

# **BIO-ECOLOGY AND MANAGEMENT OF GRAPE MITES**

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# INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the commercially important fruit crops of the world and is fairly good source of minerals like calcium, phosphorous, iron and vitamins like B<sub>1</sub> and B<sub>2</sub>. Its juice is mild laxative and acts as stimulant for kidneys. Fruits are used for table purpose, wine preparation, juice, resins and canning. Fresh and dried fruits have various uses in ayurvedic and unani medicine. The fruits are considered to be stomachic, diuretic and cooling agents. The juice of unripe berries is used as an astringent in throat infections. Tannins can also be extracted as a byproduct from wine industry. It is an important fruit crop earning foreign exchange.

The primary centre of origin for grape is suppose to be Armenia near the Black and Caspian seas in Russia, and is widely grown in temperate zone. However it has acclimatized to sub tropical and tropical agro climatic conditions prevailing as in the Indian sub-continent. It is extensively grown in France, Italy, America, Africa, Australia, Algeria and India. In the year 2010-11, major grape growing states in India are Maharashtra (62.7%), Karnataka (26.8%), Andhra Pradesh (2.2%), Mizoram (1.7%) and Tamil Nadu (4.3%), others (2.4%) amounting to nearly 90 per cent of the total production (Anon., 2011).

Remarkable success has been achieved in table grape production and yield levels of fresh grapes in India, which are among the highest in the world. India is the 13<sup>th</sup> largest producer of grapes appropriating 2.00 per cent of the global production. The area under grapes in India was 1.11 lakh hectares during 2010-11 with the production of 12.35 lakh t of fresh grapes with an average productivity of 11.1 t per hectare (Anon., 2011).

In India, Karnataka occupies second position in cultivation and production of grapes next to Maharashtra. In 2010-11, Karnataka contributed to about 14.3 per cent of the total Indian grape area (18,100ha) with production of 3.30 lakh t with productivity of 18.3 t/ha (Anon., 2011).

In Karnataka major grape growing districts are Bangalore, Chikkaballapur, Kolar, Bijapur, Belgaum, Koppal, Bagalkot and Gulbarga. In 2010-11, Bijapur district contributed an area of 6,137 ha, production of 97,592 tons, with average productivity 15 t/ha. Large acreages of grape cultivation is quite evident in Basavana Bagewadi, Bijapur, Indi, Muddebihal and Sindagi talukas of Bijapur.

Grapes have a great demand in foreign market especially in the countries like United Kingdom, Saudi Arabia and UAE fetching valuable foreign exchange for the country. For achieving the international qualitative and quantitative standards, the fruit production from the grape orchards should be free from pests and pesticide residues.

Though the grape productivity (21 t ha<sup>-1</sup>) in India is highest in the world but the quality is deteriorated for several factors. Therefore now emphasis is given on improving quality while sustaining the present high productivity. In spite of many problems farmers have tendency to grow this crop because of excellent demand towards table purpose and also as resins, wine industry.

There are several limiting factors in growth, development and production of grapes which includes both biotic and abiotic factors. Abnormal climatic conditions and uneven rainfall leads losses in grape fruits. Many times unusual torrential rains heavily affect the berry yield. Biotic factors like insect pest and diseases are of prime importance as they would cause losses up to 100% in extreme conditions unless taken control measures. Otherwise also a major proportion of production is hampered by pests and diseases. Important diseases are downey mildew, powdery mildew, anthracnose, bacterial canker, rust, leaf blight and bunch necrosis, dead arm and wilt. The insect like flea beetles, thrips, mealy bug, stem borer are key pests of grape phytophagous mites, *Spodoptera litura* have been emerged as new production constraints in grape (Anon., 2008).

Commercial cultivation of grapes trend to attract various kinds of pests to the vineyards (Alexandri, 1973). As many as 132 insects have been (Bournier, 1977) known to attack grape vine in the world wide. In India as many as 60 species of insects and a few mites have been found damaging vines (Wadhi and Batra, 1964). According to Butani (1978) over 85 species of insects are known to occur on grapes in India. Balikai and Kotikal (2003) recorded as many as 26 pests infesting grapevines in Northern Karnataka. Out of these, two insects viz., Flea beetle *Sceledonta strigicollis* Mots. and Mealy bug, *Maconellicoccus hirsutus* (Green) considered as major pests on this crop. Six species of mites viz., *Tetranychus urticae* Koch, *T. cinnabarinus* Boisduval, *T. neocoleonicus* Andre, *Oligonychus mangiferus* Rahmen and Sapra, *O. punicae* baker and *Eutetranychus orientalis* Klein are found causing damage to grapevine in India (Anon., 2008).

Out of these mites the infestation of *Tetranychus urticae* is quite considerable. Designating it as emerging sucking pests of grape these days (Chandrashekar *et al.*, 2008)

Since last couple of years red spider mite, *Tetranychus urticae* Koch (Acariformes: Tetranychidae) is causing enormous damage to grapevine in Andhra Pradesh and Karnataka. Though *Tetranychus urticae* is a polyphagous mite infecting many crops, the information pertaining to grapes has not been generated so far.

This mite causes direct effects like loss of chlorophyll, stunting of growth, stippling, webbing, leaf yellowing, defoliation, leaf burning, reduction in size and quality of fruits, appearance of various types of plant deformities etc. and all these severely affect the yield. Indirect effects include decreased photosynthesis and transpiration. The outbreak infestation may lead to death of grape vine (Brandenburg and Kennedy, 1987).

Since the degree of incidence of spider mite changes with season, it is desirable to have a thorough understanding of the seasonal incidence of the mite. However, natural enemies play a major role in mitigating the mite population in nature. An account of natural enemies is inevitable in grape ecosystem is also essential. As polyphagous pest infesting on many field crops, vegetables like and fruits crops, it is likely that *T. urticae* expanding its hosts successfully encompassing grapes too. As an irrigated and well nurtured orchard crop grapes would have offered a congenial environment to mites infestation and establishment. Since mite is a new pest in grape ecosystem in surrounding locality to Bijapur as well as state, the growers of grape presently either are ignorant of this pest or depending on management information available from other crops or area. The biological and management information about mites infesting grapes in the state was highly called for now, hence an investigation was planned with following objectives.

#### Objectives of investigation

1. Survey and surveillance for mite infestation on grapes in Karnataka.
2. To study the biology of *Tetranychus urticae* Koch. infesting grapes.
3. Management of grape mites using synthetic acaricides and biorationals.

# REVIEW OF LITERATURE

The available literature pertaining to incidence, biology and management of mite infesting grapes and their natural enemies has been glanced here undered.

## 2.1 Survey and surveillance for mite infestation on grapes

Gutierrez and Chazeau (1972) during their survey on *T. neocaledonicus* in Madagascar have reported a coccinellid, *Stethorus madecassus* Chazeau as a principal predator of the mite.

Gupta and Gupta (1985) conducted survey in eight districts of West Bengal for mites associated with vegetable crops during 1981-82 and revealed a total of 22 species of both phytophagous and predatory mites. Among those, two were phytophagous viz., *T. cinnabarinus* and *T. neocaledonicus* and one was predatory mite viz., *Amblyseius lorgoensis* noticed on brinjal.

Duso and Vettorazzo (1999) studied on mite population dynamics on different grape varieties with or without phytoseiids released. The populations were monitored in two vineyards, each having two grape varieties with different leaf hair density. In both vineyards native phytoseiids present were: *Amblyseius andersoni* in one vineyard, and *Phytoseius finitimus* in the other. The economically important predators *Kampimodromus aberrans* and *Typhlodromus pyri* were released in both vineyards in order to study their efficacy in controlling tetranychids and eriophyids and their persistence during periods of prey scarcity. In both vineyards, relative abundances of the mite species, especially phytoseiids, were found to differ on different varieties in the same vineyard. In the first experiment, *A. andersoni* reached higher densities and was more persistent on the variety with slightly pubescent leaf under-surface (Merlot). *Typhlodromus pyri* and *K. aberrans* releases were successful and the mites became more abundant on the variety with pubescent leaf under-surface (Verduzzo). In the second experiment, *P. finitimus* was more abundant on a variety with pubescent leaf under-surface (Prosecco) than with glabrous leaf under-surface (Riesling). The most interesting results of this study concerned the interactions between native and released predators. In the first vineyard, different results were obtained when releasing *T. pyri* on the two varieties. On the variety with pubescent leaves, *A. andersoni* was rapidly displaced by *T. pyri*, whereas the former species persisted on the other variety throughout the three-year study, apparently becoming dominant during the last season. In contrast to *T. pyri*, interactions between *K. aberrans* and *A. andersoni* in this vineyard did not depend on variety. The results of the experiments carried out in the second vineyard stressed the importance of interspecific competition for phytoseiid releases. *Typhlodromus pyri* colonization failed on both varieties. *Kampimodromus aberrans* releases appeared to be more successful on Riesling than on Prosecco, where *P. finitimus* was more abundant. At the end of the experiments, *K. aberrans* displaced *P. finitimus* on both varieties.

The incidence of *T. urticae* on brinjal in Vijayapura (Karnataka) appeared in moderate form on the host plant (Anon., 2000a).

A survey was conducted in Coimbatore, Dharmapuri, Vellore, Tirunelveli, Kanyakumari, Madurai, Tuticorin, Dindugul and Theni districts of Tamil Nadu. The level of incidence of *T. cinnabarinus* on brinjal was very high in Coimbatore, whereas in Dharmapuri and Madurai districts, incidence was in moderate form. Low incidence of mites was noticed in other districts (Anon., 2000b).

*T. cinnabarinus* was noticed in medium to severe form in all over the state of Punjab and some areas of Himachal Pradesh on brinjal along with predatory mites, *A. alstoniae*, *A. finlandicus*, *Phytoseius roseus*, *Phytoseius* sp., *Typhlodromus* sp. and *Pronematus* sp. (Anon., 2000c).

The incidence of *T. cinnabarinus*, *T. ludeni*, *T. neocaledonicus*, *T. evansi* and *Tetranychus* sp. were reported on brinjal from Himachal Pradesh (Anon., 2000d).

According to Anandkumar (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 in brinjal. Costello and Albers (2003) in their experimental data, showed that there was a strong relationship between sulfur dusting and the density of Pacific mite on grapes. Mites were considerably higher in number on sulfur dust-treated vines compared to all other fungicides tested (including wettable sulfur), and the response held steady whether the overall mite pressure was high (as in 1999) or low (in both 2001 and 2002).

Shibao *et al.* (2004) reported that phytoseiid mites were appeared in high densities from mid-July to mid-August in 1997 and from mid-July to mid-September in 1998 in grapes. The dominant species of phytoseiid mites were *Euseius sojaensis* from mid-June to mid-August and *Amblyseius eharai* from late August to late September.

Pozzebbon *et al.* (2005) studied predatory mite population dynamics in vineyards and the role of alternative foods. The field observations and laboratory trials showed that the availability of alternative foods can affect markedly the population dynamics of predatory mites. In north-eastern Italy, the persistence of predatory mites on cultivated grapes in condition of prey scarcity was influenced by the presence of pollen grains and grape pathogenic mildews on leaves. The study evidenced that two species of predatory mites (i.e. *Amblyseius andersoni* and *Typhlodromus pyri*) could develop and reproduce by feeding on pollen and fungi.

Chandra Sekhar *et al.* (2008) reported maximum and minimum temperatures were found to be positively correlated with the population build up of the mite. Highest population of 22.11 to 25.45 mites/cm<sup>2</sup> leaf area was observed between March and April 2005 when the temperature ranged between 35 and 37.3°C.

Walton *et al.* (2006) stated during winter, rust mites *Calepitrimerus vitis* (Nalepa) were dormant and no evidence of direct bud damage from rust mites was found inside undeveloped buds in vineyards.

Mites become more active in December and reach peak in April. Mite population was negatively correlated with the minimum temperature and relative humidity. Watering practices affect the development of mite populations. Drought stressed plants are most prone to mite outbreaks. Pest is highly active during summer months. There is outbreak of mites in hot dry conditions. High humidity and rainfall reduces mite numbers. Wind is an important agent of mite dispersal (Anon., 2008).

## 2.2 Biology of mites infesting grapes

Shih *et al.* (1976) studied *Tetranychus urticae* Koch, in order to construct a life table and to establish an intrinsic rate of increase for use in population management with predators in dwarf marigold. Completion of life cycle in the laboratory required 7.5 days at 27±1°C and 95±5% RH. Mean generation time was 16.0 days and the quiescent period between deutonymph and active adult for females was 2.4 days. The reproductive rate was 7.97 eggs /day.

Puttaswamy (1978) reported that the developmental duration of *T. ludeni* from egg to adult stage was 9.24 days at 27.4 0C to 30.3 0C and RH 55 to 75 per cent. Preoviposition, oviposition and post oviposition period for mated female lasted for 0.98, 10.85 and 2.30 days, respectively. Total number of eggs laid per female was 71.00 with mean of 6.77 per day. Similar studies were done by Manjunatha (1982) on *T. neocaledonicus*, where egg, larval, protonymphal, deutonymphal and adult stage lasted for 2.59, 1.89, 1.43, 2.33 and 14.13 days, respectively. Fecundity was 60 eggs with 3.37 eggs per day. On an average mated female took 1.98, 17.0 and 1.40 days for the pre oviposition, oviposition and post oviposition period, respectively.

Reddy *et al.* (1987) studied the total life cycle of *T. ludeni* on four varieties of brinjal and it ranged from 9.45 to 19.65 days. The developmental period of *T. urticae* averaged 4.3 to 6.23 days at 27°C temperature and 60 to 70 per cent relative humidity (Liu, 1989).

Kaneria (1988) studied the biology of *T. cinnabarinus* on brinjal under lab conditions (30.580C – 34.420C temp and 64.87 – 67.71% RH) at Junagadh, Gujarat. The eggs were laid randomly on the webbing generally on the lower surface of leaf. The average egg period was found to be 4.08 ± 0.51 days with hatching per cent of 83.39 ± 10.16. The duration of larval, protonymphal and deutonymphal stages was on an average, 2.56 ± 0.71, 2.69 ± 0.65 and 2.75 ± 0.67 days, respectively. The average longevity of mated adult male and female was 3.08 ± 0.86 and 11.53 ± 2.36 days, respectively. Whereas, it was 9.36 ± 2.98 and 8.78 ± 2.53 days for unmated adults. The fecundity for mated and unmated female was on an average, 38.88 ± 8.22 and 8.72 ± 5.04 eggs. The sex ratio was worked out to be 1: 11.46. Chahine *et al.* (1994) compared the longevity of *T. urticae* females on brinjal and tomato. It was 11 days on an average in lab at 22°C. The fecundity was significantly higher on brinjal (71.0 eggs/female) than on tomatoes (10.6 eggs/ females).

Jose and Shah (1989) studied the biology of *T. macfarlanei* on cotton at Navasari, Gujarat during June, September, October and December months and reported that incubation period was 3.30, 2.75, 2.93, and 4.5 days, respectively. The larval periods lasted for 1.0, 1.0, 1.13 and 2.71 days in the respective months.

The protonymphs had an average period of 1.27, 0.96, 1.06 and 1.67 days and the deutonymph lasted for 1.13, 0.84, 0.74 and 1.0 days, respectively. The females took 7.73, 7.43, 7.42 and 11.81 days for their development. The males developed in 6.12, 7.67 and 10.9 days during September, October and December months, respectively. As per report of Thulsiram (1991) an adult female laid an average of 5.84 eggs per day on cotton with a mean oviposition period of 20.52 days. The incubation period of female egg varied from 3.5 to 4.5 days, whereas that of the male varied from 3 to 4.5 days. The average larval, protonymphal and deutonymphal periods lasted for 2.65, 2.14 and 1.47 days, respectively in females. Similarly for males the periods were 2.35, 1.46 and 1.23 days, respectively. The pre-oviposition, oviposition and post oviposition period lasted for 1.63, 20.52 and 2.03 days, respectively. The longevity of adult male and female averages to 12.25 and 24.18 days, respectively.

The comparative biology of *T. urticae* on different brinjal cultivars was studied under laboratory conditions at average temperature 32.4°C and relative humidity 60.45 per cent by Vora (1994). There was no much variation in duration of developing stages (larval nymphal) on different varieties of brinjal (4.52 ± 6.38 to 5.25 ± 0.15 days). However, the mite responded differently to different varieties in recording oviposition period, fecundity, rate of egg laying and longevity. The mated female lived for shorter time (10.26 ± 1.29 days) and laid higher number of eggs (65.10 ± 7.48 eggs) while unmated female lived longer (12.41 ± 1.35 days), and oviposited less number of eggs (41.33 ± 7.05 eggs).

