DIVERSITY OF MITE PESTS ON SOME SUMMER VEGETABLE CROPS WITH SPECIAL REFERENCE TO MANAGEMENT OF OKRA MITE (*Tetranychus urticae* Koch.)

By

Kuldeep Koul

(Regd. No. J-14-M-363)

Thesis submitted to Faculty of Postgraduate Studies

in partial fulfillment of requirements

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

ENTOMOLOGY

Division of Entomology

Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu

Main Campus, Chatha, Jammu 180009

2016

CERTIFICATE-I

This is to certify that the thesis entitled "**Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)**" submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Entomology)** to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu is a record of bonafide research, carried out by **Mr. Kuldeep Koul** Registration No. **J-14-M-363**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

Dr. Amit K. Singh

(Major Advisor)

Place: Jammu

Date: 29/7/2016

Endorsed

Prof. & Head
Division of Entomology

SKUAST-J, Chatha

CERTIFICATE-II

We, the members of Advisory Committee of **Mr. Kuldeep Koul,** Registration No. **J-14-M-363,** a candidate for the degree of **Master of Science in Agriculture (Entomology),** have gone through the manuscript of the thesis entitled "**Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)**" and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

Place: Jammu

Date: 29/7/2016

Dr. Amit K. Singh
(Assistant Professor)
Major Advisor & Chairman
Advisory Committee

Advisory Committee members

1. **Dr. Uma Shankar**
   Assistant Professor
   Division of Entomology
   (Member from Major subject)

2. **Dr. S. K. Singh**
   Associate Professor
   Division of Plant Pathology
   (Member from Minor subject)

3. **Dr. V. K. Razdan**
   Professor
   Division of Plant Pathology
   (Dean's Nominee)

CERTIFICATE-III

This is to certify that the thesis entitled **"Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)"** submitted by **Kuldeep Koul,** Registration No. **J-14-M-363,** to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu in partial fulfillment of the requirement for the degree of **Master of Science in Agriculture (Entomology),** was examined and approved by the advisory committee and external examiner (s) on 29/08/2016

External Examiner
(Dr. A. A. Khan)
Associate Professor
Division of Entomology
Faculty of Horticulture
SKUAST-K, Shalimar

Dr. Amit Kr. Singh
(Major Advisor)
(Assistant Professor, Entomology)

Prof. & Head,
Division of Entomology

Dean,
Faculty of Agriculture
SKUAST- Jammu

ACKNOWLEDGEMENT

With heartiest reverence to my family, I admire the support and confidence bestowed on me by my parents Mr. M K Koul and Mrs. Mohani Koul who remained the pillars of inspiration for me from the very beginning of my life.

A true guide is a person who makes us create our own milestones, rather than to follow footsteps of others. It is with adnascent pleasure that I reiterate my eternal gratitude to the chairman of my advisory committee Dr. Amit Kumar Singh, Assistant Professor Division of Entomology SKUAST – Jammu for his encouraging inspiration, valuable guidance and polite behavior throughout the course of my study.

I owe special gratitude and feel highly esteemed to thank members of my advisory committee Dr. Uma Shankar, Assistant Professor, Dr. S. K. Singh, Associate Professor Division of Plant Pathology, Dr. V. K. Razdan, Dean's Nominee Professor Division of Plant Pathology, for their valuable suggestions during the course of investigation and critically going through this manuscript.

I record my sincere gratitude to the faculty members of Division of Entomology , Dr. Virender Kaul, Professor and Head, Dr. Hafeez Ahmad, Professor, Dr. R .K .Gupta, Associate Professor and Dr. Devinder Sharma, Asstt Professor.

It is my pleasure to mention the help and cooperation provided by the non-teaching staff namely Miss Bandana Sharma, Mr. R. K .Bhat, Sr. Navtej Singh and Mr. Raghubir Lal, Shallu Ram,Madanjee, Ramesh lal, Kuldeepjee.

I extend my sincere thanks to my seniors Mr. Sohail, Miss Sonika Sharma, Miss Ramandeep Kour, Mr. Amit Mondal and Amit Kumar for always being around me with a smile and helping hand.

Last but not least, my special thanks are due to Dr. Uma Shankar, Assistant Professor, and Division of Entomology for his invaluable help, critical suggestions and keen interest during the tenure of my present investigations.

Invaluable help in several ways rendered to me by those who could not find mention here is also acknowledged.

Date: 29-07-2016

Place: Jammu

Kuldeep Koul

ABSTRACT

Title of the thesis	:	**Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)**
Name of the Student	:	**Kuldeep Koul**
Registration No.	:	**J-14-M-363**
Major Subject	:	Entomology
Name of Major Advisor	:	Dr. Amit Kumar Singh, Assistant Professor
Year of award of degree	:	2016
Name of University	:	SKUAST of Jammu

Experimentation for management of okra mite (*Tetranychus urticae* Koch.) on okra was conducted at Chatha farm, SKUAST- Jammu from February 2015 till the harvest of crop (July, 2015).

In the present investigation, 10 different vegetable crops were surveyed for the diversity of mite pests and recorded five different types of phytophagous mite species such as two-spotted spider mite, *Tetranychus urticae* Koch; *Tetranychus neoealidonicus* Andre; *Polyphagotarsonemus latus* Banks; Red-legged spider mite, *Tetranychus ludeni* Zacher; and Spider mite, *Tetranychus macfarlanei* Baker & Pritchard. Apart from phytophagous mites, one predatory mite viz., *Amblyseius tetranychivorus* (Gupta) was also recorded feeding on okra mite. Further, seven other predatory fauna on *Tetranychus urticae* mite on okra such as Coccinellids beetles (*Coccinella septempunctata* and *C. sexmaculata*); Small black beetle (*Stethorus* sp.); Rove beetle (*Paederus* spp.); Green lace wing, *Chrysoperla carnea*; Spiders (*Oxyopes* spp. and others); and minute pirate bug (*Orius* spp.) were also observed in the okra field.

The seasonal incidence of okra mite observed at experimental sites indicated that okra mite, *T. urticae* was found damaging and remain active on the okra crop and attained two peaks i.e., in 18th standard week (44.13 mean number of mites per 2.5 cm^2) and in in 25th SW (55.53 mean number of mites population/2.5 cm^2), respectively. The increase in temperature coupled with decrease in relative humidity from March 2015 to June 2015 favoured the increase of *T. urticae* Koch.

The correlation studies showed that the highly significant and positively correlated with maximum temperature had existed with okra mite whereas, negatively correlated with relative humidity (highly significant with morning R.H and significant with evening R. H) and negatively correlated and significant with rainfall.

Predatory mite population build-up observed on okra crop had two peaks viz., in 19th SW (5.00 mite/leaf) and again in 27th SW (8.67 mite/leaf). Predatory mite population was positively

correlated and highly significant with minimum temperature and significant with maximum temperature, respectively. Predation study revealed that *A. tetranychivorus* (Gupta) prefer the egg stage of prey than larvae, nymph and adult. Mean consumption rate of *A. tetranychivorus* (Gupta) on *T. urticae* egg was found to be 4.16 ± 0.33 per day per gravid female.

Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide against okra mite was recorded after two spray (1st and 2nd spray). After 14th days of 1st spray, Abamectin was found to be the best treatment in reducing the mites population (74.64 per cent) on okra followed by Diafenthiuron (68.02 per cent) and Fenazaquin (60.43. per cent). Among the biopesticides, pongamia oil gave 46.32 per cent reduction followed by neem oil application resulted in only 42.68 per cent reduction in mites population at 7 days after second spray.

Bio-efficacy of some acaricides/ botanicals / insecticide in the laboratory condition through Leaf Dip Method revealed that that after 72 hours of treatments, abamectin (63.40%), diafenthiuron (61.12%), fenazaquin (51.90%) were behaved to be the effective treatments in terms of highest mortality of adult mite population.

The present investigation shall be useful in monitoring the mite pest population by encouraging the predatory mites and devising the sustainable Integrated Pest Management strategies against emerging mite pests of summer vegetable crops.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Chapter 1

INTRODUCTION

India is bestowed with the diverse climatic conditions with varied habitats which favour the cultivation of a number of commercial vegetable crops. Vegetables cultivation in our country has assumed greater importance during the last decade which not only constitutes the most important component of balanced diet but also the source of income generation among the farming communities. The technological interventions with improved gene pool and management strategies can take the vegetable production growth rate to nearly 6% per annum.

Okra, *Abelmoschus esculentus* (L.) Moench, also known as Lady's finger, is one of the important vegetable crops commercially cultivated in many parts of the world and in almost all the states in our country. Okra is the single largest green vegetable exported to many parts of the world accounting for 60% of vegetable exports, excluding onion. It is mainly used for its tender green fruits as vegetable. It is a rich source of iodine, calcium, sulfur and sodium. Its tender fruits also contains vitamin-A, C, thiamine and riboflavin.

Besides it also has dietary fibres, proteins and carbohydrates. It is basically a hot weather crop and thrives well during hot and humid climatic condition. It can be successfully grown under the temperature ranging between 25 ^{0} - 30 ^{0}C. Adequate sun shine is very important for growth and yield of the crop.

Jammu region of the J&K state is known for the production of quality vegetable crops in several pockets. However, the productivity of vegetable crops is far below the productivity in other states of the country. The income per hectare from vegetable crops is almost four times more remunerative than the cereals crops and thereby, fetches higher income in short span and generates employment to the rural masses (Thakur *et al.,* 1994; Singh, 1995). During the past three decades, our country has made commendable progress in the field of vegetable research and development, enabling it to secure second position in vegetable production and occupies 8.9 million hectare area with a total annual production of 155.9 million tonnes during 2011-12 (Anonymous, 2013a). Okra occupies an area of 2.31 lakh ha with a production of 63.5 MT and a productivity of 27.5 MT per ha (Anonymous, 2013). In Jammu region of the J&K state, okra is grown in an area of 2.52 million ha from sub tropical to high altitude intermediate zone with an annual production of 42.99 metric tonnes and productivity of 17.06 qt/ha (Anonymous, 2013-14).

The major problem in limiting the productivity of okra crop is its susceptibility to a large number of insect pests including vectors. Over 37 insect pest species have been recorded causing damage to okra crop (Nayar *et al.,* 1976). Among the various insect pests responsible for lowering the yield of okra crop, whitefly, *Bemisia tabaci* Genn. which is a vector of Yellow Vein Mosaic Virus disease; the leafhopper, *Amrasca biguttula biguttula* Ishida; the red spider mite, *Tetranychus urticae* (Koch); the shoot and fruit borer, *Earias vittella* Fabricius and *Earias insulana* Boisd; the aphid, *Aphis gossypii* Glover; the blister

beetle, *Mylabris pustulata* (Thunberg); the red cotton bug, *Dysdercus koenigii* Fabricius; the dusky cotton bug, *Oxycarenus laetus* Kirby, etc.

Phytophagous mites play an important role in agriculture by causing various types of direct damage to crops like loss of chlorophyll, stunting of growth, plant deformities resulting in reduction of yield etc. Mites have a worldwide distribution and most serious pests causing damage to several crops such as cereal, vegetable, ornamental and fruit crops. They have been recorded to feed upon more than 180 plant species (Johnson and Lyon 1991). *T. urticae* is known to attack about 1200 species of plants (Zhang, 2003), of which more than 150 are economically important (Gupta and Gupta, 1985). Defoliation, loss of chlorophyll, leaf bronzing, and even plant death occur due to direct feeding in severe infestation (Meyer, 1996; Meyer and Craemer, 1999).

Gupta (1991) described the mites of agricultural importance in India, giving details of their economic status. Reviews about agricultural acarology in India were provided by Singh *et al.* (2000) and Singh (2004) and recently, Singh and Raghuraman (2011) highlighted the most important and emerging mite pests of North India. Gupta (2010) further reported a total of 1,700 mite species from different parts of India, 998 of which were phytophagous, whereas, Singh and Raghuraman (2010) reported the total number of estimated species, including phytophagous mites to be 2,670. Among the non- insect pests of agricultural crops, mites are probably the most notorious ones and are gaining tremendous importance in the recent years due to their devastating nature.

Many reports indicated that mites suck the sap from the leaves which eventually leads to loss of green colour, gradual wilting, dryness and dropping off. The decreased vitality and leaf drop adversely affect plant growth, flowering and fruiting. In severe infestation, tetranychid mites web profusely and may form a thick sheath of webbing that

covers the entire plant (Grandjean, 1948; Jeppson et al., 1975). These webs become filled with soil particles in windy weather and inhibit the photosynthetic activity of the plant. Thus, the mite has been proved as an indirect pest causing loss in quality and quantity of the yield (Butani and Mittal, 1992). Besides being phytophagous, mites also inject toxic substances into hosts causing disruption in tissues and increase in localized growth (Channabasavanna, 1966).

In vegetable crops, spider mite damage alone causes 10 to 15 per cent loss in yield. Out of 37 mite species known to feed upon vegetable crops, six species viz., *Tetranychus cinnabarinus* (Boisduval) (=urticae Koch), *T. neocaledonicus Andre, T. ludeni* Zacher, *T. macfarlanei* Baker and Pritchard, *Aceria lycopersici* (Wolff.) and *Polyphagotarsonemus latus* (Banks) are serious pests on brinjal, okra, cucurbit, chilli, potato etc. in major parts of the country (Gupta, 1991).

When hazardous chemicals are used, careful monitoring is required periodically to check whether pest resurgence or predatory mite decline has occurred. Hence, checking crops weekly and taking leaf samples is essential to identify and determine pest and predator activity in agri-horti crop ecosystem. The emerging pest problems and intensive agriculture in India requires more input in mite research, especially studies on diversity, damage potential and exploration of bio control agents for integrated mite control. Much emphasis has been placed in recent years on the correct identification of plant mites and the symptoms they cause. However, limited effort has been dedicated to determine their actual damage, which remains a real need for the adoption of more appropriate control measures. For better management of mite pest, knowledge on seasonal population fluctuations, natural enemy complex and management of mite pest by effective chemicals is a prerequisite.

In view of the above facts and paucity of relevant information on mites infesting okra vegetable crops in Jammu region with special reference to okra, the present investigations were undertaken with the following objectives-

1. Survey on diversity of mite pest on some vegetable crops in Jammu districts
2. To study the seasonal incidence of okra mite and its predatory fauna in relation to abiotic factors
3. To evaluate the field and laboratory bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite

Chapter 2

REVIEW OF LITERATURE

This chapter deals with the work done in the past on the objectives of the present investigation. The literature available on survey of mite pests on summer vegetable crops and some ornamentals, activity of natural enemy fauna, seasonal incidence of okra mite in relation to abiotic factors, nature and extent of damage caused by them, their bionomics, distribution and management aspects of *Tetranychus urticae* Koch have been documented.

The earliest record of mite in India was given by Peal (1868), who discovered a microscopic arthropod on plant from Assam and erroneously called this as 'Red spider mite'. The first definite record of in plant feeding mite in India was published by Wood-Mason (1884) who identified that very arthropod discovered by Peal, and reported that occurrence of *Tetranychus bionoculatus* on tea from Assam. Following these, a large number of contributions have since been added in the literature gradually.

2.1 Diversity of mite pests on some summer vegetable crops and ornamentals

Ehara (1956) enumerated the tetranychoid mites of mulberry in Japan and observed *T. truncatus* as a major pest of mulberry and other plants.

Baker and Connell (1961) reported that *T. yusfi* was one of the most abundant and injurious mites to soybean in Delaware and the other economic host plants of the pest were recognized as cotton, roses, okra, sweet potato, marigold, peas, beans, cowpeas and peanuts.

Gupta (1987) gave a report on the plant mites of Arunachal Pradesh and providing information on 17 species of tetranychids which were found associated with fruit and vegetable crops and ornamentals.

