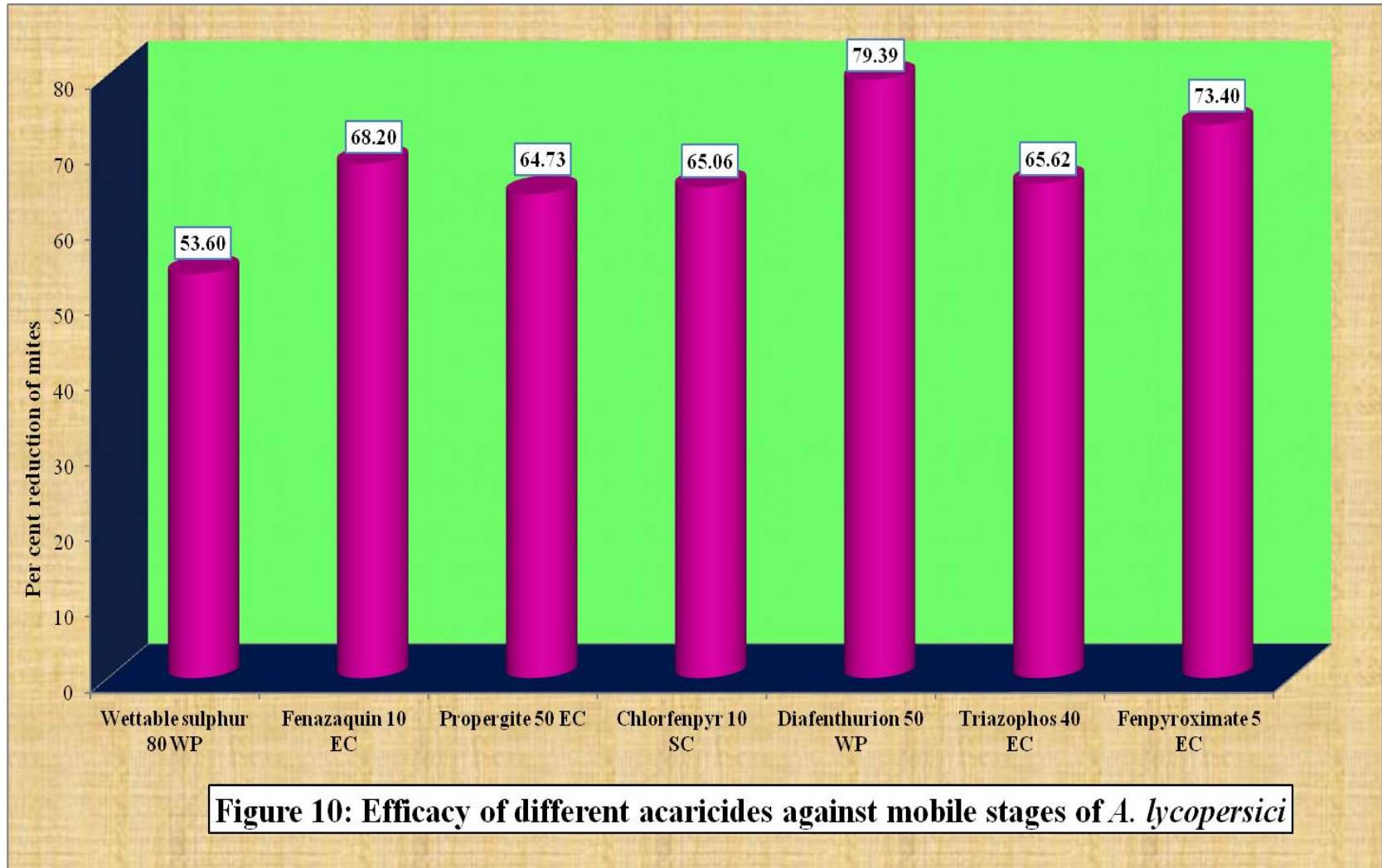
The same chemicals were also evaluated in polyhouse for their toxic effect to predatory mite, *A. longispinosus* and the results are presented in Table 64 and Figure 1.

**Table 63:- Effectiveness of different acaricidal treatments against mobile stages of *A. lycopersici* on tomato under polyhouse**

| Sr. No.               | Treatment              | Concentration (%) | Before Spray | Per cent reduction of mites at indicated period (First spray) |                                |                                |                                |                  | Per cent reduction of mites at indicated period (Second spray) |                                |                                |                                |                  | Overall pooled   |
|-----------------------|------------------------|-------------------|--------------|---|--------------------------------|--------------------------------|--------------------------------|------------------|--|--------------------------------|--------------------------------|--------------------------------|------------------|------------------|
|                       |                        |                   |              | 1 DAS   | 3 DAS                          | 7 DAS                          | 14 DAS                         | Pooled           | 1 DAS  | 3 DAS                          | 7 DAS                          | 14 DAS                         | Pooled           |                  |
| 1.                    | Wettable sulphur 80 WP | 0.20              | 21.33        | 26.50 <sup>c</sup><br>(19.94)                                 | 40.72 <sup>d</sup><br>(42.55)  | 54.69 <sup>c</sup><br>(66.59)  | 62.03 <sup>d</sup><br>(77.88)  | 45.98<br>(51.74) | 34.40 <sup>d</sup><br>(32.05)                                  | 49.10 <sup>c</sup><br>(57.05)  | 54.62 <sup>c</sup><br>(66.38)  | 54.62 <sup>c</sup><br>(66.38)  | 48.18<br>(55.46) | 47.08<br>(53.60) |
| 2.                    | Fenazaquin 10 EC       | 0.01              | 21.89        | 42.36 <sup>a</sup><br>(45.39)                                 | 56.62 <sup>a</sup><br>(69.72)  | 65.78 <sup>ab</sup><br>(83.15) | 71.71 <sup>bc</sup><br>(90.02) | 59.11<br>(72.07) | 38.61 <sup>bcd</sup><br>(39.00)                                | 53.41 <sup>bc</sup><br>(64.40) | 61.47 <sup>c</sup><br>(76.97)  | 61.47 <sup>c</sup><br>(76.97)  | 53.74<br>(64.34) | 56.42<br>(68.20) |
| 3.                    | Propargite 57 EC       | 0.05              | 21.78        | 39.00 <sup>ab</sup><br>(39.66)                                | 51.06 <sup>b</sup><br>(60.47)  | 67.98 <sup>ab</sup><br>(84.21) | 69.25 <sup>c</sup><br>(87.43)  | 56.82<br>(67.92) | 39.59 <sup>bc</sup><br>(40.62)                                 | 53.20 <sup>bc</sup><br>(64.08) | 57.30 <sup>c</sup><br>(70.74)  | 57.30 <sup>c</sup><br>(70.74)  | 51.84<br>(61.54) | 54.33<br>(64.73) |
| 4.                    | Chlorfenpyr 10 SC      | 0.01              | 21.44        | 36.88 <sup>b</sup><br>(36.11)                                 | 48.26 <sup>c</sup><br>(55.66)  | 61.11 <sup>bc</sup><br>(76.66) | 72.55 <sup>bc</sup><br>(90.99) | 53.35<br>(64.85) | 48.23 <sup>a</sup><br>(55.61)                                  | 56.04 <sup>b</sup><br>(68.78)  | 76.86 <sup>ab</sup><br>(93.36) | 76.86 <sup>ab</sup><br>(93.36) | 64.49<br>(65.27) | 58.92<br>(65.06) |
| 5.                    | Diafenthurion 50 WP    | 0.055             | 21.33        | 42.48 <sup>a</sup><br>(45.62)                                 | 58.88 <sup>a</sup><br>(73.25)  | 68.98 <sup>a</sup><br>(87.04)  | 77.50 <sup>a</sup><br>(95.25)  | 61.96<br>(75.29) | 43.22 <sup>b</sup><br>(46.90)                                  | 69.41 <sup>a</sup><br>(87.61)  | 87.13 <sup>a</sup><br>(99.75)  | 87.13 <sup>a</sup><br>(99.75)  | 71.72<br>(83.50) | 66.84<br>(79.39) |
| 6.                    | Triazophos 40 EC       | 0.1               | 22.33        | 39.26 <sup>ab</sup><br>(40.06)                                | 50.97 <sup>bc</sup><br>(60.34) | 62.77 <sup>ab</sup><br>(79.05) | 69.14 <sup>c</sup><br>(87.23)  | 55.53<br>(66.67) | 36.40 <sup>cd</sup><br>(35.25)                                 | 53.31 <sup>bc</sup><br>(64.26) | 63.39 <sup>c</sup><br>(79.40)  | 63.39 <sup>c</sup><br>(79.40)  | 54.12<br>(64.57) | 54.82<br>(65.62) |
| 7.                    | Fenpyroximate 5 EC     | 0.0025            | 22.22        | 41.38 <sup>a</sup><br>(43.71)                                 | 57.21 <sup>a</sup><br>(70.68)  | 67.67 <sup>ab</sup><br>(85.54) | 74.58 <sup>ab</sup><br>(92.87) | 74.56<br>(73.20) | 41.51 <sup>b</sup><br>(43.93)                                  | 55.80 <sup>b</sup><br>(68.35)  | 75.00 <sup>b</sup><br>(91.09)  | 75.00 <sup>b</sup><br>(91.09)  | 61.82<br>(73.61) | 68.19<br>(73.40) |
| 8.                    | Control (Water spray)  | -                 | 22.89        | -   | -                              | -                              | -                              | -                | -  | -                              | -                              | -                              | -                | -                |
| S. Em. Period (P)     |                        |                   |              | 0.96  | 0.60                           | 1.57                           | 0.81                           | 0.98             | 1.02   | 1.12                           | 2.44                           | 2.4                            | 1.75             | 1.36             |
| C. D at 5% Period (P) |                        |                   |              | 4.45  | 2.76                           | 7.32                           | 3.78                           | 4.57             | 4.76   | 5.21                           | 11.33                          | 11.33                          | 8.15             | 6.36             |
| C.V. %                |                        |                   |              | 6.65  | 3.04                           | 6.52                           | 3.04                           | 4.81             | 6.75   | 5.33                           | 9.51                           | 9.51                           | 7.75             | 6.28             |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

DAS- days after spraying



### **First spray:**

One day after the first spray the triazophos was found highly toxic to predatory mite, *A. longispinosus* by reducing 51.48 per cent population of *A. longispinosus*, however it was followed by wettable sulphur (36.31% reduction) and was at par with propargite (25.00% reduction). Diafenthiuron was found least toxic to the predatory mite (5.21% reduction). So, on the basis of toxicity to the predatory mite, *A. longispinosus* the descending order of toxicity were: triazophos (51.48%)> wettable sulphur (36.31%)> propargite (25.00%)> fenpyroximate (18.33%)> chlorfenapyr (16.43%)> fenazaquin (12.63%) > diafenthiuron (5.21%).

Three days after first spray the acaricidal treatment triazophos was found highly toxic to predatory mite in reducing its population (80.99% reduction). However, it was followed by wettable sulphur (57.99% reduction) which was at par with propargite (51.11% reduction). Among all the acaricidal treatments the treatment diafenthiuron was found least toxic (15.38% reduction) to the predatory mite.

Seven days after spray, the acaricidal treatment triazophos was found highly toxic to the predatory mite, *A. longispinosus* (91.23% reduction) however, it was at par with other acaricidal treatments *viz.*, wettable sulphur (84.30% reduction) and propargite (79.55% reduction). Among all the acaricidal treatments diafenthiuron was found least toxic to predatory mite *A. longispinosus* (17.37% reduction). The descending order of toxicity of different acaricides seven days after spray were: triazophos (91.23%)> wettable sulphur

(84.30%)> propargite (79.55%)> chlorfenapyr (37.55%)> fenpyroximate (35.60%)> fenazaquin (26.58%)> diafenthiuron (17.37%).

Fourteen days after the first spray triazophos was found most toxic to predatory mite among the available acaricidal treatments (97.01%) and was followed by wettable sulphur (80.86%) which was statistically a par with propargite (76.03%). However, diafenthiuron was found least toxic to predatory mite, *A. longispinosus* (8.49% reduction) and safer to the same under polyhouse on tomato.

On the basis of pooled data of first spray, the acaricidal treatment triazophos was found highly toxic to predatory mite (80.17% reduction while, diafenthiuron was found least toxic (11.59% reduction) among the acaricidal treatments. However, the descending order of toxicity of different acaricidal treatments to the predatory mite *A. longispinosus* were: triazophos (80.17%)> wettable sulphur (64.81%)> propargite (57.92%)> fenpyroximate (28.83%)> chlorfenapyr (28.20%)> fenazaquin (19.28%)> diafenthiuron (11.59%).

### **Second spray:**

One day after the second spray, the acaricide propargite was found highly toxic to predatory mite (31.75% reduction) However, it was at par with wettable sulphur (30.16% reduction), triazophos (23.33% reduction) and fenazaquin (16.67% reduction). The treatment diafenthiuron was found less toxic to the predatory mite (2.94% reduction).

Three days after the second spray, the acaricidal treatment propargite was found highly toxic to predatory mite

with 61.44 per cent reduction in population, however it were at par with other acaricide viz., wettable sulphur (59.26% reduction) and triazophos (57.22% reduction). Diafenthiuron was found least toxic to predatory mite, *A. longispinosus* (6.66% reduction). The rest of the acaricidal treatments also gave varying degree of toxicity against predatory mite, *A. longispinosus*.

Seven days after second spray wettable sulphur was found highly toxic to predatory mites (87.24% reduction), and at par with triazophos and propargite (80.26 and 77.84% reduction). Among all the acaricidal treatments diafenthiuron was found least toxic to the predatory mite *A. longispinosus* (13.84% reduction). On the basis of mortality of predatory mites on tomato the descending order of toxicity of various acaricidal treatments were: wettable sulphur (87.24%)> triazophos (80.26%)> propargite (77.84%)> fenpyroximate (45.78%)> fenazaquin (36.54%)> chlorfenapyr (21.51%)> diafenthiuron (13.84%).

Fourteen days after second spray diafenthiuron was found least toxic to predatory mite, *A. longispinosus* (7.60%) and was at par with chlorfenapyr (15.42%). Among all the acaricidal treatments propargite was found highly toxic to predatory mite (64.41%). On the basis of per cent mortality of predatory mite *A. longispinosus* the descending order of various acaricides were: propargite (64.41%)> triazophos (61.92%)> wettable sulphur (61.72%)> fenpyroximate (39.52%)> fenazaquin (29.49%)> chlorfenapyr (15.42%)> diafenthiuron (7.60%).

The pooled data of second spray showed that diafenthiuron was found least toxic to the predatory mite (7.76% reduction) however wettable sulphur was found highly toxic to predatory mite *A. longispinosus* (59.59% reduction). On the basis of per cent reduction of predatory mite the descending order of these acaricidal treatments were: wettable sulphur (59.59%)> propargite (58.86%)> triazophos (55.68%)> fenpyroximate (32.86%)> fenazaquin (28.48%)> chlorfenapyr (14.46%)> diafenthiuron (7.76%).

The overall toxicity of all acaricidal treatments to the predatory mite, *A. longispinosus* indicated that triazophos was highly toxic to predatory mite with 67.92 per cent mortality while diafenthiuron was found least toxic to the predatory mite with least per cent mortality (9.67% mortality). However, the descending order of toxicity of various acaricidal treatments to the predatory mite, *A. longispinosus* were: triazophos (67.92%)> wettable sulphur (62.20%)> propargite (58.39%)> fenpyroximate (30.84%)> fenazaquin (23.88%)> chlorfenapyr (21.33%)> diafenthiuron (9.67%).