According to Bhanderi (1991), *T. macfarlanei* took more or less similar duration in developing stages (7.11 ± 0.33 to 8.04 ± 0.28 days) on okra cultivars. But, the mite responded differently to different okra cultivars in regard to oviposition period, fecundity, rate and longevity. Sejalina *et al.* (1993) reported that in March and April, the developmental period of spider mite was prolonged on okra crop due to low temperature and low RH. High temperature and high RH shortened the duration. The incubation period for males and females was 4.31 days during March - April and was 3.06 days during July - August. Combined larval and nymphal period was 5.69 days for male and 6.13 days for female during March - April, while it was 4.3 days and 5.07 days, for respective sexes during July - August. Males lived longer during July - August (11.2 ± 3.71 days) than during March - April (4.31 ± 0.88 days) and female survived for 15.27 ± 4.00 and 11.30 ± 3.62 days during respective seasons. The mating lasted 1 to 2 minutes and fecundity was 69.00 ± 27.88 eggs per female during July - August.

According to Shaw and Devroy (1995), May month was the most suitable period for development of *T. neocaledonicus* at Jorhat, Assam. Males matured earlier than the females and mating took place immediately after the emergence of females. Both sexual and parthenogenetic reproductions were observed.

Bhagat and Singh (1999) studied biology of *T. cinnabarinus* on brinjal at 26.2 ± 10C temperature and 60 per cent relative humidity on an average a female laid 59.80 ± 9.36 eggs at the rate of 4.41 ± 1.14 eggs per day. The incubation period lasted for 5.6 ± 1.4 days. The duration of protonymphal and deutonymphal stages were 3.40 ± 0.54 and 7.60 ± 1.14 days, respectively. The developmental period ranged from 13 to 20 days. The mean longevity of adult females was 12.80 ± 1.92 days. In view of Kambrekar and Nandihalli (2003), the incubation period of *T. neocaledonicus* ranged from 3.5 to 4.0 days and average hatching per cent was 85 to 90. The larval, protonymphal and deutonymphal period lasted for 1.5 to 2.5, 1 to 2 and 1 to 1.5 days, respectively in brinjal.

Chandra Sekhar *et al.* (2008) reported duration of different developmental stages of *T. urticae* in grape were 3.68 days for eggs, 2.06 days for larvae, 0.74 days for I quiescent, 1.89 days for protonymph, 0.79 for II quiescent, 2.02 days for deutonymph and 0.84 days for III quiescent stages, respectively. The fecundity was 73.20 eggs/female, while pre-oviposition, oviposition and post oviposition periods lasted for 1.96 days, 10.53 days and 2.48 days, respectively. The total developmental period from egg to adult was recorded as 12.03 days and longevity of male was 8.60 days and that of female was 14.60 days in grape.

Andrew Loch (2007) observed adult Grapeleaf bud mite (*Colomerus vitis*) females laying eggs during spring inside the swelling bud and these eggs hatched after 5 to 25 days. Immature bud mites feed under the bud scale and develop into mature adults in about 20 days. Up to 12 generations are thought to occur in a year, with later generations in autumn feeding deeper in the developing bud. Anonymous (2008), reported that female mite produces 30-50 eggs. Hatching takes place in 4-6 days. The newly hatched translucent larva has six legs.

Dark spots appear soon after feeding on the dorsal side. The protonymph and deutonymphal stage has eight legs. The deutonymph stage is similar in appearance to an adult female but smaller. Nymphal period is 6-8 days. Life cycle completed in 10-14 days depending on weather conditions. Freshly emerged adult females are 0.5 mm long and devoid of spots but as the feeding begins, the spots become more distinct. Usually two large, diffuse spots appear forward. Adult spider mite females are reddish. Their pointed abdomens and smaller size easily recognize males. Adult mites live for about 15 days. Breeding is rapid in summer months. Development is greatly retarded in winter months. There are overlapping generations throughout the year.

### 2.3 Management of mites in grape orchard

Kaneria and Bharodia (1991) found dicofol (0.03% a.i.) and sulphur (0.2% a.i.) as most effective treatments against *T. cinnabarinus* in leaf disc bioassays using brinjal i.e, leaves sprayed with each chemical in laboratory and with leaves obtained from crops sprayed in field. The population density of *T. kanzawai* did not increase in brinjal plots given the integrated control programme but spraying of an acaricide (bromopropylate) was necessary in chemical control programme. In IPM plots, large number of predator, *Orius* sp. was remained on the plants (Nagai, 1991).

Kumar and Sharma (1991) reported that in summer, maximum mortality (68 to 78%) was obtained with dicofol (0.02%), sulphur (0.25%) and NSKE (0.05%) against spider mite, *Tetranychus ludeni* Zecher on okra at Pusa (Samastipur). Schwart (1991) studied on 23 vineyard pesticides on predacious mite *Amblysius addoensis* were examined in laboratory to obtain information on how to protect this important natural enemy of *Tetranychus urticae* Koch in an integrated pest management programme and recommended that pesticides with high toxicating be subjected to field testing before final decisions are made.

Verma (1992) observed cent per cent mortality of *T. cinnabarinus* with dicofol spray during a period of 18 days in brinjal. Next in the order of efficacy was monocrotophos and phosphamidon. The use of endosulfan and synthetic pyrethroids (deltamethrin and fluvalinate) resulted in the increase in mite population from 10<sup>th</sup> day onwards. Butani and Mittal (1992) recorded maximum reduction of red spider mite, *T. cinnabarinus* population in monocrotophos 0.04% (84.15) treated plot followed by DDVP 0.05% (69.83), malathion 0.05% (44.97%), endosulfan 0.07% (44.37%) and phosalone 0.07% (33.29). Carbaryl 0.2% was found ineffective.

Monocrotophos 300 g a.i. per ha showed good acaricidal effect followed by higher doses of methomyl 750 g a.i. per ha (Sridharan *et al.*, 1992). Under laboratory conditions, dicofol (0.02% and 0.04%) registered 100 per cent mortality of *T. cinnabarinus* on brinjal and was comparable with ethion 0.1% (97.33%), tetradifon 0.1% (97.33%) and monocrotophos 0.05% (95.99%). Wettable sulphur 0.025% provided least reduction of 70.66 per cent (Patel *et al.*, 1993).

Rai *et al.* (1995) opined that endosulfan 0.075% was not only safe to the predators but also as effective as promising chemicals like dicofol (0.04%) and monocrotophos (0.04%) against *T. urticae*, but were highly toxic to predators. Among different pesticides tested, dicofol 0.04%, monocrotophos 0.04% and endosulfan 0.075% were highly effective against *T. urticae* whereas tetradifon 0.1%, triazophos 0.05% and wettable sulphur 0.25% were found less effective (Vora and Rai, 1995).

Insecticides *viz.*, dimethoate (1.0 mL and 1.6 mL/L), monocrotophos (0.8 mL and 1.3 mL/L), cypermethrin (1.0 mL and 0.5 mL/L), fenvalerate (0.5 mL and 1.0 mL/L) and phosalone (0.5 mL and 1.0 mL/L) did not caused significant reduction in the population of *T. urticae* at Bangalore (Anon., 1996), But contradictory results were noticed at Ludhiana (Anon., 1996) wherein plots treated with dimethoate (0.03%), fenvalerate (0.005%) and endosulfan (0.04%) showed considerable decline in population of *T. cinnabarinus*. These pesticides adversely affected the natural enemies (predatory mites, *Scymnus* beetle and neuropteran larvae).

Costello (2003) reported that mean *T. pacificus* density was 2.7 times higher in the 'high sulfur' treatment than in the 'low sulfur' treatment. Similarly, mean cumulative mite days were 2.5 times higher under 'high sulfur' compared to 'low sulfur'. From the field studies by Sudhakar *et al.* (1998), it was clear that carbaryl 0.15% + dicofol 0.036% resulted in highest per cent reduction (44.36) of *T. neocaledonicus* over control at 10 days after spray and was significantly superior over bifenthrin 0.01% (23.68) and malathion 0.1% (29.11). Eswarareddy (2000) observed flare up in the population of *T. macfarlanei* in plots treated with carbaryl (0.2%), deltamethrin (0.003%), endosulfan (0.07%), quinalphos (0.05%), chlorpyrifos (0.04%) and carbosulfan (0.05%).

Sugeetha (1998) reported that dicofol at 0.05 percent and wettable sulphur 80 WP at 2.0 per cent was effective against *T. macfarlanei* infesting okra. Sivakumar and Hariprasad (1999) reported that among the treated chemicals, Dicofol (1.5 L/ha.) was highly effective against *T.cinnabarinus* on okra in Tamil Nadu. Dhar *et al.* (2000) reported that per cent reduction of mite was highest in fenazaquin 10 EC @ 2 mL/L (97.07) at 7 days after spraying. The next best treatment involved fenpropathrin 10 EC @ 1 mL/L (87.15) and dicofol 18.5 EC @ 3 mL/L (84.11) on *T. urticae* on okra in Kalyani, West Bengal.

Venugopal *et al.* (2003) evaluated the bio-efficacy of different acaricides against *T. cinnabarinus* on okra at Tirupati and reported that abamectin (0.05%) was the most effective acaricide 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.

Anandkumar *et al.* (2003) recorded lowest population of *T. macfarlanei* at (5.88/leaf) in diafenthiuron treated brinjal plot 875 g/ha which was followed by diafenthiuron at 625 g/ha (7.77/ leaf) and dicofol 1250 mL/ha (8.77/leaf). Next in the order of effectiveness was fenazaquin 500 mL/ha (8.99/leaf). Diafenthiuron at 875 g/ha treated plot recorded significantly highest fruit yield of 392.68 q/ha followed by fenazaquin (371.56 q/ha) and Dicofol (365.93 q/ha). According to Patil *et al.* (2004) fenpropathrin (Meothrin) 30 EC @ 200 g a.i./ha recorded lowest red spider mites per leaf (5.15) which was on par with dicofol 18.5 EC @ 250 g a.i./ha (6.35) in brinjal. In another field trial, the sequential spray of oxy-demeton methyl 25 EC, @ 200 g a.i./ha, fenpropathrin 30 EC @ 75 g a.i./ha, dipel 8L @ 800 mL/ha, fenpropathrin 30 EC @ 100 g a.i./ha, dipel 8L @ 1000 mL/ha and fenpropathrin 30 EC @ 100 g a.i./ha recorded lowest mite and other insect pest population with higher fruit yield.

Maximum per cent mortality of adult *T. urticae* on okra was recorded in dicofol 18.5% EC (0.04%), abamectin 1.9% EC (0.042%), abamectin 1.9% EC (0.014%), sulphur 80% WP (0.25%) and ethion 50% EC (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 against two-spotted mite (TSM) infesting okra (cv. Arka Anamika) in Varanasi in March-June 2000. After seven days, dicofol and abamectin showed similar response (Mani *et al.*, 2003).

Fenpyroximate (0.006%) recorded the highest mean reduction of 87.37 and 93.30 per cent against *T. urticae* on bhendi after first and second spray, respectively. Diafenthiuron 50 WP (0.09%) and diafenthiuron 50 SC (0.09%) were next in the order (Anon., 2003).

Sreedhara Rao (2003) proved the effectiveness of fenpropathrin 30 EC @ 100 ml/ac to 200 ml/ac than dicofol 18.5 EC @ 1000 ml/ac in reducing *T. urticae* population during *kharif* and *rabi* seasons. Triazophos 40 EC @ 600 ml/ac treated plots were on par with untreated plots.

Flumite at 400 and Vertimec at 250 mL per ha were considered as effective treatments in the management of brinjal mite, *T. cinnabarinus* as reported by Walunj *et al.* (2003).

Chavan *et al.* (2004) reported that avermectin (Vertimec 1.8 EC) 0.0045 per cent was found to be most promising which recorded 94.71 per cent mortality at 72 hours after treatment. This was followed by fluvalinate 0.02 per cent, flufenoxuron 0.012 per cent and methyl-oxy-demeton 0.05 per cent in which mortality of 91.21, 90.40 and 88.95 per cent was observed respectively, while dicofol 0.05 per cent and wettable sulphur 0.3 per cent recorded 86.06 and 71.51 per cent respectively on *T. cinnabarinus* on okra at Rahuri.

Ramaraju (2004) evaluated the bioefficacy of acaricides against *T. urticae* on Bhendi and brinjal in TNAU. Dicofol 0.05% proved to be the most effective causing 70.56 to 91.85 per cent reduction of mites in bhendi and 66.99 to 99.20 per cent reduction in brinjal both under field and pot culture conditions. The insecticides *viz.* wettable sulphur, phosalone and monocrotophos were next in order. Singh *et al.* (2004) reported maximum mortality of mite population with propagate 57 EC at the rate of 0.17 and 0.11 per cent (49.1 and 53.37 per three leaves, respectively) and dicofol 18.5 EC @ 0.02% (56.7 per three leaves) at 7 days after first spraying against *T. cinnabarinus* infesting okra (cv. Super Anamika) evaluated near Ghaziabad, Uttar Pradesh from April to July 2003.

Elbert *et al.* (2005) reported excellent activity of Oberon (spiromesifen) at the rate of 1.5 mL/L against spider mites in vegetables and field crops in USA and suggested a valuable tool for mite control and for resistance management.

Kumar and Singh (2005) reported that Omite at the rate of 2 mL/L alone proved significantly best in control of mites (*T. urticae* and *T. neocacedonicus*) on okra but addition of Dhanuvit @ 1 mL/L (a surfactant) enhanced the efficacy of mite culminating in the mortality of mites 94.88, 98.77, 90.99 and 71.20 per cent on okra after 1, 3, 7 and 10 days, respectively. Ethion and Phosalone were found only moderately effective and NSKE, gronim and sulphur have shown very poor control at Varanasi.

Nauen and Konanz (2005) reported that spiromesifen was highly active against tetranychid mite, *T. urticae* by contact. The product was shown to have similar or even superior efficacy compared to many commercial standards. Singh and Singh (2005) reported that maximum spider mite mortality was obtained with dicofol (81.35%), followed by monocrotophos, endosulfan and ethion (79.72, 79.37 and 78.00%, respectively), while minimum mortality was obtained with fenvalerate (50.60%), followed by azadirachtin and wettable sulfur (50.84 and 69.70%, respectively), applied at their recommended doses against spider mite (*T. urticae*) on okra crop cv. Arka Abhay at Varanasi.

Chandra Sekhar *et al.* (2008), Abamectin 2.70 g a.i. ha<sup>-1</sup> was found to be significantly reducing the mite population (92.65% reduction) in grape. Bhaskaran *et al.* (2007) reported that diafenthiuron 50 EC and 50 WP both at 450 g a.i./ha recorded the highest mean reduction of 87.95, 96.08 and 89.38, 93.79 per cent in mite population after first and second round of spraying, respectively. Fenpyroximate, fenazaquin and buprofezin were next in order against *T. urticae* on bhendi at Coimbatore. Kavitha *et al.* (2007) reported that diafenthiuron 50 WP 450 g a.i./ha was significantly superior to all other treatments and affected 95.21, 89.70, 86.32 and 88.08 per cent reduction in the mite population 3, 6, 9, 12 and 15 DAT, respectively. Fenazaquin 30 g a.i./ha was next in order. The other acaricides *viz.*, fenpyroximate 30 g a.i./ha, buprofezin 150 g a.i./ha and fenazaquin 100 g a.i./ha registered a mean population reduction of 94.19, 80.95 and 80.39 per cent over control, respectively while the standard check dicofol 231.25 g a.i./ha recorded 79.18 per cent reduction at Coimbatore on *T. urticae* on okra.

Haviland (2007) conducted experiment on willamette spider mite control in grape and he showed that all miticide treatments provided significant reductions in mite density on at least one evaluation date compared to the untreated check. Of these treatments Fujimite, Onager and Apollo provided the best overall control, with mite densities for the duration of the trial never exceeding 1.0 per leaf. This was followed by both Envidor treatments, Zeal, Vendex, Brigade and Acramite, that with only minor exceptions resulted in mite densities higher than, but statistically equivalent to the top three treatments. The four abamectin treatments (Agri-Mek, Reaper, Zoro and ABBA) resulted in significant reductions in mite densities compared to the untreated check through 35 DAT for Zoro, and through 42 DAT for the other three products. Plots treated with abamectin products had comparable pest densities to the untreated check for the final 4 weeks of the trial. Ecotrol resulted in no consistent reductions in mite densities.

Buckey and Haviland (2009) conducted experiment on willamette spider mite control in grape and reported that mite densities were low to moderate with precounts averaging 3.7 mites per leaf and the untreated checks never exceeding an average of 12 mites per leaf. Plots treated with Fujimite and Onager maintained mite densities < 1 mite per leaf until the end of the trial. Apollo, Brigade, Prevamite (12 fl oz), and Zeal also maintained mite densities < 1 mite per leaf through 34/36 DAT. Agri-Mek and Zoro (12 fl oz) reduced mite densities at 13/15 DAT, but by 20/22 DAT effects were lost. Zoro performed better at the 16 fl oz rate and mite densities were reduced through 34/36 DAT.

Rai and Singh (2008) reported that dicofol was most effective by recording maximum mortality, followed by abamectin, propargite and ethion with values of 92.55, 88.44, 82.66 and 72.44%, respectively. Diafenthiuron, acephate, clomazone and gronim showed mortality values of 68.77, 62.33, 60.88 and 55.66%, respectively.