Singh and Chauhan (2014) conducted a survey in mid-hills of Himachal Pradesh during 2011-2012 to study the mite diversity in 16 different vegetables and ornamental crops. A total of 32 species in 15 genera and 7 families were observed during this study, out of which 6 species were of phytophagous mites belonging to 2 genera and 2 families, whereas 26 species were of the predatory mites belonging to 13 genera and 5 families. Among phytophagous mites, three species viz. *Tetranychus urticae* Koch, *T. ludeni* Zacher, *T. hypogeae* Gupta were most commonly found and recorded on different crops. Among predatory mites, 4 genera viz. *Amblyseius*, *Euseius*, *Neoseiulus*, *Amblydromella* were most common. Maximum numbers of predatory mite species were recorded on rose, cucumber and brinjal. Five genera of predatory mites viz. *Paraphytoseius*, *Pennaceius*, *Typhlodromips*, *Typhlodromalus* and *Lasioseius* were the new record in the state.

2.2 Seasonal incidence of okra mite and its predatory fauna in relation to abiotic factors

Lall and Dutta (1959) reported that red spider mite, *Tetranychus telarius* Linnaeus is one of the most important pests among the various insect pests of okra, grown in different parts of India and causes 36.8 to 83.2 per cent loss in okra yield. The population density of the pest and its natural enemies changes during the course of crop growth.

Gerson and Aronowitz (1980) made a comparative study on the feeding behaviour of the carmine spidermite, *T. cinnabarinus* on seven host plants. Gupta and Nahar (1981) provided list of plant mites of agricultural importance in Bihar. Ray and Rai (1981) studied the biology and.contro1of *T. neocaledonicus* on ladies finger at Varanasi.

Puttaswamy and Channa Basavanna (1980a,b) studied the life history of *Tetranychus ludeni* under field conditions. They further in (1981) studied the influence of host plants and effect of temperature and relative humidity on the development, fecundity and longevity of *T. ludeni*.

Akbar and Aheer (1994) surveyed the mite fauna of summer vegetables in Punjab.
A preliminary survey on mites associated with some vegetable crops in Hisar, Haryana was made by Mathur et al. (1994).

Bindra and Singh (1970) observed that *Tetranychus urticae* Koch. attack a wide range of crops including fruit trees, pulses, oilseeds, millets, fiber crops, ornamental crops and vegetable crops. This mite is active on the highly susceptible crops reported so far like okra, brinjal, beans, tomato, soybean and cucurbits.

Channabsavanna (1971) observed that mite damage to the vegetable crops has been recognized as one of the limiting factors in attaining increased productivity of vegetables throughout the country.

Jeppson*et al*. (1975) observed that mites associated with plants are either phytophagous or predatory in habit and many of these seriously damage their host plants. Besides causing damage, few phytophagous mites inject toxic substances into their hosts and thereby causing disruption of tissues leading to malformation, deformation, gall formation, distortion, puckering etc.

Temperature, relative humidity are among the major deciding factors for theefficacy of predatory mites. Among the predatory mites, the *P. persimilis* require 68-82°Fand RH 60-90% for effective predation and hence it is more suitable for greenhouse (Krishnamoorthy, 1982a).

The egg-adult development of female *T. urticae*is completed in approximately 6.5 days at 30^{o}C (Sabelis, 1981) while the males are reported to complete development earlier than females. Diapausing females or eggs are the most common overwintering stage for tetranychids in response to short day lengths and cooling temperatures (Mitchell, 1973). The mites produce threads of silk, which they use to "balloon" into the wind, which sometimes carry them great distances (Smitley and Kennedy, 1985).

Out of 660 species, Gupta (1987) reported 30 species of phytophagous mites as potential pests associated with crop plants in India. Besides the injurious mites, there are some beneficial mites also which have significant importance as they help in natural suppression of mite pests population. The predatory mites belong to the families Phytoseiidae, Cheyletidae, Cunaxidae, Anystidae, Bdellidae, Tydeidae, Erythraeidae and Stigmaeidae. Although, *Tetranychus macfarlanei* Baker and Pritchard is a little known species, recorded in serious proportions on okra, cotton, brinjal, cucurbits, field crops, weed plants etc. (Sejalia, 1989). Incidence of *T. macfarlanei* on cotton occurred from October to

February and carried over to brinjal and okra from March to June and on some weed plants from July to December in Gujarat (Jose and Shah, 1989).

Bonde (1989) recorded that the Phytoseiid mites are worldwide in distribution andthey feed specially on mites of the families Tretranychidae, Eriophyidae, Tarisonemidaeand Tenuipalpidae. In addition, reports are also available on their feeding upon smallphytophagous insects like aphids, coccids and thrips.

Gupta (1991) observed that out of 37 mite species known to feed upon vegetable crops, six species viz., *Tetranychus cinnabarinus* (Boisduval) (=urticae Koch), *T. neocaledonicus* Andre, *T. ludeni* Zacher, *T. macfarlanei* Baker and Pritchard, *Aceria lycopersici* (Wolff.) and *Polyphagotarsonemus latus* (Banks) are serious pests mostly of vegetables like brinjal, okra, cucurbit, chilli, potato etc. in major parts of the country.

Singh (1994) reported that *Tetranychus urticae* Koch. had a wide range of host affinity of twenty seven vegetable crops in India, as well as few potential predatory mites were also in the record from the vegetable crops. Further, he recorded that okra is attacked by *Eutetranychus orientalis* Klein, *Oligonychus coffeae* (Nietner), *Tetranychus cinnabarinus* (Boisd), *Tetranychus macfarlanei* Baker and Pritchard, *Tetranychus ludeni* Zacher, *Tetranychus neocaledonicus* Andre, *Tetranychus puschelii* Meyer, *Brevipalpus californicus* (Banks), *B. obovatus* Dennadieu, *B. phoenicus* (Geij) and *Amblyseius* sp.

Rai *et al.* (1995) showed that *T. urticae* preferred bottom canopy leaves than middle and top canopy leaves. Among three different canopy levels, middle canopy harboured maximum mite density (50.75/4 cm^2 leaf area) followed by bottom (49.00/4 cm^2 leaf area) and top (23.65/4 cm^2 leaf area).

Spider mites, *Tetranychus* spp., are devastating pests of numerous crops, vegetables, melons, fruits and ornamentals in the field or greenhouse worldwide (Ho et al., 1997).

Global control of the mite pests mainly relies on sprays of chemical acaricides, leading to well-known ecological problems, such as chemical resistance for pest resurgence and residues in agro-products (Ambikadevi and Samarjit, 1997; Guo et al., 1998).

Kapoor *et al.* (1997) reported that the carmine spider mite, *Tetranychus cinnabarinus* (Biosduval) has assumed the status of major pest and caused 17.46 per cent yield loss in okra and often causes complete failure of okra crop. Further, they noticed high population of *T. cinnabarinus* from May to November except July while, phytoseiid reach a peak in September. The mites become serious pests because they have several generations per season. Phytophagous nature, high reproductive potential and short life cycle contributed rapid resistance development to many acaricides often after a few applications (Devine *et al.,* 2001; Stumpf and Nauen, 2001).

According to Anand kumar (2002), the mite population was highest during March (28.65/leaf) and among three districts (Raichur, Gulbarga and Bidar), the highest mite population was recorded in Bidar (31.73/leaf). The predatory population was highest during September with a mean population of 1.37 spider per plant, 1.11 *coccinellids* per plant and 0.84 eggs, 0.09 larvae and 0.34 adult *Chrysoperla* per plant.

T. urticae is the most notorious pest responsible for significant yield losses in many economic crops, vegetables and fruit trees (Salman, 2007) and also ornamental and agronomic crops worldwide (James and Price, 2002).

Okra [Abelmoschus esculentus (L.) Moench] growth and productivity are hampered by the two-spotted spider mite (*Tetranychus urticae* Koch; TSSM) from the seedling stage to harvest maturity. Mite occurrence hinders plant growth, fruit development, and yield loss from 7% to 48% (Alatawi et al., 2005).

Roopa (2005) reported that spider mites appeared much earlier on summer crop (45

DAT) as compared to kharif and rabi in brinjal. The population reached peak twice i.e., on 28th standard week, July 9-15 (14.20 individuals/4 cm^2 leaf) and 46th standard week, November 12-18 (28.73 individuals/4 cm^2 leaf). The population of phytoseiids was low throughout the observation period. The correlation studies on population of *T. macfarlanei* with biotic and abiotic factors were non-significant but the joint contribution of above parameters explained about 34 per cent variation.

Mandal et al. (2006) studied the effect of meteorological parameters on population build up ofred spider mite, *T. telarius*in okra at Pusa, Bhiar during summer seasons of 2000 and 2001. Results indicated that the activity of the insect 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 78-85per cent variability due to meterorological parameters in the population of red spider mite.

2.2.1 Predatory fauna on okra crop against okra mite

Wood et al. (1994) adopted various biological control measures of the two spotted spidermite*, T. urticae* on raspberries.

Prasanna and Prasad (2008) recorded the incidence of the tetranychid mites and their natural enemies prevailing on brinjal during the rabi and summer months of 2006-07 in selected districts/taluks of northern Karnataka, India. The results clearly signify the importance of Phytoseiids in the natural control of tetranychid mites in brinjal ecosystem.

Clotuche *et al*. (2011) observed that *T. urticae* has a very rapid population growth, short developmental time, high birth rate and long adult survival.

Prasad and Singh (2011) studied the qualitative and quantitative composition of phytophagous mites infesting brinjal and revealed that brinjal was infested with six mite pest

species, viz. *Tetranychus urticae*, *T. macfarlanei*, *T. ludeni*, *Brevipalpus phoenicis*, *Polyphagotarsonemus latus* and *Aceria lycopersici*. Out of these mite species, *T. urticae* appeared as major pest during post rainy season, as minor pest in rainy season and as mild pest in autumn. As such, *T. urticae* remained the major mite pest during post rainy and autumn and *A. lycopersici* emerged as severe pest during spring and summer season in brinjal agro-ecosystem in the agro-climatic conditions of Varanasi region.

T. urticae feeding causing aesthetic injuries as well as morphological and biochemical alterations in leaf and fruit composition has been reported earlier (Farouk and Osman, 2011). Further, Abdel-Wali *et al*. (2012) revealed that *T. urticae* infestation poses potential biotic stress to its host plant and heavy damage may cause leaves to dry and drop.

In India, spider mite is reported as serious pest of vegetables (Singh and Singh, 1996; Prasad, 2007). Average yield loss to vegetable crops was estimated to be 9.15-100% due to mite infestation, as reported by many authors in different agro-climatic conditions of the country (Gupta, 1991; Singh, 1995; Rai and Tripathi, 1999; Prasad and Singh, 2007; Prasad et al. 2007; Patil and Nandihalki, 2009 and Vinothkumar *et al.;* 2009).

2.3 Bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite

Singh and Singh (1999) evaluated four acaricides and a neem pesticide (Azadirachtin 0.03%) against *T. urticae* on okra. Azadirachtin 0.03 per cent was applied alone at 6.0, 5.0, 4.0 and 3.0 and 2.0 ml/litre and with dicofol, ethion and sulphur. Dicofol, ethion and sulphur were also applied separately at 2 ml, 1 ml and 3 g/l, respectively. Dicofol alone and in combination with Azadirachtin resulted in complete mortality of the mites after 14 days. Mixture of Azadirachtin with conventional acaricides gave better control than Azadirachtin alone.

The mites become serious pests because they have several generations per season. Phytophagous nature, high reproductive potential and short life cycle contributed rapid resistance development to many acaricides even after few applications (Stumpf and Nauen, 2001).

In India, resistance was observed against dicofol (EC), dicofol (WP), abamectin, phosalone, phosphamidon, dimethoate, dicofol and wetable sulpher in different vegetables (Kumar et al., 2001, 2002; Sridhar and Jhansi Rani, 2003, 2007).

Mani *et al*. (2003) recorded that the maximum per cent mortality of adult *T. urticae* on okra was recorded in dicofol (0.04%), abamectin (0.042%), abamectin (0.014%), sulphur (0.25%) and ethion (0.05%) with 75.0, 72.3, 66.7, 65.6, 60.7, 56.0 and 54.9 per cent mortality, respectively after one day of treatment. After seven days, dicofol and abamectin showed similar response.

Venugopal *et al*. (2003) evaluated the bio-efficacy of different acaricides against *T. cinnabarinus* on okra and reported that abamectin (0.05%) was the most effective acaricides with mean of 93.45 per cent reduction of mite population. The next most effective treatment was dicofol (0.1%) with 89.58 per cent reduction followed by flufenoxuron (0.01%), profenofos (0.1%) ethion (0.05%), phosalone (0.07%), sulphur (0.2%) and imidacloprid (0.05%) with 83.70, 81.43, 77.16, 75.45, 71.45 and 68.48 per cent reduction, respectively.

Walunj and Pawar (2000) reported that fenazaquin at 150 gha−1 a.i. was effective against chilli mites (*Polyphagotarsonemus latus* Banks). Mahajan (2002) reported that fenazaquin was highly toxic to eggs of European red mite, *Panonychus ulmi* Koch, onapple (*Malus domestica* Borkh.). Fenazaquin is effective due to translaminar movement and lack of cross-resistance with other pesticides (Ware and Whitacre, 2004) and its quick knock down effect.

Fenpyroximate (0.006%) recorded the highest mean reduction of 87.37 and 93.50 per cent against *T. urticae* on bhendi after first and second spray, respectively. Difenthiuron 50 WP (0.09%) and difenthiuron 50 SC (0.09%) were next in the order (Anonymous, 2003a).

Roopa (2005) tested the efficacy of certain insecticides /acaricides and reported that spiromesifen (0.024%), difenthiuron (0.075%) and dicofol (0.046%) were highly effective against all stages of spider mite, whereas, dimethoate (0.05%), endosulfan (0.07%), methyl demeton (0.025%) monocrotophos (0.036%) and phosalone (0.07%) were found ineffective. Maximum fruit yields were recorded in spiromesifen and difenthiuron with 240.74 and 248.97 q/ha during second and 176.33 and 163.99 q/ha during third season trial on brinjal, respectively.

Kumaran *et al*. (2007) revealed that out of these mite species, *T. urticae* is responsible for causing the loss of foliage of the crop plant resulting in reduction of the economic yield of fruits ranging from 20-45 % depending upon cropping season and agro-climatic conditions. *T. urticae* is well adapted to various environmental conditions, causing loss of quality and yield or death of plants by sucking out the contents of leaf cells (Mondel and Ara, 2006).

Pushpa and Nandhihalli (2008) reported that fenazaquin at 2 mlL^{-1} reduced the *Aceria guerreronis* (Keifer) population by 75.5%. The material has not been tested against two-spotted mite on okra.

Rai and Singh (2008) revealed that mite control has been almost solely based on chemicals. Indiscriminate pesticide use favors the outbreak of phytophagous mites. Identification of safe chemicals with better acaricidal properties, lower mammalian toxicity, and safety to natural enemies that fit in the Integrated Pest Management (IPM) concept, is necessary.

Banerjee et al. (2009) examined the persistence and dissipation behaviour of propargite (Omite 57 % EC) in okra and brinjal following two spray application @ 570 (T1) and 1140 (T2) g. ai/ha. Propargite residue was estimated by HPLC. The LOD and LOQ were found to be 0.03 mg/kg and 0.1 mg/kg, respectively for both the substrates. Initial deposits of propargite ranged from 2.95-5.68 mg/kgin okra and 2.20-4.30 mg/kg in brinjal at T1 and T2 dosages respectively. The dissipation followed first order reaction kinetics with half-lifeof 2.38-3.04 days for okra and 5.63-7.06 days for brinjal. The calculated PHI of propargite ranged from 1.08 -3.40 for okra and 1.0 -7.63days for brinjal. The residues reached below MRL of 2 mg/kg at 1 days for both the crop.