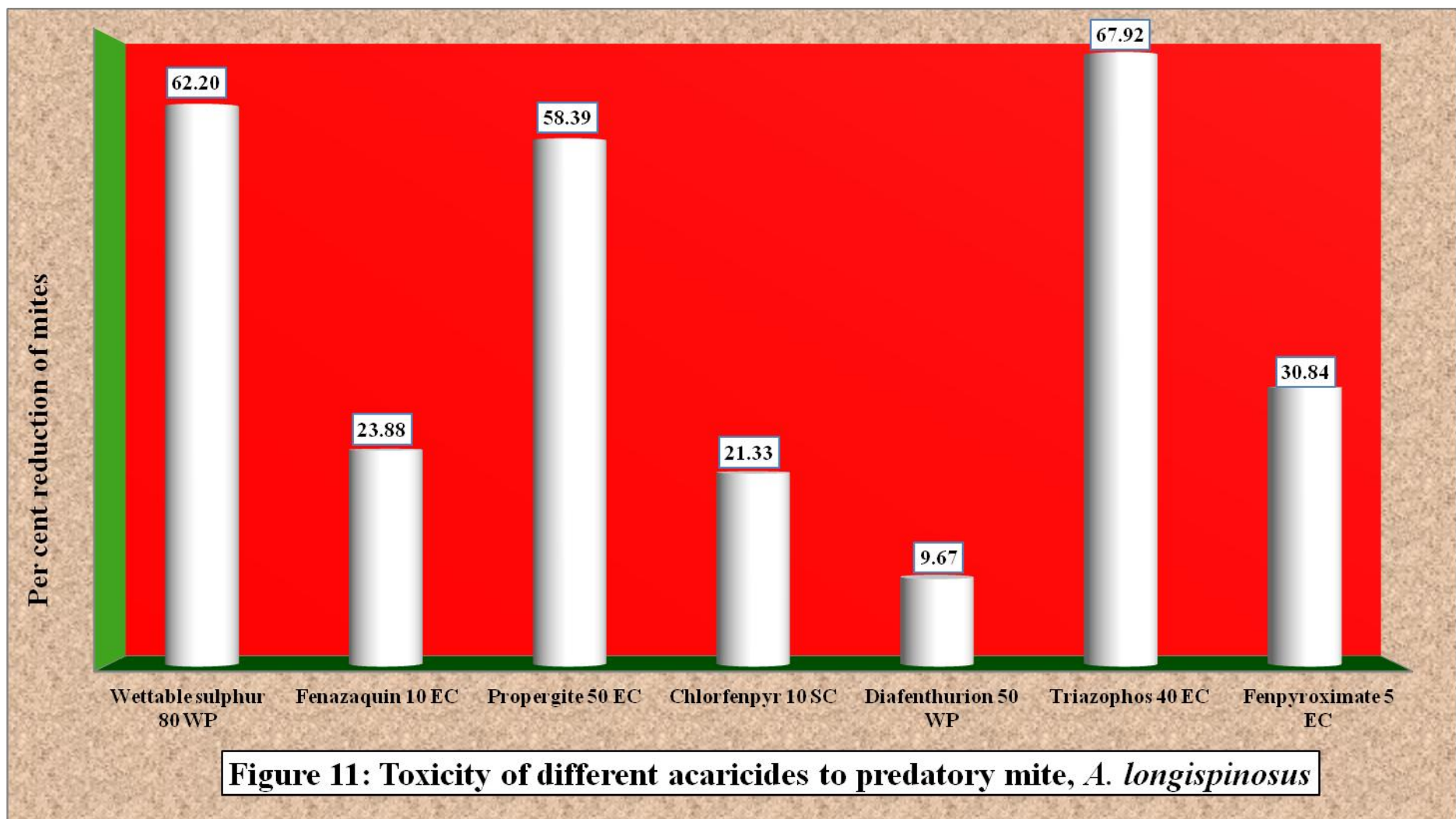
These findings are in conformity with Dey *et al.* (2001) who reported that the acaricide diafenthiuron was least toxic to the predatory mite, *Amblyseius* spp. on coconut at West Bengal. Ramaraju *et al.* (2000) reported that triazophos 40 EC was highly toxic to predatory mite fauna of coconut, under the present study similar results was recorded with triazophos, so more or less confirms the present findings 11.

**Table 64:- Toxicity of different acaricidal treatments against *A. longispinosus* on tomato under polyhouse**

| Sr. No.               | Treatment              | Concentration (%) | Before Spray | Per cent reduction of predatory mites at indicated period (First spray) |                               |                                |                                |                  | Per cent reduction of predatory mites at indicated period (Second spray) |                               |                               |                                |                  | Overall pooled   |
|-----------------------|------------------------|-------------------|--------------|---|-------------------------------|--------------------------------|--------------------------------|------------------|--|-------------------------------|-------------------------------|--------------------------------|------------------|------------------|
|                       |                        |                   |              | 1 DAS   | 3 DAS                         | 7 DAS                          | 14 DAS                         | Pooled           | 1 DAS  | 3 DAS                         | 7 DAS                         | 14 DAS                         | Pooled           |                  |
| 1.                    | Wettable sulphur 80 WP | 0.20              | 2.44         | 36.98 <sup>b</sup><br>(36.31)   | 49.64 <sup>b</sup><br>(57.99) | 67.07 <sup>a</sup><br>(84.30)  | 64.27 <sup>b</sup><br>(80.86)  | 54.49<br>(64.81) | 33.29 <sup>a</sup><br>(30.16)  | 50.42 <sup>a</sup><br>(59.26) | 69.08 <sup>a</sup><br>(87.24) | 51.79 <sup>a</sup><br>(61.72)  | 51.14<br>(59.59) | 52.81<br>(62.20) |
| 2.                    | Fenazaquin 10 EC       | 0.01              | 2.67         | 20.79 <sup>d</sup><br>(12.63)   | 34.14 <sup>c</sup><br>(32.04) | 30.64 <sup>bc</sup><br>(26.58) | 22.45 <sup>cd</sup><br>(5.89)  | 27.00<br>(19.28) | 23.80 <sup>ab</sup><br>(16.67)   | 33.73 <sup>b</sup><br>(31.25) | 37.05 <sup>b</sup><br>(36.54) | 32.49 <sup>bc</sup><br>(29.49) | 31.76<br>(28.48) | 29.38<br>(23.88) |
| 3.                    | Propargite 57 EC       | 0.05              | 3.11         | 29.92 <sup>bc</sup><br>(25.00)  | 45.63 <sup>b</sup><br>(51.11) | 63.50 <sup>a</sup><br>(79.55)  | 60.70 <sup>b</sup><br>(76.03)  | 49.93<br>(57.92) | 34.27 <sup>a</sup><br>(31.75)  | 51.67 <sup>a</sup><br>(61.44) | 62.13 <sup>a</sup><br>(77.84) | 53.43 <sup>a</sup><br>(64.41)  | 50.37<br>(58.86) | 50.15<br>(58.39) |
| 4.                    | Chlorfenpyr 10 SC      | 0.01              | 3.33         | 23.75 <sup>cd</sup><br>(16.43)  | 34.80 <sup>c</sup><br>(32.62) | 37.73 <sup>b</sup><br>(37.55)  | 30.42 <sup>dc</sup><br>(26.21) | 31.67<br>(28.20) | 17.89 <sup>bc</sup><br>(12.63)   | 16.73 <sup>c</sup><br>(8.30)  | 27.50 <sup>c</sup><br>(21.51) | 22.15 <sup>cd</sup><br>(15.42) | 21.06<br>(14.46) | 26.36<br>(21.33) |
| 5.                    | Diafenthurion 50 WP    | 0.055             | 4.22         | 11.68 <sup>e</sup><br>(5.21)  | 22.71 <sup>d</sup><br>(15.38) | 24.02 <sup>c</sup><br>(17.37)  | 14.35 <sup>d</sup><br>(8.49)   | 18.19<br>(11.59) | 7.50 <sup>c</sup><br>(2.94)  | 13.27 <sup>c</sup><br>(6.66)  | 21.41 <sup>c</sup><br>(13.84) | 15.08 <sup>d</sup><br>(7.60)   | 14.31<br>(7.76)  | 16.25<br>(9.67)  |
| 6.                    | Triazophos 40 EC       | 0.1               | 3.22         | 45.85 <sup>a</sup><br>(51.48)   | 64.15 <sup>a</sup><br>(80.99) | 72.77 <sup>a</sup><br>(91.23)  | 82.45 <sup>a</sup><br>(97.01)  | 66.30<br>(80.17) | 28.85 <sup>ab</sup><br>(23.33)   | 49.17 <sup>a</sup><br>(57.22) | 63.65 <sup>a</sup><br>(80.26) | 52.20 <sup>a</sup><br>(61.92)  | 48.46<br>(55.68) | 57.38<br>(67.92) |
| 7.                    | Fenpyroximate 5 EC     | 0.0025            | 3.56         | 25.00 <sup>cd</sup><br>(18.33)  | 35.48 <sup>c</sup><br>(33.80) | 36.41 <sup>b</sup><br>(35.60)  | 31.21 <sup>c</sup><br>(27.61)  | 32.02<br>(28.83) | 24.72 <sup>ab</sup><br>(17.78)   | 31.90 <sup>b</sup><br>(28.36) | 42.54 <sup>b</sup><br>(45.78) | 38.75 <sup>b</sup><br>(39.52)  | 34.47<br>(32.86) | 33.24<br>(30.84) |
| 8.                    | Control (Water spray)  | -                 | 3.56         | -   | -                             | -                              | -                              | -                | -  | -                             | -                             | -                              | -                | -                |
| S. Em. Period (P)     |                        |                   |              | 1.79  | 1.85                          | 2.41                           | 3.07                           | 2.28             | 2.53   | 2.26                          | 1.99                          | 2.77                           | 2.38             | 2.33             |
| C. D at 5% Period (P) |                        |                   |              | 8.38  | 8.60                          | 11.18                          | 14.26                          | 10.60            | 11.74  | 10.48                         | 9.26                          | 12.86                          | 11.08            | 10.84            |
| C.V. %                |                        |                   |              | 17.26   | 12.00                         | 13.46                          | 18.64                          | 15.34            | 27.55  | 16.47                         | 11.44                         | 19.34                          | 18.70            | 17.02            |

\* Figures in parentheses are retransformed value while those outside are arc sine transformed values

DAS- days after spraying



#### **4.4.5 Yield and economics of different acaricidal treatments:**

Data on economics of various acaricidal treatments are presented in Table 65 and gross realization Rs/1000m<sup>2</sup> over untreated control was highest in acaricidal treatment comprising diafenthiuron (Rs. 11920.58/1000m<sup>2</sup>) followed by fenpyroximate (Rs. 11512.93/1000m<sup>2</sup>), chlorfenapyr (Rs. 10459.00/1000m<sup>2</sup>), triazophos (Rs.10270.31/1000m<sup>2</sup>), fenazaquin (Rs.5776.84/1000m<sup>2</sup>), propargite (Rs. 5621.27/1000m<sup>2</sup>) and wettable sulphur (Rs. 5453.78/1000m<sup>2</sup>). The corresponding figures for net profit obtained over control were 6772.58, 6364.93, 5311.00, 5122.31, 628.84, 473.27 and 305.78 Rs/1000m<sup>2</sup>.

Looking to net ICBR, diafenthiuron stood first (1:10.50) and followed by fenpyroximate (1:10.40). the order of net ICBR of rest of the acaricidal treatments were triazophos (1:8.26), chlorfenapyr (1:8.15), fenazaquin (1:1.04), propargite (1:0.70) and wettable sulphur (1:0.50).

It could be concluded from the present results that diafenthiuron (1:10.50) gave effective control of both the phytophagous mites *i.e.* *T. urticae* and *A. lycopersici*.

#### **4.5. Diversity of phytophagous mites on various vegetables crops:**

Mites are known pests of many vegetables (Sardana, 1985 and Gupta, 1985). Therefore, to know the diversity of different mite fauna on different vegetables a survey was carried out at University fauna, Navsari Agricultural University, Navsari during the period of one year starting

Table 65:- Economics and acaricidal treatments of tomato

| Treatment                  | Total spray | Qty. of insecticide (15 lit. of water) | Cost of insecticide (Rs/ha) | Labour cost (Rs/ha) | Total cost of plant protection (Rs/ha) | Yield (Kg/ 1000m <sup>2</sup> ) | Gross income (Rs/ha) | Net gain (Rs/ha) | Net profit over control | ICBR    |
|----------------------------|-------------|--|-----------------------------|---------------------|--|---------------------------------|----------------------|------------------|-------------------------|---------|
| T-1: Wettable sulphur 80WP | 2           | 37.50                                  | 7.22                        | 600                 | 607.27                                 | 551                             | 6061                 | 543.78           | 305.78                  | 1:0.50  |
| T-2: Fenazaquin 10EC       | 2           | 1.50                                   | 3.16                        | 600                 | 603.16                                 | 580                             | 5380                 | 5776.84          | 628.84                  | 1:1.04  |
| T-3: Propargite 57 EC      | 2           | 22.50                                  | 26.73                       | 600                 | 626.73                                 | 568                             | 6248                 | 5621.27          | 473.27                  | 1:0.70  |
| T-4: Chlorfenapyr 10SC     | 2           | 15.00                                  | 51.00                       | 600                 | 651.00                                 | 1010                            | 11110                | 10459.00         | 5311.00                 | 1:8.15  |
| T-5: Diafenthiuron 50 WP   | 2           | 16.50                                  | 41.42                       | 600                 | 641.42                                 | 1142                            | 12562                | 11920.58         | 6772.58                 | 1:10.50 |
| T-6: Triazophos 40 EC      | 2           | 37.50                                  | 19.69                       | 600                 | 619.69                                 | 990                             | 10890                | 10270.31         | 5122.31                 | 1:8.26  |
| T-7: Fenpyroximate 5 EC    | 2           | 7.50                                   | 9.07                        | 600                 | 609.07                                 | 1102                            | 12122                | 11512.93         | 6364.93                 | 1:10.40 |
| T-8: Control (Water spray) | 2           | -                                      | -                           | -                   | -                                      | -                               | 5148                 | -                | -                       | -       |

Price:

Cost of insecticides:

\*prevailing market price of tomato: Rs. 11.00/kg

\*Labour charge= 150 Rs/ spray \*Spray fluid: 15 lit/ 1000m<sup>2</sup>.

\*Cost of insecticides (Rs/ml or gm)

Diafenthiuron: 21503 Rs/Kg

Wettable sulphur: 2059.2 Rs/Kg

Triazophos: 525 Rs/lit

Fenazaquin: 2106 Rs/lit

Fenpyroximate: 1290.3 Rs/lit

Chlorfenapyr: 3400 Rs/lit

Propargite: 1188 Rs/lit

Gross income= yield x price per kg of tomato

Net gain= Gross income- total cost of plant protection

ICBR= Net profit/ total cost of plant protection

Net profit over control= Net gain of treatment- control

from first fortnight of January 2014 to last fortnight of December 2014.

The specimens collected from various vegetables were identified as, *Tetranychus urticae*, *T. neocaledonicus*, *T. ludeni*, *T. macfarlanei*, *T. cinnabarinus*, *Oligonychus biharensis*, *Brevipalpus californicus*, *B. phoenicis*, *Eutetranychus orientalis*, *Polyphagotarsonemus latus* and *Aceria lycopersici* from various vegetables viz., tomato, okra, brinjal, chilli, capsicum, cowpea, little gourd, ridge gourd, bottle gourd, pointed gourd, bitter gourd, smooth gourd, pumpkin, spine gourd, french bean, cucumber and guar. The crop wise phytophagous mite diversity were presented herewith.

#### **4.5.1 Tomato:**

Tomato crop was surveyed both during summer and *kharif* seasons. From the Table 66, it is revealed that on open cultivated tomato crop five phytophagous mite species were recorded. These were *T. urticae*, *T. neocaledonicus*, *P. latus*, *B. phoenicis* and *A. lycopersici*. Among all these phytophagous mites two spotted spider mite, *T. urticae* was found all times on the tomato crop, where as the specimens of other spider mite, *T. neocaledonicus* were collected only during September to December months. The specimens of tarsonemid mite, commonly called as yellow mite, *P. latus* were collected during September to November. The specimens of Tenuipalpid mite, *B. phoenicis* were also collected during October to December on tomato, while eriophyid mite which is commonly known as tomato russet mite, *A. lycopersici* were collected during August to December. Therefore, from

the above survey on tomato crop it was found that five species of phytophagous mites were present on tomato under open cultivated conditions. Further under polyhouse tomato, survey results revealed that *T. urticae* and *A. lycopersici* were present on tomato crop during January to June. No other phytophagous mites were recorded from the tomato crop grown under polyhouse condition.