The lowest mortality was recorded for mitex-s (50.22%), followed by lannate (53.88%) in Varanasi during summer months of 2005-06, all applied at their recommended doses, against the two-spotted mite, *T. urticae* on okra. Fungi *Beauveria bassiana*, *Verticillium lecanii*, *Hirsutella thompsonii* and *Pacilomyces fumosoroseus* are known to cause mortality in mites. These fungal pathogens can be used in the management of spider mites on grapevine. Different neem formulations containing azadirachtin depending upon the strength of botanical *viz.*, 1% @ 2.0 mL and 5% @ 0.5 mL/L can be sprayed Anon. (2008).

Varadaraju (2010) concluded that newer acaricide molecules *viz.*, abamectin 1.9 EC (0.2 mL/L) and diafenthiuron 50 WP (2 g/l) were significantly superior in reducing tetranychid mite population.

The higher fruit yield of 17.59 t/ha was recorded in abamectin 1.9 EC with highest cost benefit ratio of 1: 4.80. The next best treatments were diafenthiuron 50 WP (17.15 t/ha) and fenazaquin 10 EC (16.15 t/ha). The standard check *i.e.*, dicofol recorded 14.83 tons fruit yield per ha.

Sarma (2010) studied on relative toxicity and concluded that dicofol was the most effective acaricide (LC<sub>50</sub>=206.177 ppm) followed by spiromesifen (LC<sub>50</sub>1061.64 ppm), propargite (LC<sub>50</sub>=2061.64 ppm), milbemectin (LC<sub>50</sub> =2652.87 ppm) and diafenthiuron (LC<sub>50</sub>=3306.34 ppm) against infesting. The field screening of acaricides revealed that spiromesifen 240 SC has recorded the lowest mite population of 5.90 mites/6.25 cm<sup>2</sup> leaf area followed by diafenthiuron and dicofol and the net returns were highest in spiromesifen (Rs. 1,04,500/-) followed by dicofol (Rs. 82,800/-).

Karbhantanal *et al.* (2012), studied on bio efficacy of different acaricides against mites in grape and showed that there was non significant difference between treatments one day before spraying to disclose the uniformity of mite population among the treatment. At five days after first spray, the efficacy of propargite at the rate of 2.5mL/L (11.02mites / leaf), propargite at the rate of 2.5mL/L (11.89 mites / leaf), spiromycifen 240SC at the rate of 0.75mL/L (13.03 mites / leaf) and abemectin 1.9SC at the rate of 0.50ml/ l (14.66) were statistically equally effective in reducing the severity of mites in grape. The standard check dicofol 20EC at the rate of 2.50 mL / l was found to least effective (30.86 mites / leaf) compared to other acaricides and found significantly superior than untreated control (52.64 mites / leaf). Similar trend was noticed in subsequent second and third sprays. Five days after third spray, the mite population was negligible in former four treatments (ranging from 0.07 to 1.02 / leaf). On the contrary, in untreated control the population of mite was as high as 42.39 per leaf. The acaricides like propargite 57EC at the rate of 1.50mL/L, fenazaquin 10EC at the rate of 2.50ml/ l and milbemectin 1EC at the rate of 1.00mL / l were found to be on par with each other in reducing the mite infestation. Further the efficacy of acaricides is reflected in yield. Wherein, significantly higher grape yield and TSS was registered in propargite 57EC at the rate of 2.5 mL / l (359 q/ha & 19.0 °R), it was statistically on par with propargite at the rate of 2.0mL/L (341 q/ha & 18.90 °R), spiromycifen 240SC at the rate of 0.75mL/L (348 q/ha & 18.90°R) and abemectin (341 q/ha & 18.80°R).

### 2.3.1 Management of tetranychid mites using biorationals

Hanchinal and Manjunath (2000) reported that *Metarhizium anisopliae* (Metch.) Sorokin (1.5 x 10<sup>14</sup> spores/ha) + dicofol (0.03%) recorded 88.35 per cent mortality. Whereas, *M. anisopliae* alone recorded 75.92 per cent mortality of *T.neocaledonicus* on bhendi.

In the field experiment with brinjal, neem oil + pungam oil 60 EC (NOPO) 3 per cent, neem oil 3 per cent and NSKE 5 per cent recorded 44.89 to 51.64, 36.76 to 59.43 and 42.95 to 59.95 per cent reduction of red spider mite, *T. urticae* population, respectively after two rounds of spraying (Ramaraju, 2001).

Chundawat and Sharma (2003) recorded 67.60 to 74.03 per cent reduction in red spider mite, *T. cinnabarinus* infesting brinjal with two sprays of Azadirachtin 10,000 ppm (0.01-0.15%) which were equally effective as chemical pesticides *viz.*, dicofol (0.037%), profenofos (0.075%) and ethion (0.075%). Commercial neem seed kernel extract formulation Vijayneem® at 2500 mL per ha and neem oil + nirma soap powder (3:1) were found least effective in controlling *T. macfarlanei* and increasing yield of brinjal. Dose mortality bioassay revealed that *Beauveria bassiana* (Bals.) Vuill caused mortality upto 80 to 88 per cent at a dose 1x10<sup>8</sup> conidia per ml, while *M. anisopliae* (Metch) Sorokin and *Paecilomyces tumosorozeus* (Wise) Brown and Smith caused 60 and 80 per cent mortality on *Polyphagotarsonemus latus* Bank, respectively (Nugroha and Ibrahim, 2004).

In a glasshouse experiment, sprays of *B. bassiana*, *Hirsutella thompsonii*, *M. anisopliae*, *Verticillium lecanii* and Naturalis-L reduced *T. urticae* populations in tomato crop (Chandler *et al.*, 2005).

Roopa (2005) reported that neem oil at 2 per cent and NSKE at 5 per cent were effective against *T. macfarlanei* on brinjal in Dharwad..

Seventeen isolates of *M. anisopliae* and two isolates of *B. bassiana* were proved pathogenicity against the tobacco spider mite. *T. evansi* Baker and Pritchard caused mortality between 22.00 and 82.60 per cent (Wekesa *et al.*, 2005).

## MATERIAL AND METHODS

The studies on grape mites with reference to biology were carried out in entomology laboratory of Agriculture College, Bijapur, University of Agricultural Sciences, Dharwad. Bijapur situated at 16°49' N latitude, 75°43' E longitude and 593 m elevation. The experiment on management aspect was carried out in a farmer's field at Toravi (Tq and Dt: Bijapur). Bijapur district falls under Northern Dry Zone of Karnataka characterized with annual rainfall of 590.7 mm. The soil type and climatic conditions are well suited for grape cultivation. The population dynamics studies were carried out in farmer's fields at Bijapur and Atharga (Tq:Indi, Dt:Bijapur). The roving survey for mites incidence in grapes was undertaken during 2012-13 encompassing Bijapur, Belgum, Bagalkot, Koppal, Bangalore and Chikkaballapur districts of Karnataka state.

### 3.1 Survey and surveillance for mite infestation on grapes

#### 3.1.1 Survey for infestation of mites in grapes

##### 3.1.1.1 Survey locations

Survey was undertaken to know species of mites and their natural enemies on grapes in Bijapur, Koppal, Bagalkot, Belgaum, Bangalore, Chikkaballapur districts during 2012-13. In district two taluks were covered with a minimum of one to maximum of five villages/tq. Thus a total of 23 villages have been surveyed across the state. The details of survey localities are presented in the Table 1 (Fig. 1).

##### 3.1.1.2 Method of survey

Roving survey was undertaken to record the incidence of the mites and their natural enemies prevailing on grape during *rabi* and summer months of 2012-13. In each location two fields were selected for the purpose of computing average incidence of mites and simultaneously natural enemies on mites were also recorded.

##### 3.1.1.3 Sampling and observations

For sampling, five vines were randomly selected in each field. Three canes and five leaves per cane were selected in each vine covering top, middle and bottom canopy of the crop. The leaves were collected separately and observed under 7x magnifier hand lens (Plate 1 and 2). The numbers of phytophagous mites were counted on per square inch area basis in each leaf. The predatory mites were recorded on per leaf basis from the sampled leaves and predatory insect population was observed on per plant basis.

##### 3.1.1.4 Identification of specimen

The phytophagous and predatory mites specimens were mounted on glass slides in Hoyer's media (Appendix I) and sent to All India Coordinated Research Project on Agricultural Acarology, University of Agricultural Sciences, Bangalore for identification. Infested leaf samples were also used to support the identification process.

#### 3.1.2 Population dynamics

Population dynamics studies were under taken in two fixed plots of Bijapur district *viz.*, Jumnal (Tq: Bijapur) and Atharga (Tq: Indi) for surveillance. Observations were made in selected farmer's grapevine garden at weekly intervals throughout the season.

##### 3.1.2.1 Sampling and observations

For observation five vines were selected and tagged in each location. Every plant served as a replication. Three canes/vine and five leaves/cane were selected covering top, middle and bottom canopy for observation with respect to mites. The leaves were collected separately in polythene bags and brought to the laboratory for observation under stereo-binocular microscope. The numbers of phytophagous mites were counted on per square inch area basis in each leaf. The predatory mites were recorded per leaf basis from the sampled leaves. The plants selected for this study at both sites were kept unsprayed for insect pests / mite incidence.

#### 3.1.3 Statistical analysis

The data on the incidence of mites (pestiferous and predatory) from the survey has been presented as range and mean values both village wise as well as district wise.



**Fig 1: Locations of roving survey for infestation of mites in grapes**



**Plate 1: 7<sub>x</sub> Magnifier used for field observations of mites**



**Plate 2: Survey and surveillance kit for studies on mites**

Similarly the data on seasonal incidence of mites in grape at fixed plots has been presented as mean data on standard week basis. Further the data of phytophagous mites correlated with weather parameters viz., maximum and minimum temperature, morning and evening relative humidity and rainfall. The meteorological data of these two villages has been presented as Appendix II. For simple correlation and multiple regression analysis SPSS programme was used.

### 3.2 Biology of mites infesting grapes

The life history of *T. urticae* was studied under laboratory conditions on grape var, Thompson seedless under laboratory conditions at College of Agriculture, Bijapur in rabi and summer season 2012-13 at ambient temperature of  $26\pm 5^{\circ}\text{C}$  and relative humidity of  $74\pm 5$  per cent. Thirty gravid female mites from the mass culture were released on a fresh grape leaf bit maintained in turgid conditions and allowed to lay eggs overnight. Next day morning the number of eggs laid by these mites was counted and adults were removed from the leaf. After egg hatching, the newly emerged hexapod larvae were lifted carefully with the help of a moistened zero size camel hair brush and kept on leaf bits (2 cm X 2 cm) at the rate of one larva per leaf bit per petriplate. Such thirty plates were maintained to study the biology. The development of various stages of the mite was observed at 2 hr interval with the help of stereobinocular microscope. The leaf bits were replaced regularly to avoid leaf deterioration and consequent poor nutrition. The observations on life history included incubation period, larval period, protonymph, deutonymph, quiescent stages, pre-oviposition, oviposition and post oviposition periods, fecundity, longevity of adults. The morphometric parameter of eggs was recorded with the help of a standardized ocular micrometer fitted to a stereo binocular microscope. Comparative biology studies have been under taken with mulberry (var, S1635) host also followed same procedure.

### 3.3 Management of grape mites

A field trial was carried out in a commercial Thompson seedless vineyard (Plate 15) from December 2012 to March 2013 at Toravi (Tq/Dt: Bijapur) to evaluate the efficacy of different acaricides and biorationals against grape mites. Toravi is situated at  $16^{\circ}49'50.33''$  N,  $75^{\circ}41'32.13''$  E and 611.7 MSL elevation.

#### 3.3.1 Experimental details

The experiment comprised of 14 treatments replicated thrice in randomized block design. Details of treatments have been depicted in Table 2. The acaricides were applied as foliar sprays by using knapsack sprayer and a total of three sprays were taken based on infestation. The orchard was six years old and three months from date of pruning. The fungicides difencanazole (Score 25% EC), propicanazole (Tilt 25% EC), hexaconazole (Contaf 5% EC), penconazole (Topas 10%), bordaux mixture, mancozeb (Indofil M45 WP), metalaxyl (Ridomyl MZ 72 WP), carbendazim (Bavistin 50 WP) and cymoxanil 8% + mancozeb 64% (Curzate) were used to protect grape garden from diseases like powdery mildew, downy mildew and anthracnose etc. The orchard was kept free from other insect pests and hence there was no interference of any other plant protection operations on the targeted studies.

#### 3.3.3 Observations and analyses

The observations were recorded on incidence of mites a day before and after one, five and ten days after application. The population of mite *T. urticae* and yield was recorded as mentioned below.

Number of vines/ treatment	: Five
Number of canes/vines	: Three
Number of leaves/cane	: Nine (selected randomly)
Fruit yield	: kg/vine and ton/ha

The mite population recorded was on per leaf basis and presented as mites/ four leaves. The data on mites was transformed to  $\sqrt{X+0.5}$  before subjecting to analysis. Both data (mite population and yield) was subjected to ANOVA and F test.

**Table 1: Roving survey locations of mite infestation in grape orchard**

Sl. No.	District	Taluk	Place/Village	Geographical position
1	Bijapur	Bijapur	Jumnal	16°44' 20.57" N 75°43' 18.15" E 606.9m elevation
			Chikkalaki cross	16°35'18.01" N 75°28'12.57"E 546m elevation
			Babaleshwar	16°59' 25.89" N 75°47' 00.23" E 518.7m elevation
			Toravi	16°49'50.33" N 75°41' 32.13" E 611.7m elevation
		Sindagi	Devarahipparagi	16°54'43.61"N 76°13'56.04"E 495m elevation
			Tillagola	16°34'17.38" N 76°10' 26.50" E 557.4m elevation
2	Belgaum	Gokak	Kalligutti	16°10'04.91" N 74°49'20.51" E 552.3m elevation
			Chippala katte	16°00'30.25" N 75°11' 43.45" E 594.3m elevation
		Athani	Athani	16°43' 26.70" N 75°03 49.82 E 576.6m elevation
3	Bagalkot	Badami	Katageri	15°54'53.78" N 75°40'36.52"E 549.6m elevation
			Hunageri	15°57'11.59"N 75°46'47.15" E 527.7m elevation
		Bilagi	Anagawadi	16°20'27.02" N 75°37'41.66"E 581.7m elevation
4	Koppal		Koppal	15°32'09.79"N 76°16'15.90"E 1922ft elevation
			Yelaburga	15°35'44.51"N 76°00'18.48"E 582.6m elevation
5	Bengaluru		Rajanakunte	13°10' 47.83" N 77°33'01.72" E 895.8m elevation
			Devanahalli	13°14' 36.65" N 77°42' 33.15" E 886.2m elevation

			Hosakote	13 <sup>o</sup> 04'09.91"N 77 <sup>o</sup> 47'19.89" E 891.3m elevation
			Doddaballapura	13 <sup>o</sup> 17' 22.03" N 77 <sup>o</sup> 32'03.04" E 891.3m elevation
6	Chikkaballapura		Dasarahalli	13 <sup>o</sup> 02'44.91"N 77 <sup>o</sup> 30'39.82"E 886.2m elevation
			Chikksagarana halli	13 <sup>o</sup> 19'34.71"N 77 <sup>o</sup> 44'06.26"E 887.1m elevation
			Doddasagarana halli	13 <sup>o</sup> 20' 06.80" N 77 <sup>o</sup> 42'22.38" E 911.1m elevation
			Muddena halli	13 <sup>o</sup> 24' 25.35" N 77 <sup>o</sup> 41' 46.32" E 937.5 elevation

**Table 2: Details of acaricides and biorationales evaluated against grape mites under field condition**

Sl .no	Treatments	Dosage	Trade names
1.	Dicofol 18.5 EC	2.50 mL/L	Kelthane
2.	Fenpyroximate 5SC	1.00 mL/L	Neon
3.	Diafenthuron 50SC	0.80 mL/L	Polo
4.	Sulphur 80WP	2.00 g/L	Sulfex
5.	Abamectin 1.9 EC	0.50 mL/L	Abacin
6.	Neemazal 3000ppm	2.00 mL/L	Neemark
7.	Hexythiazox 5.45EC	1.50 mL/L	Maiden
8.	Spiromecifen 240SC	0.50 mL/L	Oberon
9.	Propargite 57% EC	2.00 mL/L	Omite
10.	Ethion 50EC	2.00 mL/L	Fosmite
11.	<i>Verticillium lecanii</i> (2.5 x 10 <sup>7</sup> spores/ml)	2.00 g/L	-
12.	Fenzaquin 10% EC	1.00 mL/Lt	Magister
13.	<i>Hirsutella thompsonii</i> (2.5 x 10 <sup>9</sup> spores/ml)	1.00 g/L	-
14.	Untreated control	-	-

## EXPERIMENTAL RESULTS

The results of investigations on different aspects of bio-ecology and management of mites infesting grapes are elucidated in this chapter.