Rai (2009) studied the various life stages, their duration, measurements and sexual behavior and chemical control of red spider mite on brinjal in summer months of 2005-2006. The duration of life cycle of female was found longer than the male. Eight insecticides/ acaricides were used to control the mite in field conditions. Dicofol (0.04%) was found to be best whereas, triazophos (0.05%) was found to be least effective

Singh (2010) reported that mites have been developed high levels of resistance to chemicals like TEPP, parathion, malathion, tetradifon and binapacryl etc. They also developed resistance to dicofol, dimethoate, monocrotophos and mevinphos. However, some of the new chemicals like omite and palictran gave better results without harming the predatory fauna of mite pests. Therefore, resistance management involved such mechanisms which extendnumber of generations that a given pest population might be controlled economically by a pesticide in judicious way.

Prasad and Singh (2011) stated that the spider mite, *Tetranychus urticae* Koch, poses serious threat to okra crop particularly during spring, summer and post rainy seasons. This crop is infested mainly by six different mite pest species, *viz*., *Tetranychus urticae*, *T.*

macfarlanei, *T. ludeni*, *Brevipalpus phoenicis*, *Polyphagotarsonemus latus* and *Aceria lycopersici*

Karabhantanal et al. (2012) evaluated the effect of acaricides against the natural enemies like spiders, ants and Coccinellids in comparison with the untreated control. After first spray,there was no statistical variation was noticed in all thetreatments. After second and third sprays, spider and ant population were equally reduced the all natural enemies except coccinellids compared to the untreated control. The acaricides viz., propargite 57 EC at the rate of 2.0ml/l, spiromycifen 240 SC at the rate of 0.75 ml/l and abemectin 1.9 SC at the rate of 0.50 ml/l are quite effective and can be used in the management of grape mite.

Sangeetha and Ramaraju (2013) evaluated a new acaricide, fenazaquin 10 EC, for effective control of two-spotted spider mites [*Tetranychus urticae* Koch (Acari:Tetranychidae)] in pot culture and under field conditions on okra. Fenazaquin was used at 75, 100, 125, or 150 g·ha^{-1}a.i. and compared with the standard acaricide dicofol 18.5 EC at 250 g·ha^{-1}a.i. and an untreated control. The adulticide bioassay, ovicidal action to *T. urticae* and safety of Dwarf honey bees (*Apis florae* Fabricius), was performed under laboratory conditions. Pot culture and two field trials were conducted to evaluate efficacy. Impact on okra yield and phytotoxicity were determined. The LC_{50} was 1.440 mgL^{-1} and LT_{50} at 1.50 mgL^{-1} was ~8 hours. Fenazaquin produced more than 70% egg mortality in all doses for *T. urticae*. Fenazaquin at 125 and 150 gha^{-1}a.i. caused the highest reduction in numbers of mites in pot culture and field experiments. Fruit yields (9.89 Mtha^{-1}, 10.59 Mtha^{-1}) and cost–benefit ratio (1:3.25, 1:3.48) were higher in fenazaquin-treated plants at 150 gha^{-1}a.i in field experiments. No test doses were phytotoxic and all doses were relatively safe to Dwarf honey bees.

Monica et al. (2014) determined the population dynamics of two spotted spider mite, *Tetranychus urticae* Koch on brinjal crop 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^2 leaf area. Population gradually increased from April to June and recorded maximum 6.91 mites per cm^2 leaf are ain the first week of June and then sharply declined from 4^{th} 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.

Patil et al. (2014) tested the acaricides for the bio-efficacy against *Tetranychus urticae* under polyhouse conditions and revealed that all the acaricidal treatments were significantly superior to untreated control in checking the mite population under polyhouse conditions. Among acaricides, propargite 0.05 per cent gave 69.19 per cent mite population reduction after two application. The next best treatment in order of effectiveness was abamectin 0.0025 per cent (63.34%) and it also exhibited consistent performance as second best treatment, followed by dimethoate 0.03 per cent (57.97%). However, the benefit cost ratio showed that propargite and dimethoate were most economical with net BCR of 1: 8.98 and 1: 8.93, respectively and gave effective control of *T. urticae.*

Singh et al. (2014) tested the comparative bio-efficacy of clofentezine 50(SC) along with standard acaricides cyflumetofen, 20 (SC), fenpyroximate 5 (EC), propargite 57 (EC), dicofol 18.5 (EC), including bio pesticides azadirachtin, 0.03(EC), NSKE (5%), neem oil, and mycopathogen, *Paeciomycesf umosoroseuc* ($1x10^6$) is used as a form of foliar spray and dust was evaluated against *Tetranychus urticae* on okra. Clofentezine 50(SC) (89.94 %) was

most effective in controlling *T. urticae* in okra during two consecutive seasons (Feb-June 2013 and Feb-June 2014) and also cyflumetofen, 20(SC), fenpyroximate 5(EC), propargite 57(EC) suppressed the mites (82.27, 77.27 and 71.62 %), respectively. The responses of these bio-pesticides to be relatively safe to the natural enemies.

Kavya et al. (2015) evaluated the newer acaricides against *Tetranychus urticae* on brinjal plants inthe University of Agricultural Sciences, GKVK, Bangalore during 2013. All the tested acaricides affected the two mites survival. In propargite (0.78 mites/leaf) and spiromesifen (1.05 mites/leaf) reduced the overall mite population more significantly than other acaricides with in three days of application and this will leads to corresponding increase in higher fruit yield. Buprofezin, spiromesifen and HMO treated plots quit safe to predatory mite population.

Kumar et al. (2015) studied the population fluctuation of phytophagous mite (*Tetranychus urticae* Koch) in okra and its relation with different weather variables during 2010 and 2011crop seasons under unprotected conditions Varanasi region. The results revealed that the mite population commenced from 9th and 10th standard week in 2010 and 2011, respectively. The highest population mites per 2.5cm^2 leaf area was recorded on 21st standard week (47.75) in 2010 while the maximum population was recorded in 18th standard week (45.99) during 2011. It was found that the mite infestation was heavy during May in both the years. The maximum number of predatory mites was recorded on 15th standard week (11.86) in 2010 while in 2011 population of predatory mite was highest in 18th standard week (15.98). The population of predatory mites, mean temperature, sunshine hours and wind velocity showed a significant positive correlation with the mite pest whereas, a negative correlation was established with relative humidity and rainfall.

Halder et al. (2016) tested three different pest management modules against major sucking pests complex of chilli (*Capsicum annuum* L.) (thrips, yellow mites) and occurrence of Pepper leaf curl virus transmitted by whitefly [*Bemisia tabaci* (Gem.)] and compared with the untreated control. Two promising varieties (Kashi Anmol and Kashi Gaurav) weresown at experimental plots of IIVR and three pest management modules, viz. biointensive module (M1), integrated module (M2) and chemical module (M3) were examined for two consecutive years (2011-12 and 2012-13). All thetested modules were found significantly applicable over the control in terms of pest and disease management. Amongthese, integrated module (M2) comprising seedling dip with Imidacloprid 17.8% SL@ 1 ml/ l of water, spraying of Buprofezin 25%SC @ 1 ml/l at 25 DAT, Fipronil 5% SC@ 2 ml/l at 35 DAT, *Lecanicillium* (=*Verticillium*) *lecanii* @5 g/l at 45 DAT, Chlorfenapyr 10% SC@ 1.5 ml/l at 55 DAT, neem oil 1% at 65 DAT and their need based rotationwas most effective in reducing the thrips and mite population in chilli and significantly enhancing the yield overcontrol. Reduced yellow mite population was observed in both the varieties, i.e. Kashi Anmol (79.16%) and KashiGaurav (73.59%). Likewise, reduction in thrips population was also recorded in Kashi Anmol (58.09%) and in KashiGaurav (48.16%) varieties. However, occurrence of Pepper leaf curl virus was lowest in chemical module (M3), viz.7.04% and 11.18% lower leaf curl infestation was observed, respectively in Kashi Anmol and Kashi Gaurav varieties followed by integrated module (M2) with 8.36% and 12.64% less leaf curl infestation. In terms of cost benefit ratio, integrated module (M2) was found applicable for both the varieties, *i.e.,* 1:2.26 and 1:6.66 cost benefit ratios were recorded respectively in Kashi Anmol and Kashi Gaurav. Thus, integrated module (M2) may be adopted to get rid of these sucking pests menace.

Chapter 3

MATERIALS AND METHODS

The experiments of the present study entitled, "Diversity of mite pests on some summer vegetable crops with special reference to management of Okra mite (*Tetranychus urticae* Koch.)" were conducted under field conditions at the Research field, Division of Entomology, Chatha, Jammu.

The materials employed and methodology adopted during the entire course of investigation to study various objectives viz., Survey on diversity of mite pest on some vegetable crops in Jammu districts, seasonal incidence of okra mite and its predatory fauna in relation to abiotic factors and to evaluate the field and laboratory bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite have been portrayed in this chapter.

3.1 Details of the experiments

3.1.1 Location and site of the experimental plots for studying seasonal incidence

The site located at the Chatha Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu was selected for laying out the field experiment. The experiments

were conducted during the year 2015. The main field selected for the experiments was ploughed two times. Plots of 5 m × 3 m dimensions were made and certified seeds of Okra (var. Nemo Hybrid, Amazon Co.) were sown on 2nd week of February, 2015 at recommended rate of 20 kg/ha^{-1} under natural conditions without the application of any manure and fertilizer. The overnight soaked okra seeds were sown in plots at a distance of 60× 60 cm. The crops were raised as per the recommended package of practices of SKUAST-Jammu except for plant protection. The experiments were laid out in randomized block design (RBD) with three replications of each treatment. The meteorological data for the period of experimentation (*i.e.*, 2015) was obtained from the Agro-meteorological section, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu.

3.1.2 Layout of the Experiment for field bio-efficacy

Crop	:	Okra
Variety	:	Nemo Hybrid
Design	:	Randomized Block Design (RBD)
Plot size	:	5× 3 m^2 area
Spacing	:	60 x 60 cms
Treatments	:	10
Replications	:	3

3.1.3 Crop Variety

The okra variety “Nemo Hybrid” was used for the experiments. This variety is good for fresh consumption in the local market. The leaves are broad and green. The first fruit picking commences at 45 days after transplanting; the fruits are attractive and dark green in colour, 14-17 cm long, having excellent shelf life.

3.1.4 Cultural Operations

Cultural operations were done according to the package of practices SKUAST-J (2015) (Plate-1).

3.1.5 Species composition

The samples of mites were collected and identified for the species composition present in okra crop. Samples were sent to the Insect Identification service, Department of Entomology and agricultural Zoology, Banaras Hindu University, Varanasi and mollusk sample was sent to IIHR, Bangalore for correct identification of the pest species. The service rendered in identification of mite species by Prof. R. N. Singh was highly acknowledged.

3.1.6 Harvesting

The fruits were harvested at frequent intervals in the early morning hours by hand picking. The fruits were harvested by bending the pedicel with a jerk or by using sharp knife.

3.2 Survey on diversity of mite pest on some summer vegetable crops in Jammu district

Survey was conducted at fortnightly interval at Chatha campus and its surroundings and in Marh Block which is known as the intensive vegetable growing pockets and 30 Km away from the Main campus in Jammu district. Survey was confined to collect the different types of phytophagous mites infesting the summer vegetable crops, some ornamentals and garden plants. Leaf samples were examined with 10X hand lens, collected in polythene bags properly tied and brought to the laboratory. These samples were observed under the binocular microscope and mite specimens were picked with the help of fine needle or camel hair brush and preserved in a mixture of 70% alcohol and glycerine (10:1) for further identification of mite species.

3.3 Seasonal incidence of okra mite and its predatory fauna in relation to abiotic factors

The seasonal incidence of okra mites and its predatory fauna were recorded at weekly interval during the experimentation at Chatha farm. For sampling and monitoring,

Plate - 1 Experimental view of Okra crop at Chatha Farm, SKUAST-Jammu

(A) Field ploughing by tractor for lay-out of experimental trial

(B) Lay-out and plotting for okra seed sowing at Chatha Farm, SKUAST-Jammu

(C) Germinated plants of okra at Chatha Farm

(D) View of okra field at Chatha Farm

five plants were randomly selected in each plot. Three leaves covering top, middle and bottom canopy of okra plants were sampled in polythene bags. These leaves were brought to the laboratory, cut into 2.5 cm^2 size and were observed under Stereo-Binocular Microscope for enumeration of mite population. Further, sampling was carried out weekly until the end of the harvesting of crops (Plate-2). Weekly data on different weather parameters viz. maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days and Sunshine hours were collected from Section of Agro-Meteorology, SKUAST of Jammu and subjected to simple correlation studies and linear regression analysis.

3.3.1 Predation/ Consumption of okra mites by predatory mite, *Amblyseius tetranychivorus* on *T. urticae*

The present study was carried out under laboratory condition to work out the predating potentiality of locally available predatory mites *Amblyseius tetranychivorus* (Gupta) on different stages of *T. urticae*. For this purpose, prey of *T. urticae* and was used as food for phytoseiid mites. Different stages of prey viz. egg, larvae, nymph and adult were taken for study to work out the preference of predatory mite to the stage of prey. Predator and prey ratio was maintained as 1:5 in all sets of experiments. It means one predatory mite was released against 5 eggs/larvae/nymphs/adult of *T. urticae*.

Three sets of experiments in the fraction of 10, 20, 30, 40 and 50 population of different stages of prey were taken for study. The corresponding number of predatory mite *A. tetranychivorus* was kept in the fraction of 2, 4, 6, 8 and 10; in each set thereby maintaining a ratio of 1:5. Each set of experiments was replicated thrice.

3.4 Evaluation of bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite

Field experiments were conducted at Chatha farm, SKUAST-J during 2015. The okra variety Nemo hybrid was used for evaluation of bio-efficacy of some acaricides/botanicals/allelochemicals/insecticide against phytophagous okra mite on okra crop. The experiment was laid out in RBD (randomized Block Design) with three replications and ten treatments. The okra seeds were sown directly in 2^{nd} SW of February 2015. The plot size was 3×2 m^2 and plant geometry was 60×60 cm^2. The details of experiment were presented in table 1.

Plate - 2 Monitoring of experimental field, Chatha for incidence of mite and its natural enemy

(A) View of okra field at Chatha Farm, SKUAST-Jammu

(B) weekly monitoring in okra field

(C) Close-up view of okra crop for mite incidence at Chatha Farm, SKUAST-Jammu

(D) First Picking of okra fruits

3.4.1 Observation of data

A total of two pesticidal applications were done during 2015 after the commencement of incidence of mites at a month interval with knapsack sprayer. Pre treatment count population of the mites on okra was recorded one day before the spray of the respective pesticide. Details of the different acaricides / botanicals / allelochemicals / insecticide tested in the present study along with and trade name and doses/concentrations are presented in table 1.