#### 4.5.2 Okra:

Phytophagous mite specimens collected from okra were presented in Table 66. On okra three tetranychid mites were recorded. Among them two spotted spider mite, *T. urticae* were recorded during February to October, while the specimens of another spider mite, *T. macfarlanei* were collected during July to October and the specimens of spider mite, *T. cinnabarinus* was only collected in the month of October from okra. So, it is very much clear from the Table 64, that *T. urticae*, *T. macfarlanei* and *T. cinnabarinus* were commonly found on okra.

#### 4.5.3 Brinjal:

The brinjal crop was also surveyed through crop seasons *i.e.* summer brinjal and the mite diversity were presented in the Table 66, from brinjal crop specimens of three species of tetranychids *viz.*, *T. urticae*, *T. cinnabarinus* and *T. ludeni* were collected. *T. urticae* was collected during February to August, whereas *T. cinnabarinus* was collected during June to August. However the specimens of *T. ludeni* were collected during March to May. Specimens of eriophyid mite, *A. lycopersici* were also collected from brinjal crop. They were collected during May to August. The tenuipalpid

mite, *B. phoenicis* were also found on brinjal during the months of May to June. So from above discussion it was found that three species of tetranychidae and one species each of eriophyidae and tenuipalpidae family were collected from brinjal crop.

#### **4.5.4 Chilli:**

The chilli crop was regularly observed and it was found that throughout the crop season specimens of yellow mite, *P. latus* were collected from chilli. The specimens of *P. latus* were collected during August to December months. No other phytophagous mites were collected from chilli.

#### **4.5.5 Capsicum:**

The capsicum crop grown under the polyhouse conditions were also regularly observed for phytophagous mite specimens. It was found that the specimens of yellow mite, *P. latus* were collected during the period of January to June. No other phytophagous mites were collected from capsicum.

#### **4.5.6 Cowpea:**

The cowpea crop grown at Horticultural farm was regularly observed and the mite specimens were collected. The Table 66 revealed that six species of phytophagous mites were found on cowpea. Among them four belongs to family Tetranychidae and one each belongs to Tenuipalpidae and Tarsonemidae family. Among the tetranychids the specimens of *T. urticae* were collected during August to October, while the specimens of *Oligonychus biharensis* were collected during october. The specimens of *T. neocalodenicus* were collected during August-September and the specimens of *T.*

*ludeni* were collected during September month. The specimens of tenuipalpid mite, *B. phoenicis* were collected during September-October month and the specimens of tarsonemid mite, *P. latus* were collected during the month of July-October.

#### **4.5.7 Little gourd:**

The little gourd crop was also observed and it was found that two species of tetranychids and one specimen of tenuipalpid mites were collected during the crop season. The specimens of *T. urticae* were collected during January to September months, while the specimens of *T. cinnabarinus* were collected during the month of April to August. The specimens of tenuipalpid mite, *B. phoenicis* were collected during June to September months. So from foregoing discussion it can be concluded that on little gourd crop three species of phytophagous mites were collected. Out of which two species belongs to family Tetranychidae and one belongs to family Tenuipalpidae.

#### **4.5.8 Ridge gourd:**

The ridge gourd crop were regularly observed for phytophagous mite fauna, and it was found that *T. urticae* were collected during January to May, then the spider mite were absent on the crop during the months of June to August and the specimens were collected again during September to December. Another spider mite *T. cinnabarinus* were collected during March to May. The specimens of tenuipalpid mite, *B. phoenicis* were collected during September to December and the specimen of tarsonemid mite, *P. latus* were collected during January to April and December months. So

from the above findings it can be concluded that on ridge gourd two species of spider mites (Tetranychidae) and one species each of tarsonemid and tenuipalpid mites were collected.

#### **4.5.9 Bottle gourd:**

It is evident from the Table 66, that the specimens of four species of phytophagous mites were collected from the bottle gourd. The specimens of spider mite, *T. cinnabarinus* specimens were collected during January to May and in December. The specimens of *B. phoenicis* were collected during October to December, while the specimens of *P. latus* were collected during February to April and November to December. The specimens of eriophyid mite, *A. lycopersici* were also collected from bitter gourd plants during the month of May. So, from the above survey it can be concluded that four phytophagous mite species each representing family Tetranychidae, Tarsonemidae, Tenuipalpidae and Eriophyidae were found on bottle gourd.

#### **4.5.10 Pointed gourd:**

The survey was also carried out on pointed gourd and the results of the survey were presented in Table 66. From pointed gourd two species of phytophagous mites were recorded. The spider mite, *T. macfarlanei* were recorded during January to March and November to December, where as tenuipalpid mite, *B. californicus* were recorded round the year on pointed gourd *i.e.* January to December. So, from pointed gourd two species of phytophagous mites were recorded.

#### 4.5.11 Bitter gourd:

The mite species were collected from bitter gourd were presented in Table 64. It was found that four species of phytophagous mites infests the bitter gourd. Among them three species belongs to family Tetranychidae and one belongs to family Tenuipalpidae. Among the tetranychids, *T. urticae*<sup>231</sup> were collected during May and October to December, *T. neocaledonicus* were collected during May and specimens of *Eutetranychus orientalis* were collected during March to May. The tenuipalpid mite, *B. phoenicis* were also recorded during March to May. So, from above survey it can be concluded that four mite species were recorded on bitter gourd crop.

#### 4.5.12 Smooth gourd:

The survey was carried out on smooth gourd and it was found that two tetranychid mite and one tenuipalpid mite were collected from smooth gourd during crop period. Specimens of *T. urticae* were collected during January to May as well as during September to December. The *Eutetranychus orientalis* were collected during the month of March to May while the specimens of *B. phoenicis* were collected during the month of January to May and October to December. From the above survey it can be concluded that two tertranychid species and one tenuipalpid mite were found on smooth gourd.

#### 4.5.13 Pumpkin:

The survey was conducted on pumpkin crop grown at Horticultural farm. Specimens of two phytophagous mites were collected. Two spotted spider mite, *T. urticae* were collected during February and September to December, while

tenuipalpid mite, *B. californicus* were also collected during the same period. It can be concluded that pumpkin crop was infested by two phytophagous mites.

#### **4.5.14 Cucumber:**

The survey was carried out in the cucumber grown under polyhouse conditions. Under the polyhouse conditions three species of phytophagous mites were recorded. The specimens of the two spotted spider mite, *T. urticae* were recorded during March to September. The tarsonemid mite, *P. latus* commonly known as yellow mite were also recorded from cucumber. The specimens were collected during June to September. An eriophyid mite, *A. lycopersici* were recorded from cucumber. The specimens were collected during August and September. From the present survey it was found that *T. urticae*, *P. latus* and *A. lycopersici* were infesting the cucumber crop under polyhouse conditions.

#### **4.5.15 French bean:**

The french bean grown at biological control laboratory plot of Department of Entomology were also recorded. The specimens of phytophagous mites were collected throughout the crop season and it was found that four species of phytophagous mites were recorded among them two species belonging to family Tetranychidae, while one belongs to family Tarsonemidae and another one belongs to family Tenuipalpidae. The specimens of two spotted spider mite *T. urticae* were recorded during February to August, while another spider mite, *T. ludeni* were collected during April-May as well as July-August. The yellow mite, *P. latus* were collected during June to August. The specimens were

collected during April to June. From the present survey carried out on french bean four phytophagous mite species were recorded.

#### 4.5.16 Cluster bean:

The guar or cluster bean crop grown for vegetable purpose was also observed to record phytophagous mite fauna. It was found during present survey that yellow mite, *P. latus* belonging to family Tarsonemidae were recorded during February to June. Another species which was recorded during the survey was flat mite, *B. phoenicis* belonging to family Tenuipalpidae. The specimens of *B. phoenicis* were collected during May to June on guar. Hence it was found that the guar grown for vegetable purpose was attacked by two mite species *i.e.* *P. latus* and *B. phoenicis*.

As per the past reports of various workers *T. urticae*, *T. neocaledonicus*, *T. cinnabarinus*, *T. ludeni* and *Eutetranychus orientalis* were observed to feed on one or more vegetables crop plants *viz.*, tomato, brinjal, okra, cowpea, french bean as well as different cucurbits (Bindra and Kittur, 1961, Pande and Yadava, 1975, Gupta, 1976, Pandey *et al.*, 1979, Jose and Shah, 1989, Sejalina, 1989 and Patel *et al.*, 1993). Sadana (1985) and Gupta (1985) reported that *B. phoenicis*, *B. californicus* and *P. latus* were recorded from different vegetables from various parts of India. Cowpea was recorded as host for *O. biharensis* by Sangeetha and Ramani (2011c). So, more or less confirms the present findings.

**Table 66:- Diversity of phytophagous mites on different vegetable crops**

|                                  | January | February | March | April | May | June | July | August | September | October | November | December |
|----------------------------------|---------|----------|-------|-------|-----|------|------|--------|-----------|---------|----------|----------|
| <b>Crop- Tomato</b>              |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>Tetranychus urticae</i>       | P       | P        | P     | P     | P   | -    | P    | P      | P         | P       | P        | P        |
| <i>T. neocaledonicus</i>         | A       | A        | A     | A     | A   | -    | A    | A      | P         | P       | P        | P        |
| <i>Polyphagotarsonemus latus</i> | A       | A        | A     | A     | A   | -    | A    | A      | P         | P       | P        | A        |
| <i>Brevipalpus phoenicis</i>     | A       | A        | A     | A     | A   | -    | A    | A      | P         | P       | P        | P        |
| <i>Aceria lycopersici</i>        | A       | A        | A     | A     | A   | -    | A    | P      | P         | P       | P        | P        |
| <b>Tomato (Polyhouse)</b>        |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>                | P       | P        | P     | P     | P   | P    | -    | -      | -         | -       | -        | -        |
| <i>A. lycopersici</i>            | P       | P        | P     | P     | P   | P    | -    | -      | -         | -       | -        | -        |
| <b>Okra</b>                      |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>                | P       | P        | P     | P     | P   | P    | P    | P      | P         | P       | -        | -        |
| <i>T. macfarlanei</i>            | A       | A        | A     | A     | A   | A    | P    | P      | P         | P       | -        | -        |
| <i>T. cinnabarinus</i>           | A       | A        | A     | A     | A   | A    | A    | A      | A         | P       | -        | -        |
| <b>Brinjal</b>                   |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>                | -       | P        | P     | P     | P   | P    | P    | P      | -         | -       | -        | -        |
| <i>T. cinnabarinus</i>           | -       | A        | A     | A     | A   | P    | P    | P      | -         | -       | -        | -        |
| <i>T. ludeni</i>                 | -       | A        | A     | A     | P   | P    | P    | P      | -         | -       | -        | -        |
| <i>Brevipalpus phoenicis</i>     | -       | A        | A     | A     | P   | P    | A    | A      | -         | -       | -        | -        |
| <i>Aceria lycopersici</i>        | -       | A        | P     | P     | P   | A    | A    | A      | -         | -       | -        | -        |
| <b>Chilli</b>                    |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>P. latus</i>                  | -       | -        | -     | -     | -   | -    | A    | P      | P         | P       | P        | P        |
| <b>Capsicum (Polyhouse)</b>      |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>P. latus</i>                  | P       | P        | P     | P     | P   | P    | -    | -      | -         | -       | -        | -        |
| <b>Cowpea</b>                    |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>                | -       | -        | -     | -     | -   | A    | A    | P      | P         | P       | -        | -        |
| <i>T. neocaledonicus</i>         | -       | -        | -     | -     | -   | A    | A    | A      | A         | -       | -        | -        |
| <i>T. ludeni</i>                 | -       | -        | -     | -     | -   | A    | A    | P      | P         | A       | -        | -        |
| <i>Oligonychus biharensis</i>    | -       | -        | -     | -     | -   | A    | A    | A      | P         | P       | -        | -        |
| <i>P. latus</i>                  | -       | -        | -     | -     | -   | A    | P    | P      | P         | P       | -        | -        |
| <i>B. californicus</i>           | -       | -        | -     | -     | -   | A    | A    | A      | P         | A       | -        | -        |

Table 66:- Contd.....

|                                | January | February | March | April | May | June | July | August | September | October | November | December |
|--------------------------------|---------|----------|-------|-------|-----|------|------|--------|-----------|---------|----------|----------|
| <b>Little gourd</b>            |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>              | P       | P        | P     | P     | P   | P    | P    | P      | P         | -       | -        | -        |
| <i>T. cinnabarinus</i>         | A       | A        | A     | P     | P   | P    | P    | P      | A         | -       | -        | -        |
| <i>B. phoenicis</i>            | A       | A        | A     | A     | A   | P    | P    | P      | P         | -       | -        | -        |
| <b>Ridge gourd</b>             |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>              | P       | P        | P     | P     | P   | A    | A    | A      | P         | P       | P        | P        |
| <i>T. cinnabarinus</i>         | A       | A        | P     | P     | P   | A    | A    | A      | A         | A       | A        | A        |
| <i>B. phoenicis</i>            | A       | A        | A     | A     | A   | A    | A    | A      | P         | P       | P        | P        |
| <i>P. latus</i>                | P       | P        | P     | P     | A   | A    | A    | A      | A         | A       | A        | P        |
| <b>Bottle gourd</b>            |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. cinnabarinus</i>         | P       | P        | P     | P     | P   | -    | -    | A      | A         | A       | A        | P        |
| <i>B. phoenicis</i>            | A       | A        | A     | A     | A   | -    | -    | A      | A         | P       | P        | P        |
| <i>P. latus</i>                | A       | P        | P     | P     | P   | -    | -    | A      | A         | A       | P        | P        |
| <i>A. lycopersici</i>          | A       | A        | A     | A     | A   | -    | -    | A      | A         | A       | A        | A        |
| <b>Pointed gourd</b>           |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. macfarlanei</i>          | P       | P        | P     | P     | P   | A    | A    | A      | A         | A       | P        | P        |
| <i>B. californicus</i>         | P       | P        | P     | P     | P   | P    | P    | P      | P         | P       | P        | P        |
| <b>Bitter gourd</b>            |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>              | A       | A        | A     | A     | P   | -    | -    | -      | A         | P       | P        | P        |
| <i>T. neocaledonicus</i>       | A       | A        | A     | A     | P   | -    | -    | -      | A         | A       | A        | A        |
| <i>Eutetranyhus orientalis</i> | P       | P        | P     | P     | P   | -    | -    | -      | A         | A       | P        | P        |
| <i>B. phoenicis</i>            | A       | A        | P     | P     | P   | -    | -    | -      | A         | A       | A        | A        |
| <b>Smooth gourd</b>            |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>              | P       | P        | P     | P     | P   | -    | -    | A      | P         | P       | P        | P        |
| <i>E. orientalis</i>           | P       | P        | P     | P     | P   | -    | -    | A      | A         | P       | P        | P        |
| <i>B. phoenicis</i>            | A       | A        | P     | P     | P   | -    | -    | A      | A         | A       | A        | A        |
| <b>Pumpkin</b>                 |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>              | A       | P        | -     | -     | -   | -    | A    | A      | P         | P       | P        | P        |
| <i>B. californicus</i>         | A       | P        | -     | -     | -   | -    | A    | A      | P         | P       | P        | P        |

Table 66:- Contd.....