### 4.1 Survey and surveillance for mite and their natural enemies' incidence in grapes in Karnataka

#### 4.1.1 Roving survey in Karnataka state

The study was conducted during the year 2012-13 from November to February encompassing Bijapur, Belgaum, Bagalkot, Koppal, Bangalore and Chikkaballapur districts in the state. During field visits the incidence of two spotted spider mite *T. urticae* Koch, a predatory phytoseiid mite (*Euseius* sp.) and coccinellid beetle (*T.bengalorensis*) were observed. The district wise data have been presented in Table 3.

##### 4.1.1.1 Incidence of grape mite *T. urticae* in different districts

A total of 23 villages have been surveyed across four districts in Northern Karnataka and two districts in Southern Karnataka where grape is being grown predominantly.

##### 4.1.1.1.1 Incidence of grape mites in Bijapur district

In Bijapur taluk four villages were surveyed viz., Jumnal, Chikkalaki cross, Babaleshwar, Savalagi and Toravi. Besides, other taluk covered was Sindagi, where only two villages viz., Devarahipparagi and Tilagola were visited. Among the four villages surveyed in Bijapur taluk, a maximum population of  $22.1 \pm 2.8$  mites per sq inch was observed in Babaleshwar followed by  $21.5 \pm 3$  in Jumnal. The least number of mites  $15.5 \pm 1.5$  was noticed in Savalagi. The population of mites in Bijapur taluk ranged between  $15.5 \pm 1.5$  to  $22.1 \pm 2.8$  per sq inch. The crop during the survey was of more than pea sized berries except in Jumnal and Chikkalaki cross where the berry size was more than sorghum grains. In all fields the variety was Thompson seedless only. The age of the garden was six years old in Jumnal and Chikkalaki cross, where as in Babaleshwar, Toravi and Savalagi it was four, seven and five years respectively (Table 3). In Sindagi taluk, the population of  $17.6 \pm 1.0$  and  $16.7 \pm 1.8$  mites per sq inch was recorded in Tilagola and Devarahipparagi, respectively. Thus the population in Sindagi was higher than that of in Savalagi (Bijapur Tq) (Table 3).

##### 4.1.1.1.2 Incidence of grape mites in Belgaum district

In Gokak taluk, the highest population of  $16.7 \pm 2.0$  mites per sq inch was recorded in Chippalakatte. In Kalligutti  $15.9 \pm 1.8$  mites per sq inch were recorded. The crop was at pea sized berries stage and more than pea size aslo. The gardens were four and six years old in Chippalakatte and Kalligutti, respectively. The grape variety grown was Thompson seedless in both the villages. In Athani the population of mites was  $19.2 \pm 1.7$  per sq inch with in a pea size berry Thompson seedless grape vineyard established eight years back. Thus in Belgaum district major grape growing area there was  $15.9 \pm 1.8$  to  $19.2 \pm 1.7$  mite incidence on sq inch area basis of the leaves (Table 3)

##### 4.1.1.1.3 Incidence of grape mites in Bagalkot district

In Bilagi taluk, the population of  $11.5 \pm 1.3$  mites per sq inch was recorded in Anagawadi. The berries were at pea size and the variety was Thompson seedless in two years old garden. In Badami taluk the mite infestation was  $12.0 \pm 1.4$  and  $11.7 \pm 1.8$  per sq inch at Katageri and Hunageri respectively. Here also the crop was at peanut sized berry stage but the garden was three to four years old with Thompson seedless variety. Thus across Bagalkot district the mite infestation ranged from  $11.5 \pm 1.3$  to  $12.0 \pm 1.4$  per sq inch (Table 3).

##### 4.1.1.1.4 Incidence of grape mites in Koppal district

In two villages surveyed in Koppal district the population ranged  $7 \pm 1.18$  (Koppal) to  $8.2 \pm 1.1$  (Yelaburga) per sq inch only. At both places Thompson seedless only was grown and crop was at pea size berry stage. The gardens were three to four years old (Table 3).

##### 4.1.1.1.5 Incidence of grape mites in Bangalore district

In the district, the highest population of mites were observed in Devanahalli ( $0.5 \pm 0.7$  mites / sq inch) and least of  $0.2 \pm 0.4$  per sq inch in Hosakote. The grape varieties grown were Banagalore blue and Anab-E-Shahi. At all the places the grape berries were at pea size or slightly more.

The age of the garden was three to five years. Thus in Bangalore district the mites' incidence was negligible compared to the districts of Northern Karnataka (Table 3).

#### 4.1.1.1.6 Incidence of grape mites in Chikkaballapura district

In Chikkaballapura, the highest populations of mites observed was in Dasarahalli with  $1.4 \pm 0.4$  /sq inch and least  $1.2 \pm 0.7$  in Chikkasagarahalli. No population of mites was observed in Doddsagarahalli and Muddenahalli. The crop was at pea size berries stage in three and six years old orchard in Dasarahalli, Chikkasagarahalli respectively. Crop was at new flesh stage in six, four years old orchards of Doddsagarahalli and Muddenahalli, respectively. Thompson seedless, Banaglore blue and Anab-E-Shahi varieties were encountered in all the villages except Muddenalli where only Thompson seedless was observed during the survey. Thus in Chikkaballapura district the mite population appeared to be slightly higher than that of in Bangalore district but still less compared to Northern Karnataka.

In entire state the incidence ranged from  $0.25 \pm 0.2$  to  $18.41 \pm 2.48$  per sq inch, higher being in the Northern part (Table 4).

#### 4.1.1.2 Incidence of arthropod predators of grape mites *T. urticae*

During the survey across the state a predatory mite *Euseius sp* (Plate 6) and coccinellid beetle *T. bengalorensis* were found actively engaged in natural control action against *T. urticae* in grape orchards (Table 3 and 4).

##### 4.1.1.2.1 Incidence of predatory mite *Euseius sp*.

A prey dependent abundance of predatory mite *Euseius sp* (Plate 6) was observed during the survey. Thus the population was more in Northern Karnataka and least in south Karnataka districts. The predatory mite population altogether ranged  $0.25 \pm 0.5$  to  $4.2 \pm 1.5$  per leaf. The predatory mites activity was in fact noticed in every field visited in Bijapur and Belgaum districts.

At Devarahipparagi (Tq Sindagi) predatory mite activity was highest ( $4.2 \pm 1.5$  per leaf) and a least of  $2.1 \pm 0.8$  per leaf at Chikkalaki cross in Thompson seedless variety in Bijapur district. In Belgaum and Bagalkot district the predatory mite activity was to the maximum of  $0.5 \pm 0.6$  mites/leaf only. In Koppal village  $0.75 \pm 1.0$ /leaf predatory mites were noticed, but in Yelaburga the population was nil. Similarly in Bangalore and Chikkaballapura district not a single event of predatory mite activity was encountered (Table 3).

##### 4.1.1.3 Incidence of coccinellid beetle *Telsimia bengalorensis* Kapur

The incidence of coccinellid beetles (adults) (Plate 5) was noticed only in Jumnal, Babaleshwar and Devarahipparagi villages of Bijapur district. In other places this insect was not noticed. The population ranged from  $1.0 \pm 0.8$  to  $2.7 \pm 0.9$  per plant highest being at Jumnal (Table 3).

#### 4.1.2 Population dynamics of *T. urticae* and praedatory mites in grape

The seasonal dynamics of pestiferous mite *T. urticae* in grape and its predatory mite *Euseius sp*. has been studied in two geographically isolated locations viz., Bijapur and Atharga (Tq Indi) of Bijapur district during 2012-13 (Table 5).

##### 4.1.2.1 Seasonal dynamics of mite *T. urticae*

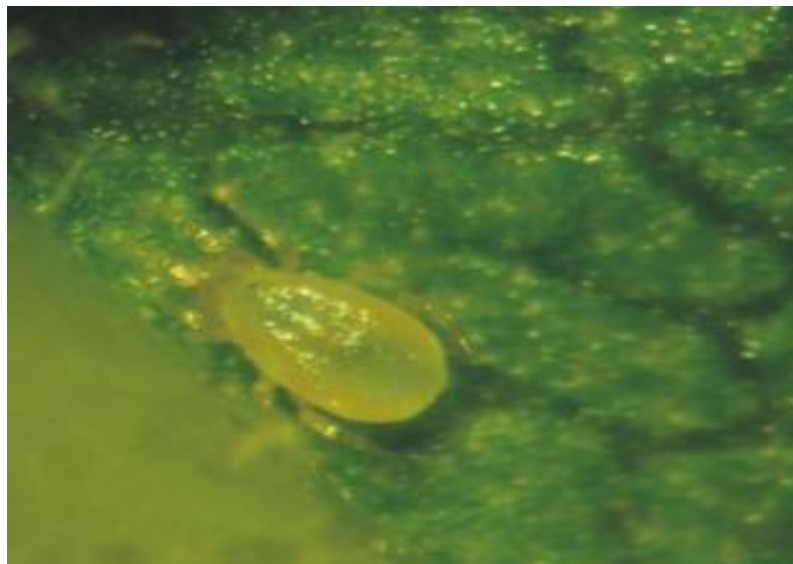
In rabi summer fruit crop, mite incidence was recorded from the standard week 45 of November 2012 to 17 of April 2013 in Bijapur and Atharga.

In Bijapur low mite incidence was noticed during 48 to 52 standard week (SW) and recorded  $0.6 \pm 0.1$  to  $9.7 \pm 0.4$  mites per sq inch. Population trend was in increasing with advancement of the season. The highest population trend was observed in 13 to 15<sup>th</sup> SW with  $21.4 \pm 1.2$  to  $25.5 \pm 0.9$  mites per sq inch. The mean incidence in the season was  $13.7 \pm 7.8$  at Bijapur with range of  $0.6 \pm 0.1$  to  $25.5 \pm 0.9$  (Table 5).

Similarly at Atharga, low mite incidence was noticed during 46 to 51<sup>st</sup> standard week with a minimum of  $0.6 \pm 0.1$  to  $9.8 \pm 0.9$  mites per sq inch. The high range of population was observed in 13 to 17 standard weeks with  $20 \pm 0.1$  to  $24.9 \pm 1.4$  mites per sq inch. The seasonal mean was  $14.6 \pm 7.5$  with range of  $0.6 \pm 0.1$  to  $24.9 \pm 1.4$  per sq inch (Table 5).



**Plate 5: Predatory lady bird beetle**



**Plate 6: Phytoseiid mite *Euseius sp.* Mite**

**Table 3: Incidence of mites *Tetranychus urticae* and predatory arthropods on grapes in Karnataka during 2012-13**

SI No.	District/ Taluk	Villages	Date of visit	Variety	Age of garden	Stage of crop	No. of mites /sq inch of leaf ( $\pm$ SD)	Predatory mites /leaf ( $\pm$ SD)	Coccinellid beetles/plant ( $\pm$ SD)
<b>Bijapur</b>									
1	Bijapur	Jumnal	05/01/2013	<i>Thompson seedless</i>	6yrs	Pea size & Sorghum size	21.5 $\pm$ 3.0	4.0 $\pm$ 0.9	2.7 $\pm$ 0.9
		Babaleshwar	05/01/2013	<i>Thompson seedless</i>	4yrs	>Pea size	22.1 $\pm$ 2.8	3.5 $\pm$ 1.1	1.2 $\pm$ 0.1
		Chikkalaki Cross	05/01/2013	<i>Thompson seedless</i>	6yrs	>Sorghum size	18.3 $\pm$ 1.2	2.1 $\pm$ 0.8	-
		Toravi	05/01/2013	<i>Thompson seedless</i>	7yrs	Pea size	17.2 $\pm$ 1.2	2.5 $\pm$ 0.95	-
		Savalagi	05/01/2013	<i>Thompson seedless</i>	5yrs	>Pea size	15.5 $\pm$ 1.5	3.2 $\pm$ 0.8	-
	Sindagi	Devarahipparagi	10/01/2013	<i>Thompson seedless</i>	6yrs	>Pea size	16.7 $\pm$ 1.8	4.2 $\pm$ 1.5	1.0 $\pm$ 0.8
		Tilagola	10/01/2013	<i>Thompson seedless</i>	4yrs	Pea size	17.6 $\pm$ 1.0	3.13 $\pm$ 0.8	-
<b>Belgaum</b>									
2	Gokak	Kalligutti	25/01/2013	<i>Thompson seedless</i>	9yrs	>Pea size	15.9 $\pm$ 1.8	0.25 $\pm$ 0.5	-
		Chippalakatte	25/01/2013	<i>Thompson seedless</i>	5yrs	Pea size	16.7 $\pm$ 2.0	-	-
	Athani	Athani	25/01/2013	<i>Thompson seedless</i>	8yrs	Pea size	19.2 $\pm$ 1.7	0.25 $\pm$ 0.5	-
<b>Bagalkot</b>									
3	Bilagi	Anagawadi	29/12/12	<i>Thompson seedless</i>	2yrs	Pea size	11.5 $\pm$ 1.3	0.50 $\pm$ 0.6	-
	Badami	Katageri	29/12/12	<i>Thompson seedless</i>	4yrs	Pea size	12.0 $\pm$ 1.4	0.25 $\pm$ 0.5	-
		Hunageri	29/12/12	<i>Thompson seedless</i>	3yrs	Pea size	11.7 $\pm$ 1.8	0.00 $\pm$ 0.6	-
<b>Koppal</b>									
4		Koppal	14/1/2013	<i>Thompson seedless</i>	3yrs	Pea size	8.2 $\pm$ 1.1	0.75 $\pm$ 1.0	-

	Koppal	Yelaburga	14/1/2013	<i>Thompson seedless</i>	4yrs	Pea size	7±1.8	-	-
<b>Bengaluru</b>									
5	Bengaluru	Devanahalli	28/11/13 & 1/02/2013	<i>Bangalore blue, Anab-E-Shahi</i>	5yrs	New flesh	0.5±0.7	-	-
		Rajanakunte	28/11/13 & 1/02/2013	<i>Bangalore blue, Anab-E-Shahi</i>	3yrs	Pea size	0.3±0.5	-	-
		Hosakote	28/11/13 & 1/02/2013	<i>Bangalore blue, Anab-E-Shahi</i>	5yrs	>Pea size	0.2±0.4	-	-
		Doddaballapura	28/11/13 & 1/02/2013	<i>Bangalore blue, Anab-E-Shahi</i>	5yrs	>Pea size	-	-	-
<b>Chikkaballapur</b>									
6	Chikkaballapur	Dasarahalli	28/11/13 & 2/02/2013	<i>Thompson seedless</i>	3yrs	Pea size	1.4±0.4	-	-
		Chikkasagara halli	28/11/13 & 2/02/2013	<i>Thompson seedless, Bangalore blue, Anab-E-Shahi</i>	6yrs	Pea size	1.2±0.7	-	-
		Doddasagarana halli	28/11/13 & 2/02/2013	<i>Thompson seedless, Bangalore blue, Anab-E-Shahi</i>	6yrs	New flesh	-	-	-
		Muddena halli	28/11/13 & 2/02/2013	<i>Thompson seedless</i>	4yrs	New flesh	-	-	-

**Table 4: District wise incidence of grape mite *Tetranychus urticae* in Karnataka during 2012-13**

SI No	District	No. of mites per sq inch (± SD)	Predatory mites per leaf (± SD)
1	Bijapur	18.41 ± 2.48	3.23 ± 0.76
2	Belgaum	17.08 ± 1.83	0.16 ± 0.14
3	Bagalkot	11.75 ± 0.25	0.25 ± 0.25
4	Koppal	7.58 ± 0.82	0.37 ± 0.53
5	Bengaluru	0.25 ± 0.20	-
6	Chikkaballapur	0.65 ± 0.75	-