Table1: List of chemicals selected for bio-efficacy with trade name and dosage

Treatments	Name of Acaricides/ Insecticides	Trade name	Concentrations (%)/ Doses
T1	Diafenthiuron 50WP	Pegasus 50 WP	0.075 (1.0 g /l)
T2	Dicofol 18.5EC	Kelthane 18.5 EC	0.046 (2.5 ml/l)
T3	Dimethoate30EC	Rogor 30 EC	0.05 (2ml/l)
T4	Fenazaquin10EC	Magister 10 EC	0.02 (2.0 ml/l)
T5	Propargite 57EC	Omite 57 EC	0.142 (3.0 ml/l)
T6	*Agel marmalous* oil/*Ocimum* oil	-	(3 ml/l)
T7	Neem oil	4%	4 ml/lit
T8	Pongamia oil 2 EC	Derrisom	2 ml/lit
T9	Abamectin 18 CE	Vertimac 10 EC	0.4 ml/lit
T10	Control (water spray)		

The observation on the mites was recorded from five randomly selected plants from each treatment replication wise. Three leaves of a plant were plucked and kept in polythene bags, with proper labeling pertaining to the particular treatment and replication were brought to the laboratory for proper counting of mite population under the binocular microscope.

Post treatment observations were recorded after 1, 3, 7 and 14 days of spraying after each of two foliar spray to the crop. The mite population was counted on the basis of number of mites/2.5 cm^2 of the leaf area and finally mean number of mites/2.5 cm^2 of three leaves were calculated.

The per cent reduction of mite population caused by the respective pesticide was calculated for each date of observation in order to express the efficacy of respective treatment against mite infesting the crop.

The per cent bio-efficacy of various treatments against mites in comparison to control treatment was calculated using the formula as suggested by Henderson and Tilton (1955) given below:

$$\text{Per cent efficacy} = 1 - (Ta/Tb \times Ca/Cb) \times 100$$

where,

Cb = Number of larvae on untreated check before treatment.

Ta = Number of larvae on treated plot after treatment.

Tb = Number of larvae on treated plot before treatment

Ca = Number of larvae on untreated check after treatment.

The data on the per cent reduction of mite population were transferred in to the Arc sine percentage. The Data thus obtained were subjected to the statistically analysis of variance following RBD and the efficacy of the insecticides was evaluated at 5 per cent level of significance.

3.5 Evaluation of bio-efficacy of acaricides / botanicals / insecticide under laboratory condition against okra mite

The studies reported in this topic were carried out under laboratory condition in the Division of Entomology, Faculty of Agriculture, Sher e Kashmir University Agricultural Sciences and Technology of Jammu during May 2016. The present experiment was aimed to study the effect of various acaricides/insecticides/botanical pesticides viz., diafenthiuron, fenazaquin, abamectin, propergite, dicofol, dimethoate, pongamia oil, neem oil, *Ocimum* oil against Okra mite in laboratory conditions.

Lay out of experiment and observation

The experiment was conducted in the laboratory to observe individual and overall effect of different acaricides/insecticides/ botanical pesticides at recommended concentration (Table-1) against okra mite (*T. urticae*) on okra leaves in Completely Randomized Design (C.R.D.) with three replications. A water treated control was also maintained in each set of experiment. In each replication of various pesticides

concentration treatments, including control, adult mites (*T. urticae*) were placed on clean and dry treated leaves. The leaves were dipped up to five second in the pesticides solution, to ensure complete wetting and allowed them to dry. The leaves were placed in the petridishes on the moist cotton wool and at the same time the petiole of the treated leaves was covered with moist cotton bud for avoiding the dryness of the treated leaves. The leaves were kept on moist cotton wool for an adequate period. The treated leaves were observed and mortality of mite was recorded after 24, 48, and 72 hrs. All the acaricides/ insecticides/ botanical pesticides were treated through "Leaf Dip Method" (FAO method No. 10a, Busvine, 1980).

The data of mortality of mite population in laboratory experiments were calculated into per cent mortality by using following formula:

$$\text{Per cent mortality} = \frac{\text{Average reduction in population}}{\text{Average pre treatment population}} \text{x}100$$

The per cent mortality data taken on mite population at various intervals were subjected to Angular transformation for further statistical analysis.

Chapter 4

RESULTS

In the present investigation an effort was made to understand the survey on diversity of mite pests on some summer vegetable crops and on ornamentals, incidence of okra mite in relation to abiotic factors on okra, seasonal activity of predatory fauna of okra mite and bio-efficacy of acaricides / botanicals / allelochemicals / insecticides against okra mite. The results obtained are presented under following sub-heads:

4.1 Survey on diversity of mite pest on some vegetable crops and ornamentals in Jammu districts

In the present investigation, 10 different vegetable crops such as okra, brinjal, chilli, tomato, bell pepper, cowpea, French bean, sem, cucumber and round gourd were regularly surveyed in and around main campus and in Marh Block, intensive vegetable growing pockets which was 30 Km away from the Main campus in Jammu district during 2015. Six different types

of phytophagous mite species of one genera were collected from these plants in Jammu districts. Six species of one genera belonging to one phytophagous families viz. Tetranychidae and one predatory families viz. Phytoseiidae was observed (Table 2). Two-spotted spider mite, *Tetranychus urticae* Koch were recorded on Okra, Red vegetable mite, *Tetranychus neoealidonicus* Andre was recorded on brinjal; Yellow mite/Broad mite, *Polyphagotarsonemus latus* Banks were recorded on chilli and bell pepper; Red-legged spider mite, *Tetranychus ludeni* Zacher were observed on Cowpea, French bean and sem; and Spider mite, *Tetranychus macfarlanei* Baker & Pritchard observed on cucumber and round gourd (Plate 3-4).

4.2 Seasonal incidence of okra mite on okra during 2015

The result on the seasonal incidence of okra mite recorded on okra is given below:

The observations on natural infestation of okra mite, *Tetranychus urticae* Koch in the main field of okra crop were recorded at weekly intervals starting from 11th SW to 30th SW during the year 2015. The seasonal incidence of okra mite observed at experimental sites indicated that okra mite, *T. urticae* was found damaging and remain active on the okra crop during the different stages of crop growth. The correlation studies indicated that abiotic factors such as weather parameters played a cumulative role in population build-up of okra mite on okra crop. The pest incidence data of okra mite was correlated with the weather data obtained from Meteorology section SKUAST-Jammu, Chatha (Annexure-I).

During 2015, mean number of okra mite population/ 2.5 cm^2 on okra ranged from 0.47 to 55.53. Infestation was first observed nearly a month after seed sowing *i.e.*, from 11th standard week with an initial population of 0.47 mites per 2.5 cm^2. The mean weekly temperature and relative humidity during the period were recorded to be 16.35°C and 76 per cent, respectively. From there, the population was observed to be increasing gradually till

Table 2: Diversity of mite pest on some vegetable crops, garden plants and ornamentals in Jammu districts

S. No.	Plants surveyed	Common name mite pest	Scientific name*	Status
1.	Okra, *Abelmoschus esculentus*	Two-spotted spider mite	*Tetranychus urticae* Koch	Major
2.	Brinjal, *Solanum melongena*	Red vegetable mite	*Tetranychus, neoealidonicus* Andre	Major
3.	Chilli, *Capsicum annuum*	Yellow mite/Broad mite	*Polyphagotarsonemus latus* Banks	Major
4.	Tomato, *Solanum lycopersicum*	-	-	-
5.	Bell Pepper, *Capsicum annuum*	Yellow mite/Broad mite	*Polyphagotarsonemus latus* Banks	Major
6.	Cowpea, *Vigna unguiculata*	Red-legged spider mite	*Tetranychus ludeni* Zacher	Major
7.	French bean, *Phaseolus vulgaris*	Red-legged spider mite	*T. ludeni* Zacher	Major
8.	Sem, *Dolichus lab-lab*	Red-legged spider mite	*T. ludeni* Zacher	Minor
9.	Cucumber, *Cucumis sativus*	Spider mite	*Tetranychus macfarlanei* Baker & Pritchard	Minor
10.	Round gourd, *Luffa cyclindrica*	Spider mite	*T. macfarlanei* Baker & Pritchard	Minor

*Six mite species including one predatory mite were identified by Prof. R. N. Singh, Acarologist, Institute of Agricultural Sciences, BHU, Varanasi.

Plate - 3 Survey of mite pests on some summer vegetable crops

(A) Chilli mite, *Polyphagotarsonemus latus* Banks

(B) Cucumber leaf covered with web caused by *T. urticae*

(B) Brinjal crop infested with *Tetranychus urticae* Koch

(C) Brinjal leaf infested by *Tetranychus macfarlenei* Baker & Pritchard

Plate - 4 Survey of mite pests on some summer vegetable crops and ornamentals

(A) Okra leaves and tender fruits infested with *T. urticae* Koch

(B) Okra fruits covered with web caused by *T. urticae* Koch

(C) Leaves of round gourd attacked by *Tetranychus macfarlanei* Baker & Pritchard

(D) Bean leaf is attacked by *Tetranychus ludeni* Zacher

18th standard week of May ’15 recording a maximum of 44.13 mean number of mites per 2.5 cm^2 on okra. During this period, the mean temperature and relative humidity in 18th standard week were observed to be 25.55°C and 51 per cent, respectively. After 18th SW, the mites population was observed to be fluctuated due to fluctuation in environmental conditions and again in 25th SW (55.53 mean number of mites population/2.5 cm^2) was observed as the second peak (Table 3). Thus, there were two peaks of okra mite population build-up observed on okra (Fig. 1). The mite population was observed to be declining 0.87 due to continuous rainfall after 25th SW up to 30th SW.

4.2.1 Effect of Abiotic Factors on population build-up of okra mite on okra during 2015

The effect of key weather parameters on the incidence of okra mite was studied using correlation matrix. Table 4 showed the relationship okra mite incidence on okra crop with maximum and minimum temperature, morning and evening relative humidity and rainfall during 2015. The correlation studies showed that the okra mite was highly significant and positively correlated with maximum temperature whereas, negatively correlated with relative humidity (highly significant with morning R.H and significant with evening R.H) and negatively correlated and significant with rainfall (Table 4). The value of multiple linear regression equations for okra mite was calculated to be Y= 160.434–1.545X1+1.607X2–1.635 X3 + 0.062 X4 – 0.038X5. The corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.697 and was found statistically significant at 5% level of significance. The overall impact of weather factors on population build-up of mite was 69.70 per cent which reflects that there were some other factors such as solar radiation, sunshine, rainy days and wind velocity who was responsible to govern the 30.30 per cent role in population build-up of okra mites on okra (table 5).

Table 3: Seasonal incidence of okra mite in relation to abiotic factors during 2015

Standard Meteorological Weeks	Date & month	Mean Mites Population/ 2.5 cm^2	Max. temp. (^{0}C)	Min. temp. (^{0}C)	RH Morn (%)	RH Even (%)	Rainfall (in mm)
11	12-18 March	0.47	22.6	10.1	89	63	107.4
12	19-25	0.93	29.1	13.5	83	47	0.0
13	26-1 Apr	2.2	26.1	15.5	85	67	99.6
14	2-8	5.27	25	15.1	83	58	112
15	9-15	14.47	31.4	16.8	74	46	0.0
16	16-22	25.07	32.1	17.8	77	48	30.0
17	23-29	33.67	35.1	19.2	63	63	0.0
18	30-6 May	44.13	34.3	16.8	67	35	0.0
19	7-13	27.6	37.3	21.5	63	44	9.1
20	14-20	20.53	36.4	21.4	76	34	8.4
21	21-27	17.33	39.7	20.8	59	20	0.0
22	28-3 Jun	34.53	37.2	21.5	59	29	1.8
23	4-10	40.13	37.6	21.6	60	34	0.0
24	11-17	48.47	37.4	22.7	61	37	4.4
25	18-24	55.53	37.7	24.5	65	45	16.3
26	25-1 July	44.4	36.7	23.6	67	48	89.8
27	2-8	26.13	36.5	26	75	55	31.8
28	9-15	11.53	33.5	24	85	64	146.9
29	16-22	6.47	33.5	26.4	83	71	102.6
30	23-29	0.87	34.5	24.9	84	62	126.2

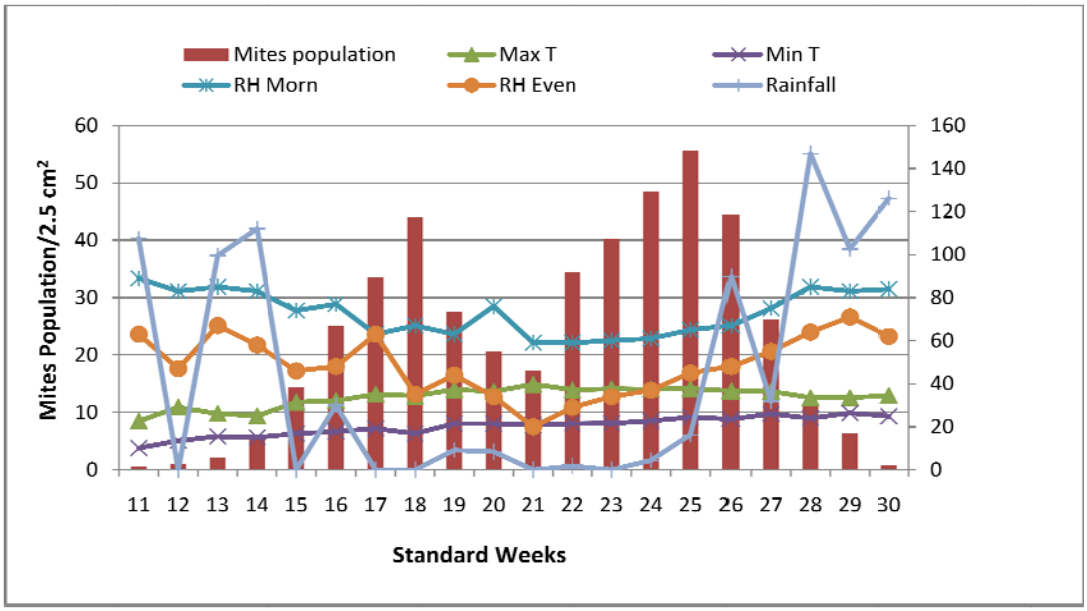

Fig 1: Seasonal incidence of okra mite in relation to abiotic factors

Table 4: Correlation between Seasonal population incidence of okra mite, *Tetranychus urticae* and abiotic factors

Insect pests	Temperature (^{0} C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
Okra mite, *Tetranychus urticae*	0.682**	0.393	-0.815**	-0.527*	-0.556*

**. Significant at the 0.01 level

*. Significant at the 0.05 level

Table 5: Regression equations and co-efficient of multiple determination (R^2) of okra mite in relation to abiotic factors

Regression linear equations of Okra mite	Corelation co-efficient (r)	Co-efficient of determination (R^2)	Co-efficient of Variation (%)
Y=160.434–1.545X1+1.607X2–1.635 X3 + 0.062 X4 – 0.038X5	0.835	0.697	69.70

Where,

Y=Mean No. of Mites Populn./2.5 cm^2
X1= Max Temp.
X2= Min Temp.
X3=RH Morning
X4=RH Evening
X5=Rainfall

4.2.2 Seasonal incidence of predatory mite, *Amblyseius tetranychivorus* (Gupta) in relation to abiotic factors during 2015

The predatory mite population was ranged from 0.67 to 8.67 per leaf during the course of investigation. The initial population of predatory mite was observed during 11th SW (0.67 mite/leaf) and gradually increased up to the 19th SW (5.00 mite/leaf). The mean weekly temperature and relative humidity during the period were recorded to be 29.4°C and 53.5 per cent, respectively. After 19th SW, the predatory mite population was observed to be fluctuated due to fluctuation in environmental conditions and again in 27th SW (8.67 mite/leaf) was observed (Table 6). Thus, there were two peaks of predatory mite population build-up observed on okra crop (Fig. 2). The predatory mite population was observed to be declining with the decline in prey densities and adverse weather factors.