|                             | January | February | March | April | May | June | July | August | September | October | November | December |
|-----------------------------|---------|----------|-------|-------|-----|------|------|--------|-----------|---------|----------|----------|
| <b>Spine gourd</b>          |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>           | -       | -        | -     | -     | -   | -    | A    | A      | A         | P       | P        | P        |
| <i>P. latus</i>             | -       | -        | -     | -     | -   | -    | A    | A      | P         | P       | A        | A        |
| <i>B. californicus</i>      | -       | -        | -     | -     | -   | -    | A    | A      | A         | P       | A        | P        |
| <b>Cucumber (Polyhouse)</b> |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>           | -       | A        | P     | P     | P   | P    | P    | P      | P         | -       | -        | -        |
| <i>P. latus</i>             | -       | A        | A     | A     | A   | P    | P    | P      | P         | -       | -        | -        |
| <i>A. lycopersici</i>       | -       | A        | A     | A     | A   | A    | A    | P      | P         | -       | -        | -        |
| <b>French bean</b>          |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>T. urticae</i>           | P       | P        | P     | P     | P   | P    | P    | P      | -         | -       | -        | -        |
| <i>T. ludeni</i>            | A       | A        | A     | A     | A   | P    | P    | P      | -         | -       | -        | -        |
| <i>P. latus</i>             | A       | A        | P     | P     | P   | P    | A    | A      | -         | -       | -        | -        |
| <i>B. phoenicis</i>         | A       | A        | P     | P     | P   | A    | P    | P      | -         | -       | -        | -        |
| <b>Cluster bean</b>         |         |          |       |       |     |      |      |        |           |         |          |          |
| <i>P. latus</i>             | P       | P        | P     | P     | P   | P    | -    | P      | P         | P       | P        | -        |
| <i>B. phoenicis</i>         | A       | A        | A     | A     | P   | P    | -    | -      | -         | -       | -        | -        |

Note:- P= Presence of host, A= Absence of host,“-”= Unavailability of host



*T. ludeni*



*T. neocaledonicus*



*T. urticae*



*O. biharensis*



*B. californicus*



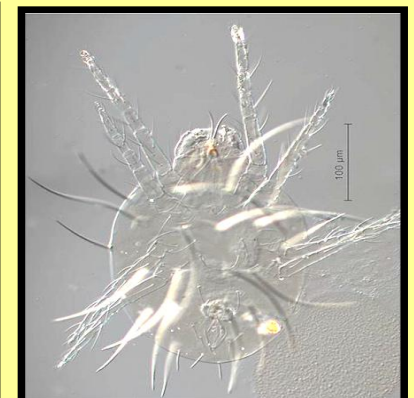
*B. phoenicis*



*P. latus*



*A. lycopersici*



*E. orientalis*

**Plate12: Permanent mount of plant mites collected from various vegetables**



**SUMMARY  
AND  
CONCLUSION**

## 5. SUMMARY AND CONCLUSION

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Tomato is one of the most important commercial vegetable of the world and also of India. It is also grown on commercial scale in Gujarat particularly in South Gujarat. Crop however is attacked by a number of pests, amongst them phytophagous mites, *Tetranychus urticae* Koch and *Aceria lycopersici* Wolffenstein are the most important and of economic values. There is very limited literature available for these phytophagous mites on biology, incidence, chemical control and diversity on vegetables both under polyhouse and open conditions. Hence, the present investigations on the biology, seasonal incidence of phytophagous mites and their natural enemies, chemical control of phytophagous mites and toxicity to predators and their diversity on different vegetables in polyhouse of AINP on Agril. Acarology as well at polyhouse of Department of Vegetable sciences, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during 2014.

The results obtained from various trials both laboratory and polyhouse were summarized and conclusion drawn from the present experiments are presented in this chapter.

### 5.1 **Biology of *T. urticae* on tomato**

Biology of *T. urticae* was studied under laboratory during three seasons *i.e.* summer (June-August), monsoon (August-September) and winter (November-December) with average of whole year.

The eggs of the *T. urticae* were smooth, soft, spherical and translucent white. The colour changed to dirty white as aged. The size of egg measured on an average  $0.11\pm 0.02$  mm in diameter. The incubation period of egg was found to be prolonged  $5.13\pm 0.74$  days during the winter season. While the incubation period of egg was  $3.93\pm 0.56$  days and  $4.20\pm 0.67$  days during summer and monsoon period, where the room temperature was much higher as compared to winter.

The newly emerged hexapodous larva was spherical in shape and creamy white in colour. The larval body measured  $0.13\pm 0.02$  mm in length and  $0.08\pm 0.02$  mm in breadth, respectively. The larval period was also influenced during the seasons as it lasted for  $1.80\pm 0.67$ ,  $2.06\pm 0.25$  days and  $2.60\pm 0.50$  for male while it was  $2.84\pm 0.62$ ,  $2.06\pm 0.25$  and  $2.86\pm 0.33$  days for female during summer, monsoon and winter. The larva entered into a stage of quiescent *i.e.* nymphochrysalis stage by anchoring itself to the leaf surface. The colour of nymphochrysalis was dark green. The body in this stage measured  $0.17\pm 0.01$  mm in length and  $0.10\pm 0.01$  mm in breadth. The nymphochrysalis period of male lasted for  $0.69\pm 0.32$ ,  $0.74\pm 0.36$  and  $1.02\pm 0.27$  days, while that of the female for  $1.47\pm 0.82$ ,  $0.62\pm 0.36$  and  $3.19\pm 1.11$  days during summer, monsoon and winter seasons.

Protonymph emerged from nymphochrysalis. It was different from larva by having four pairs of legs. The body of this stage was oval, more pigmented having dark green colour in the beginning which turned to amber colour later on. The length and breadth of body were on an average  $0.18\pm 0.03$  and

0.11±0.01 mm. The protonymphal period for male was 2.73±0.45, 3.60±0.52 and 4.46±1.06 days and for female, it was 3.26±0.66, 3.00±0.57 and 6.24±0.83 days during different seasons. The protonymph entered into a quiescent stage known as deutochrysalis. In this stage, all the activities of mite were suspended and it remained anchored to the leaf surface. The body was shrunked and reduced in size. The colour of this stage was dark green. The deutochrysalis stage measured 0.19±0.03 mm in length while 0.12±0.01 mm in breadth. This period lasted for 0.80±0.34, 0.92±0.29 and 1.05±0.09 days for male, while for female, it lasted for 1.63±0.91, 0.86±0.42 and 3.63±1.33 days during summer, monsoon and winter season.

After moulting from deutochrysalis stage, the activity regained and mite entered to deutonymphal stage. The body of this stage was carmine in colour and was larger and broader than protonymph. The body shape was oval with rounded abdomen in case of female, while in case of male, it was slender with pointed abdomen. The colour of male was light carmine, whereas that of female, it was dark carmine. In this stage, male and female can be easily distinguished. The length and breadth of deutonymph was 0.30±0.07 and 0.14±0.04 mm, respectively. The deutonymphal period of male lasted for 2.53±0.51, 3.46±0.51 and 3.80±0.41 days, that of lasted for female as 3.58±0.60, 2.88±0.66 and 6.12±0.72 days during summer, monsoon and winter seasons, respectively.

The deutonymph entered a quiescent stage known as teleochrysalis. In this stage, the body shrunked and reduced in size. The colour was light carmine and creamy. The length and breadth were 0.31±0.09 and 0.17±0.02 mm, respectively.

The teleochrysalis period lasted for  $0.60\pm 0.20$ ,  $0.74\pm 0.21$  and  $0.94\pm 0.09$  days for male and  $1.66\pm 0.73$ ,  $0.81\pm 0.22$  and  $3.33\pm 0.69$  days for female during three seasons.

Total developmental period of the spider mite from egg to adult emergence was  $9.28\pm 0.73$ ,  $11.61\pm 1.34$  and  $13.89\pm 1.07$  days for male and the same for the female were  $14.81\pm 2.37$ ,  $10.29\pm 1.19$  and  $32.13\pm 4.40$  days during three seasons, respectively.

At the end of teleochrysalis stage the outer skin of this stage turned silvery white and a horizontal slit appeared on the dorsal side between the second and third pair of legs which splited at the time of ecdysis for adult emergence. The male emerged earlier than the females and found waiting near teleochrysalis from which females were to be emerged. More time was required for the development at lower temperature and *vice-versa*.

The adult male had oval body with distinctly pointed abdomen. The colour of the body was slightly greenish which later on turned to pinkish as it aged. The size of the female was bigger than the male. The body of the female was oblong in shape with rounded abdomen. The body of the male measured  $0.40\pm 0.08$  mm in length and  $0.17\pm 0.01$  mm in breadth, while that of female, measured  $0.46\pm 0.02$  mm in length and  $0.20\pm 0.02$  mm in breadth. The adult period lasted for  $8.80\pm 1.20$ ,  $9.73\pm 1.03$  and  $11.46\pm 1.06$  days for male, while it lasted for  $11.46\pm 2.16$ ,  $16.33\pm 2.19$  and  $17.46\pm 2.03$  days for unmated female whereas the same period for mated female was  $10.00\pm 1.19$ ,  $12.36\pm 1.38$  and  $19.84\pm 1.46$  days during all the three seasons. Thus, female lived longer than male.

Mating was started immediately after the final moulting of the female. The male crawled its head underneath the posterior abdomen of the female and arched the end of its abdomen upward to accomplish coupling. The mating lasted for about 1 to 2 minutes.

The adult period of female consisted of three demarkable periods *viz.*, pre-oviposition, oviposition and post-oviposition period. The pre-oviposition period lasted for  $3.60 \pm 1.35$ ,  $7.06 \pm 1.38$  and  $6.93 \pm 1.16$  days for unmated female, while in case of mated female, it was  $2.44 \pm 0.71$ ,  $2.60 \pm 0.81$  and  $5.52 \pm 0.87$  days, during three seasons, respectively. The oviposition period lasted for  $5.33 \pm 1.30$ ,  $6.06 \pm 1.27$  and  $6.66 \pm 1.29$  days unmated female and it was  $4.96 \pm 1.30$ ,  $7.46 \pm 1.70$  and  $8.04 \pm 0.61$  days for mated female in summer, monsoon and winter seasons, respectively. The post-oviposition period for unmated female was  $2.66 \pm 0.97$ ,  $3.13 \pm 0.63$  and  $3.86 \pm 0.51$  days and for mated female it was  $3.04 \pm 0.73$ ,  $2.32 \pm 1.28$  and  $3.90 \pm 0.71$  days during summer, monsoon and winter, respectively. The fecundity for unmated female was  $26.06 \pm 8.33$ ,  $31.86 \pm 6.01$  and  $19.13 \pm 3.86$  eggs with average eggs per female per day as  $5.23 \pm 2.32$ ,  $5.59 \pm 1.96$  and  $2.95 \pm 0.76$ , while for mated female, it was  $55.24 \pm 13.84$ ,  $71.80 \pm 15.48$  and  $66.48 \pm 10.72$  eggs during summer, monsoon and winter seasons, respectively.

The rate of male to female (sex ratio) of bisexual reproduction was 1: 2.57, 1: 3.16 and 1: 2.84 in all three seasons, whereas in case of parthenogenic reproduction, cent per cent males were produced.

## 5.2 Biology of *A. lycopersici* on tomato

The eggs were usually round to oval and almost transparent which later turned white. The eggs were laid singly on leaves and stems of tomato plants. The average incubation period of male was  $2.08 \pm 0.49$  days and for female it was  $2.86 \pm 0.22$  days. The newly emerged larva was very small, vermiform and transparent. It started feeding soon after emergence. The larval period of male was  $1.00 \pm 0.32$  days and for female it was  $1.56 \pm 0.36$  days. The fully grown larvae stopped feeding and entered into a resting stage known as quiescent stage. This period lasted for  $0.49 \pm 0.19$  days for male and  $0.85 \pm 0.14$  days for female.

The newly emerged nymph was pale whitish and this period lasted for  $1.76 \pm 0.29$  days for male and  $2.60 \pm 0.38$  days for female. The fully grown nymph then becomes quiescent and this period lasted for  $0.90 \pm 0.12$  days for male and  $1.96 \pm 0.45$  days for female.

The total development period of male *A. lycopersici* was  $6.23 \pm 0.70$  days while for the female it was  $9.87 \pm 0.88$  days. The adult period of female consisted of three demarkable stages *i.e.* pre oviposition, oviposition and post oviposition period. The pre oviposition period of mated female was  $5.32 \pm 0.90$  days whereas in case of unmated female it was  $2.76 \pm 0.72$  days. The oviposition period of mated female was  $14.44 \pm 1.38$  days and for unmated female it was  $5.72 \pm 0.93$  days. The post oviposition period of unmated female was  $4.96 \pm 0.79$  days while in case of unmated females it was  $2.32 \pm 0.55$  days.

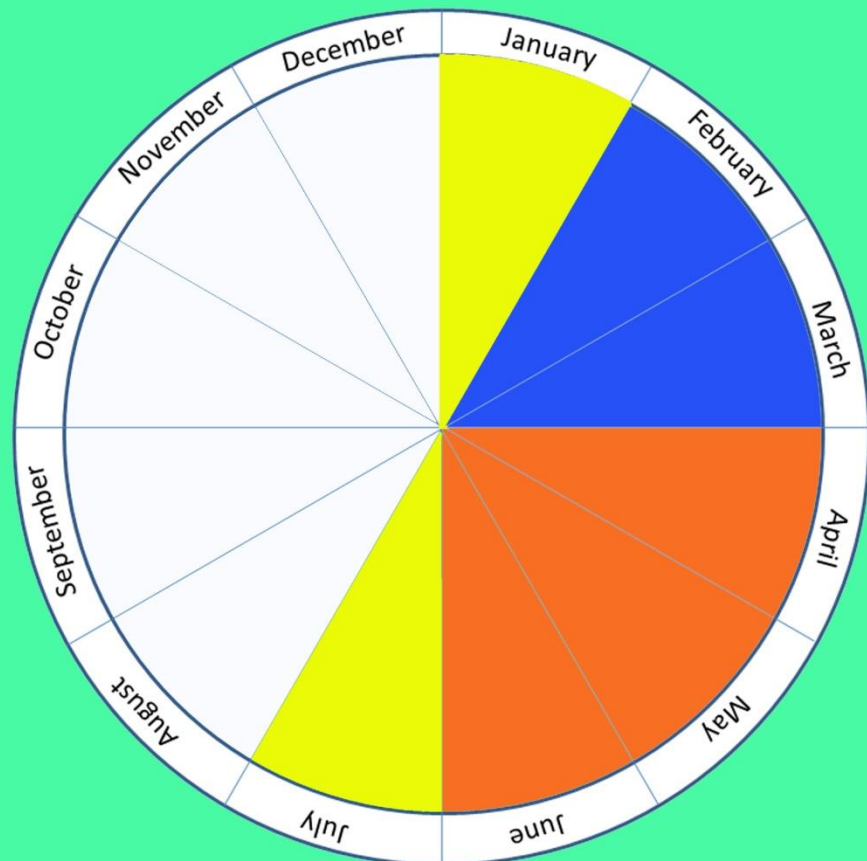
The adult period of male was  $20.63 \pm 1.70$  days while the same period for mated female were  $24.76 \pm 1.79$  days and  $10.80 \pm 1.38$  days for unmated females. The rate of egg laying for unmated female was  $15.52 \pm 2.78$  eggs while for mated female it was  $42.52 \pm 5.90$  eggs. The total life period of male was  $20.63 \pm 1.70$  days while for mated female it was  $34.59 \pm 2.23$  days and for unmated female it was  $20.67 \pm 1.60$  days.

### **5.3 Seasonal incidence of phytophagous mites and their natural enemies:**

Under the present study the two phytophagous mites *viz.*, *T. urticae* and *A. lycopersici* and their natural enemies *i.e.* phytoseiid predatory mite, *A. longispinosus* and predatory thrips *S. indicus* were recorded on tomato grown under the polyhouse conditions. The population of these were recorded during January to July 2014.