**Plate 3: Symptoms caused by grape mites on leaves.**

**Table 5: Population dynamics of *Tetranychus urticae* and predatory mite *Euseius* sp. at Bijapur and Atharga**

Bijapur			Atharga	
Year and Std Weeks	<i>T. urticae</i> / sq inch of leaf ( $\pm$ SD)	Predatory mites/leaf ( $\pm$ SD)	<i>T. urticae</i> / sq inch of leaf ( $\pm$ SD)	Predatory mites/leaf ( $\pm$ SD)
2012- 45	-	-	-	-
46	-	-	0.6 $\pm$ 0.1	-
47	-	-	3.3 $\pm$ 0.4	-
48	0.6 $\pm$ 0.1	-	5.5 $\pm$ 1.3	-
49	3.3 $\pm$ 0.6	-	5.0 $\pm$ 0.5	-
50	5.1 $\pm$ 0.6	-	8.3 $\pm$ 1.1	-
51	7.5 $\pm$ 0.5	-	9.8 $\pm$ 0.9	0.1 $\pm$ 0.3
52	9.7 $\pm$ 0.4	0.1 $\pm$ 0.3	10.4 $\pm$ 0.5	0.1 $\pm$ 0.3
2013- 1	10.6 $\pm$ 0.3	0.3 $\pm$ 0.5	11.3 $\pm$ 0.7	0.2 $\pm$ 0.4
2	10.6 $\pm$ 0.4	0.8 $\pm$ 0.6	13.7 $\pm$ 0.6	0.5 $\pm$ 1.0
3	13.7 $\pm$ 1.5	0.7 $\pm$ 0.5	14.6 $\pm$ 0.9	0.7 $\pm$ 0.7
4	16.2 $\pm$ 0.6	1.0 $\pm$ 0.8	14.8 $\pm$ 1.1	0.7 $\pm$ 1.0
5	11.7 $\pm$ 0.2	0.8 $\pm$ 0.6	16.5 $\pm$ 0.2	0.8 $\pm$ 1.0
6	13.6 $\pm$ 0.2	1.2 $\pm$ 0.5	15.4 $\pm$ 1.4	0.9 $\pm$ 0.6
7	10.7 $\pm$ 0.7	1.3 $\pm$ 0.5	20.8 $\pm$ 0.5	1.0 $\pm$ 1.4
8	16.2 $\pm$ 1.3	1.1 $\pm$ 0.6	21.1 $\pm$ 0.8	1.1 $\pm$ 0.9
9	21.6 $\pm$ 0.1	2.2 $\pm$ 0.5	19.6 $\pm$ 0.8	1.1 $\pm$ 0.6
10	25.1 $\pm$ 0.4	2.0 $\pm$ 1.6	20.4 $\pm$ 0.5	2.2 $\pm$ 1.1
11	20.1 $\pm$ 0.5	2.5 $\pm$ 0.6	19.0 $\pm$ 1.5	2.2 $\pm$ 0.6
12	22.4 $\pm$ 2.1	2.7 $\pm$ 0.3	21.7 $\pm$ 1.5	2.5 $\pm$ 0.6
13	21.4 $\pm$ 1.2	2.9 $\pm$ 1.0	20.0 $\pm$ 0.1	2.9 $\pm$ 1.1
14	23.2 $\pm$ 3.1	3.1 $\pm$ 0.6	21.0 $\pm$ 0.4	2.9 $\pm$ 1.0
15	25.5 $\pm$ 0.9	3.4 $\pm$ 0.9	23.9 $\pm$ 0.7	3.1 $\pm$ 1.3
16	-	-	24.2 $\pm$ 0.7	3.2 $\pm$ 1.0
17	-	-	24.9 $\pm$ 1.4	3.1 $\pm$ 1.3
<b>Mean</b>	<b>13.7<math>\pm</math>7.8</b>	<b>1.2<math>\pm</math>0.6</b>	<b>14.6<math>\pm</math>7.5</b>	<b>1.1<math>\pm</math>0.6</b>

**Table 6: Influence of abiotic factors and predatory mites on population of *Tetranychus urticae* at Bijapur**

	Temp Max.	Temp Min.	RH Morning.	RH Evening.	Rainfall	Predatory mite
<i>Tetranychus urticae</i>	0.852*	0.675*	-0.914*	-0.892*	-0.09	0.913*

\* Significant at 5%

Table 'r' value = 0.36 (N=21)

$R^2 = 0.915$

**Table 7: Linear regression equation for *Tetranychus urticae* , abiotic factors and predatory mites at Bijapur**

Parameters	Linear regression	R <sup>2</sup>
Temp Max.	Y= 2.15X -57.72	0.727
Temp Min.	Y= 1.56X -13.62	0.456
RH Morning.	Y= -0.56X + 50.60	0.836
RH Evening	Y= -0.85X + 38.46	0.796
Rainfall	Y= -0.36X + 13.99	0.008
Predatory mite	Y= 6.18X + 5.96	0.835
Over all	Y= -1.84X <sub>1</sub> + 1.23X <sub>2</sub> + 0.06X <sub>3</sub> -0.78X <sub>4</sub> -0.42X <sub>5</sub> +3.95X <sub>6</sub>	0.915

X<sub>1</sub>\_ Maximum temperature  
X<sub>3</sub>\_ Morning relative humidity  
X<sub>5</sub>\_ Minimum temperature

X<sub>2</sub>\_ Minimum temperature  
X\_ Evening relative humidity  
X<sub>6</sub>\_Predatory mite

**Table 8. Influence of abiotic factors and predatory mites on population of *Tetranychus urticae* at Atharga**

	Temp Max.	Temp Min.	RH Morning.	RH Evening.	Rainfall	Predatory mite
<i>Tetranychus urticae</i>	0.804*	0.021	-0.970*	-0.952*	0.235	0.852*

\* Significant at 5%, Table 'r' value = 0.36 (N=25) R<sup>2</sup> = 0.956

**Table 9: Linear regression equations for *Tetranychus urticae*, abiotic factors and predatory mites at Atharga**

Parameters	Linear regression	R <sup>2</sup>
Temp Max.	Y= 1.99X -51.10	0.647
Temp Min.	Y= 0.03X +13.96	0.0004
RH Morning.	Y= -0.63X + 54.43	0.941
RH Evening	Y= -0.85X + 42.08	0.907
Rainfall	Y= 3.60X + 14.12	0.055
Predatory mite	Y= 5.41X + 8.25	0.727
Over all	Y= 0.33X <sub>1</sub> -0.11X <sub>2</sub> - 0.50X <sub>3</sub> -0.34X <sub>4</sub> -0.17X <sub>5</sub> -1.93X <sub>6</sub>	0.956

X<sub>1</sub>\_ Maximum temperature  
X<sub>3</sub>\_ Morning relative humidity  
X<sub>5</sub>\_ Minimum temperature

X<sub>2</sub>\_ Minimum temperature  
X<sub>4</sub>\_ Evening relative humidity  
X<sub>6</sub>\_Predatory mite

Thus in both places (Bijapur and Atharga) the mite incidence was sizable from January onwards (15 SW) with considerable increase in number consequently without any dwindling till the end of the season. Therefore the mite depredation was almost along with reproductive phase of the crop. Hence the population appeared to be detrimental to the crop (Table 5).

#### 4.1.2.2 Population dynamics of predatory mites *Euseius* sp.

In Bijapur incidence of predatory mite was noticed from 52<sup>nd</sup> SW with a low population of  $0.1 \pm 0.3$  mites/leaf. The peak incidence was seen during 15 SW ( $3.4 \pm 0.9$  mites/leaf). Population trend was found increasing with increase in phytophagous mites' population. The mean incidence was  $1.2 \pm 0.6$  per leaf with range of  $0.1 \pm 0.3$  to  $3.4 \pm 0.9$  per leaf (Table 5).

In Atharga also same trend was followed with respect to the incidence of predatory mites. The peak incidence of  $3.2 \pm 1.0$  mites/leaf was noticed at 16<sup>th</sup> standard week. Predatory mites population increases with increase in phytophagous mites. The mean population was  $1.1 \pm 0.6$  with range of  $0.1 \pm 0.3$  to  $3.1 \pm 1.3$  per leaf (Table 5).

#### 4.1.2.3 Influence of abiotic factors and predatory mites on the incidence of *T. urticae* population

The relationship between *T. urticae* population and weather parameters as well as phytoseiid mite was assessed through simple correlation and regression studies. As presented in Table 6 at Bijapur, a significantly positive correlation was observed between *T. urticae* and maximum temperature ( $r = 0.852$ ) and minimum temperature ( $r = 0.675$ ). Whereas significantly negative correlation was found between *T. urticae* and morning relative humidity ( $r = -0.914$ ) and evening relative humidity ( $r = -0.892$ ). Significantly positive correlation was found between predatory mite and *T. urticae* ( $r = 0.913$ ). All these factors governed the mite population to the tune of 91 per cent ( $R^2=0.915$ ) as revealed in Table 7.

In Atharga also (Table 8) there was significantly positive correlation was observed between *T. urticae* and maximum temperature ( $r = 0.804$ ), whereas minimum temperature ( $r = 0.021$ ) had non-significant effect. Further significantly negative correlation was found between *T. urticae* and morning relative humidity ( $r = -0.970$ ) as well as evening relative humidity ( $r = -0.952$ ). A non significant correlation was found between *T. urticae* and rainfall ( $r = 0.235$ ). Significantly positive correlation was found between predatory mite and *T. urticae* ( $r = 0.852$ ) also. All these factors together governed (Table 9) the mite population to the tune of 95 per cent ( $R^2=0.95$ ).

## 4.2 Comparative biology of *Tetranychus urticae* (Koch) on grape and mulberry leaves

The comparative biology of *T. urticae* on grape and mulberry leaves was studied (Plate 4). The description and developmental periods of different stages are presented as below (Table 10 and 11).

### 4.2.1 Oviposition and egg

The eggs (Plate 8) were laid on the lower surface of leaves inside the webbings. Freshly laid eggs were smooth, spherical in shape, translucent white and appeared like a tiny drop of water measuring about 0.1mm (Plate 7) in size. Eggs gradually turned brownish progressively towards hatching. At this stage, the area along the egg periphery became transparent and red eye spots corresponding to simple eyes of larvae were clearly visible. The incubation period ranged from 3.67 - 4.50 days with an average of  $4.02 \pm 0.2$  days on grape (Table 10). This period varied in laboratory host mulberry ( $3.39 \pm 0.1$  days) with a range of 3.08 - 3.75 days (Table 11). The larva emerged out of the egg by making a vertical slit on one side of the cohesion. The larva widened this opening by pushing it apart with its legs and came out leaving the egg shell intact on the leaf surface. In most cases, the egg shells were not easily visible after hatching.

### 4.2.2 Larva

The newly emerged hexapod larva (Plate 9) was almost spherical or slightly oval in shape with two prominent red spots (simple eyes) on the dorsal propodosomal region. Initially the larva crawled around for some time and settled at a place to feed on the cell sap. The neonate larva was creamy white in color and turned green upon initiation of feeding and finally to dark green when it had fed for some time with dark specks appearing dorsolaterally. The larval period of male ranged from 1.83- 2.25 days with an average of  $2.08 \pm 0.1$  days when reared on grape and that of mulberry host the period ranged from 1.25 - 1.50 days with average of  $1.31 \pm 0.09$  days (Table 10 and 11).



Plate 4: Mass culturing of *Tetranychus urticae* in laboratory on grape and mulberry leaves.

**Table 10: Biology of *T. urticae* on grape cv. Thomson seedless**

Developmental stages	Duration in Days	
	Range	Mean $\pm$ S.D
Egg	3.67-4.50	4.02 $\pm$ 0.20
Larval	1.83-2.25	2.08 $\pm$ 0.10
Quiescent- I	0.67-0.92	0.76 $\pm$ 0.07
Protonymph	1.75- 2.25	1.99 $\pm$ 0.15
Quiescent- II	0.75-0.92	0.81 $\pm$ 0.06
Deutonymph	1.83-2.25	2.01 $\pm$ 0.12
Quiescent- III	0.75-1.00	0.88 $\pm$ 0.07
Total development	11.8-13.20	12.55 $\pm$ 0.82
Pre-ovipositon period	1.75-2.25	1.99 $\pm$ 0.13
Ovipositon period	10.0-11.00	10.54 $\pm$ 0.26
Post-ovipositon period	2.25-2.83	2.57 $\pm$ 0.16
Female longevity	14.5-15.80	15.09 $\pm$ 0.56
Male longevity	8.25-9.10	8.63 $\pm$ 0.30
Fecundity(number)	56-76 / female	66.53 $\pm$ 4.93/ female

**Table 11: Biology of *T. urticae* on mulberry cv. S 1635**

Developmental stages	Duration in Days	
	Range	Mean $\pm$ S.D
Egg	3.08-3.75	3.39 $\pm$ 0.10
Larval	1.25-1.50	1.31 $\pm$ 0.09
Quiescent- I	0.75-1.17	0.90 $\pm$ 0.07
Protonymph	0.67-1.00	0.80 $\pm$ 0.08
Quiescent- II	0.58-1.08	0.84 $\pm$ 0.08
Deutonymph	0.83-1.50	1.04 $\pm$ 0.15
Quiescent- III	0.58-1.50	1.03 $\pm$ 0.16
Total developmental	8.67-10.17	9.31 $\pm$ 0.81
Pre-ovipositon period	1.67-2.00	1.86 $\pm$ 0.10
Ovipositon period	7.67-8.25	7.98 $\pm$ 0.16
Post-ovipositon period	2.08-2.42	2.24 $\pm$ 0.10
Female longevity	11.58-12.10	12.08 $\pm$ 0.35
Male longevity	6.75-7.40	7.12 $\pm$ 3.00
Fecundity (number)	48-64 / female	55.50 $\pm$ 4.73/ female

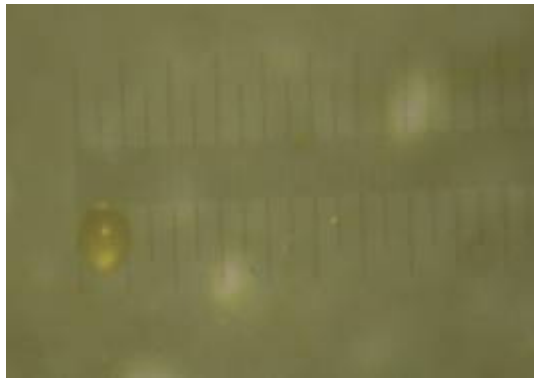


Plate 7: Morphometry of *Tetranychus urticae* egg

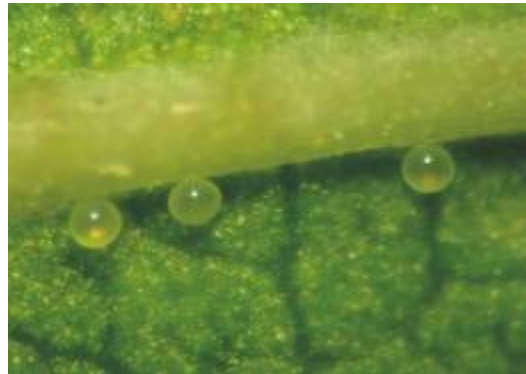


Plate 8: Eggs of *Tetranychus urticae*



Plate 9: Larvae of *Tetranychus urticae*

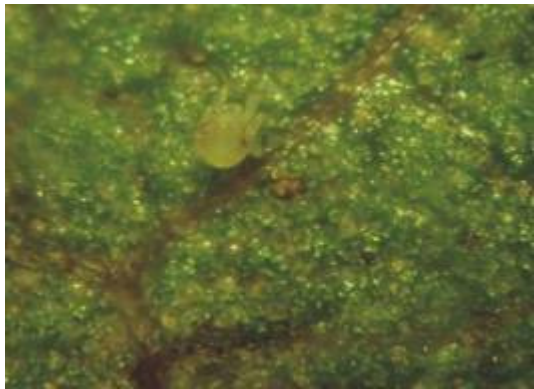


Plate 10 : Quiescent I of *Tetranychus Urticae*

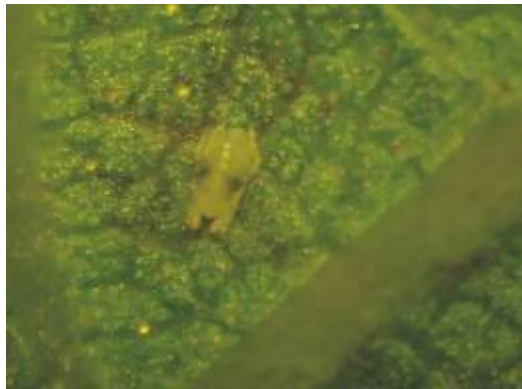


Plate 11: Quiescent II of *Tetranychus Urticae*

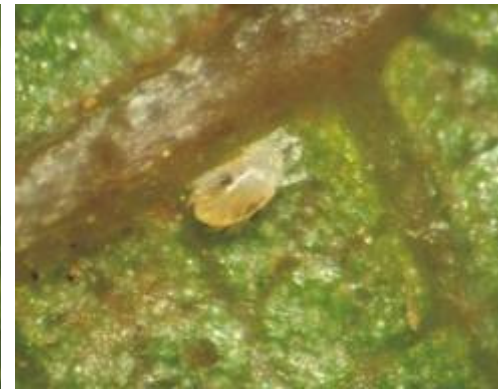


Plate 12: Quiescent III of *Tetranychus Urticae*

#### 4.2.3 Quiescent stage I

The matured larva ceased to feed and entered a quiescent stage (Plate 10) by anchoring itself to a leaf surface or the webbing assuming a characteristic static position. During this quiescent stage, the anterior two pairs of legs were extending forward and kept close to each other and posterior legs were extended backwards and held close to the sides of opisthosoma. This stage lasted for 0.67- 0.92 days with an average of  $0.76 \pm 0.07$  days in grape (Table 10). It varied in mulberry with range of 0.75- 1.17days and with an average of  $0.90 \pm 0.07$  days (Table 11).

#### 4.2.4 Protonymph

The newly emerged protonymph was oval shaped and amber to light creamy coloured. It was slightly bigger in size than the larva and was easily distinguished because of the presence of four pairs of legs. Feeding protonymph was greenish in the beginning and in due course it turned to dark green. The dark specks on the dorsum increased in size as the time passed. The protonymphal period of grape mite ranged from 1.75- 2.25 days and with an average of  $1.99 \pm 0.15$  days (Table 10). It varied in mulberry host with a range of 0.67 - 1.00 days and with an average of  $0.80 \pm 0.08$  days (Table 11).