The correlation studies showed that the predatory mite population was positively correlated and highly significant with minimum temperature and significant with maximum temperature, respectively. Although, morning relative humidity and rainfall showed a negative correlation but they were found to be non-significant on predatory mite population (Table 7). The value of multiple linear regression equations for okra mite was calculated to be Y= 3.413–0.044X1+0.272X2–0.086 X3 + 0.051 X4 – 0.003X5. The corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.467 and was found statistically non-significant at 5% level of significance. The overall impact of weather factors on population build-up of mite was 46.70 per cent which reflects that there were some other factors which might play a more pronounced role in population build-up of predatory mites on okra (table 8).

4.2.3 Predatory fauna on okra crop against okra mite during 2015

During the experimentation, Predatory fauna against okra mite was recorded and

Table 6: Seasonal incidence of predatory mite in relation to abiotic factors

Standard Meteorological Weeks	Date & month	Predatory mites /leaf	Max. temp. (^{0}C)	Min. temp. (^{0}C)	RH Morn (%)	RH Even (%)	Rainfall (in mm)
11	12-18 March	0.67	22.6	10.1	89	63	107.4
12	19-25	1.33	29.1	13.5	83	47	0.00
13	26-1 Apr	1.67	26.1	15.5	85	67	99.6
14	2-8	2.00	25	15.1	83	58	112.0
15	9-15	2.67	31.4	16.8	74	46	0.0
16	16-22	3.00	32.1	17.8	77	48	30
17	23-29	3.67	35.1	19.2	63	63	0.00
18	30-6 May	4.67	34.3	16.8	67	35	0.00
19	7-13	5.00	37.3	21.5	63	44	9.1
20	14-20	1.67	36.4	21.4	76	34	8.4
21	21-27	2.33	39.7	20.8	59	20	0.00
22	28-3 Jun	2.67	37.2	21.5	59	29	1.8
23	4-10	3.33	37.6	21.6	60	34	0.00
24	11-17	4.00	37.4	22.7	61	37	4.4
25	18-24	5.67	37.7	24.5	65	45	16.3
26	25-1 July	7.33	36.7	23.6	67	48	89.8
27	2-8	8.67	36.5	26	75	55	31.8
28	9-15	5.33	33.5	24	85	64	146.9
29	16-22	3.67	33.5	26.4	83	71	102.6
30	23-29	1.67	34.5	24.9	84	62	126.2

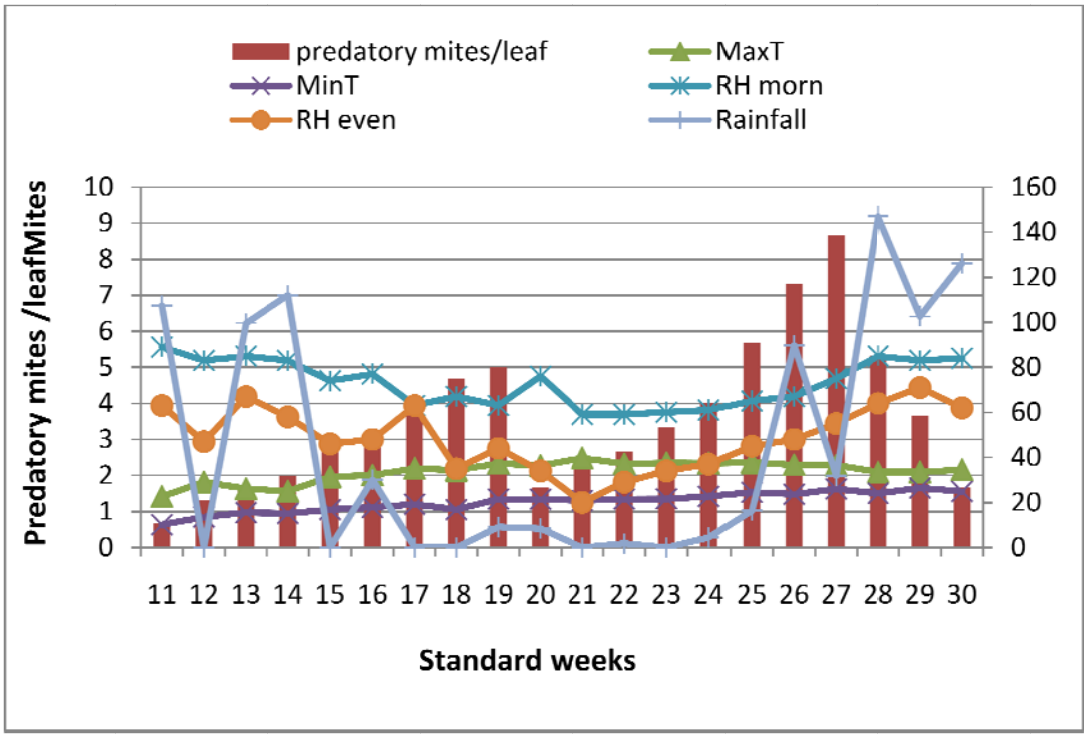

Fig. 2: Seasonal incidence of predatory mites/leaf in relation to abiotic factors

Table 7: Correlation between Seasonal population incidence of predatory mite and abiotic factors

Insect pests	Temperature (^{0} C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
Predatory mite	0.523*	0.628**	-0.339	0.001	-0.056

**. Significant at the 0.01 level

*. Significant at the 0.05 level

Table 8: Regression equations and co-efficient of multiple determination (R^2) of Predatory mite in relation to abiotic factors

Regression linear equations of Okra mite	Corelation co-efficient (r)	Co-efficient of determination (R^2)	Co-efficient of Variation (%)
Y=3.413–0.044X1+0.272X2– 0.086 X3 + 0.051 X4 – 0.003X5	0.683	0.467	46.70

Where,

Y=Mean No. of predatory Mites/leaf
X1= Max Temp.
X2= Min Temp.
X3=RH Morning
X4=RH Evening
X5=Rainfall

their prevalence with phytophagous mite hosts is presented in Table 9. Coccinellids beetles (*Coccinella septempunctata* and *C. sexmaculata*); Small black beetle (*Stethorus* sp.); rove beetle (*Paederus* spp.); Predatory mites, *Amblyseius tetranychivorus* (Gupta); Green lace wing, *Chrysoperla carnea*; Spiders (*Oxyopes* spp. and others); and minute pirate bug (*Orius* spp.) were the dominant predators abundantly found in okra field (Plate 5). Besides the natural enemy fauna, some pollinating bee insects were also observed visiting the flowers for performing the vital pollination services during flowering period in okra.

4.2.4 Predation/ Consumption of okra mites by predatory mite, *A. tetranychivorus* on *T. urticae*

The data recorded on the predation of different stages of tetranychid mite species, *T. urticae* at every twenty four hours. Study revealed that *A. tetranychivorus* (Gupta) prefer the egg stage of of prey than larvae, nymph and adult. Mean consumption rate of *A. tetranychivorus* (Gupta) on *T. urticae* egg was found to be 4.16 ± 0.33 per day per gravid female. Results showed that *A. tetranychivorus* prefers egg as food than other stages of *T. urticae.* Preference of larvae as a food of *A. tetranychivorus* was found to be 1.26 ± 0.23 larvae per day. But in case of nymphal stage (both protonymph and deutonymph equally distributed) *A. tetranychivorus* consumed 0.91 ± 0.27 nymph per day. At adult stage of *T. urticae*, *A. tetranychivorus* consumed 0.84 ± 0.19 adult per day (Table 10). The mean number of consumption of mite per female per day in descending order on different stages of *T. urticae* by *A. tetranychivorus* were found as follows- Eggs (4.16) > larvae (1.26) >Nymphs (0.91) > Adults (0.84).

4.3 Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide against okra mite

Table 9: List of predatory fauna observed on okra mites in Okra crop

Sl. No.	Predators	Family	Order
1.	Lady bird beetle, *Coccinella septumpunctata* L.	Coccinellidae	Coleoptera
2.	*Coccinella sexmaculata* Fab.	Coccinellidae	Coleoptera
3.	Small black beetle, *Stethorus sp*.	Coccinellidae	Coleoptera
4.	Rove beetle, *Paederus* spp.	Staphylinidae	Coleoptera
5.	Predatory mites, *Amblyseius tetranychivorus* (Gupta)	Phytoseiidae	Acari
6.	Green lace wing, *Chrysoperla carnea* (Stephens)	*Chrysopidae*	Neuroptera
7.	Spiders (*Oxyopes* spp. and others)	Salticidae	Araneae
8.	Minute pirate bug, *Orius* spp.	Anthocoridae	Hemiptera

Table 10: Predation of okra mites by predatory mite, *Amblyseius tetranychivorus* (Gupta) on different life stages of *Tetranychus urticae* Koch.

Set No.	No. of predatory Mite / Host mite stage	Mean No. of consumption of mite per female per day			
		Eggs	Larvae	Nymph	Adult
1.	2/10	3.66	1.25	1.00	0.88
2.	4/20	4.66	1.66	1.33	1.16
3.	6/30	4.00	1.33	0.94	0.66
4.	8/40	4.37	1.04	0.62	0.62
5.	10/50	4.13	1.03	0.66	0.90
Average		4.16	1.26	0.91	0.84
SD		0.33	0.23	0.27	0.19

Plate-5

Predatory fauna recorded on Okra crop

(A) Predatory mites, *Amblyseius tetranychivorus* (Gupta)

(B) Small black beetle, *Stethorus sp.* feeding on mite

(C) Nymph of minute pirate bug feeding on mite

(D) *Coccinella septumpunctata* on okra crop

(E) Rove beetle on okra crop

(F) Spider on okra crop

A total of ten (10) treatments, which included nine insecticides/acaricides treatment and one control with water spray were evaluated for their field bio-efficacy against okra mite on okra. The field bio-efficacy of the treatments was determined in terms of per cent reduction of population over control in the adult population of okra mite after 1, 3, 7 and 14 days of application, taking into account three randomly selected plants in each replication.

4.3.1 Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide on okra mite population

First Spray

The pre-treatment population of okra mite ranged from 54.00 to 55.33 per 5 leaves in different plots during 1st spray. However, one day after application of various treatments, Diafenthiuron was the most effective causing 43.64 per cent population reduction which was followed by Fenazaquin (37.64) sprayed plots. Whereas, the plots treated with Propargite and Dicofol, the reduction was 36.64 and 36.45 per cent, respectively. Abamectin applied in plots reduces the mite population by 33.60 per cent whereas, dimethoate caused a population reduction of 28.61 per cent. *Ocimum* oil was the least effective, resulting in only 24.53 per cent reduction (Table 11).

After three days of first spray, the best effect was observed in Abamectin which reduced the mite population by 53.12 per cent. This was followed by the treatment of Diafenthiuron in different plots, causing a reduction of 51.73 per cent. Application of Pongamia oil resulted in 49.39 per cent reduction while in case of Fenazaquin (49.00 per cent reduction); application of propargite resulted in 48.04 per cent reduction whereas, neem oil caused a suppression of 45.93 per cent over control. *Ocimum* oil *was* the least effective, giving a reduction of 36.24 per cent.

Table 11: Evaluation of field bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite during 2015

S. No.	Pesticide(s)	First spray					Second spray				
		1DBS	Percent reduction of mite population				1DBS	Percent reduction of mite population			
			1 DAS	3 DAS	7 DAS	14 DAS		1 DAS	3 DAS	7 DAS	14 DAS
1.	Diafenthiuron 50WP	54.00	47.67 (43.64)	61.67 (51.73)	76.00 (60.67)	86.00 (68.02)	15.00	50.67 (45.36)	60.33 (50.94)	74.33 (59.56)	86.67 (68.59)
2.	Dicofol 18.5EC	55.33	35.33 (36.45)	50.33 (45.17)	64.33 (53.32)	71.00 (57.40)	14.33	83.67 (66.17)	53.00 (46.70)	66.00 (54.32)	74.67 (59.79)
3.	Dimethoate30EC	54.33	23.00 (28.61)	46.33 (42.87)	60.67 (51.15)	69.00 (56.15)	14.33	24.67 (29.74)	46.33 (42.87)	62.33 (52.12)	69.00 (56.15)
4.	Fenazaquin10EC	54.67	37.33 (37.64)	57.00 (49.00)	68.00 (55.54)	75.67 (60.43)	14.33	41.00 (39.79)	55.33 (48.04)	65.00 (53.72)	81.00 (64.17)
5.	Propargite 57EC	54.33	35.67 (36.64)	55.33 (48.04)	65.67 (54.12)	72.00 (58.04)	15.00	34.33 (35.83)	57.67 (49.39)	68.00 (55.55)	77.00 (61.33)
6.	*Ocimum* oil	54.67	17.33 (24.53)	35.00 (36.24)	30.00 (33.16)	20.00 (26.54)	14.33	21.67 (27.68)	38.00 (38.02)	32.00 (34.40)	25.33 (30.17)
7.	Neem oil	55.00	19.67 (26.28)	51.67 (45.93)	41.33 (39.98)	33.00 (35.04)	15.33	21.33 (27.41)	58.33 (49.78)	46.00 (42.68)	38.33 (38.21)
8.	Pongamia oil 2 EC	55.00	21.33 (27.48)	57.67 (49.39)	50.33 (45.17)	37.67 (37.84)	18.67	24.67 (29.70)	55.33 (48.04)	52.33 (46.32)	38.00 (38.02)
9.	Abamectin 18 EC	54.33	30.67 (33.60)	64.00 (53.12)	77.00 (61.34)	86.67 (68.59)	17.67	43.33 (41.14)	69.33 (56.36)	84.00 (66.47)	92.67 (74.64)
10.	Control (water spray)	55.33	0.00	0.00	0.00	0.00	15.67	0.00	0.00	0.00	0.00
SeM ±		**0.035**	**0.323**	**0.197**	**0.796**	**0.233**	**0.165**	**0.423**	**0.239**	**0.280**	**0.575**
CD at 5 %		**N.S.**	**0.977**	**0.596**	**2.406**	**0.703**	**N. S**	**1.281**	**0.722**	**0.848**	**1.739**

Figures in parenthesis angular transformed values

N. S.= Non-Significant; DBS=Days before Spray, DAS=Days after spray

resulted in 54.32 and 53.72 per cent reduction, respectively. Ocimum oil was against the least effective, giving a reduction of only 34.40 per cent. Among the biopesticides pongamia oil gave 46.32 per cent reduction followed by neem oil application resulted in only 42.68 per cent reduction in mites population.

At 14 days after second spray, Abamectin (74.64) was again found to be the best treatment in reducing the mites population on okra followed by Diafenthiuron (68.59 per cent) and Fenazaquin (64.17 per cent). Overall, Abamectin is the most effective treatment after two sprays up to 14^{th} days in reducing the mites population and found to be significantly different from Diafenthiuron and Fenazaquin at 5 per cent level of significance (table 11).

4.3.2 Bio-efficacy of certain acaricides/ botanicals / insecticide against okra mite under Laboratory Condition

Bio-efficacy of some acaricides/ botanicals / insecticide in the laboratory condition consists of nine treatments including one control. The leaves were treated through "Leaf Dip Method" (FAO method No. 10 a, Busvine, 1980) to evaluate bio-efficacy against okra mite. The laboratory bio-efficacy was determined in terms of mean per cent mortality of released mite (30 numbers) on each replication over control. The observation on mortality of okra mite was recorded after 24 hrs., 48 hrs. and 72 hrs. of application in each replication. The treatment was evaluated on the basis of per cent mortality of mites.