The egg laying of *T. urticae* was started on the tomato leaves during 2<sup>nd</sup> SMW (2<sup>nd</sup> week of January) and three distinct peaks were recorded *i.e.* first during 12<sup>th</sup> SMW (3<sup>rd</sup> week of March) with 2.80 eggs per leaf, while the second peak was recorded during 18<sup>th</sup> SMW (1<sup>st</sup> week of May) with 4.93 eggs per leaf and the third peak was recorded during 24<sup>th</sup> SMW (2<sup>nd</sup> week of June) with 5.33 eggs per leaf. The maximum number of eggs were recorded from top leaves followed by bottom and lower leaf canopy. The correlation between number of eggs and average temperature and relative humidity showed a significant positive relationship ( $r=0.690$

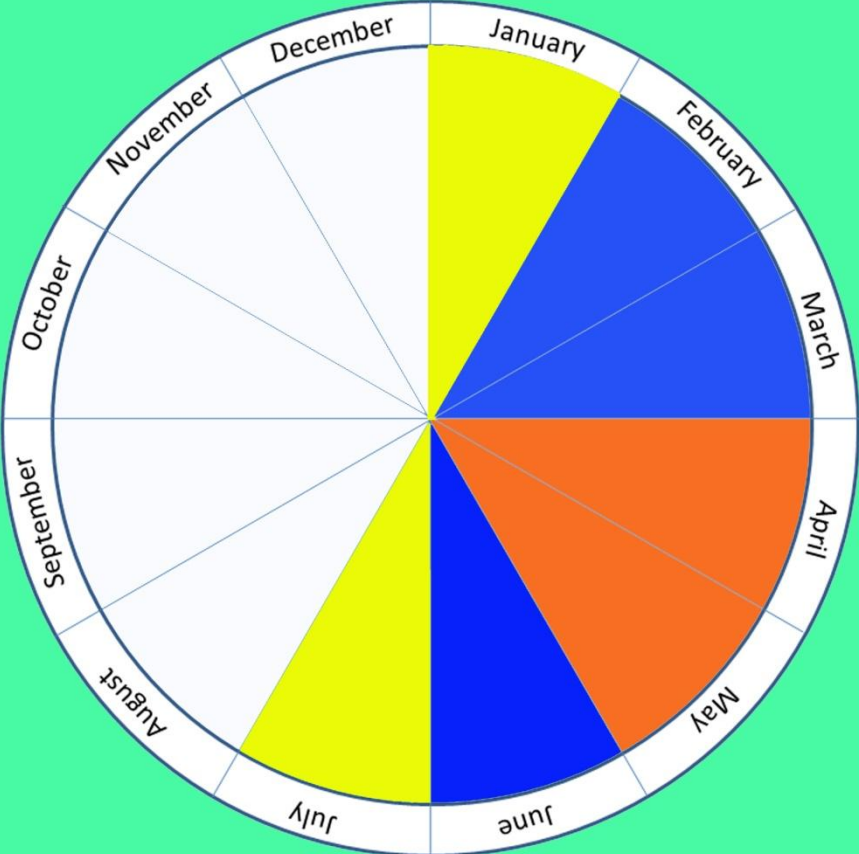
## PEST CALENDER OF *TETRANYCHUS URTICAE* ON TOMATO



and  $r=0.671$ , respectively). The population of mobile stages of *T. urticae* were also recorded throughout the crop season. Two peaks were observed, the first peak was recorded during 15<sup>th</sup> SMW (2<sup>nd</sup> week of April) with 6.06 mites per leaf and the second was observed during 24<sup>th</sup> SMW (2<sup>nd</sup> week of June). The mite population during this period were 7.33 per leaf. The highest number of mobile stages of *T. urticae* were collected from top leaf canopy and followed by middle and bottom. The correlation between mobile stages and abiotic factors of polyhouse were also worked out and the mite population (mobile stage) showed a significant positive correlation with average temperature ( $r=0.678$ ) and relative humidity ( $r=0.574$ ), respectively.

The population dynamics of russet mite, *A. lycopersici* were also recorded throughout the crop season. The russet mite starts egg laying during 4<sup>th</sup> SMW (3<sup>rd</sup> week of January). The maximum number of eggs were recorded during 21<sup>st</sup> SMW (4<sup>th</sup> week of May) *i.e.* 9.20 eggs per leaf. The russet mite, *A. lycopersici* lays maximum eggs on top leaves followed by middle and bottom leaves. The correlation studies showed a significant positive correlation between number of eggs and average temperature ( $r=0.508$ ) and average relative humidity ( $r=0.499$ ). The activities of mobile stages of *A. lycopersici* were also recorded and it was found that the peak activities of mobile stages was recorded during 21<sup>st</sup> SMW (4<sup>th</sup> week of May) with 9.00 mobile stages per leaf. The correlation studies between mobile stages of *A. lycopersici* showed that a significant positive correlation exists between

**PEST CALENDER OF ACERIA LYCOPERSICI ON TOMATO**

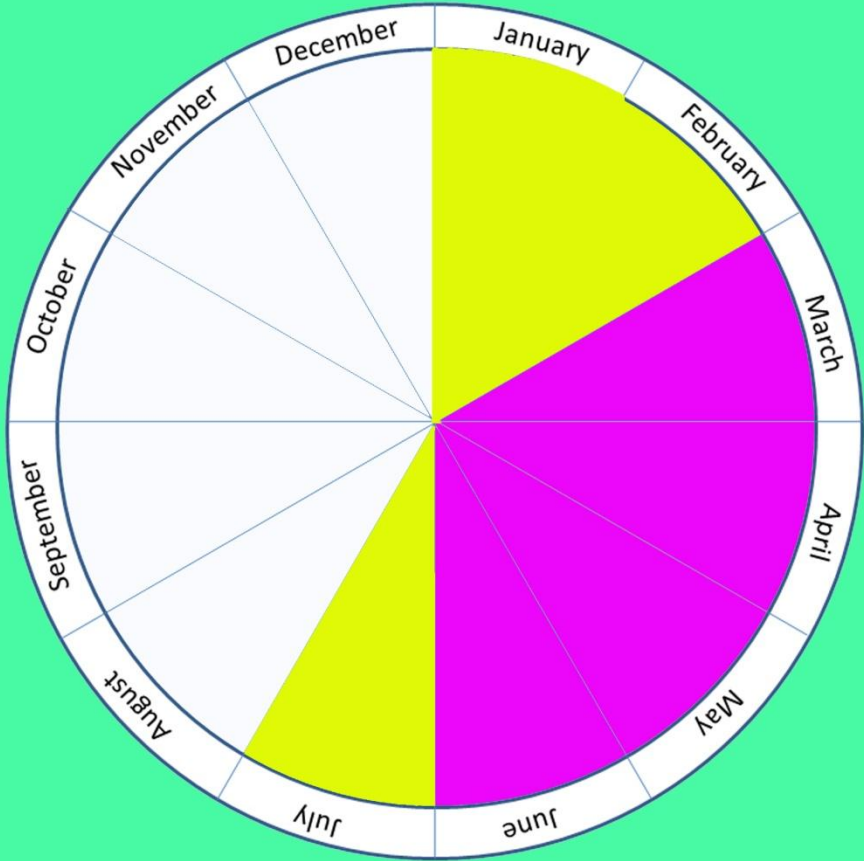


mobile stages and average temperature ( $r=0.441$ ) and relative humidity ( $r=0.406$ ). The distribution of mobile stages of *A. lycopersici* showed that the mobile stages population was maximum on top leaf canopy followed by middle and bottom canopy.

The activities of predatory mite, *A. longispinosus* were also recorded throughout the crop season and it was found that the predatory mite, *A. longispinosus* population was highest during 13<sup>th</sup> SMW (4<sup>th</sup> week of March) with 2.67 mites per leaf. The second peak was recorded during 25<sup>th</sup> SMW (3<sup>rd</sup> week of June) with 2.67 mites per leaf. The predatory mite, *A. longispinosus* population was higher on top leaves followed by middle and bottom strata. The significantly positive correlation exist between predatory mite, *A. longispinosus* and its prey *i.e.* *T. urticae* and *A. Lycopersici*. However, a significant positive correlation were also existed between predatory mite, *A. longispinosus* and both the abiotic factors of polyhouse ( $r=0.515$  and  $0.401$ ).

The activities of predatory thrips, *S. indicus* were also recorded throughout the crop season and peak activities of *S. indicus* was recorded during 26<sup>th</sup> SMW (4<sup>th</sup> week of June) with average population of 3.00 thrips per leaf. The predatory thrips, *S. indicus* population showed a significant positive correlation with the eggs and mobile stages of its prey *i.e.* *T. urticae* and *A. lycopersici*. The correlation between predatory thrips and abiotic factors *i.e.* average temperature and relative humidity of polyhouse were also significantly positive ( $r=0.822$  and  $0.663$ ). The activities of predatory were

ACTIVITY CALENDER OF *AMBLyseius longispinosus* ON TOMATO



LOW

MEDIUM

maximum on top leaves of tomato followed by middle and bottom leaves.

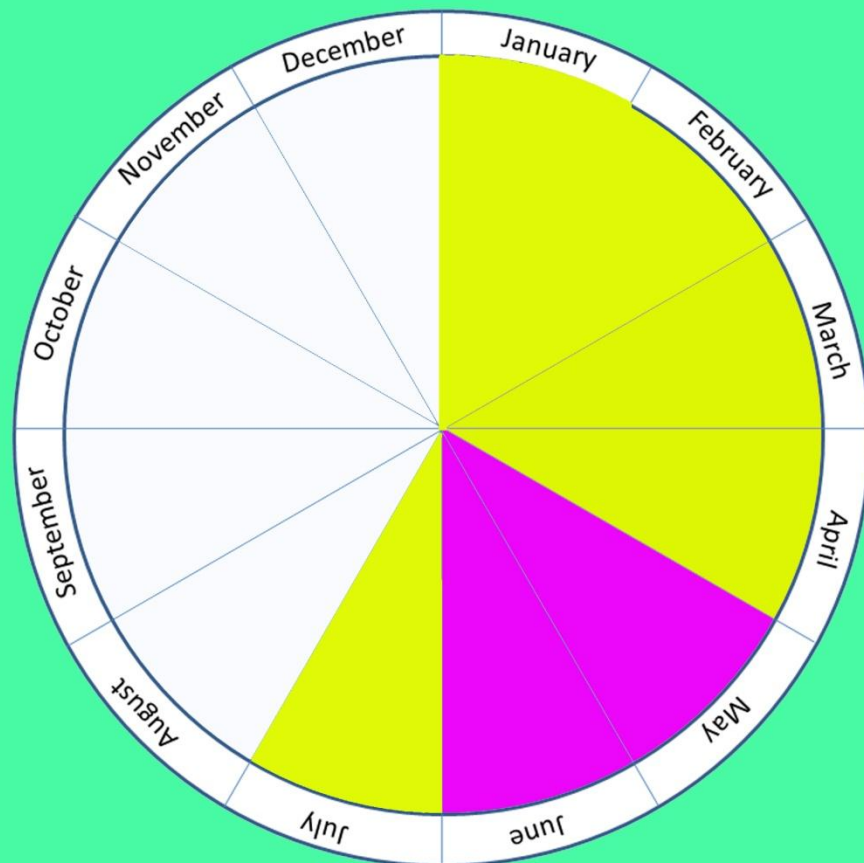
#### **5.4 Chemical control of phytophagous mites and adverse effect of acaricides on predatory mite**

Different acaricidal treatments were tested for their bioefficacy against *T. urticae* and *A. lycopersici* and their toxic effect on predatory mites, *A. longispinosus* both under laboratory as well as polyhouse conditions.

In laboratory conditions against *T. urticae* diafenthiuron 50 WP (0.055%) was found most effective treatment followed by chlorfenapyr 10 SC (0.01%) and fenazaquin 10 EC (0.01%) while wettable sulphur 80 WP (0.20%) proved to be the least effective. Further, the acaricidal treatment diafenthiuron 50 WP (0.055%) also showed best ovicidal action. The other acaricidal treatments like propargite 57 EC (0.05%), fenazaquin 10 EC (0.01%) and chlorfenapyr 10 SC (0.01%) had also showed better ovicidal action. 72 hours after spray the acaricidal treatment diafenthiuron 50 WP (0.055%) was found very effective in reducing *T. urticae* population.

The acaricidal treatments were also tested for their bioefficacy against *A. lycopersici* under the polyhouse conditions. Among different acaricidal treatments diafenthiuron 50 WP (0.055%) was found most effective for controlling *A. lycopersici* while wettable sulphur was found least effective. The ovicidal properties of different acaricides showed that diafenthiuron was the best ovicide as it recorded

ACTIVITY CALENDER OF *SCOLOTHRIPS INDICUS* ON TOMATO



LOW

MEDIUM

the lowest egg hatching while wettable sulphur found less ovicidal action against *A. lycopersici*. 72 hours after the spraying of various acaricidal treatments the diafenthiuron was found most effective with maximum per cent mortality whereas wettable sulphur was found least effective.

The toxicity of different acaricidal treatments were evaluated to phytoseiid predatory mite, *A. longispinosus* through slide dip technique at various time intervals. It was found that though not a single acaricidal treatment was non toxic to predatory mite, *A. longispinosus*. Diafenthiuron was comparative less toxic as it showed lower mortality for longer period after treatment, while wettable sulphur was found highly toxic due to cent per cent mortality after 6 hours after treatment.

Various acaricides were tested for their efficacy against *T. urticae* and *A. lycopersici* on tomato under polyhouse along with their toxicity to phytoseiid predatory mite, *A. longispinosus*. Against egg stages of *T. urticae* the acaricidal treatment diafenthiuron was found highly effective followed by fenpyroximate and chlorfenapyr while wettable sulphur was found least effective. On the basis of overall efficacy against the egg stages of *T. urticae* the descending order of various acaricidal treatments were: diafenthiuron (87.52%)> fenpyroximate (72.52%)> chlorfenapyr (67.76%)> triazophos (62.45%)> propargite (62.17%)> fenazaquin (60.25%)> wettable sulphur (56.01%). Similarly, against mobile stages of *T. urticae* among all the acaricidal treatments diafenthiuron was found highly effective in reducing mobile

stages on tomato and followed by fenpyroximate and chlorfenapyr. While wettable sulphur was found least effective in reducing mobile stages.

The bioefficacy of various acaricidal treatments were also evaluated against egg and mobile stages of *A. lycopersici* under polyhouse. Among all the acaricidal treatments diafenthiuron was found most effective (88.64% reduction), while wettable sulphur was found least effective against egg stages of russet mite. So, on the basis of overall per cent reduction in eggs of *A. lycopersici*, the descending order of various acaricidal treatments were: diafenthiuron (88.64%) > chlorfenapyr (75.10%) > triazophos (61.55%)> fenazaquin (67.26%)> propargite (56.82%)> fenpyroximate (56.76%)> wettable sulphur (53.16%).