#### 4.2.5 Quiescent stage II

At maturity, the protonymph like larva entered into a brief quiescent stage known as deutochrysalis (Plate 11). At this stage, the mite suspended all activities of feeding and remained anchored to the leaf surface. The body shrunk and decreased in size. On grape the deutochrysalis stages ranged from 0.75 - 0.92 days with an average of  $0.81 \pm 0.06$  (Table 10) and on mulberry host it ranged from 0.58 - 1.08 days and with an average of  $0.84 \pm 0.08$  days (Table 11).

#### 4.2.6 Deutonymph

The newly emerged deutonymph was yellowish in colour, the body size was large and broader than the protonymph. Sexual dimorphism was quite noticeable during this period. The male deutonymph was smaller in size and elongated whereas, the female deutonymph was broader and large. The deutonymphal period ranged 1.83 - 2.25 days and with average of  $2.01 \pm 0.12$  days (Table 10) on grape leaves. It varied from 0.83 - 1.50 days with an average of  $1.04 \pm 0.15$  days (Table 11) on mulberry host.

#### 4.2.7 Quiescent stage III

The matured deutonymph entered into a quiescent stage which is known as the teleiochrysalis (Plate 12). At this stage the body was shrunk and decreased in size. The colour was light carmine. The average teleiochrysalis period ranges from 0.75 - 1.00 days in grape with an average of  $0.88 \pm 0.07$  days (Table 10). Like in all previous stages here also it varied with mulberry host from 0.58 - 1.50 days with an average of  $1.03 \pm 0.16$  days (Table 11).

#### 4.2.8 Total developmental period

The total duration from egg to adult emergence in grape host was  $12.55 \pm 0.82$  days and from that of mulberry host it was  $9.31 \pm 0.81$  days. The total developmental period ranged 11.8 - 13.2 in grape and 8.67 - 10.17 days (Table 10) when reared on mulberry (Table 11).

#### 4.2.9 Adult male

The adult males (Plate 14) had a narrow body with a distinctly pointed abdomen and were smaller than female. Two red spots corresponding to the simple eyes were clearly visible. Body colour was creamy when newly emerged turning to light yellowish to dark as they aged. The first pair of legs was longer than the fourth pair while the second and third pairs were of similar size and were mostly found wandering or waiting over the quiescent female deutonymph ie. teleiochrysalis stage. On an average it lived for 18-20 days in grape host and 15-16 days in mulberry. However, the longevity was average  $8.63 \pm 0.28$  days in grapes and  $7.12 \pm 3.0$  days in mulberry. The longevity ranged 8.25-9.1 on grape (Table 10) and 6.75-7.40 days where reared on mulberry (Table 11).

#### 4.2.10 Adult female

The adult females (Plate 13) soon after emergence were light creamy in colour. After a period of feeding the colour changed to dark yellowish. The simple eyes were seen as two spots on the sides of dorsal propodosomal region. As age advances two black spots were clearly observed on dorsal propodosomal region. The female was found bigger with a rounded and oval shaped abdomen.



**Plate 13: Female adult *Tetranychus urticae***



**Plate 14: Male adult *Tetranychus urticae***

On an average it lived for 26-27 days on grape host (Table 10) and 21-22 days on mulberry host (Table 11). The longevity ranged from 14.5-15.8 on grape (Table 10) and 11.58-12.10 days (Table 11) when reared on mulberry.

#### 4.2.11 Mating

Males emerged little earlier than females and wandered on the leaf surface in search of a quiescent female deutonymph. On coming across a quiescent female deutonymph, it placed the anterior pair of legs on female and waited for its emergence. Sometimes three or four males were seen fighting aggressively amongst themselves near the female deutonymph and during this fight they were even seen extending their chelicerae and pricking the other individuals. Mating process was usually accomplished immediately after the last moult of female. In many cases, males were found helping the adult female to emerge out of the deutonymphal skin, by pulling out the ecdysial skin with its two anterior pair of legs. As soon as the male succeed in pulling out the female from the ecdysial skin, the male slide underneath the female with its hysterosoma upturned, while the female raised its posterior abdominal region to accommodate the male for mating. The female was held by the front two pairs of legs of the male in the process of coupling. The mating lasted for about one to three minutes. Single male was observed to mate with several females, but a female usually mated only once soon after emergence. However, males were occasionally observed attempting to mate with older females. But, these were of short duration.

#### 4.2.12 Pre oviposition period

Soon after getting adult stage the female laid eggs only after a lapse of certain period and on grapes this period lasted for range of 1.75 - 2.25 days with an average of  $1.99 \pm 0.13$  days (Table 10). It varied in mulberry host with a range of 2.00 - 1.67 days and an average of  $1.86 \pm 0.10$  days (Table 11).

#### 4.2.13 Oviposition period and fecundity

Oviposition period prevailed about  $10.54 \pm 0.26$  days ranging from 10.00-11.00 days on grape host and on that of mulberry it ranged from 7.67 - 8.25 days with an average of  $7.98 \pm 0.16$  days (Table 10 and 11). Fecundity data revealed that total eggs laid ranged from 56 – 76 with an average of  $66.53 \pm 4.93$  eggs/female (Table 10) when grape was used as host. It was comparatively less in mulberry which ranged from 48-64 with an average of  $55.50 \pm 4.73$  eggs /female (Table 11).

#### 4.2.14 Post oviposition period

Post oviposition period in grape host ranged from 2.83 - 2.25 days with an average of  $2.57 \pm 0.16$  days and in mulberry it was  $2.24 \pm 0.10$  days average, with a range of 2.42 to 2.08 days (Table 10 and 11).

#### 4.2.15 Adult longevity

Male adult longevity in grape host lasted for  $8.63 \pm 0.3$  days and that of female  $15.09 \pm 0.56$  days. In mulberry male longevity was  $7.12 \pm 3.0$  days, where as female lived for  $12.08 \pm 0.35$  days (Table 10 and 11).

### 4.3 Management of grape mites using synthetic acaricides and biorationals

Results of field investigation (Plate 15) carried out for bio efficacy of acaricides and biorationals against mites infesting grape are presented here under. A total of three sprays were under taken. Uniformity in mite population in experimental plot was evident from non significant difference in pre treatment count among treatments before first spray. However population density ranged from 154.00 to 193.33 mites per four leaves (Table 12).

#### 4.3.1 Mite population after first spray

Hexythiazox 5.45 EC at 1.50 mL/L treatment depicted a significantly lowest mite incidence (130.00 mites/4 leaves) at one day after application. However, fenpyroximate 5 SC at 1.00 mL/L, difenthurion 50 SC at 0.80 mL/L, abamectin 1.9 EC at 0.50 mL/L and propargite 57 EC at 2.00 mL/L were on par with hexythiazox in reducing the mite population. Spiromecifen 240 SC at 0.50 mL/L was best in the order of efficacy next to above five treatments at one DAS with 132.67 mites per four leaves (Table 12).

**Table 12: Bio efficacy of acaricides against grape mites (after first spray)**

	Treatments	Dosage	Mean population of mites/ 4 leaves			
			1DBS	1DAS	5DAS	10DAS
T1	Dicofol 18.5 EC	2.50 mL/L	168.33 (12.99) <sup>a</sup>	140.33 (11.87) <sup>cd</sup>	125.33 (11.22) <sup>d</sup>	120.67 (11.01) <sup>f</sup>
T2	Fenpyroximate 5 SC	1.00 mL/L	165.33 (12.88) <sup>a</sup>	130.67 (11.45) <sup>ab</sup>	98.67 (9.96) <sup>c</sup>	84.67 (9.23) <sup>cd</sup>
T3	Diafenthiuron 50 SC	0.80 mL/L	178.00 (13.36) <sup>a</sup>	130.33 (11.44) <sup>ab</sup>	115.33 (10.76) <sup>d</sup>	101.67 (10.11) <sup>e</sup>
T4	Sulphur 80 WP	2.00 g/L	182.33 (13.52) <sup>a</sup>	164.67 (12.85) <sup>f</sup>	148.00 (12.19) <sup>e</sup>	152.67 (12.38) <sup>h</sup>
T5	Abamectin 1.9 EC	0.50 mL/L	187.50 (13.71) <sup>a</sup>	131.24 (11.48) <sup>ab</sup>	72.12 (8.52) <sup>a</sup>	61.00 (7.84) <sup>a</sup>
T6	Neemazal 3000ppm	2.0mL/L	154.00 (12.43) <sup>a</sup>	141.67 (11.92) <sup>d</sup>	137.67 (11.75) <sup>e</sup>	142.67 (11.97) <sup>g</sup>
T7	Hexythiazox 5.45 EC	1.50 mL/L	185.21 (13.63) <sup>a</sup>	130.00 (11.42) <sup>a</sup>	65.67 (8.13) <sup>a</sup>	56.32 (7.54) <sup>a</sup>
T8	Fenazaquin 10 EC	1.00 mL/Lt	181.33 (13.48) <sup>a</sup>	140.33 (11.87) <sup>cd</sup>	117.33 (10.85) <sup>d</sup>	116.31 (10.81) <sup>f</sup>
T9	Propargite 57 EC	2.00 mL/L	178.33 (13.37) <sup>a</sup>	130.33 (11.44) <sup>ab</sup>	88.23 (9.42) <sup>b</sup>	87.67 (9.39) <sup>d</sup>
T10	Ethion 50 EC	2.00mL/L	173.67 (13.20) <sup>a</sup>	147.67 (12.17) <sup>e</sup>	140.00 (11.85) <sup>e</sup>	135.67 (11.67) <sup>g</sup>
T11	<i>Verticillium lecanii</i> (2.5 x 10 <sup>7</sup> spores/mL)	1.00 g/L	171.00 (13.10) <sup>a</sup>	174.00 (13.21) <sup>g</sup>	177.40 (13.34) <sup>f</sup>	175.33 (13.26) <sup>j</sup>
T12	Spiromecifen 240 SC	0.50 mL/L	171.67 (13.12) <sup>a</sup>	132.67 (11.54) <sup>b</sup>	86.33 (9.32) <sup>b</sup>	68.00 (8.28) <sup>b</sup>
T13	<i>Hirsutella thompsonii</i> (2.5 x 10 <sup>9</sup> spores/mL)	1.00 g/L	176.67 (13.31) <sup>a</sup>	178.33 (13.37) <sup>h</sup>	175.67 (13.27) <sup>f</sup>	165.67 (12.89) <sup>i</sup>
T14	Untreated control	2.50 mL/L	193.33 (13.92) <sup>a</sup>	233.67 (15.30) <sup>i</sup>	236.33 (15.39) <sup>g</sup>	243.67 (15.63) <sup>k</sup>
	<b>CD @ 5.0%</b>		<b>NS</b>	<b>0.09</b>	<b>0.51</b>	<b>0.35</b>
	<b>SEm ±</b>		<b>0.54</b>	<b>0.03</b>	<b>0.17</b>	<b>0.12</b>
	<b>CV (%)</b>		<b>8.58</b>	<b>6.36</b>	<b>8.96</b>	<b>5.69</b>

Figures in the parenthesis are  $\sqrt{(X + 0.5)}$  transformations

Means with similar alphabets do not differ significantly by DMRT (P=0.05)

DBS : Day before spray. DAS : Days after spray



**Plate 15: Experimental plot of management studies – a general view.**

At five days after first spray, hexythiazox 5.45 EC at 1.50 mL/L and abamectin 1.9 EC at 0.50 mL/L were on par with each other and significantly superior over other treatments in recording lowest mites per four leaves (65.67 and 72.12), respectively. Next best treatments were spiromecifen 240 SC at 0.50 mL/L and propargite 57 EC at 2.00 mL/L which were on par with each other (Table 12).

After 10 days after first spray also hexythiazox 5.45 EC at 1.50 mL/L and abamectin 1.9 EC at 0.50 mL/L remained on par with each other and significantly superior over other treatments with 56.32 and 61.00 mites per four leaves. Next best treatment was spiromecifen 240 SC at 0.50 mL/L with 68.00 mites per four leaves (Table 12).

The population of mites in bioagent treatments viz, *Verticillium lecanii* (T<sub>11</sub>) and *Hirsutella thompsonii* (T<sub>13</sub>) were in increasing trend at one day and five days after first spray and there after exhibited decreasing trend. At ten DAS after first spray the population was 165.67 and 175.33 per four leaves in T<sub>13</sub> and T<sub>14</sub> respectively, both being at par statically. The neemazal spray was significantly superior over fungal treatment at 10 DAS after application. The mite population remained significantly lesser in all treatments compared to untreated (T<sub>14</sub>) where the incidence was 233.63, 236.33, and 243.67 at one, five and ten DAS after first spray (Table 12).

#### 4.3.2 Mite population after second spray

Bio actively superior acaricides as evident in previous observations revealed the similar trend after second spray also. Hexythiazox 5.45 EC at 1.50 mL/L, propargite 57 EC at 2.00 mL/L and abamectin 1.9 EC at 0.50 mL/L were on par with each other and significantly superior over other treatments with of 85.37, 89.00, 95.67 mites/4 leaves, respectively. Next best treatment, spiromecifen 240 SC at 0.50 mL/L was recorded 99.36 mites/4 leaves. Further it was followed by fenpyroximate 5 SC at 1.00 mL/L which recorded 10.3.1 mites/ 4 leaves (Table 13).

After 5 days of second spray, hexythiazox 5.45 EC at 1.50 mL/L and abamectin 1.9 EC at 0.50 mL/L were on par with each other and significantly superior over other treatments as they recorded lowest incidence of mites (45.33 and 51.67 mites/4 leaves respectively). Next best treatments were spiromecifen 240 SC at 0.50 mL/L (59.23 mites/ 4 leaves) and propargite 57 EC at 2.00 mL/L (57.23 mites/4leaves), which were on par with each other (Table 13).

After 10 days of second spray also hexythiazox 5.45 EC at 1.50 mL/L and abamectin 1.9 EC at 0.50 mL/L were on par with each other and significantly superior over other treatments with lowest mite population of 28.33 mites/ 4 leaves and 38.00 mites/4 leaves, respectively. The next best treatment was propargite 57 EC at 2.00 mL/L and recorded 53.33 mites / 4 leaves (Table 13).

The bio agents treatments *V. lecanii* and *H. thompsonii* could not show appreciable bio-activity at one DAS after second spray. However a decreasing trend of mite population was noticed at five, ten days after second spray as they recorded comparatively low mite population ie.136.00 and 128.00 mites/ 4 leaves. After ten days of second spray, there treatments recorded 129.33 mites/ 4 leaves and 112.67 mites / 4leaves respectively. Whereas commercial neem formulation at 2.00 mL was found to be significantly superior (141.2 mites/4 leaves) to untreated control (252.66 mites/ 4leaves) (Table 13).

#### 4.3.3 Mite population after third spray

Before third round of treatment imposition the mite incidence varied between 45.67 and 220.33 / 4 leaves in the experimental unit (Table 14). At one days after third spray, hexythiazox 5.45 EC at 1.50 mL/L and abamectin 1.9 EC at 0.50 mL/L continued to maintain their superiority by restricting mite population to 15.67 and 21.32 mites/ 4 leaves, respectively both being on par statistically. Next best treatments were propargite 57 EC at 2.00 mL/L (23.67 mites/ 4 leaves) and spiromecifen 240 SC at 0.50 mL/L (31.25 mites/ 4 leaves) which were also on par with each other. Similar trend was continued even after 5 days after third spray. However by ten days after the spray hexythiazox remained significantly superior over rest of the treatments with 3.67 mites/4 leaves. It was followed by abamectin which remained significantly superior over propargite and spiromecifen where population was 8.00, 12.67 and 12.35 respectively (Table 14). Other treatments though found significantly superior over untreated control (221.67 mites/4 leaves) their efficacy was not appreciable in containing the population of phytophagous mites. The bioagents appeared slow in their efficacy as they could show comparative reduction in incidence of mite population at 10 days after third spray. Fungal pathogens *V. lecanii* and *H. thompsonii* recorded 78.75 and 71.2 mites/4 leaves which were nearer to the efficacy of synthetic acaricides viz, dicofol and ethion.