All the pesticidal treatments were found significantly superior over the control after 24 hours of application (Table 12). The maximum mortality of mites population (55.39 %) was recorded in diafenthiuron treatment. However, it was at par in fenzaquin treatment which showed 54.04 per cent mortality in targeted pest. Among the other insecticides/botanicals/acaricides tested, *Ocimum* oil was found to be least effective showed

Table 12: Evaluation of bio-efficacy of certain acaricides/ botanicals / insecticide against okra mite under laboratory condition

S. No.	Pesticides	Concentrations	*Mean per cent mortality (hr.)		
			24	48	72
1.	Diafenthiuron 50WP	0.075 %	67.77 (55.39)	55.18 (47.96)	76.67 (61.12)
2.	Dicofol 18.5EC	0.046 %	51.11 (45.61)	43.17 (41.05)	51.85 (46.04)
3.	Dimethoate30EC	0.05%	37.77 (37.90)	46.39 (42.91)	52.22 (46.25)
4.	Fenazaquin10EC	0.02 %	65.55 (54.04)	54.85 (47.77)	61.67 (51.90)
5.	Propargite 57EC	0.142 %	52.22 (46.25)	37.30 (37.60)	48.15 (43.91)
6.	*Ocimum* oil	3 ml/lit.	17.77 (24.90)	20.28 (26.75)	28.18 (32.04)
7.	Neem oil	4 ml/lit.	18.89 (25.73)	24.33 (29.54)	30.52 (33.52)
8.	Pongamia oil 2 EC	2 ml/lit.	22.22 (28.09)	34.30 (35.83)	41.91 (40.31)
9.	Abamectin 1.8 EC	0.6 ml/lit.	62.22 (52.05)	53.03 (46.71)	80.00 (63.40)
10.	Control (water spray)	-	7.77 (16.10)	00.00 (00.00)	00.00 (00.00)
SeM±			**0.76**	**1.04**	**1.60**
CD at 5 %			**2.27**	**3.10**	**4.7**

***Mean of three replication; each replication consist of 30 mites**

Figures in parenthesis are Angular transformation value

24.90 per cent mortality. The order of effectiveness of various treatments based on per cent mortality of adult mites were diafenthiuron (55.39%) > fenazaquin (54.04%) > abamectin (52.05%) > propergite (46.25%) > dicofol (45.61%) > dimethoate (37.90%) > pongamia oil (28.09%) > neem oil (25.73%) > *Ocimum* oil (24.90%) > control (16.10%). Similarly, after 48 hours of treatments, all the treatments were found significantly superior over control. The treatments diafenthiuron, abamectin and fenpyroximate were found to be non-significantly different but significantly superior than rest of the treatments. The next best treatments were dimethoate and dicofol which were observed to be significantly superior to propargite. The order of effectiveness of various treatments on the basis of per cent mortality was as below-

Diafenthiuron (47.96%) > fenazaquin (47.77%) > abamectin (46.71%) > dimethoate (42.91%) > dicofol (41.05%) > propargite (37.60) > pongamia oil (35.83%) > neem oil (29.54%) > *Ocimum* oil (26.75%).

Abamectin showed highest per cent mortality after 72 hours of treatments and found to at par with diafenthiuron but significantly different from fenazaquin. The order of effectiveness of various treatments on the basis of per cent mortality was found to be abamectin (63.40%) > diafenthiuron (61.12%) > fenazaquin (51.90%) > dimethoate (52.22%) > dicofol (46.04%) > propargite (43.91) > pongamia oil (41.91%) > neem oil (30.52%) > *Ocimum* oil (28.18%) (Table 12). Thus, it can be stated that after 72 hours of treatments, abamectin, diafenthiuron, fenazaquin were behaved to be the effective treatments in terms of highest mortality of adult mite population in laboratory condition.

Chapter 5

DISCUSSION

In recent years, the problem of phytophagous mites has attained the major pest status next to borer insect pests during summer months due to excessive use of pesticidal application which resulted into development of resistance and resurgence and control failures. Phytophagous mites are the emerging pest problems and they constitute one of the most destructive groups of arthropod pests affecting a large magnitude of summer vegetable crops. Predatory fauna and diversity of mites on summer vegetable crops of Jammu and Kashmir State is quite fragmentary and poorly documented. Keeping these facts in view, the present investigation was carried out with objectives to study the diversity of mites pests on summer vegetable crops, garden plants and some ornamentals, seasonal incidence of two spotted spider mite, *Tetranychus urticae* Koch and its chief predatory fauna in relation to weather factors and evaluation of bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite on okra crop. Studies on diversity of mites pests, seasonal incidence, natural enemy fauna and bio-efficacy of certain acaricides/ botanicals /

allelochemicals / insecticide against okra mite may become helpful in formulating the Integrated Pest Management strategies against the growing menace of mite pest.

The results obtained in the present study 'Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)' are discussed logically, compared and analyzed in the light of previous work done under the following heads.

5.1 **Survey on diversity of mite pest on some vegetable crops and ornamentals in Jammu districts**

In the present study, out of 10 different vegetable crops such as okra, brinjal, chilli, tomato, bell pepper, cowpea, French bean, sem, cucumber and round gourd were surveyed for phytpphagous mites. Six species of one genera belonging to one phytophagous families *viz*., Tetranychidae and one predatory families *viz*., Phytoseiidae was observed. *Tetranychus urticae* were recorded on okra, *T. neoealidonicus* was recorded on brinjal; *Polyphagotarsonemus latus* were recorded on chilli and bell pepper; *T. ludeni* were observed on cowpea, French bean and sem; and *T. macfarlanei* observed on cucumber and round gourd.

The present findings are in conformity with the results obtained by Rai and Inderajeet (2011) who reported that *T. urticae*, *T. ludeni*, *T. neocaledonicus* Andre and *T. macfarlanei* Baker and Pritchard infesting many vegetables like okra, brinjal, cowpea, chilli, pumpkin, bitter gourd, cucumber, bottle gourd, sponge gourd, tomato, watermelon etc. in two district of eastern Uttar Pradesh. Similar findings are also observed by Dhooria, 2009a; Dhooria, 2009b who reported *Tetranychus urticae* on rose in polyhouse and showed that *Tetranychus cinnabarinus* (Boisd.) and *Eutetranychus orientalis* (Klein) were reported as serious pests on ornamental crops from Punjab.

5.2 Seasonal incidence of okra mite on okra

The seasonal incidence of okra mite observed at experimental sites indicated that okra mite, *T. urticae* was found damaging and remain active on the okra crop and attained two peaks i.e., in 18^{th} standard week (44.13 mean number of mites per 2.5 cm^2) and in in 25^{th} SW (55.53 mean number of mites population/2.5 cm^2), respectively.

The seasonal incidence of tetranychid mites varies with the species, climate and the host plant. It is evident from the data recorded that mites are affected by maximum temperature and relative humidity. The increase in temperature coupled with decrease in relative humidity from March 2015 to June 2015 favoured the increase of *T. urticae* Koch. The Peak population of spider mites in May-June was in accordance with results of Puttaswamy (1978), Gupta and Gupta (1985), Pande and Sharma (1985), Mishra *et al*. (1990) and Kapoor *et al*. (1997). Spider mite incidence was very less probably due to heavy splash of rainfall.

The severe occurrence of two spider mite population in May to mid June is in close conformity with results of Pande and Yadava (1975) and Gupta and Gupta (1985) who also reported that the occurrence of *T. cinnabarinus* was severe from May to middle of July in West Bengal. It may be due to variations in temperature, relative humidity and rainfall during the congenial period of crop growth. The present findings are in close conformity with that of Prasad and Singh (2003) who reported that the mite population started building up on the crop from the second fortnight of March and continued until the first fortnight of July.

5.2.1 Effect of Abiotic Factors on population build-up of okra mite on okra

Among the abiotic factors, the climatic factors such as temperature, relative humidity, rainfall, play an important role in reproduction, development and survival of the insect pests. Weather parameters had greater influence on fluctuation of mite population. The correlation studies showed that the highly significant and positively correlated with maximum temperature had existed with okra mite whereas, negatively correlated with relative humidity (highly significant with morning R.H and significant with evening R. H) and negatively correlated and significant with rainfall.

The present findings are in conformity with Puttaswamy (1978) and Kumar *et al.* (2003) who observed that the mite population showed a non-significant positive correlation with relative humidity and weekly rainfall in French marigold. The present findings are in agreement with that of Prasad and Singh (2003) who observed a significant positive correlation between mite population and temperatures.

On the contrary, Roopa (2005) reported positive correlation of maximum temperature and negative correlation of other parameters *viz*., minimum temperature, relative humidity (morning and evening) and rainfall with mite population, which were not significant on other brinjal mite, *T. macfarlanei* population.

Among the weather factors, maximum temperature was positively correlated while, relative humidity was negatively correlated and significant which was in conformity with Sanap *et al*. (1985), Borah (1987) and Lingeri *et al*. (1998) who reported that higher temperature and lower relative humidity played an important role in development and population build up of mite. Thus, it may be inferred that higher temperature and relative humidity at 0700 hrs are congenial weather parameters for increase in mite population.

5.2.2 Seasonal incidence of predatory mite, *Amblyseius tetranychivorus* (Gupta) in relation to abiotic factors

One predatory mite family viz. Phytoseiidae predatory mite population build-up observed on okra crop had two peaks viz., in 19th SW (5.00 mite/leaf) and again in 27th SW (8.67 mite/leaf). Predatory mite population was positively correlated and highly significant with minimum temperature and significant with maximum temperature, respectively.

In vegetables, eight species of predatory mites were recorded on cucumber and were associated with *T. urticae*, *T. ludeni* and whitefly. Earlier, *Amblyseius largoensis*, *A. herbicolus* and *Euseius finlandicus* were reported on pointed gourd and cowpea associated with *Polyphagotarsonemus latus* (Banks), *T. urticae* and *Panonychus citri* (McGregor) (Karmakar and Gupta, 2011).

5.2.3 Predatory fauna on okra crop against okra mite

Coccinellids beetles (*Coccinella septempunctata* and *C. sexmaculata*); Small black beetle, *Stethorus sp.;* rove beetle (*Paederus* spp.); Predatory mites, *Amblyseius tetranychivorus* (Gupta); Green lace wing, *Chrysoperla carnea*; Spiders (*Oxyopes* spp. and others); and minute pirate bug (*Orius* spp.) were the dominant predatory insects abundantly found in okra field.

Earlier workers reported the importance of phytoseiids as effective predators of plant feeding mites all over the world in many diverse crop ecosystem (Jeppson *et al*., 1975 and Huffaker *et al*., 1969). In India, 29 species have been reported as predaceous on plant mites (Gupta, 1991). On tetranychid mites, four insect predators and two predatory mites were recorded in different places. The staphylinid predator, *Oligota* sp. fed on all stages of tetranychids. The beetle was feeding on tetranychid mites as reported by Manjunath (1982) and Roopa (2005). A predatory thrips, *Scolothrips rhagebianus* was found to feed on all stages of tetranychid mites. *S. sexmaculatus* was found to feed on tetranychids as reported by Puttaswamy and Channabasavanna (1981) and Roopa (2005).

On contrary, Roopa (2005) recorded *A. longispinosus, A. indicus* and *Phytoseius* sp. in brinjal ecosystem. The present study may help to understand the severity of mite infestation and relative abundance of species composition of natural enemies. The relative importance of these bio control agents to be studied in depth and also their susceptibility to the commonly used pesticides in formulating and planning a viable integrated management strategy against the mites (Roopa, 2005).

5.2.4 Predation/ Consumption of okra mites by predatory mite

Predation study revealed that *A. tetranychivorus* (Gupta) prefer the egg stage of prey than larvae, nymph and adult. Mean consumption rate of *A. tetranychivorus* (Gupta) on *T. urticae* egg was found to be 4.16 ± 0.33 per day per gravid female.

Similar results were obtained by Takafuji and Chant (1976) studied the predating potentialities of *P. persimilis* against pacific spider mite. During experiment calculated the percentage of eaten each stage and reported the *P. persimilis* consumed more of the eggs. In the present study the results same and showed the higher rate of consumption of eggs. Puttaswamy and Channa Basavanna (1979) has also observed that ovipositing female of *A. tetranychivorus* feed 3.98 eggs and 1.45 nymphs of *T. ludeni*.

5.3 Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide against okra mite

After 14^{th} days of 1^{st} spray, Abamectin was found to be the best treatment in reducing the mites population (74.64 per cent) on okra followed by Diafenthiuron (68.02 per cent) and Fenazaquin (60.43. per cent). Among the biopesticides, pongamia oil gave 46.32 per cent reduction followed by neem oil application resulted in only 42.68 per cent reduction in mites population at 7 days after second spray. Overall, Abamectin is the most effective treatment after two sprays up to 14^{th} days in reducing the mites population and found to be significantly different from Diafenthiuron and Fenazaquin at 5 per cent level of significance.

Dicofol 0.05 per cent proved to be the most effective in causing 70 per cent maximum reduction of mites in okra and brinjal both under field and pot culture conditions in the finding of Ramaraju (2004). Whereas, Akashe *et al.* (2006) reported abamectin 0.0025 per cent as most effective in checking *T. urticae* population on rose and Singh *et al.* (2006) reported that dimethoate 0.06 per cent was found best against *T. urticae* on rose. However, Singh and Choudhary (2008) showed that abamectin 1.9 EC was most effective on okra in mite population reduction and propargite 0.05 per cent stood next to this treatment. In other findings, diafenthiuron at different formulations recorded the highest reduction of *T. urticae* population (Bhaskaran *et al.,* 2007 and Patel *et al.,* 2009).

Present finding is in conformity with Kulkarni *et al.,* (2008) have reported that abemectin 1.9SC at the rate of 0.30ml/l proved very effective against grape mite. Sreenivas *et al*., (2008) observed significantly lower number of *Tetranychus* mite per leaf in okra at seven and ten days after treatment observation. Singh and Choudhary (2008) registered 84.67 per cent reduction of red spider mite population in okra with the application propargite 57EC at the rate of 1500ml per ha whereas, Tomar and Singh (2011) who reported that propargite 57EC was most effective in reducing the mite incidence in Brinjal.

The present study was comparable with Tomar and Singh (2011). They observed that application of propargite 57% EC @ 1000ml/ha and fenpyroximate 5%EC @500ml/ha was significantly more effective in reducing *T. urticae* population to 1.6 to 1.8 mites/4cm^2 leaf area compared to 8.8 mites/4cm^2 leaf area in untreated control 15 days after application on brinjal, which could increase the fruit yield significantly (>80q/acre *vs* 64q in control). Chinniah (2013) also reported that spiromesifen 240SC @0.7ml/lit., abamectin 1.8%EC @ 0.5ml/lit., propargite 57% EC @3ml/lit and fenpyroximate 5%EC @ 0.8ml/ lit. were equally effective in suppressing spider mite population.

The effectiveness of abamectin and difenthiuron in reducing tetranychid mite population on different crop ecosystem was reported by Karmate and Chandele (1997), Anand kumar (2002), Mani *et al*. (2003), Walunj *et al*. (2003) and Roopa (2005). Other acaricides *viz*., fenazaquin and propargite also found effective and present findings are in agreement with Anand kumar (2002), Singh *et al*. (2004) and Roopa (2005).

Bio-efficacy of some acaricides/ botanicals / insecticide in the laboratory condition through Leaf Dip Method revealed that that after 72 hours of treatments, abamectin (63.40%), diafenthiuron (61.12%), fenazaquin (51.90%) were behaved to be the effective treatments in terms of highest mortality of adult mite population.

The present findings of the laboratory experiments was in conformity with the finding of Akashe *et al.* (2006) who reported that abamectin at 0.0005 per cent showed comparatively higher persistency than other acarcides against *T. urticae* on rose and Shah and Shukla (2014) who demonstrated that Diafenthiuron 50WP was most effective (68.79% reduction) and was at par with other treatments *viz.*, fenpyroximate 5% EC, buprofezin 25%EC, abamectin 1.9%EC and fenazaquin 10% against *Tetranychus urticae* infesting gerbera under polyhouse conditions.