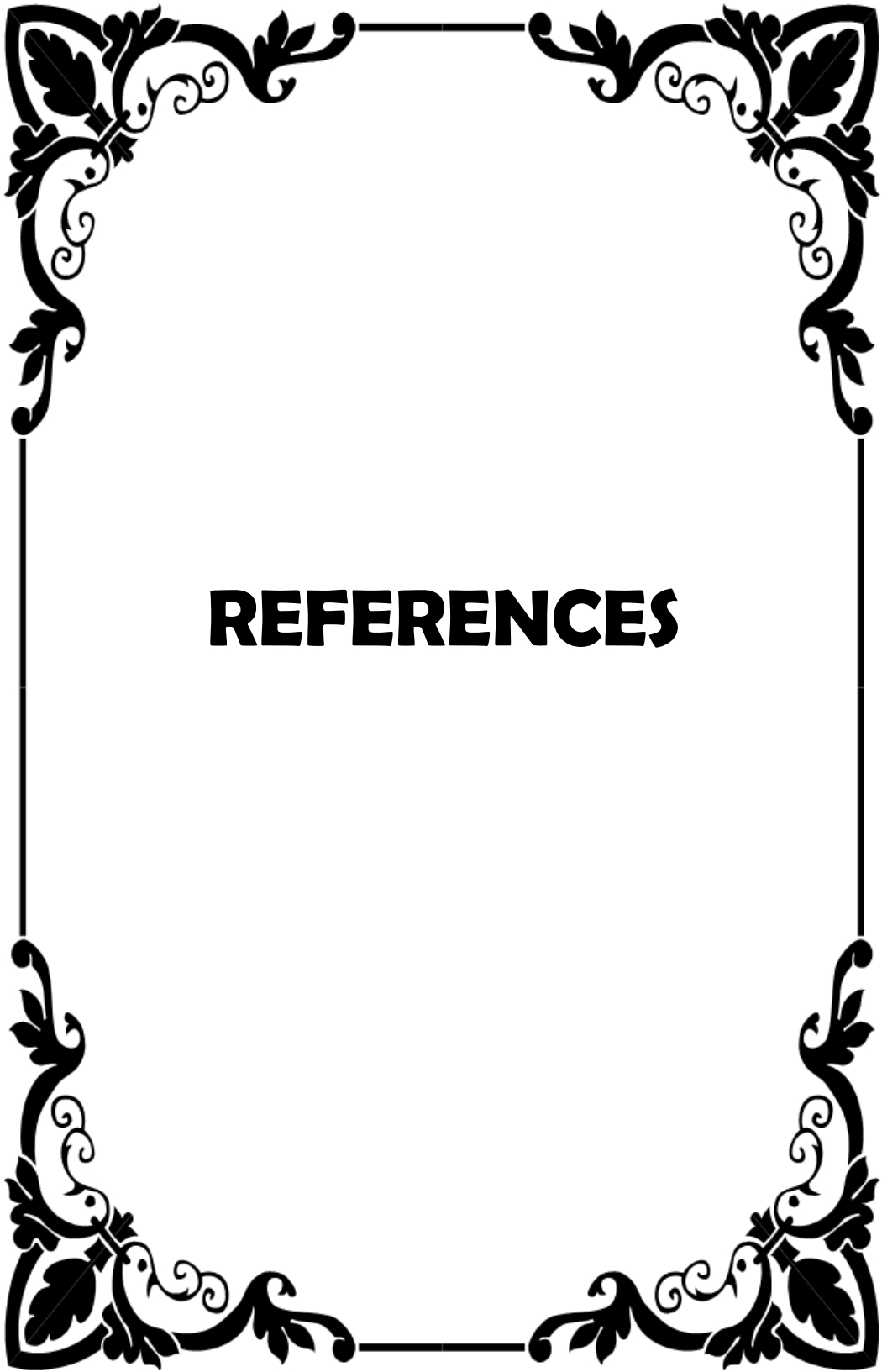
Similarly, against mobile stages of *A. lycopersici* diafenthiuron was most effective in reducing mobile stages of russet mite and was at par with fenpyroximate (73.40% reduction). However, among all the acaricidal treatments wettable sulphur was found least effective in reducing the mobile stages of russet mite, *A. lycopersici*. On the basis of per cent mortality, the overall descending order of different acaricidal treatments were: diafenthiuron (79.39%)> fenpyroximate (73.40%)> fenazaquin (68.20%)> triazophos (65.62%)> chlorfenapyr (65.06%)> propargite (64.73%) > wettable sulphur (53.60%). On the basis of ICBR, diafenthiuron (1:10.50) stood first among all the acaricidal treatments followed by fenpyroximate (1: 9.40).

## 5.4 Diversity of phytophagous mites on various vegetable crops

To investigate the diversity of various phytophagous mites during January to December, 2014, the survey was carried out on tomato, okra, brinjal, chilli, capsicum, cowpea, little gourd, ridge gourd, bottle gourd, pointed gourd, bitter gourd, smooth gourd, pumpkin, spine gourd, french bean, cucumber and guar at monthly interval during January to December, 2014 at University farm. The following species of phytophagous mites along with their families were recorded.

| Crop         | Species   | Family        |
|--------------|---|---------------|
| Tomato       | <i>Tetranychus urticae</i> , <i>T. neocaledonicus</i>   | Tetranychidae |
|              | <i>Polyphagotarsonemus latus</i>  | Tarsonemidae  |
|              | <i>Brevipalpus phoenicis</i>  | Tenuipalpidae |
|              | <i>Aceria lycopersici</i>   | Eriophyidae   |
| Okra         | <i>T. urticae</i> , <i>T. macfarlanei</i> , <i>T. cinnabarinus</i>                              | Tetranychidae |
| Brinjal      | <i>T. urticae</i> , <i>T. cinnabarinus</i> , <i>T. ludeni</i>                                   | Tetranychidae |
|              | <i>B. phoenicis</i>   | Tenuipalpidae |
|              | <i>A. lycopersici</i>   | Eriophyidae   |
| Chilli       | <i>P. latus</i>   | Tarsonemidae  |
| Capsicum     | <i>P. latus</i>   | Tarsonemidae  |
| Cowpea       | <i>T. urticae</i> , <i>T. neocaledonicus</i> , <i>Oligonychus biharensis</i> , <i>T. ludeni</i> | Tetranychidae |
|              | <i>P. latus</i>   | Tarsonemidae  |
|              | <i>Brevipalpus californicus</i>   | Tenuipalpidae |
|              |   |               |
| Little gourd | <i>T. urticae</i> , <i>T. cinnabarinus</i>  | Tetranychidae |
|              | <i>B. phoenicis</i>   | Tenuipalpidae |
| Ridge gourd  | <i>T. urticae</i> , <i>T. cinnabarinus</i>  | Tetranychidae |
|              | <i>B. phoenicis</i>   | Tenuipalpidae |
| Bottle gourd | <i>P. latus</i>   | Tarsonemidae  |
|              | <i>T. urticae</i> , <i>T. cinnabarinus</i>  | Tetranychidae |

|               |  |               |
|---------------|--|---------------|
|               | <i>B. phoenicis</i>  | Tenuipalpidae |
|               | <i>P. latus</i>  | Tarsonemidae  |
|               | <i>A. lycopersici</i>  | Eriophyidae   |
| Pointed gourd | <i>T. macfarlanei</i>  | Tetranychidae |
|               | <i>B. californicus</i>   | Tenuipalpidae |
| Bitter gourd  | <i>T. urticae, T. neocaledonicus,</i><br><i>Eutetranychus orientalis</i> | Tetranychidae |
|               | <i>B. phoenicis</i>  | Tenuipalpidae |
| Smooth gourd  | <i>T. urticae, E. orientalis</i>   | Tetranychidae |
|               | <i>B. phoenicis</i>  | Tenuipalpidae |
| Pumpkin       | <i>T. urticae</i>  | Tetranychidae |
|               | <i>B. californicus</i>   | Tenuipalpidae |
| Spine gourd   | <i>T. urticae</i>  | Tetranychidae |
|               | <i>P. latus</i>  | Tarsonemidae  |
|               | <i>B. californicus</i>   | Tarsonemidae  |
| Cucumber      | <i>T. urticae</i>  | Tetranychidae |
|               | <i>P. latus</i>  | Tarsonemidae  |
|               | <i>A. lycopersici</i>  | Eriophyidae   |
| French bean   | <i>T. urticae, T. ludeni</i>   | Tetranychidae |
|               | <i>P. latus</i>  | Tarsonemidae  |
|               | <i>B. californicus</i>   | Tenuipalpidae |
| Cluster bean  | <i>P. latus</i>  | Tarsonemidae  |
|               | <i>B. californicus</i>   | Tenuipalpidae |



# **REFERENCES**



- urticae* by predatory mite and pesticide mixture on rose. *Korean J. Appl. Entomol.*, **43**(1): 71-79.
- Akashe, V. B. (2004a). Toxicity of some newer miticides against *Tetranychus urticae* (Koch.) on Roses irrespective of resistance development. *J. Maharashtra Agric. Univ.*, **29**(1): 94-95.
- Akashe, V. B. (2004b). Management of spotted spider mite (*Tetranychus urticae* Koch.) of rose during summer season. *J. Maharashtra Agric. Univ.*, **29**(1): 96-97.
- Akashe, V. B., Darekar, K. S. and Kharbade, S. B. (2003). Toxicity of selective miticides against *Tetranychus urticae* (Koch) on roses. *Pestology*, **27**(1): 30-31.
- Akashe, V. B., Indi, D. V., Patil, A. J., Gud, M. A. and Ghadge, S. M. (2006). Persistence and toxicity of some miticides against *Tetranychus urticae* Koch on rose foliage. *J. Maharashtra Agric. Univ.*, **31**(3): 318-320.
- Alam, SK. F., Patra, B., Chatterjee, M., Dey, P. K., Dhar, P. P., Samanta, A. and Somchoudhury, A. K. (2014). Bioefficacy of spiromesifen 240 Sc (w/v) against white fly and red spider mites *Tetranychus* spp. infesting tomato. *J. Ent. Res.*, **38**(2): 105-109.
- Al-Atawi, F. J. (2011). Phytophagous and predaceous mites associated with vegetable crops from Riyadh, Saudi Arabia. *Saudi J. Biol. Sci.*, **18**(3): 239–246.
- Anonymous (1968). Biological control of the spider mite, *Zachch. Rest.*, **13**(7): 26-29.

- Anonymous (2002). Evaluation of efficiency of acaricides, applied singly and in mixtures, for control of *Aceria guerreronis* Keifer, 1985 (Prostigmata: Eriophyidae), a mite causing coconut necrosis in the valley of San Francisco. *Revista Brasileira de Fruticultura*, **24**(1): 72-76.
- Anonymous (2010). National Horticulture Board, Gurgaon. Ministry of Agriculture, Government of India.
- Anonymous (2012). *Aculops lycopersici*. Available from: [http://www.faunauer.org/distribution\\_table.php](http://www.faunauer.org/distribution_table.php).
- Ansaloni, T. and Perring, T. M. (2014). Biology of *Aceria guerreronis* (Acari: Eriophyidae) on queen palm, *Syagrus romanzoffiana* (Arecaceae). *Internat. J. Acarol.*, **30**(1):44-46.
- Arthanari, P. M., Balasubramanian, G. N., Elvaraju, R. and Kanndyon, S. (2002). Influence of weather parameters on eriophyid mite. *J. Agrometeorology*, **4**(2): 153-157.
- Ashley, J. L., Herbert, D. A., Lewis, E. E., Brewster, C. C. and Huckaba, R. (2006). Toxicity of three acaricides to *Tetranychus urticae* (Tetranychidae: Acari) and *Orius insidiosus* (Anthocoridae: Hemiptera). *J. Econ. Entomol.*, **99**(1): 54-59.
- Badawia, A., Abdel-Satter, M., Al-zzazy Mahmoud, M. (2011). Environmental management and biological aspects of two eriophyid mango mites in Egypt: *Aceria Mangiferae* and *Metaculus Mangiferae*. *Acarologia*, **51**: 481-497.

- Baradaran, P. and Daneshvar, H. (1992). Studies in the biology and chemical control of tomato russet mite, *Aculops lycopersici* (Acari:Eriophyidae) in Varamin. *Applied Entomology and Phytopathology*, **59**(1-2): 25-27.
- Bhandari, G. R. (1991). An ecology of *Tetranychus macfarlanei* Baker and Pritch (Acari:Tetranychidae) in relation to different okra cultivars and its control. M. Sc. (Agri.) thesis submitted to Gujarat Agricultural University, Sardarkrushinagar (Unpublished).
- Bhaskaran, E. V. and Ramaraju, K. (2007). Population dynamics of coconut eriophyid mite *Aceria guerreronis*. *J. Acarol.*, **16**(142): 72-75.
- Bhaskaran, E. V., Ramaraju, K. and Gunasekaran, K. (2007). Evaluation of new acaricides against two spotted spider mite, *Tetranychus urticae* Koch. on bhendi. *Pestology*, **31**(12): 31-34.
- Bhusal, S. B. (2011). Biology, population dynamics, varietal screening and chemical control of chrysanthemum mite (*Tetranychus urticae* Koch.). M.Sc. (Agri.) Thesis (Unpublished, Navsari Agricultural University, Navsari).
- Bindra, O. S. and Kittur, S. V. (1961). Two new records of tetranychid mites as crops pests in Madhya Pradesh. *Indian J. Ent.*, **23**: 71.
- Celar and Valic (2003). Tomato russet mite (*Aculops lycopersici*) (Tryon, 1917) (Eriophyidae) in

- Slovenia. *Zbornikpredavani in referator C. Slovenskegaposvetovanja o. varstva Rastilin Zrece*, 489-492.
- Cermeliz, L. M., Doreste, S. E. and Balen, L. V. (1982). *Aculops lycopersici* (Masse,1937) (Acari, Eriophyidae) a new pest of tomato crops in Venezuela. *Revista de la Facultad de Agronomia Universidad central de Venezuela*, **12**(3-4): 227-234.
- Chandrika Mohan and Nair, C. P. R. (2000). Distinguish the nut infestation by Eriophyid mite and Coreid bug in coconut. *Indian Coconut Journal*, **31**: 60-61.
- Chavan, B. P., Darekar, K. S., Kharbade, S. B. and Kadam, J. R. (2004). Efficacy of some acaricides against red spider mite, *Tetranychus cinnabarinus* (Boisd) infesting okra. *Pestology*, **28**(2): 26-27.
- Choudhary, C. S., Dhane, A. S., Naik, R. L. and Chandele, A. G. (2007). Evaluation of Milbemectin 1% EC against rose mites under polyhouse conditions. *Crop Prot. Prod.*, **4**(1): 1-3.
- Davis, D. W. (1961). Biology of *Tetranychus multisetis* the polychaetous form from *Tetranychus cinnabarinus* (Acarina: Tetranychidae). *Ann. Ent. Soc. America*, **49**(1): 30-34.
- Deka, S., Tanwar, R. K., Sumtha, R., Sabir, N., Bambawale, O. M. and Singh, B. (2011). Relative efficacy of agricultural spray oil and azadirachtin against two spotted spider mite (*Tetranychus urticae*) on

- cucumber (*Cucumis sativus*) under greenhouse and laboratory conditions. *Indian Journal of Agricultural Sciences*, **81**(2): 158-162.
- Dey, P. K. and Somchoudhary, A. K. (2001). Bio-efficacy of fenpyroximate against eriophyid mite of coconut (*Aceria guerreronis* Keifer) and its impact on *Amblyseius* spp. *Pestology*, **25**(1): 25-26.
- Dey, P. K., Sarkar, P. K., Gupta, S. K. and Somchoudhary, A. K. (2001). Evaluation of fenazaquin against eriophyid mite, *A. guerreronis* Keifer on coconut *vis-à-vis* its impact on *Amblyseius* spp. *Pestology*, **25**(1): 34-39.
- Dhar, T., Dey, P. K. and Sarkar, P. K. (2000). Influence of abiotic factors on population build up of red spider mite *Tetranychus urticae* on okra *vis-à-vis* evaluation of some new pesticides for their control. *Pestology*, **24**(9): 34-37.
- Dhooria, M. S. (1999). Two spotted spider mite, *Tetranychus urticae* a serious pest of roses in polyhouses and its control. *J. Acarol.*, **14** (1&2): 84-87.
- Doreste, S. E. (1968). The coconut flower mite, *Aceria guerreronis* Keifer in Venezuela. *Agronomia Tropical*, **18**: 379-386.
- Duchovskiene, L. (2007). Effect of abamectin on the two spotted spider mite (*Tetranychus urticae* Koch.) in rose under greenhouse conditions. *Sodininkysteir Darzininkyste*, **26**(1): 93-101.
- Duso, C., Castagnoli, M., Somini, S., Agnell, G. (2010). The impact of eriophyids on crops: recent issues of

- Aculus schlechtendali*, *Calepitrimerus vitis* and *Aculops lycopersici*. *Exp. Appl. Acarol.*, **55**: 151-168.
- Forghani, S. H. R. and Honarparvar, N. (2012). Determination of the dominant spider mite (Acari:Tetranychidae) on cotton fields in Golestan province, Iran. *Biharean Biologist.*, **6**(2): 116-121.
- Gangopadhyay, C. and Sarkar, P. K. (2001). Relative efficacy of some pesticides against adult stages of *Tetranychus cinnabarinus* (Boisduval) (Acari:Tetranychidae) infesting bhendi (cv. IA Hybrid Vijaya) under west Bengal condition. *Pestology*, **25**(12): 30-32.
- Gerson, U. and Aronowitz, A. (1981). Spider mite webbing. V. The effect of various host plants. *Acarologia*, **22**(3): 277-281.
- Ghosh, S. K. (2013). Incidence of red spider mite (*Tetranychus urticae* Koch) on okra (*Abelmoschus esculentus* (L.) Moench) and their sustainable management. *Current Biotica*, **7**(1&2): 40-50.
- Ghoshal, S. (2013). Population dynamics and biochemical fluctuations in relation to the infestation of *Tetranychus neocaledonicus* Andre on the leaves Of Tulsi (*Ocimum Sanctum*). *Int. J. Life Sc., Bt and Pharm. Res.*, **2**(3): 225-229
- Girisha, R. C. (2005). Management of the coconut perianth mite, *Aceria guerreronis* Keifer using sprayers and neem products along with soil amendments. M.Sc.