**Table 13: Bioefficacy of acaricides against grape mites (after second spray)**

	Treatments	Dosage	Mean population of mites/ 4 leaves			
			1DBS	1DAS	5DAS	10DAS
T1	Dicofol 18.5 EC	2.50 mL/L	144.67 (12.05) <sup>ef</sup>	127.67 (11.32) <sup>e</sup>	120.33 (10.99) <sup>ef</sup>	118.33 (10.90) <sup>f</sup>
T2	Fenpyroximate 5 SC	1.00 mL/L	121.14 (11.03) <sup>bcd</sup>	103.1 (10.18) <sup>c</sup>	87.33 (9.37) <sup>c</sup>	81.63 (9.06) <sup>d</sup>
T3	Diafenthiuron 50 SC	0.80 mL/L	135.33 (11.65) <sup>cd</sup>	114.67 (10.73) <sup>d</sup>	101.24 (10.09) <sup>d</sup>	90.83 (9.56) <sup>d</sup>
T4	Sulphur 80 WP	2.00 g/L	156.33 (12.52) <sup>f</sup>	142.33 (11.95) <sup>f</sup>	126.33 (11.26) <sup>fg</sup>	124.2 (11.17) <sup>f</sup>
T5	Abamectin 1.9 EC	0.50 mL/L	106.67 (10.35) <sup>b</sup>	95.67 (9.81) <sup>abc</sup>	51.67 (7.22) <sup>a</sup>	38.00 (6.20) <sup>ab</sup>
T6	Neemazal 3000 ppm	2.0 ml /l	146.67 (12.13) <sup>ef</sup>	143.33 (11.99) <sup>f</sup>	138.4 (11.79) <sup>h</sup>	141.2 (11.90) <sup>g</sup>
T7	Hexythiazox 5.45 EC	1.50 mL/L	97.67 (9.91) <sup>a</sup>	85.37 (9.27) <sup>a</sup>	45.33 (6.77) <sup>a</sup>	28.33 (5.37) <sup>a</sup>
T8	Fenazaquin 10 EC	1.00 mL/L	146.00 (12.10) <sup>ef</sup>	115.67 (10.78) <sup>d</sup>	107.67 (10.40) <sup>d</sup>	110.33 (10.53) <sup>e</sup>
T9	Propargite 57 EC	2.00 mL/L	119.33 (10.95) <sup>bc</sup>	89.00 (9.46) <sup>ab</sup>	57.23 (7.60) <sup>b</sup>	53.33 (7.34) <sup>b</sup>
T10	Ethion 50 EC	2.00mL/L	146.33 (12.12) <sup>ef</sup>	119.33 (10.95) <sup>e</sup>	112.33 (10.62) <sup>e</sup>	107.33 (10.38) <sup>e</sup>
T11	<i>V. lecanii</i> (2.5 x 10 <sup>7</sup> spores/mL)	1.00 g/L	168.67 (13.01) <sup>g</sup>	144.67 (12.05) <sup>f</sup>	136.00 (11.68) <sup>gh</sup>	129.33 (11.39) <sup>f</sup>
T12	Spiromecifen 240 SC	0.50 mL/L	112.31 (10.62) <sup>bc</sup>	99.36 (9.99) <sup>bc</sup>	59.23 (7.73) <sup>b</sup>	55.33 (7.47) <sup>c</sup>
T13	<i>H. thompsonii</i> (2.5 x 10 <sup>9</sup> spores/mL)	1.00 g/L	151.5 (12.33) <sup>ef</sup>	143.67 (12.01) <sup>f</sup>	128.00 (11.34) <sup>fgh</sup>	112.67 (10.64) <sup>f</sup>
T14	Untreated control	2.50 mL/L	237.67 (15.43) <sup>h</sup>	245.00 (15.67) <sup>g</sup>	253.67 (15.94) <sup>i</sup>	252.66 (15.91) <sup>h</sup>
	<b>CD @ 5.0%</b>		<b>0.73</b>	<b>0.62</b>	<b>0.52</b>	<b>1.25</b>
	<b>SEm ±</b>		<b>0.24</b>	<b>0.21</b>	<b>0.17</b>	<b>0.42</b>
	<b>CV (%)</b>		<b>9.23</b>	<b>6.22</b>	<b>5.75</b>	<b>10.02</b>

Figures in the parenthesis are  $\sqrt{(X + 0.5)}$  transformations

Means with similar alphabets do not differ significantly by DMRT (P=0.05)

DBS : Day before spray. DAS : Days after spray

**Table 14: Bioefficacy of acaricides against grape mites (after third spray)**

	Treatments	Dosage	Mean population of mites/ 4 leaves			
			1DBS	1DAS	5DAS	10DAS
T1	Dicofol 18.5 EC	2.50 mL/L	112.67 (10.64) <sup>d</sup>	95.36 (9.79) <sup>e</sup>	74.1 (8.64) <sup>d</sup>	78.29 (8.88) <sup>h</sup>
T2	Fenpyroximate 5 SC	1.00 mL/L	95.67 (9.81) <sup>c</sup>	55.67 (7.49) <sup>c</sup>	31.67 (5.67) <sup>c</sup>	29.23 (5.45) <sup>d</sup>
T3	Diafenthiuron 50 SC	0.80 mL/L	91.67 (9.60) <sup>c</sup>	68.67 (8.32) <sup>d</sup>	45.67 (6.79) <sup>c</sup>	43.53 (6.64) <sup>e</sup>
T4	Sulphur 80WP	2.00 g/L	121.67 (11.05) <sup>d</sup>	103.33 (10.19) <sup>f</sup>	93.33 (9.69) <sup>e</sup>	104.00 (10.22) <sup>f</sup>
T5	Abamectin 1.9 EC	0.50 mL/L	55.33 (7.47) <sup>a</sup>	21.32 (4.67) <sup>a</sup>	11.00 (3.39) <sup>a</sup>	8.00 (2.92) <sup>b</sup>
T6	Neemazal 3000 ppm	2.0mL/L	131.33 (11.48) <sup>e</sup>	119.00 (10.93) <sup>g</sup>	102.67 (10.16) <sup>e</sup>	98.67 (9.96) <sup>f</sup>
T7	Hexythiazox 5.45 EC	1.50 mL/L	45.67 (6.79) <sup>a</sup>	15.67 (4.02) <sup>a</sup>	5.33 (2.41) <sup>a</sup>	3.67 (2.04) <sup>a</sup>
T8	Fenazaquin 10 EC	1.00 mL/L	108.33 (10.43) <sup>d</sup>	75.67 (8.73) <sup>d</sup>	61.24 (7.86) <sup>d</sup>	64.84 (8.08) <sup>f</sup>
T9	Propargite 57 EC	2.00 mL/L	73.00 (8.57) <sup>b</sup>	23.67 (4.92) <sup>b</sup>	15.67 (4.02) <sup>b</sup>	12.67 (3.63) <sup>c</sup>
T10	Ethion 50 EC	2.00 mL/L	102.32 (10.14) <sup>c</sup>	85.21 (9.26) <sup>e</sup>	67.21 (8.23) <sup>d</sup>	70.31 (8.41) <sup>g</sup>
T11	<i>V. lecanii</i> (2.5 x 10 <sup>7</sup> spores/mL)	1.00 g/L	107.33 (10.38) <sup>d</sup>	91.53 (9.59) <sup>e</sup>	87.23 (9.37) <sup>e</sup>	78.75 (8.90) <sup>h</sup>
T12	Spiromecifen 240 SC	0.50 mL/L	63.26 (7.98) <sup>b</sup>	31.25 (5.63) <sup>b</sup>	15.23 (3.97) <sup>b</sup>	12.35 (3.58) <sup>c</sup>
T13	<i>H. thompsonii</i> (2.5 x 10 <sup>9</sup> spores/mL)	1.00 g/L	101.33 (10.09) <sup>c</sup>	87.3 (9.37) <sup>e</sup>	78.11 (8.87) <sup>d</sup>	71.2 (8.47) <sup>g</sup>
T14	Untreated control	2.50 mL/L	220.33 (14.86) <sup>f</sup>	223.33 (14.96) <sup>h</sup>	222.33 (14.93) <sup>f</sup>	221.67 (14.91) <sup>i</sup>
	<b>CD @ 5.0%</b>		<b>0.74</b>	<b>0.65</b>	<b>1.25</b>	<b>0.92</b>
	<b>SEm ±</b>		<b>0.25</b>	<b>0.21</b>	<b>0.42</b>	<b>0.32</b>
	<b>CV (%)</b>		<b>8.21</b>	<b>5.87</b>	<b>9.87</b>	<b>6.65</b>

Figures in the parenthesis are  $\sqrt{(X + 0.5)}$  transformations

Means with similar alphabets do not differ significantly by DMRT (P=0.05)

DBS : Day before spray. DAS : Days after spray

**Table 15: Effect of different acaricides and biorationals on grape yield**

Sl. No.	Treatments	Dosage	Kg vine <sup>-1</sup>	Q ha <sup>-1</sup>
T <sub>1</sub>	Dicofol 18.5 EC	2.50 mL/L	11.03 <sup>c</sup> (3.38) <sup>c</sup>	245.15 <sup>c</sup>
T <sub>2</sub>	Fenpyroximate 5 SC	1.00 mL/L	11.85 <sup>bc</sup> (3.44) <sup>bc</sup>	263.39 <sup>bc</sup>
T <sub>3</sub>	Diafenthiuron 50 SC	0.80 mL/L	11.63 <sup>bc</sup> (3.41) <sup>bc</sup>	259.07 <sup>bc</sup>
T <sub>4</sub>	Sulphur 80 WP	2.00 g/L	10.81 <sup>c</sup> (3.29) <sup>c</sup>	240.25 <sup>c</sup>
T <sub>5</sub>	Abamectin 1.9 EC	0.50 mL/L	15.2 <sup>ab</sup> (3.96) <sup>ab</sup>	337.81 <sup>ab</sup>
T <sub>6</sub>	Neemazal 3000ppm	2.0mL/L	10.14 <sup>c</sup> (3.25) <sup>c</sup>	226.09 <sup>c</sup>
T <sub>7</sub>	Hexythiazox 5.45 EC	1.50 mL/L	16.01 <sup>a</sup> (1.06) <sup>a</sup>	355.71 <sup>a</sup>
T <sub>8</sub>	Fenazaquin 10 EC	1.00 mL/Lt	11.23 <sup>c</sup> (3.35) <sup>c</sup>	250.05 <sup>c</sup>
T <sub>9</sub>	Propargite 57 EC	2.00 mL/L	14.4 <sup>ab</sup> (3.86) <sup>ab</sup>	320.11 <sup>ab</sup>
T <sub>10</sub>	Ethion 50 EC	2.00mL/L	11.24 <sup>c</sup> (3.35) <sup>c</sup>	250.07 <sup>c</sup>
T <sub>11</sub>	<i>V. lecanii</i> (2.5 x 10 <sup>7</sup> spores/mL)	1.00 g/L	10.72 <sup>c</sup> (3.34) <sup>c</sup>	238.25 <sup>c</sup>
T <sub>12</sub>	Spiromecifen 240 SC	0.50 mL/L	14.21 <sup>ab</sup> (3.83) <sup>ab</sup>	316.15 <sup>ab</sup>
T <sub>13</sub>	<i>H. thompsonii</i> (2.5 x 10 <sup>9</sup> spores/mL)	1.00 g/L	10.85 <sup>c</sup> (3.38) <sup>c</sup>	241.50 <sup>c</sup>
T <sub>14</sub>	Untreated control	2.50 mL/L	8.45 <sup>d</sup> (2.91) <sup>d</sup>	187.81 <sup>d</sup>
	<b>CD @ 5.0%</b>		0.42	50.42
	<b>SEm ±</b>		0.14	20.25
	<b>CV (%)</b>		6.66	11.5

#### 4.4 Effect of different acaricides on yield of grape

A maximum grape berry yield of 16.01 kg/vine was harvested from hexythiazox 5.45 EC at 1.50 mL/L treatment. Abamectin 1.9 EC and propargite 57 EC with 15.20 and 14.40 kg berries / vine were on par with hexythiazox impact. These two treatments were on par with each other also. Thus, acaricides hexythiazox, abamectin and propargite appeared to be promising even in terms of grape yield. In terms of q/ha the yield was 355.71 in hexythiazox treatment which was significantly highest over rest of the treatments (Table 15). Spiromecifen was also on par with propargite and abamectin in terms of grape yield. Fenpyroximate and difenturon application emerged as treatments better than popular acaricides *viz.*, dicofol /ethion /sulpur as per yield data both in kg/vine or q/ha. In untreated control plots the yield was significantly lowest *i.e.*, 187.81 q/ha or 8.45 kg/vine indicating the necessity of protection against the mites in grape.

## DISCUSSION

Grape (*Vitis venifera* L.) an important fruit crop of Karnataka and livelihood of majority of farmers in Northern dry zone (zone 3) and Bangalore (zone 5 Eastern dry zone) of Karnataka. It has been always a tedious task to grape growers to maintain an insect pest free crop which take a heavy toll in the yields. Despite the conventionally associated insect pests and diseases a new problem *i.e.*, of mites is being encountered by grape growers quiet recently. Hence present investigation was undertaken to unearth bio-ecological and management clues with respect to mites which could be of immediate importance to the farmers.

### 5.1 Survey and surveillance for mites and their natural enemies incidence in grapes in Karnataka

Survey and surveillance are the basis for any successful plant protection strategy which depends upon early detection of pest incidence followed by timely adoption and application of preventive measures (Sudarshan Rao., 1975).

#### 5.1.1 Roving survey in Karnataka state

During the state wise survey the mite incidence was quite common in Bijapur, Belgaum and Bagalkot districts. The mean incidence in Bijapur, Belgaum and Bagalkot was  $18.41 \pm 2.4$ ,  $17.08 \pm 1.8$  and  $11.75 \pm 0.25$ , respectively which were higher in order of incidence. On the contrary in the Southern part of Karnataka the incidence was either negligible or nil (Fig 2), however the population ranged from  $0.25 \pm 0.2$  to  $0.6 \pm 0.7$  in Bangalore / Chikkaballapur districts. The variety grown was Thompson seedless throughout the North Karnataka among the survey spots considered and Anab-E-Shahi as well as Bangalore blue were dominating in Southern part. The highest mite population in entire survey observed was  $22.1 \pm 2.8$  in Baballeshwar followed by Jumnal and Chikkalaki cross of Bijapur district. Thus mite incidence appeared to be wide spread and rampant in Bijapur, Belgaum and Bagalkot districts. There might be quite congenial atmosphere for establishment and spread of mites *T. urticae* in these districts in terms of environmental factors and crop husbandry. The variety grown (Thompson seedless) in large areas throughout the North Karnataka may also be a reason for spread of mite menace. On the contrary the varieties grown in South Karnataka *viz.*, Bangalore blue, Sharad, Anab-E-Shahi which exhibit different plant growth habit with thick leaves and velvety under surface might be hindering the establishment of mites. In fact Anab-E-Shahi is known to resist mites infesting grape vineyard as reported by Rathar (2006).

A report from National Research Centre for Grapes, Pune (Maharashtra, India) disclosed six species of mites *Viz.* *T. urticae*, *T. sinnabarinus*, *T. neocoleonicus*, *Oligonicus mangiferus*, *Oligonicus punicae* and *Eutetranychus orientalis* infesting grapes in India (Anon., 2008). The report also projects two spotted red spider mite *T. urticae* as a pest causing severe loss in Maharashtra and Andhra Pradesh. This fact was quite evident in the present investigation also as *T. urticae* found in severe proportions in Northern part of Karnataka. However, no other species of mites were found in present study. Chandra Sekhar *et al.* (2008) also reports *T. urticae* as serious pest around Hyderabad (Andhra Pradesh, India). Thus from available reports it appears that the mites particularly *T. urticae* is well established in conventional areas of grape cultivation in Maharashtra, Karnataka and Andhra Pradesh where in Thompson seedless variety is dominant one. This area is known for hot humid climate which encourages more pest and diseases compared to Bangalore and Chikkaballapur districts. The NRC report (Anon., 2008) also stresses upon the opinion that drought prone areas succumbing to mite outbreak is quite common phenomenon in Northern part of Karnataka. The hot dry conditions essentially lead to outbreak of mites. Hence, a serious proportion of mites have been observed in Bijapur and other districts. The present roving survey appears to be first attempt across Karnataka for mite infestation in grapes (and other crops too) and hence it lacks published literature for comparison. It is also likely that prevailing pest management practices targeting other insect pests might have lead to the resurgence of mites especially the use of synthetic pyrethroids against thrips and mealy bugs in this area. Personal discussion with farmers revealed that usage of pyrethroids in their pest management schedule.

#### 5.1.2 Incidence of predatory mite *Euseius* sp.

In the roving survey, the incidence of phytoseiid mite *Euseius* sp. and a predatory insect *Coccinellid* sp. was also noticed, latter being negligible one. The population of predatory mites ranged from  $0.25 \pm 0.5$  to  $4.0 \pm 0.9$  in the state, however it confined mostly to the Northern parts of Karnataka.