Chapter 6

SUMMARY AND CONCLUSION

The thesis embodies the results of present investigation made on “Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)” carried out during cropping season of 2015. The broad objectives of present studies were as follows:

1. Survey on diversity of mite pest on some vegetable crops in Jammu districts
2. To study the seasonal incidence of okra mite and its predatory fauna in relation to abiotic factors
3. To evaluate the field and laboratory bio-efficacy of acaricides / botanicals / allelochemicals / insecticide against okra mite

Experimentation for management of management of okra mite on okra was conducted at Chatha farm, SKUAST- Jammu from February 2015 till July 2015 up to the harvest of crop.

6.1 Diversity of mite pest on some vegetable crops and ornamentals in Jammu districts

In order to visualize the phytophagous mites problem associated with summer vegetables, garden plants and some ornamentals, fortnightly surveys were conducted to record the occurrence of mites and their natural enemies on respective crops in Jammu district during 2015. In the present study, six species of phytophagous mites were recorded on 10 different crop. Out of these, Two-spotted spider mite, *Tetranychus urticae* Koch were recorded on okra; Red vegetable mite, *Tetranychus, neoealidonicus* Andre was recorded on brinjal; Yellow mite/Broad mite, *Polyphagotarsonemus latus* Banks were recorded on chilli and bell pepper; Red-legged spider mite, *Tetranychus ludeni* Zacher were observed on Cowpea, French bean and sem; Spider mite, *Tetranychus macfarlanei* Baker & Pritchard observed on cucumber, round gourd was recorded.

6.2 Seasonal incidence of okra mite on okra

Infestation of *T. urticae* was first observed nearly a month after seed sowing *i.e*., from 11th standard week with an initial population of 0.47 mites per 2.5 cm^2. From there, the population was observed to be increasing gradually till 18th standard week of May ’15 recording a maximum of 44.13 mean number of mites per 2.5 cm^2 on okra. After 18th SW, the mites population was observed to be fluctuated due to fluctuation in environmental conditions and again in 25th SW (55.53 mean number of mites population/2.5 cm^2) was observed as the second peak. Thus, there were two peaks of okra mite population build-up observed on okra crop.

6.2.1 Effect of Abiotic Factors on population build-up of okra mite on okra

The correlation studies showed that the okra mite was highly significant and positively correlated with maximum temperature whereas, negatively correlated with

relative humidity (highly significant with morning R.H and significant with evening R.H) and negatively correlated and significant with rainfall. The corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.697 and was found statistically significant at 5% level of significance. The overall impact of weather factors on population build-up of mite was 69.70 per cent which reflects that there were some other factors such as solar radiation, sunshine, rainy days and wind velocity who was responsible to govern the 30.30 per cent role in population build-up of okra mites on okra

6.2.2 Seasonal incidence of predatory mite, *Amblyseius tetranychivorus* (Gupta) in relation to abiotic factors

Predatory mite population build-up observed on okra crop had two peaks viz., in 19th SW (5.00 mite/leaf) and again in 27th SW (8.67 mite/leaf). Predatory mite population was positively correlated and highly significant with minimum temperature and significant with maximum temperature, respectively. The correlation studies showed that the predatory mite population was positively correlated and highly significant with minimum temperature and significant with maximum temperature, respectively. Although, morning relative humidity and rainfall showed a negative correlation but they were found to be non-significant on predatory mite population.

6.2.3 Predatory fauna on okra crop against okra mite

Eight predatory fauna such as Coccinellids beetles (*Coccinella septempunctata* and *C. sexmaculata*); Small black beetle, *Stethorus sp.;* rove beetle (*Paederus* spp.); Predatory mites, *Amblyseius tetranychivorus* (Gupta); Green lace wing, *Chrysoperla carnea*; Spiders (*Oxyopes* spp. and others); and minute pirate bug (*Orius* spp.) were the dominant predatory fauna recorded against *T. urticae* on okra.

6.2.4 Predation/ Consumption of okra mites by predatory mite

Predation study showed that *A. tetranychivorus* (Gupta) prefer the egg stage of prey than larvae, nymph and adult. Mean consumption rate of *A. tetranychivorus* (Gupta) on *T. urticae* egg was found to be 4.16 ± 0.33 per day per gravid female. Preference of larvae, nymphs and adults as a food of *A. tetranychivorus* were 1.26 ± 0.23 larvae per day, 0.91 ± 0.27 nymph per day and 0.84 ± 0.19 adult per day, respectively.

6.3 Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide against okra mite

The pre-treatment population of okra mite ranged from 54.00 to 55.33 per 5 leaves in different plots during 1st spray. However, one day after application of various treatments, Diafenthiuron was the most effective causing 43.64 per cent population reduction which was followed by Fenazaquin (37.64) sprayed plots. After three days of first spray, the best effect was observed in Abamectin which reduced the mite population by 53.12 per cent. This was followed by the treatment of Diafenthiuron in different plots, causing a reduction of 51.73 per cent. Application of Pongamia oil resulted in 49.39 per cent reduction. After seventh days after 1st spray, the maximum reduction of mite population was observed in the application of Abamectin (61.34 %). This was followed by application of Diafenthiuron in various plots (60.67 %), Fenazaquin (55.54 %), Propargite (54.12 %) and dicofol (53.32 %). After 14th days of 1st spray, Abamectin was found to be the best treatment in reducing the mites population on okra followed by Diafenthiuron (68.02 per cent) and Fenazaquin (60.43. per cent).

One day after the second spray the highest population reduction was observed in dicofol treated plots, which caused a reduction of 66.17 per cent, followed by Diafenthiuron which resulted in 45.36 per cent reduction over control. Third day after second spray, abamectin was the most effective insecticide, causing 56.36 per cent reduction, followed by

Diafenthiuron with 50.94 per cent, propargite with 49.39 per cent, neem oil (49.78 %). At 7 days after second spray, the maximum population reduction of mites was achieved due to abamectin treatment (66.47%), followed by Diafenthiuron (59.56 %). At 14 days after second spray, Abamectin (74.64) was again found to be the best treatment in reducing the mites population on okra followed by Diafenthiuron (68.59 per cent) and Fenazaquin (64.17 per cent).

Overall, Abamectin is the most effective treatment after two sprays up to 14^{th} days in reducing the mites population and found to be significantly different from Diafenthiuron and Fenazaquin at 5 per cent level of significance

6.3.1 Bio-efficacy of certain acaricides/ botanicals / allelochemicals / insecticide against okra mite in laboratory condition

Bio-efficacy of some acaricides/ botanicals / insecticide in the laboratory condition through Leaf Dip Method revealed that that after 72 hours of treatments, abamectin (63.40%), diafenthiuron (61.12%), fenazaquin (51.90%) were behaved to be the effective treatments in terms of highest mortality of adult mite population.

The conclusion drawn during present investigation is summarized below:

- Okra is an extensively grown vegetable crops in and around Jammu district which harbours a large magnitude of insect pests. Among several insect- pests, phytophagous mites are the emerging pest problems causing a significant economic loss to the okra crop.
- Predatory fauna of mite pests were equally abundant in okra ecosystem and maintained the natural balance by devouring the mite population. Predatory insects like *Amblyseius tetranychivorus* (Gupta) and coccinellid beetles were the dominantly found in the okra crop for suppressing the mite pest population.

- Predation study revealed that *A. tetranychivorus* (Gupta) prefer the egg stage of prey than larvae, nymph and adult. Mean consumption rate of *A. tetranychivorus* (Gupta) on *T. urticae* egg was found to be 4.16 ± 0.33 per day per gravid female.
- Evaluation of certain acaricides/ botanicals / allelochemicals / insecticide for bio-efficacy against okra mites revealed that after two sprays, Abamectin was found to be the best treatment in reducing the mites population (74.64 per cent) on okra followed by Diafenthiuron (68.02 per cent) and Fenazaquin (60.43. per cent).
- Bio-efficacy in laboratory experiment showed that that after 72 hours of treatments, abamectin (63.40%), diafenthiuron (61.12%), fenazaquin (51.90%) were behaved to be the effective treatments in terms of highest mortality of adult mite population.

REFRENCES

Abdel-Wali, M., Mustafa, T. and Al-Lala, M. 2012. Residual toxicity of abamectin, milbemectin and chlorfenapyr to different populations of two-spotted spider mite, *Tetranychus urticae* Koch, (Acari: Tetranychidae) on cucumber in Jordan. *World Journal of Agriculture Sciences*, 8(2): 174-178.

Akbar, S. and Aheer, G. M. 1994. Mite fauna of summer vegetables in Punjab. *Pakistan Journal of Zoology*, **26**: 339- 345.

Alatawi, F. J., Opit, G. P., Margolies, D. C. and Nechols, J. R.2005. Within-plant distribution of two-spotted spider mites (Acari: Tetranychidae) on Impatiens: Development of a presence–absence sampling plan. *Journal of Economic Entomology*, **98**(3):1040–1047.

Ambikadevi, D. and Samarjit, R. 1997. Chemical control of red spider mite, *Tetranychus cinnabarinus* (Boisduval) on okra. *Journal of Tropical Agriculture*, **35**: 38–40.

Anand Kumar, V. 2002, Survey and management of brinjal pests with special reference to biology of *Leucinodes orbonalis* Guen. M. Sc. Thesis, University of Agriculture Science, Dharwad (India).

Anonymous. 1996. Estimation of crop losses due to mites. AICRP on Agricultural Acarology, Progress Report, 6-31pp.

Anonymous, 2003. Progress Report (2000-03). AINP on Agricultural Acarology, *University of* Agricultural *Sciences,* Bangalore. p. 52-56.

Anonymous. 2013. State of Indian Agriculture 2012-13. Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Economics and Statistics, New Delhi.

Anonymous. 2013a. Indian Horticulture Database, National Horticulture Board. www.nhb.gov.in/.

Anonymous. 2014. Area and Production Report, National Horticulture Board, Ministry of Agriculture, Government of India, New Delhi-110 012.

Baker, J. E. and Connell, W.A. 1961.Mites on soybean in Deaware. *Journal of Economic Entomology*, **54**: 1024-1026.

Banerjee, H., Chowdhury, A. G., Banerjee, D., Paramasivam, M., Banerjee, T. and Roy, S. 2009. Propargite residues in okra and brinjal fruits. *Journal of Crop and Weed*, **5**(2): 110-112.

Belmans, K. 1994. Biological control of mites on cherry and plum. *Fruitteelt-Nieuws*, 7(4): 10-11.

Bindra, O. S. and Singh, G. 1970. Mite pests of ornamental plants in India. *Pesticides*, 6:17-24.

Bonde, J. 1989. Biological studies including population growth parameters of the predatory mite, *Amblyseius barkeri* (Acari: Phytoseiidae) at 25°C in the laboratory. *Entomophaga*, **34**: 275–287.

Busvine, J. R. 1980. Recommended methods for measurement of pest resistance to pesticides. FAO, *Plant production and Protection*, **21**: 1-132.

Butani, P. G. and Mittal, V. P. 1992. Chemical control of red spider mite (*Tetranychus cinnabarinus* Boisduval) infesting brinjal. *In*: Man, Mites and Environment, Haq, H. A. and Ramani, N. (Eds.), pp. 1-4.

ChannaBasavanna, G. P. 1966. A contribution to the knowledge of Indian eriophyid mites (Eriophyoidea:Trombidiformes:Acarina). University Agriculture Science Hebbal, Bangalore: 1-154.

ChannaBasavanna, G. P. 1971. The present status of our knowledge of Indian.Plant feeding mites. Proceedings of 3rd International Congress of Acarology, Prague: 201-204.

Clotuche, G., Mailleux, A. C., Astudillo, Fernandez, A., Deneubourg, J. L., Detrain C. and Hance, T. 2011. The formation of collective silk balls in the spider mite *Tetranychus urticae* Koch. *PLoS ONE*, **6**(4):e18854.

Devine, G. J., Barber, M. and Denholm, P. S. 2001. Incidence and inheritance of resistance to acaricides in European strains of the two-spotted spider mite (*Tetranychus urticae*) (Acari: Tetranychidae). *Pest Management in Agricultural Science*, **57**: 443-448.

Ehara, S. 1956. Tetranychoid mites of mulberry in Japan. *Journal of the faculty of Science*. Hokkaido University, Series 6, Zoology, **12**: 499–510.

Farouk, S. and Osman, M. A. 2011. The effect of plant defense elicitors on common bean (*Phaseolus vulgaris* L.) growth and yield in absence or presence of spider mite (*Tetranychus urticae* Koch) infestation. *Journal of Stress Physiology and Biochemestry*, **7**(3): 6-22.

Gerson, V. and Aronowitz, A. 1980.Feeding of the carmine spider mite on seven host plant species. *Entomologia Experimentalis et Applicata,* **28** : 109-115.

Ghai J. K. and Bhullar M. B. 2003. Population dynamics of mites infesting okra (*Hibiscus esculentus*) in Punjab during the period 2000-01. *Annals of Agricultural and Biological Research,* **8**: 69-71.

Goff, M. L. 1986. Spider mites (Acari:Tetranychidae) in the Hawaiian Islands. *International Journal of Acarology*, **12**: 43-49.

Grandjean, F. 1948. Sur les Hydrozetes (Acariens) de l'Europeoccidentale. - *Bull. Mus. Nat. Rist. Natur*. **20** : 328-335.

Guo, F., Zhang, Z. and Zhao, Z. 1998. Pesticide resistance of *Tetranychus cinnabarinus* (Acari: Tetranychidae) in China: a review. *Systematic and Applied Acarology*, **3**: 3-7.

Gupta, S. K. 1985. Handbook on Plant mite of India. Zoological Survey of India, Kolkata. 520 pp.

Gupta, S. K. 1987. Some new species and records of Phytoseiidae (Acari: Mesostigmata) from North East India. *Oriental Insect*, **21**: 111–128.

Gupta, S. K. 1991. Annual Report. All India Coordinated Research Project on Agricultural Acarology, ICAR. 256 p.

Gupta S. K. 2010. Acari - their importance and status in India and highlights of gaps in knowledge. *International Symposium-cum-Workshop in Acarology*. BCKV, Kalyani, West Bengal, pp. 22–25.

Gupta, S. K. and Nahar, S. C. 1981. Plant mites (Acari) of agricultural importance in Bihar. pp. 6–11. *In*: ChannaBasavanna, G. P. (Ed.). Contribution to Acarology in India, Acarological Society of India, University of Agricultural Sciences, Banglore, pp 6-11.

Gupta, V. N. and Gupta, S. K. 1985. Mites associated with vegetable crops in West Bengal. *Indian Journal of Acarology*, **10:**61–64.

Halder, J., Kodandaram, M. H., Rai, A. B. and Kumar, R. 2016. Impact of different pest management modules against the major sucking pests complex of chilli (*Capsicum annuum*). *Indian Journal of Agricultural Sciences*, **86** (6): 792–795.

Hazan A., Gerson V. and Tahori, A. S. 1974.Spider mite webbing. The production of webbing under various environmental conditions. *Acarologia*, **16**: 68–84.

Ho, C. C., Lo, C. C. and Chen, W. H. 1997. Spider mite (Acari:Tetranychidae) on various crops in Taiwan. *Journal of Agricultural Research of China*,**46**: 333–346.

James, D. G. and Price, T. S. 2002. Fecundity in two-spotted spider mite (Acari: Tetranychidae) increased by direct and systemic exposure to imidacloprid. *Journal of Economic Entomology*, **95**(4): 729–732.

Jeppson, L. R., Keifer, H. H. and Baker, E. W. 1975.Mites injurious to economic plants. Berkeley: University of California Press,U.S.A. 614 pp.