- (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India.
- Griffith, R. (1984). The problem of the coconut mite, *Eriophyes guerreronis* (Keifer) in the coconut groves of Trinidad and Tobago. In: R. Webb, W. Knausenberger and L. Yntema (Editors). *Proc. of 20<sup>th</sup> Ann. Meet. of the Caribbean Food Crops Soc.*, East Caribbean Centre, College of the Virgin Islands and Caribbean Food Crops Soc., St. Croix, Virgin Islands, USA, pp.128-132.
- Gulati, R. (2004). Incidence of *Tetranychus cinnabarinus* infestation on different varieties of *Abelmoschus esculentus* Ann, *Pl. Protec. Sci.*, **12**: 45-47.
- Gupta, S. K. (1976). Contribution to the knowledge of tetranychid mites (Acarina) with descriptions of three new species. *Oriental Insects*, **10**: 327-351.
- Gupta, S. K. (1985). Handbook of plant mites of India. Zoological survey of India, Calcutta. pp.520.
- Gupta, S. K. and Karmakar, K. (2011). Diversity of mites (Acari) on medicinal and aromatic plants in India. *Zoosymposia*, **6**: 56–61.
- Gupta, S.K. (1991). The mites of agricultural importance in India with remarks on their economic status. *Modern Acarol.*, **1**: 509-522.
- Haghghadam, Z. M. and Arbabi, M. (2012). Study of Mites fauna and their natural enemies on the ornamental plants in greenhouses of Guilan and West

- Mazandaran province. *Intl. J. Agri. Crop Sci.*, **4**(11): 674-679.
- Haji, F. N. P., Moraes, G. J. D., Lacerda, C. A. de. and Neto, R. S. (1988). Chemical control of the tomato russet mite *Aculops lycopersici* (Masse, 1937). *Anais da Sociedade Entomologica do Brasil*, **17**(2): 437-442.
- Haq, M. A. (1999). Coconut mite threat in Kerala. *J. Acarol.*, **14**(1&2): 58-63.
- Haque, M. M. and Kawai, A. (2002). Population growth of tomato russet mite, *Aculops lycopersici* (Acari: Eriophyidae) and its injury effect on the growth of tomato plants. *J. Acarol. Soc. Jpn.*, **11**(1): 1-10.
- Henderson, C. F. and Tilton, E. W. (1955). Test with acaricides against the brown wheat mite. *J. Econ. Ent.*, **48**(2): 157-161.
- Hernandez, R. F. (1977). Chemical control of the coconut eriophyid, *Aceria guerreronis* (K.) on the coast of Guerrero. *Agricultural Tecnica en Mexico*, **4**: 23-28.
- Hole, U. B. and Salunkhe, G. N. (1997). Incidence of mites in relation to meteorological Parameters on rose. *J. Maharashtra Agric. Univ.*, **22**(2): 226-230.
- Howard, F. W., Abreu-Rodriguez, E. and Denmark, H. A. (1990). Geographical and seasonal distribution of the coconut mite, *Aceria guerreronis* (Acari: Eriophyidae) in Puerto Rico and Florida, USA. *J. Agric. Univ., Puerto Rico*, **74**: 237-251.
- Jana, S. K. and Somchoudhury, A. K. (2005) Bioefficacy of fenprothrin against tea red spider mite,

- Oligonychus coffeae* Nietner at Terai, Darjeeling (West Bengal). *J. ent. Res.*, **29**(3): 209-210.
- Jayachandran, M. (2003). Evaluation of new acaricides against rose mites. *Pestology*, **27**(3): 28-30.
- Jayasinghe, G. G. and Mallik, B. (2010). Growth stage based economic injury levels for two spotted spider mite, *Tetranychus urticae* Koch (Acari, Tetranychidae) on Tomato, *Lycopersicon esculentum* Mill. *Tropical Agricultural Research*, **22**(1): 54 – 65.
- Jeppson, L. R., Keifer, H. H. and Baker, E. W. (1975). Mites Injurious to Economic Plants. University of California Press, Berkeley, 614 p.
- Jhansi, B. and Sridhar, V. (2005). Bio-efficacy of a new acaricide, bifenazate against the two spotted spider mite, *Tetranychus urticae* Koch, on rose under protected cultivation. *J. Ornamental Hort.*, **8**(1): 59-61.
- Jose, V. T. and Shah, A. H. (1989). Bionomics of the spider mite, *Tetranychus macfarlanei* injurious to cotton in Gujarat, India. In: Progress in Acarology (Ed. G. P. Channa Basavanna and Viraktamath, C. A.). Vol. **2**: 23-28. Oxford and IBH publication Co. Pvt. Ltd., New Delhi.
- Kachhawa, D. and Rahman, S. (2013). Factors influencing incidence of red spider mite of tea, *Oligonychus coffeae* (Nietner) in Assam. *The Journal of Plant Protection Sciences*, **5**(2): 33-39.

- Kamau, A. W. (1977). Effect of eriophyid mite, *Aculops lycoersici* Masee (Acarina: Eriophyidae) on tomato. *Kenya Entomologist's news letter*, **7**(3): 4-16.
- Kamburov, S. S. (1971). Feeding, development and reproduction of *Amblyseius longoensis* on various food substances. *J. Econ. Entomol.*, **4**(3): 643-648.
- Kannaiyan, S., Rabindra, R. J., Ramaraju, K. and Sarbithadoraiswamy.(2002). Integrated management of eriophyid mite on coconut, Tamil Nadu Agricultural University, Coimbatore.
- Kannaiyan, S., Sabithadoraisamy, Rabindra, R. J., Ramakrishna, G. and Bhaskaran, R. (2000).Integrated packages for the management and control of coconut eriophyid mite. Paper presented during the 66<sup>th</sup> *Scientific Workers Conf.*, held at Tamil Nadu Agric. Univ., Coimbatore on 19<sup>th</sup> and 20<sup>th</sup> July, 2000, pp. 7-8.
- Kasap, I. (2004). Effect of apple cultivar and of temperature on the biology and life table parameters of the two spotted spider mite *Tetranychus urticae*. *Phytoparasitica*, **32**(1): 73-82.
- Kaushik, D., Srivastava, S., Nath, B. C., Chauhan V. B. and Singh R. N. (2013). Correlation between mite population (*Aceria cajani*) and environmental factors causing sterility mosaic disease of Pigeon pea. *Int. J. of Life Sciences*, **1**(3): 228-232.

- Kay, I. R. (1986). Tomato russet mite: A serious pest of tomatoes. *Queensland Agricultural Journal*, **112**(5): 231-232.
- Kay, I. R. and Shepherd, R. K. (1988). Chemical control of the tomato russet mite on tomatoes in the dry tropics of Queensland. *Queensland Journal of Agriculture and Animal sciences*, **45**(1): 1-8.
- Kottalagi, P. and Veerendra, A. C. (2014). Efficacy of different acaricides against acid lime mite, *Schizotetranychus baltazari* Rimmando, predatory mite and grading of fruits. *Academic Journal of Entomology*, **7**(4): 134-139.
- Kumar, D. and Raghuraman, M. (2013). Biology of carmine mite (*Tetranychus urticae* Koch) on brinjal leaf. *Bioinfolet*, **10**(4c): 1420-1423.
- Kumar, S. and Singh, R. N. (2005). Effect of omite and some other acaricides against the mites, *Tetranychus urticae* Koch. and *T. neocaledonicus* Andre on okra and brinjal under field conditions in Varanasi, Uttar Pradesh. *Pestology*, **29**(8): 15-19.
- Kumari, S., Brar, M. B. and Kaur, P. (2011). Efficacy of acaricides, biopesticides and mineral oil against two spotted spider mite, *Tetranychus urticae* Koch on okra. *J. Res. Punjab. Agric. Univ.*, **48**(3&4): 136-139.
- Kumral, N. A. and Kovanci, B. (2007). The diversity and abundance of mites in agrochemical-free and conventional deciduous fruit orchards of Bursa, Turkey. *Türk. entomol. derg.*, **31**(2): 83-95.

- Lahiri, S., Roy, I., Podder, S., Saha, G. K., Gupta, S. K. (2005). Notes on phytophagous and predatory mites of medicinal plants of Kolkata. *Zoos' Print Journal*. **20**(7): 1931-1932.
- Lall, B. S., Dutta, C. P. and Jayaswal, A. P. (1965). Bionomics and control of red spider mite, *Tetranychus telarius* Linn. (Acarina: Tetranychidae). *Indian J. Ent.*, **27**: 389-392.
- Lal, S. S. (1982). Influence of weather factors on the population of spider mites (Acari: Tetranychidae) and thrips (Thysanoptera) on cassava in Kerala. *Indian J. Acar.*, **7**: 5-10.
- Leite, G. L. D., Picanco, M., Marguini Da Silva, F., Casali, V. W. D., Galvan, T. and Cavalcante, T. R. M. (2000). Distribution of *Aculops lycopersici* on *Lycopersicon esculentum* and *Lycopersicon hirsutum* canopy and leaves. *Agro Ciencia*, **17**(2): 259-263.
- Malaviya, M. D. (1994). Incidence of different mite species on Indian bean with emphasis to biology and control of *Tetranychus ludeni* (Zacher) (Acari: Tetranychidae). M.Sc. (Agri.) thesis submitted to Gujarat Agricultural University, S. K. Nagar.
- Mallik, B., Chinnamade Gowda, C., Srinivasa, N. and Onkarappa, S. (2005). Management of coconut eriophyid mite (*Aceria guerreronis*) insight into a

- farmers practice. *Indian Coconut Journal*, **12**(9): 3-7.
- Mondal, S. K., Sattar, A. and Banerjee, S. (2006). Impact of meteorological parameters on population build up of red spider mite in okra, *Abelmoschus esculentus* L. under North Bihar Condition. *Jour. Agric. Physics*, **6**(1): 35-38.
- Manjulata, K., Shashi, B., Varma, B.R., Kapur, M. and Bhalla, S. (2002). Pest risk involved in important of roses and its germplasm. *Indian J. Ent.*, **64**(4): 465-470.
- Mariau, D. (1977). *Aceria guerreronis* an important pest of African and American coconut groves. *Oleagineux*, **32**(3): 110-111.
- Mariau, D. and Julia, J. F. (1970). The attack by the mite, *A. guerreronis* a pest of coconut. *Oleagineux*, **25**(8-9): 459-464.
- Mazid, S., Rajkhowa, R. C. and Kalita, J. C. (2015). Seasonal incidence of red spider mite, *Oligonychus coffeae* Nietner on tea plantation in Assam. *Indian Journal of Research*, **4**(3): 6-7.
- Mehta, P. K., Sood, A. K., Sharma, P. C. and Banyal, D. K. (2012). ICAR short course on pest management in high-value crops under protected environment. Department of Entomology CSK Himachal Pradesh Krishi Vishvavidyalya, Palampur, India. pp. 181.

- Meyer, M. K. P. and Rodriguez, M. (1966). Acari associated with cotton in Southern Africa. *Revistadaj de Inves Colultramar*, **13**: 1- 33.
- Misra, H. P. (2011). Bio-efficacy of fenazaquin 10 EC against two spotted spider mite, *Tetranychus urticae* Koch. (Acari:Tetranychidae) in tomato. *Pest Management in Horticultural Ecosystem*, **17**(1): 19-22.
- Mohammed, M. E. and Elmoghazy. (2014). Abundance and diversity of mites associated with date palm, olive and citrus trees in Sakaka, Kingdom of Saudi Arabia. *Egypt. Acad. J. Biolog. Sci.*, **6**(2): 11- 16.
- Mohite, P. B., Dhobale, S. Y. and Moholkar, P. R. (1992). Relative efficacy of some modern synthetic pesticides against two spotted spider mites, *Tetranychus urticae* Koch on rose. *Pestology*, **16**(4): 11-13.
- Mondal, M. and Ara, N. (2006). Biology and fecundity of the two spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) under laboratory condition. *J. Life Earth Sci.*, **1**(2): 43-47.
- Monica, V. L., Kumar, A., Chand, H., Paswan, S. and Kumar, S. (2014). Population dynamics of *Tetranychus urticae* Koch on brinjal crop under north Bihar conditions. *Pest Management in Horticultural Ecosystem*, **20**(1): 47-49.
- Moraes, J. G. and Castro, G. T. (2007). Mite Diversity on plants of different families found in the Brazilian

- Atlantic forest. *Neotropical Entomology*, **36**(5): 774-782.
- Muthiah, C. and Bhaskaran, R. (1999). Screening of coconut genotypes and management of Eriophyid mite *Aceria guerreronis* Keifer (Acari: Eriophyidae) in Tamil Nadu. *Indian Coconut Journal*, **30**(6): 10-11.
- Naher, N., Islam, W., Khalequzzaman, M. and Haque, M. (2008). Study on the developmental stages of spider mite (*Tetranychus urticae* Koch) infesting country bean. *J. Bio. Sci.*, **16**: 109-114.
- Naik, D. B. (2000). Biology of predatory mite, *Amblyseius longispinosus* (Evans) and its interaction with tetranychids and role of biopesticides in their control. M.Sc. (Agri.) thesis, Gujarat Agricultural University, Sardarkrushinagar.
- Naik, R. L., Lolage, G. R. and Dethe, M. D. (2005). Bioassays of flufenzin and fenpyroximate on life-stages of red spider mite *Tetranychus cinnabarinus* (Boisd.). *Indian J. Ent.*, **67**(2): 150-154.
- Nair, C. P. R., Chandrika, M., Rajan, P., Murali. G., Mayilvaganon, M., Chandramohanan, P. and Sukumaran, A. S. (2003). Studies on nut infesting eriophyid mite in coconut plantations. *CPCRI Annual Rep.*, pp.61-65.
- Nair, C. P. R., Fernanado, C. P., Moraes, G. J. and Wickramananda, I. R., (2002). Seasonal abundance of coconut mite. *Proceedings of the International Workshop on Coconut mite Aceria guerreronis*,

- Coconut Research Institute, Sri Lanka, 6-8 January, 2000, pp.9-12.
- Nair, V. V., Beevi, S. N. and Visalakshi, A. (1990). On the control of the mite *Tetranychus neocaledonicus* on rose. *South Indian Hortic.*, **38**(3): 175-176.
- Nakat, R. V. and Chede, P. V. (2004). Residual toxicity of new acaricides against french bean mite *Tetranychus neocaledonicus* Andre on french bean. *Pestology*, **28**(11): 21-23.
- Nandihalli, B. S. (2007). Seasonal incidence of coconut perianth mite, *Aceria guerreronis* Keifer at Dharwad. *J. Acarol.*, **16**(1&2): 76-77.
- Nasareen. P. N. M. and Ramani. N. (2014). Seasonal variation in the population density of the gall mite, *Aceria pongamiae* Keifer 1966 (Acari:Eriophyidae) within the leaf galls of *Pongamia pinnata* (L.). *Journal of Entomology and Zoology Studies*, **2**(3): 126-130.
- Natarajan, K., Ramaraju, K., Babu, P. C. S. and Palaniswamy, S. (2002). Studies on coconut eriophyid mite, *A. guereronis* in Tamil Nadu, India. *Proceedings of the International Workshop on Coconut mite, A. guereronis*, Coconut Research Institute, Sri Lanka, 6-8 January, 2000, **18**: 13-31.
- Nayak, H. G., Hugar, P. S. and Hegde. M. (2008). Biology of Leaf Mite, *Oligonychus oryzae* (Hirst.) on Paddy. *Ann. Pl. Protec. Sci.*, **16**(1): 81-82.