Jhansi Rani, B. and Sridhar, V. 2002. Efficacy of new formulations of dicofol and sulphur against two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) on rose in polyhouse. *Pestology*, 26: 37–38.

Johnson, W. T. and Layon, H. H. 1991.Insects that feed on trees and shrubs. Comstock Publishing and Cornell University press, Ithaca, New York. 416 pp.

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 (ChannaBasavanna, G. P. and Viraktamath, C.A. *Eds*.). Oxford and IBH publication Co. Pvt. Ltd., New Delhi.Vol. **2**: 23–28.

Kapoor, V. C., Paul, M. and Kapur, J. 1997. Seasonal incidence of mite species infesting okra (*Hibiscus esculentus*) and brinjal (*Solanum melongena*) in Punjab. *Indian Journal of Agriculture Sciences*, **67**(7): 325–326.

Karabhantanal, S. S., Udikeri, S. S., Vastrad, S. M., and Wali, S. Y. 2012. Bio efficacy of different acaricides against red spider mite, *Tetranychus urticae*on grapes. *Pest Management in Horticultural Ecosystems*, **18**(1): 94–97.

Kavya, M. K., Srinivasa, N., Ravi, G. B. and Vidyashree, A. S. 2015. Relative toxicity of selected acaricides on two spotted spider mite (*Tetranychus urticae*) of brinjal. *The Bioscan*,**10**(2): 605–608.

Krishnamoorthy, A. 1982. Mass rearing technique for an indigenous predatory mite *Amblyseius* (Tryphlodromins) *tetranychivorus* (Gupta) (Acarina:Phytoseiidae). *Entomon*, **7**: 47–49.

Kumar, D., Raghuraman, M. and Singh, J. 2015. Population dynamics of spider mite, *Tetranychus urticae*Koch on okra in relation to abiotic factors of Varanasi region. *Journal of Agrometeorology*, **17**(1):102-106.

Kumar, P. L., Dunkan, G. H., Roberts, I. M., Jones, A. T. and Reddy, D. V. R. 2002. Cytopathology of pigeonpea sterility mosaic virus in pigeonpea and *Nicotiana benthamiana*: similarities with those of eriophyid mite-borne agents of unidentified etiology. *Annals of Applied Biology,* **140**: 87-96.

Kumar, S., Prasad, S. and Singh, R. N.2003. Population trends of two-spotted spider mite (*Tetranychus urticae*) in relation to abiotic factors on French marigold (*Tagetes patula*). *Indian Journal of Agricultural Sciences*, **73**(5): 303-304.

Lall, B. S. and Dutta, C. P. 1959. On the biology of the red spider mite, *Tetranychus telarius* L. *Science and Culture,***25**: 204-205.

Livshits, I. Z. and Mitrofanov, V. I. 1981. Beneficial insects and mites in fruit orchards. *Zashchita Rastenii*, **6**: 49-52.

Mahajan, S. 2002. Studies on toxicity of some chemicals to European red mite, *Panonychus ulmi* (Koch) infesting apple. Ph.D. Thesis, Department of Entomology and Apiculture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, India.

Mandal, S. K., Sattar, A. And Banerjee, S. 2006. Impact of meteorlogical parameters on population build up of red spider mite in okra, *Abelmoschus esculentus* L. under North Bhiar condition. *Journal of Agriculture Physics*, 6(1): 35-38.

Mani, C., Kumar, S. and Singh, R. N. 2003.Efficacy of acaricides and botanicals against two spotted mite, *Tetranychus urticae* Koch on okra. *Anals of Plant Protection Science*, **11**(1):153-154.

Mathur, S., Putatunda, B. N. and Mathur, R. B. 1994. Mites associated with some fruit trees in Hisar, Haryana. Abstract V Natural Symposium of Acarology, Bangalore, p. 13–14.

Meyer, S. M. K. P. 1996. On some spider mites (Acari: Tetranychidae) of Yemen. *Fauna of Saudi Arabia*, **15**: 5-19.

Meyer, S. M. K. P. and Craemer, C. 1999. Mites (Arachnida: Acari) as crop pests in southern Africa: an overview. *African Plant Protection,* **5**(1): 37-51.

Mitchell, R. 1973. Growth and population dynamics of a spider mite (*Tetranychus urticae* K., Acarina: Tetranychidae). *Ecology*, **54**:1349-1355.

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 Ecosystems*, 20(1): 47-49.

Nayar, K. K., Annthakrishnan, T. N. and David, B. V. 1976. General and Applied Entomology. Tata McGraw Hill Publ. Co. Ltd., New Delhi, pp. 489.

Patil, D. L., Patel, K. A., Toke, N. R. and Ambule, A. T. 2014. Bio-efficacy of acaricides against two spotted spider mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) infesting Carnation (*cv*. Beaumonde) under protected cultivation. *International Journal of Plant Protection*, **7**(2): 429-432.

Patil, R. S. and Nandihalli, B. S. 2009. Seasonal incidence of mite pests on brinjal and chilli. *Karnataka Journal of Agriculture Sciences,* **22**: 729-731.

Peal, S. E. 1868. Letter for forwarding specimens and drawing of 'Red Spider'. *Journal of Agriculture and Horticulture Society*, India 1: 69.

Peter, C. and David, B.V. 1988. Evaluation of some insecticides for the control of major insect pests of okra and their side effects. *Tropical Pest Management***, 34**: 76-80.

Prasad, R. 2007. Mite pest fauna of okra and their management. *Uttar Pradesh Journal of Zoology*, **27** (3): 319-323.

Prasad, R. and Singh, J. 2007. Estimation of yield loss in okra caused by red spider mite (*Tetranychus urticae* Koch) under the influence of two dates of sowing. *Journal of Entomology*, **69**(2): 127-132.

Prasad, R. and Singh, J. 2011. Status of mite pest fauna prevailing in brinjal agro-ecosystem, *Uttar Pradesh Journal of Zoology*, **31**: 15–23.

Prasad, R., Prasad, U. K., Sathi, S. K. and Prasad, D. 2007. Mite pest scenario and their status associated with common vegetables. *Indian Journal of Current Science,* **10** (1): 269-274.

Prasanna, K. P. and Prasad, K. 2008. Survey of Tetranychid Mites and their Natural Enemies on Brinjal in Northern Karnataka. *Karnataka Journal of Agricultural Sciences,* **21**(3): 448-449.

Pushpa, V. and Nandihalli, B. S. 2008. Bio-efficacy of chemicals in the management of coconut eriophyid mite, *Aceria guerreronis* Keifer. *Journal of Plant Protection Environment*, **5**(1):85–89.

Puttaswamy, M. 1978. Studies on the ecology of *Tetranychus ludeni* Zacher (Acari:Tetranychidae) and its interaction with predator, *Typhlodromipus*

tetranychivorus Gupta (Acari : Phytoseiidae). Ph. D. Thesis, University of Agriculture Science, Bangalore (India).

Puttaswamy, M. and ChannaBasavanna, G. P. 1981. Influence of host plants on reproductive biology of *T. neocaledonicus* (Acari :Tetranychidae). *Indian Journal of Acaroogy*, **6**: 72–76.

Rai, A. B., Vora, V. T. and Patel, C. V. 1995. Investigations on the integrated control of *Tetranychus urticae* (Acari:Tetranychidae) infesting brinjal in South Gujarat. In: Proc. in fifth National Symposium on Acarology, Bangalore. 20 -22 pp.

Rai, S. N. and Singh, J. 2008. Efficacy of some acaricides/insecticides against *Tetranychus urticae* Koch on okra. *Indian Journal of Entomology*, **70**(2): 169–171.

Rai, S. N. and Tripathi, M. K. 1999. Estimation of crop loss due to *Tetranyshus cinnabarinus* on okra (*Abelmosches esculentus*) in Varansai. *Bihar Journal of Agricultural Marketing,* **7** (4): 430-444.

Ray, R. and Rai, L. 1981.Biology and Control of *Tetranychus neocaledonicus* (Acari: Tetranychidae) on lady's finger at Varanasi. *In*: ChannaBasavanna, G. P. (*Ed*.). Proceedings of All India Symposium in Acarology, Acarological Society of India. University of Agricultural Sciences, India. 41-46.

Rock, G.C. and Yeargan, D.Y. 1973.Toxicity of apple orchard herbicides and growth regulating chemicals to *Neoseiulus fallacis* and two spotted spider mite.*Journal of Economic Entomology*,**66**: 1342–1343.

Roopa, S. P. 2005.Investigations on mite pests of solanceous vegetables with special references to brinjal. Ph. D. Thesis, Univercity of Agriculture Science, Bangalore, India.

Sabelis, M.W. 1981. Biological control of two-spotted spider mites using phytoseiid predators. Part 1. Modeling the predator-prey interaction at the individual level. Agricultural Research Reports No. 910, Wageningen, Netherlands.

Salman, M. S. 2007. Comparative toxicological studies of certain acaricides on two-spotted spider mite, *Tetranychus urticae* Koch and its predator, *Stethorus gilvifrons* Mulsant. Ph.D. Thesis, Plant Protection Department, Faculty of Agriculture, Suez Canal University.

Sangeetha, S. and Ramaraju, K. 2013. Relative toxicity of fenazaquin against two-spotted spider mite on okra, *International Journal of Vegetable Science*, **19(**3):282-293.

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. *Gujrat Agricultural Univercity Research Journal*, **19**(1): 32-37.

Singh, B. N. and Singh, J. 1999. Evaluation of azadirachtin and some comentional acaricides against two spotted mite, *Tetranychus urticae*. *Indian Journal of Entomology*, 61: 188-191.

Singh, J. 2004. Mite pest scenario in India. *In*: Subrahmanyam, B., Ramamurthy, V.V. & Singh, V.S. (*eds*.) Frontier Areas of Entomological Research, Proceeding National Symposia.

Singh, S. 2010. Resistance development in mites to plant protection chemicals: A review. *Journal of Entomological Research*, **34**(2):117-123.

Singh, J. and Raghuraman, M. 2010. Paradigm of human resource development in agricultural acarology. *In*: Abstract Proceedings of International Symposium-cum-Workshop in Acarology. BCKV, Kalyani, West Bengal, pp. 11–13.

Singh, J. and Raghuraman, M. 2011. Emerging scenario of important mite pests in North India. *Zoosymposia*, **6:** 170–179.

Singh, M., Gupta, P. R. and Rehallia, A. S. 2000.Occurrence of phytophagous mites in apple in Kinnaur district of Himachal Pradesh. *Insect Environment*, **40**: 170-171.

Singh, R. N. and Singh, J. 1996. Qualitative composition of vegetable mites of eastern Uttar Pradesh. *Journal of Insect Science*, **9** (1): 81-83.

Singh, R. N.1995. Mites of deciduous fruits and vegetables of eastern part of India and their economic status. *Advance Agricultural Research* **3**: 179-93.

Singh, S. K., Singh, A. P. and Singh, R. N. 2014. Comparative bio-efficacy of bio pesticides and new molecules of acaricides in the management of *Tetranychus urticae* Koch (Acari: Tetranychidae) inokra. *The Ecoscan*, **VI**: 279-283.

Singh, V. and Chauhan, U. 2014. Diversity of Mite (Acari) fauna associated with vegetables and ornamental plants in midhill conditions of Himachal Pradesh, India. *Journal of Biological Control*, 28.

Sivritepe, N., Kumral, N. A., Erturk, U., Yerlikaya, C. and Kumral, A. 2009. Responses of grapevines to two spotted spider mite mediated biotic stress. *Journal of Biological Science*, **9**(4): 311-318.

Smitley, D. R. and Kennedy, G. G. 1985. Photo-oriented aerial-dispersal behavior of *Tetranychus urticae* (Acari, Tetranychidae) enhances escape from the leaf surface. *Annals of the Entomological Society of America*, **78**: 609-614.

Sridhar, V. and Jhansi, R. B. 2003. Relative susceptibility in open and greenhouse populationsof two-spotted spider mite, *Tetranychus urticae* Koch on Rose to Dicofol. *Research Pest Management Newsletter*, **12**: 83.

Sridhar, V. and Jhansi, R. B. 2007. Resistance in two-spotted spider mite, *Tetranychus urticae* Koch on rose from different polyhouses to dicofol and wettable sulphur. *Journal of Acarology*, **17**: 48-50.

Stumpf, N. and Nauen, R. 2001. Cross resistance, inheritance, and biochemistry of mitochondrial electron transport inhibitor acaricide resistance in *Tetranychus urticae* (Acari: Tetranychidae). *Journal of Economic Entomology,* **94**: 1577-1583.

Thakur, R. K., Bienefeld, K. and Keller, R. 1994. Repeatability of *Varroa* defence traits in *Apis mellifera* carnica. *Pszczelnicze Zesyty Naukowe*, 41: 191-198.

Tomasevic, R. and Mijuskovic, M. 1974. Role of predators and diseases in the reduction of mass populations of *Panonychus citri* McGregor (Acarina: Tetranychidae) on citrus on the Yugoslav littoral. *Arhiv Za Poljoprivredne Nauke,* **27**: 75-88.

Venugopal, V., Govardhana Naidu, V. and Ragendra Prasad, P. 2003. Evaluation of new acaricides against red spider mite, *Tetranychus cinnabarinus* (Boisduval) on okra. *Pestology*, **27** (4):29-34.

VinothKumar, S., Chinniah, C., Muthiah, C. and Sadasakthi, A. 2009. Field evaluation of acaricides/insecticide molecules for their bio-efficacy against *Tetranychus urticae* Koch on brinjal. *Karnataka Journal of Agriculture Science*, **22**: 706-706.

Walunj, A. R. and Pawar, S. A. 2000. Evaluation of fenazaquin, a new acaricide for the control of *Hemitarsonemus latus* on chilli. *Tests Agrochem Cultivivars*, 21: 1–2.

Ware, G. W. and Whitacre D. M. 2004.The pesticide book, 6th edition. Meister Pro Information Resources, Willoughby, Ohio.

Wood Mason, J. 1884. Report of the tea mite and tea bug of Assam, London, 20p.

Wood, L., Raworth, D. A. and Mackauer, M. 1994. Biological control of the two spotted spider mite in rasp berries with the predator mite, *Phytoseiulus persimilis*. *Journal of the Entomological Society of British Columbia*, **91**: 59 – 61.

Zhang, Z. 2003. *Mites of Greenhouses.* CABI Publishing Oxon, UK. pp. 244.

VITA

Name of student	**Kuldeep Koul**
Father's name	Shri. M. K. Koul
Mother's name	Smt. Mohani Koul
Date of birth	02-12-1962
Permanent home address	H.No. 71, Bank colony, Camp Road Tallab Tillo, Jammu (J&K) 180002.

Educational Qualifications

Bachelor's Degree	B.Sc. Agriculture
University	CCS University, Meerut
Percent Marks	66.30 %
Year of award	1987
Soil and water conservation training	Bellary, Karnatka (ICAR)
Year of award	2008
Master's degree	M. Sc. Entomology
University	SKUAST-Jammu
Year of award	2016
OGPA	7.63/10
Title of Master's Thesis	Diversity of mite pests on some summer Vegetable crops with special reference to management of okra mite (*Tetramychus urticae* Koch)

CERTIFICATE-IV

Certified that all necessary corrections as suggested by external examiner and the advisory committee have been duly incorporated in the thesis entitled **"Diversity of mite pests on some summer vegetable crops with special reference to management of okra mite (*Tetranychus urticae* Koch.)"** submitted by **Mr. Kuldeep Koul,** Registration No. **J-14-M-363.**

Dr. Amit K. Singh

Major Advisor

Place : Jammu

Date: 02/12/2016