- Onkarappa, S., Mallik, B. and Kumar, H. M. (1999). Spatial distribution of *Tetranychus urticae* on open cultivated rose. *J. Acarol.*, **15**(1-2): 44-46.
- Pakyari H., Masood, A., Kim, D. and Enkegaard, E. (2012). Oviposition model of *Scolothrips longicornis* feed on two spotted spider mite. *Academics Journal of Entomology*, **5**(2): 65-72.
- Pakyari, H. (2011). Development rate of *Scolothrips longicornis* (Thysanoptera:Thripidae) at various temperature. *Academics Journal of Entomology*, **4**(1): 01-06.
- Pande, Y. D. and Yadava, S. R. S. (1975). A new host record of *Tetranychus macfarlanei* B. & P. *Labadev J. Sci. Tech.*, **13**(1/2): 75. (Fide: RAE, **65**: 2637).
- Pandey, A. K., Maurya, R. P. and Mall, P. (2014). Bioefficacy of fenpyroximate 5 SC against European red mite, *Panonychus ulmi* Koch infesting apple. *Indian J. Ent.*, **76**(3): 197-201.
- Pandey, S. N., Yadava, C. P. S. and Kanwat, P. M. (1979). Plant mites from the semiarid region of Rajasthan. *Indian J. Ent.*, **41**(2): 197-200.
- Papasolomontos, A. (2004). Integrated production and protection in the Mediterranean region under protected cultivation. *Cahiers Options Mediterraneennes*, **31**: 413-424
- Patel, C. B., Shah, A. H. and Rai, A. B. (1993). Problems of mite pests of crops in Gujarat and their

- management. *Tech. Bull.*, No.1: 22pp. Dept. of Entomology, Gujarat Agricultural University Navsari.
- Patel, J. A., Dodia, D. A., Barad, C. S., and Rabari, G. N. (2013). Management of red spider mite, *Tetranychus urticae* Koch on brinjal. *Pestology*, **37**(1): 51 -53.
- Patel, K. A., Patel, M. B., Patel, H. M., Desai, H. R. and Patel, A. J. (2009). Efficacy of diafenthiuron against two spotted spider mite (*Tetranychus urticae* Koch) and its safety to predatory mite on rose. *Pestology*, **33**(6): 58-60.
- Patil, D. L. (2010). Management of *Tetranychus urticae* Koch (Acarina: Tetranychidae) of carnation under polyhouse condition. M.Sc. (Agri.) Thesis (Unpublished, Navsari Agricultural University, Navsari.
- Patra, S., Mohasin, M. and Sarkar, P. (2001). Chemical control of rose mites. *Environ. Ecol.*, **19**(4): 774-775.
- Perdikis, D., Kapaxidi, E. and Papadoulis, G. (2008). Biological control of insect and mite pests in greenhouse solanaceous crops. *European Journal of Plant Science and Biotechnology*, **2**: 125-144.
- Prasad, R. and Singh, J. (2010). Biological studies on two spotted red spider mite, *Tetranychus urticae* Koch on okra. *J. Insect Sci.*, **23**(3): 344-347.
- Prasanna, K. P. and Kumar, P. (2008). Survey of Tetranychid mites and their natural enemies on brinjal in

- Northern Karnataka. *Karnataka J. Agric. Sci.*, **21**(3): 448-449.
- Pushpa, V. (2006). Management of coconut perianth mite, *Aceria guerreronis* Keifer. M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India.
- Raghavendra, Y. R. (2004). Seasonal incidence and management of the coconut perianth mite, *A. guerreronis* Keifer. M.Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka, India.
- Rai, S. N. and Indrajeet. (2011). Note on phytophagous mites associated with common vegetables in Varanasi and Azamgarh Districts of Eastern Uttar Pradesh. *J. Insect Sci.*, **24**(2): 199-200.
- Rajkumar, E., Huger, P. S. and Kattimani, K. N. (2005b). Seasonal incidence of red spider mite, *Tetranychus urticae* Koch. (Acari:Tetranychidae) on jasmine. *Karnataka J. Agric. Sci.*, **18**(1): 150-153.
- Rajkumar, E., Huger, P. S. and Patil, B. V. (2005a). Biology of red spider mite, *Tetranychus urticae* Koch. (Acari: Tetranychidae) on jasmine. *Karnataka J. Agric. Sci.*, **18**(1): 147-149.
- Ramaraju, K., Baskaran, E. V., Varadarajan, M. K. and Palaniswamy, S. (2003). Bioecological studies on nut infesting eriophyid mite, *Aceria guerreronis* K. on coconut. *National Symp. on Bio-Management of Insect Pests*, 29-31<sup>st</sup> March, 2003.
- Ramaraju, K., Natarajan, K., Sundarababu, P. C. and Palanisamy, S. (2000). Studies on coconut

- eriophyid mite *A. guerreronis* K. in Tamil Nadu, India. Paper Presented at *International Workshop on Coconut Eriophyid Mite*. Coconut Research Institute, Sri Lanka, Jan. 5-7, 2000 pp.8-9.
- Reddy, D. S. and Pushpalatha, M. (2013). Efficacy of certain new acaricides against two spotted spider mite, *Tetranychus urticae* Koch. on ridge gourd. *Pest Management in Horticultural Ecosystem*, **19**(2): 199-202.
- Reddy, S. L. and Naik, S. L. (2000). Spread of eriophyid mites into the coconut gardens of Chittor district, Andhra Pradesh. *Indian Coconut Journal*, **30**: 8-9.
- Rice, R. E. and Strong, F. E. (1962). Bionomics of the tomato russet mite, *Vasates lycopersici* (Masse). *Ann. Entomolo. Soc. Ann.*, **55**: 431-435.
- Rishi, N. D. and Rather, A. Q. (1983). Life cycle of phytophagous mite *Tetranychus urticae* Koch. and its predatory mite *Amblyseius finlandicus* Oudemans together with effect of certain acaricides/fungicides on them. *J. Ent. Res.*, **7**(1): 39-42.
- Roopa S. and Nandihalli, B.S. (2009). Seasonal incidence of mite pests on brinjal and chilli. *Karnataka J. Agric. Sci.*, **22** (Special Issue): 729-731.
- Rudramuni, T., Reddy, K. M. and Puttaswamy. (2003). Evaluation of (Flufenoxuron) Cascade against the two spotted spider mite, *Tetranychus urticae* Koch

- (Acarina: Tetranychidae) infesting roses in polyhouses. *Pestology*, **27**(7): 17-19.
- Sadana, G. L. (1985). Plant feeding mites of India (Tetranychidae). Kalyani Publishers, New Delhi. pp.99.
- Sangeetha, G. K. and Ramani, N. (2011a). Biology of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) A Pest of Velvet Bean. *Indian Journal of Fundamental and Applied Life Science*, **1**(3): 22-28.
- Sangeetha, G. K. and Ramani, N. (2011b). Life cycle of *Tetranychus cinnabarinus* (Biosduval) (Acari: Tetranychidae) on lablab bean. *Indian Journal of Fundamental and Applied Life Sciences*, **1**(2): 43-47.
- Sangeetha, G. K. and Ramani, N. (2011c). Biology of *Oligonychus biharensis* (Hirst) (Acari: Tetranychidae) on cowpea. *J. Exp. Zool. India*, **14**(1): 27-30.
- Saradamma, K., Beevi, S. N., Mathew, T. B., Sheela, M. S. and Visalakshi, A. (2000). Eriophyid mite, *Aceria guerreronis* Keifer infesting coconut palm in Kerala. *Paper Presented in the 4<sup>th</sup> International Symposium on Recent Trends in Life Sciences*, 7<sup>th</sup>-9<sup>th</sup> February, 2000, Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum and Indian Society of Life Sciences, Kanpur.
- Sarkar, P. K., Talukdar, B. and Somchoudhury, A.K. (2009). Relative efficacy of diafenthiuron (50 WP) alone

- and with two different adjuvants against adult and egg stages of tea red spider mite, *Oligonychus coffeae* (Nietner) under laboratory condition. *J. ent. Res.*, **33**(2): 109-112.
- Satio, Y. (1977). Study on the spinning behavior of the spider mite (Acarina:Tetranychidae). II. The process of silk secretion and the webbing on the various stages of *Tetranychus urticae* Koch. under different environmental conditions. *Jpn. J. Appl. Entomol. Zool.*, **21**(3): 150-157. (Fide: RAE, 66:2498).
- Sejalia, A. S. (1989). Studies on Bioecology and Control of okra mite, *Tetranychus macfarlanei* Baker and Pritchard (Acarina:Tetranychidae). M.Sc. (Agri.) Thesis submitted to Gujarat Agricultural University, Sardarkrushinagar (Unpublished).
- Sejalia, A. S., Rai, A. B., Patel, C. B. and Radadia, G. G. (1993). On the biological aspect of *Tetranychus macfarlanei* (Acari: Tetranychidae) infesting okra (*Abelmoschus esculentum*) in south Gujarat. *GAU Res. J.*, **19**(1): 32-37.
- Sekhar, D. C., Reddy, D. J., Rahman, S. J., Reddy, A. R. and Narendranath, V. V. (2008). Ecology and management of red spider mite, *Tetranychus urticae* Koch on grape. *Acta Horticulturae*, **785**: 335-342.
- Sidumo, A., Langa, S., Manjate, J., Mulima, E., Dava, L. and Cossa, S. (2007). Biodiversity of spider mites (*Tetranychus* spp) and their natural enemies in

- Mozambique. *African Crop Science Conference Proceedings*, **8**: 1087-1089.
- Shah, D. R. (2014). Studies on mite (*Tetranychus urticae* Koch.) infesting gerbera (*Gerbera jamesonii*) under polyhouse condition. M.Sc. (Agri.) Thesis Unpublished, Navsari Agricultural University, Navsari.
- Shah, D. R. and Shukla, A. (2014). Biology of spider mite *Tetranychus urticae* (Koch) (Acari: Tetranychidae) on gerbera. *Pest Management in Horticultural Ecosystem*, **20**(2): 162-169.
- Shah, D.R. and Shukla, A. (2014). Chemical control of two spotted spider mite, *Tetranychus urticae* (Koch) (Acari: Tetranychidae) infesting gerbera. *Pest Management in Horticultural Ecosystem*, **20**(2): 155-161.
- Singh, B. (2005). Protected cultivation of vegetable crops. Kalyani Publishers, New Delhi, India. pp. 168.
- Singh, B., Singh, R. and Kumar, R. (2006). Studies on chemical control of two spotted spider mite, *Tetranychus urticae* Koch (Acarina:Tetranychidae) on screen house roses. *J. Ornamental Hort.*, **9**(3): 212-214.
- Singh, J. and Raghuraman, M. (2011). Emerging scenario of important mite pests in north India. *Zoosymposia*, **6**: 170-179.
- Singh, S. and Choudhary, D. P. (2008). Efficacy of some acaricides against mite, *Tetranychus urticae* Koch

- (Acarina:Tetranychidae) on okra. *Pestology*, **32**(11): 25-27.
- Singh, S. and Dhooria, M. S. (2008). Biology of red spider mite, *Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae) on different cucurbits. *Indian J. Ento.*, **70**(3): 269-272.
- Sobha, T. R. and Haq, M. A. (2011). Postembryonic development of the coconut mite, *Aceria guerreronis*, on coconut in Kerala, India. *Zoosymposia*. **6**: 68-71.
- Sridhar, V. and Jhansi, R. B. (2004). Bio- efficacy of milbemectin 1% EC on the two spotted Mite *Tetranychus urticae* Koch on rose grown under protected condition. *J. Ornamental Hort.*, **7**(2): 210-212.
- Srikanth, P. N. (2001). Studies on dispersal, population dynamics and management of coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae). *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore, Karnataka, India.
- Srinivasan, P. M., Govindarajan, R., Ragupathy, A. and Subramaniam, T. R. (1975). Evaluation of certain acaricides for control of red spider mites, *Tetranychus telarius* L. on bhendi. *Pesticides*, **9**:35.
- Sudhirkumar, S. and Shelke, S. S. (2008a). Seasonal incidence of two spotted spider mite (*Tetranychus urticae* Koch.) on Rose. *J. Maharashtra Agric. Univ.*, **33**(3): 406-407.

- Sudhirkumar, S. and Shelke, S. S. (2008b). Bioefficacy of newer miticides against two spotted spider mite (*Tetranychus urticae* Koch.) on rose under polyhouse condition. *J. Maharashtra Agric. Univ.*, **33**(3): 407-408.
- Sujata, A., Anilkumar, D., Rao, N. B. V. C. and Rao, V. R. (2004). Evaluation of certain new chemicals against coconut eriophyid mite, *Aceria guerreronis* (K.) in Andhra Pradesh. *Pestology*, **28**(3): 7-11.
- Toke, N. R. (2010). Biology, population dynamics, varietal screening and chemical control of rose mite (*Tetranychus urticae* Koch.). M.Sc. (Agri.) Thesis Unpublished, Navsari Agricultural University, Navsari.
- Tomar, A. S. and Singh, S. P. (2011). Efficacy of selected acaricides against mite, *Tetranychus urticae* Koch (Acarina:Tetranychidae) on okra. *Pestology*, **35**(5): 27 -29.
- Tripathi, M. K., Kumar, A. and Srivastava, D. K. (2014). Seasonal incidence of mites, *Tetranychus urticae* Koch and *T. ludeni* Zacher on okra and brinjal crops. *Ann. Pl. Protec. Sci.* **22**(1): 52-55
- Valunj, A. R., Pawar, S. A., Kadam, U. K. and Khaire, V. M. (1999). A new acaricide AC-303-630 (Chlorfenapyr 10 EC) against carnation mite, *Tetranychus cinnabarinus* Biosd. *Pest Management in Horticultural Ecosystem*, **5**(1): 21-23.
- Varadarajan, M. K. and David, P. M. M. (2000). Population dynamics of the coconut mite, *A. guerreronis*

- Keifer (Acari: Eriophyidae) and associated arthropods in Tamil Nadu, India. *Insect Sci. Appl.*, **22**(1): 47-59.
- Venugopal, V., Naidu, V. and Prasad, P. (2003). Evaluation of new acaricides against red spider mite, *Tetranychus cinnabarinus* (Boisduval) on okra. *Pestology*, **27**(4): 29-34.
- Vidyasagar, P. S. P. V. (2000). Eriophyid mites on coconut and their management. *Indian Coconut Journal*, **31**: 15-16.
- Villanueva, R. T. and Walgenbach, J. F. (2006). Acaricidal properties of spinosad against *Tetranychus urticae* and *Panonychus ulmi* (Acari: Tetranychidae). *J. Econ. Entomol.*, **92**(6): 843-849.
- Zalom, F. G., Kitzmiller, J. and Wilson, I. T. (1986). Observation of tomato russet mite (Acari: Eriophyidae) damage symptom in relation to tomato plant development. *Journal of Economic Entomology*, **79**(4): 940-942.
- Zuluaga, C. and Sanches, P. A. (1971). Larona O Escoriacion delosfrutos del cocotero (*Cocos nucifera*L.) en Colombia. *Oleagineux*, **26**: 767-776.

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