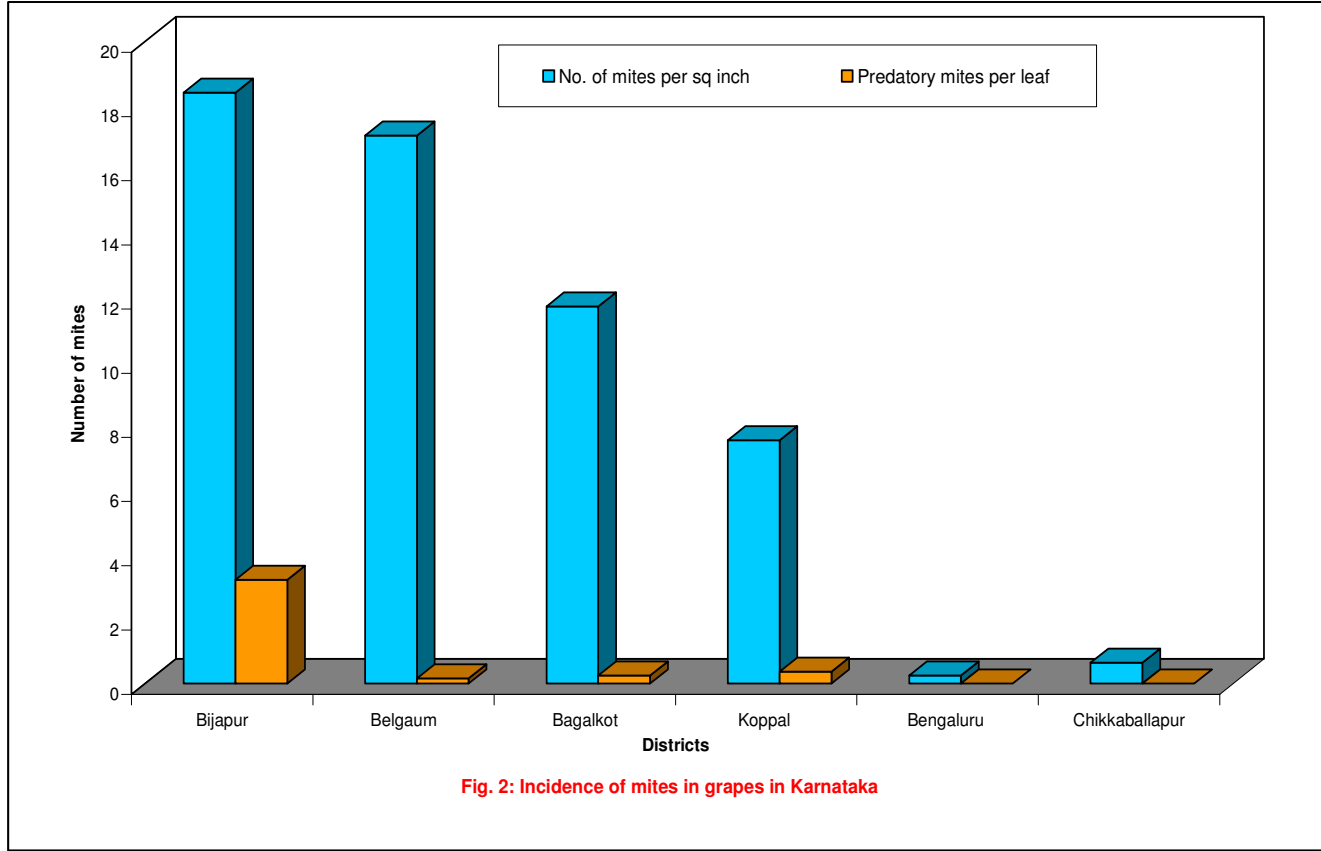
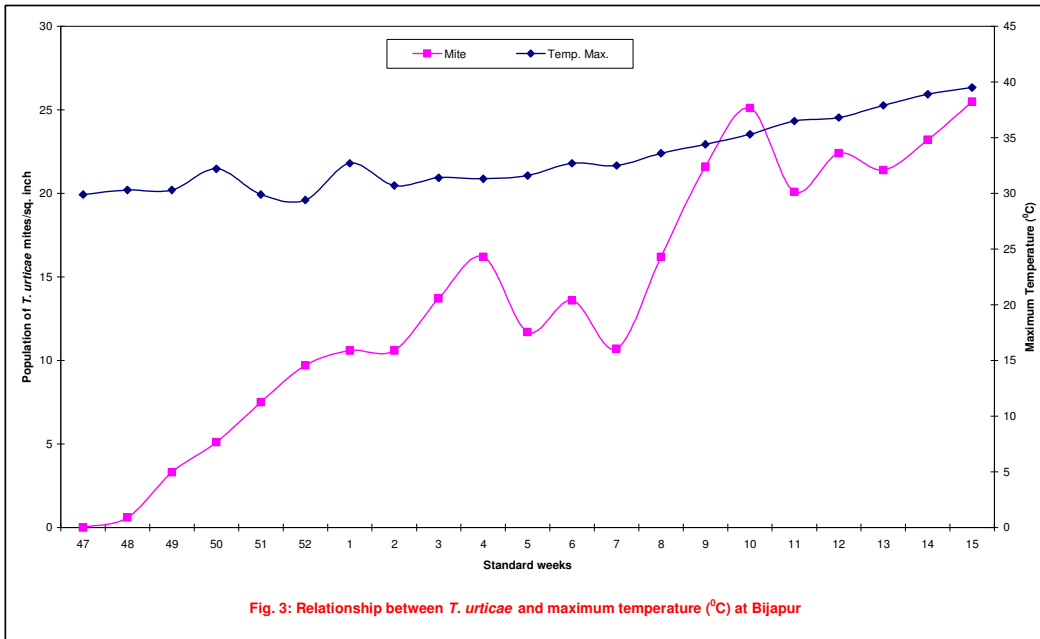
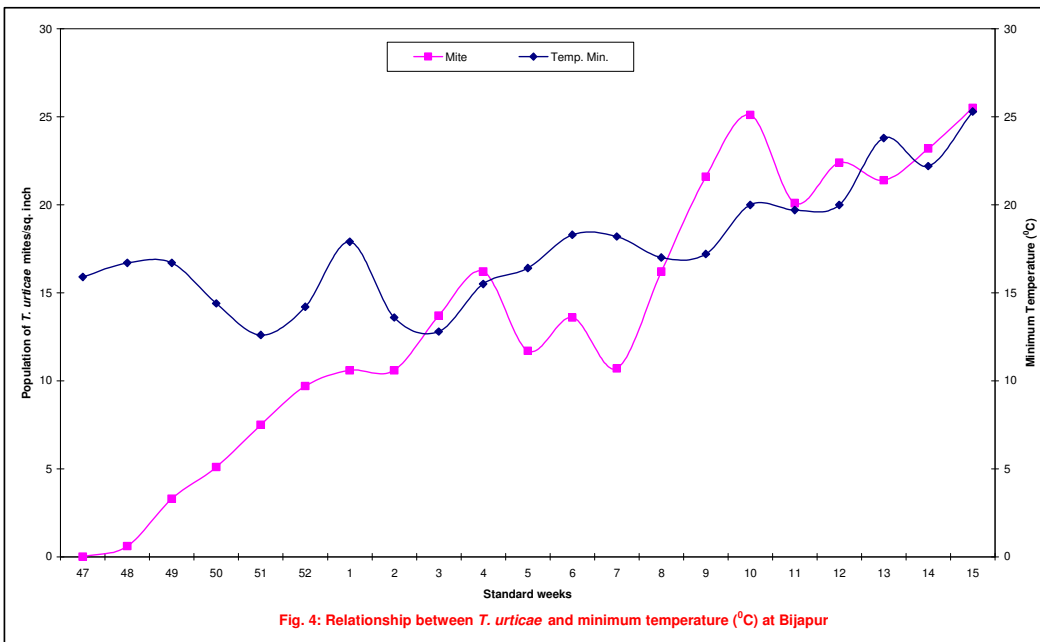


Fig. 2: Incidence of mites in grapes in Karnataka

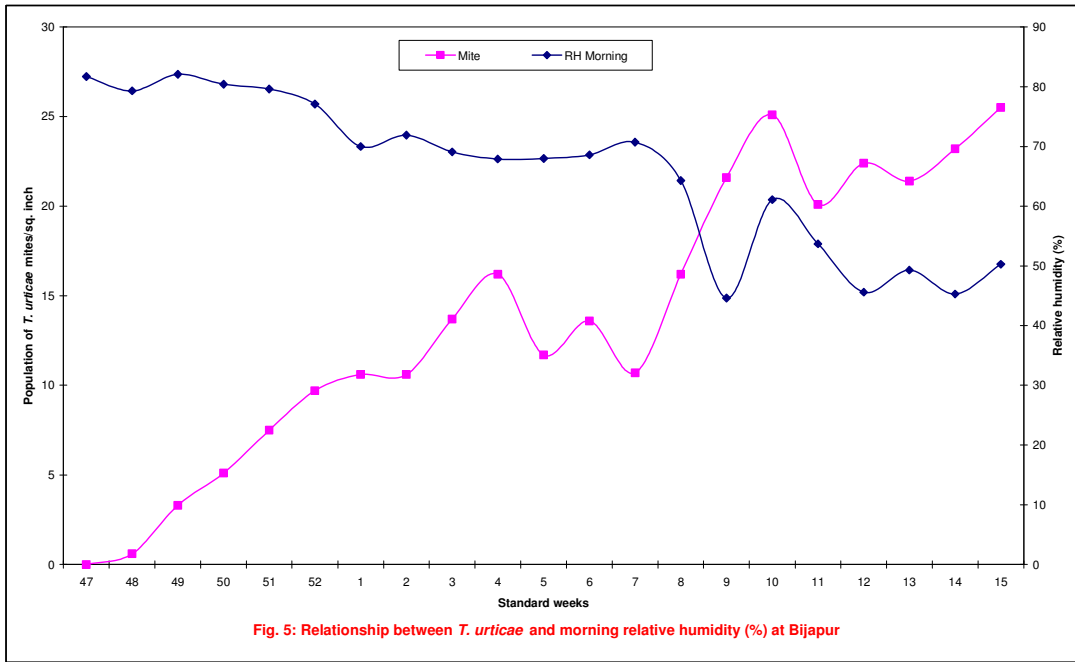
Fig. 2: Incidence of mites in grapes in Karnataka



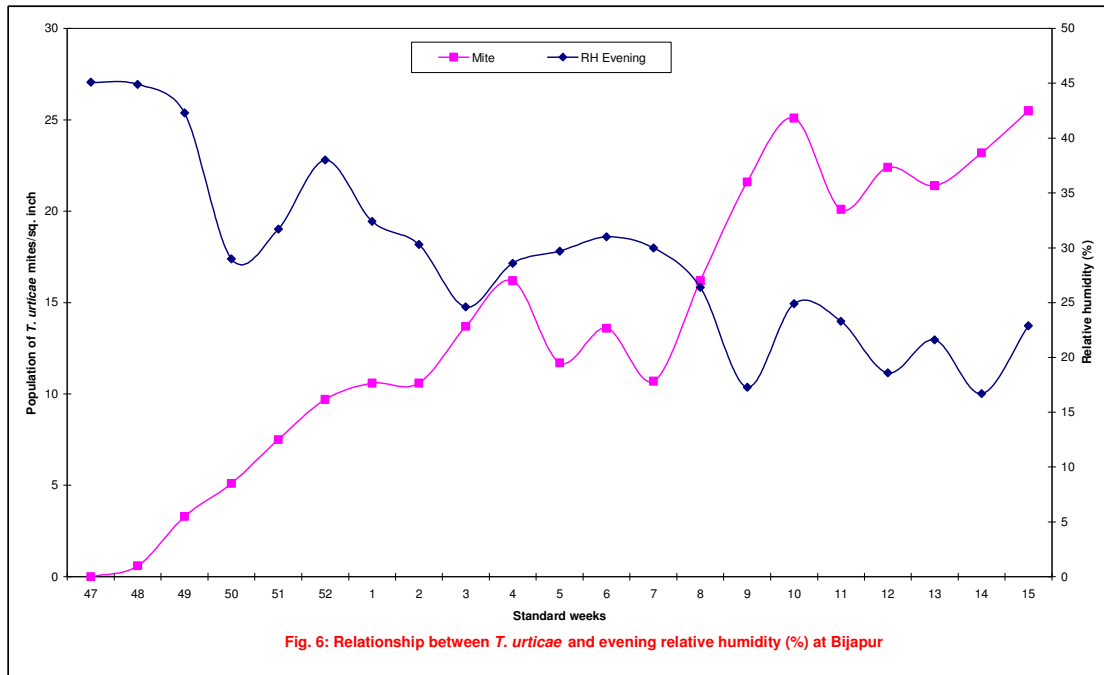
**Fig. 3: Relationship between *T. urticae* and maximum temperature (0C) at Bijapur**



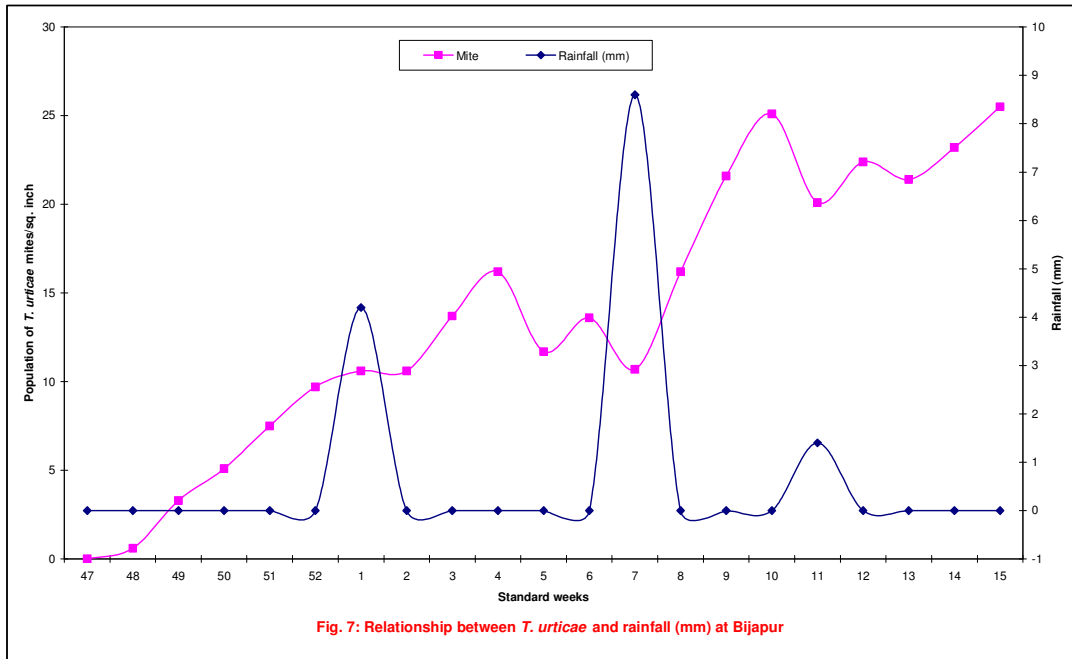
**Fig. 4: Relationship between *T. urticae* and minimum temperature (0C) at Bijapur**



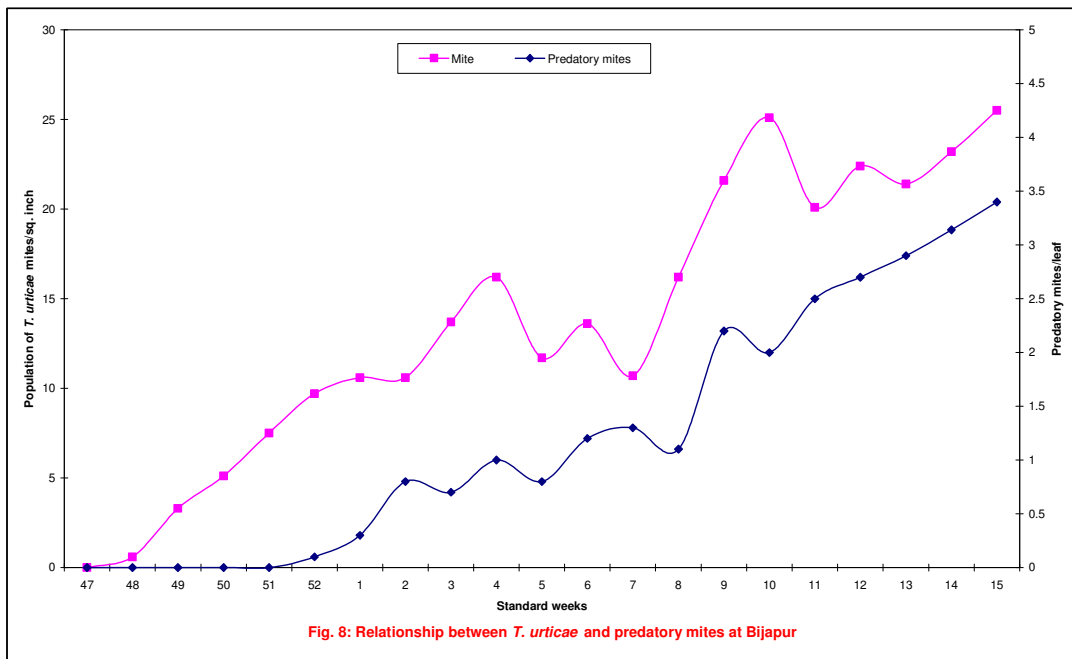
**Fig. 5: Relationship between *T. urticae* and morning relative humidity (%) at Bijapur**



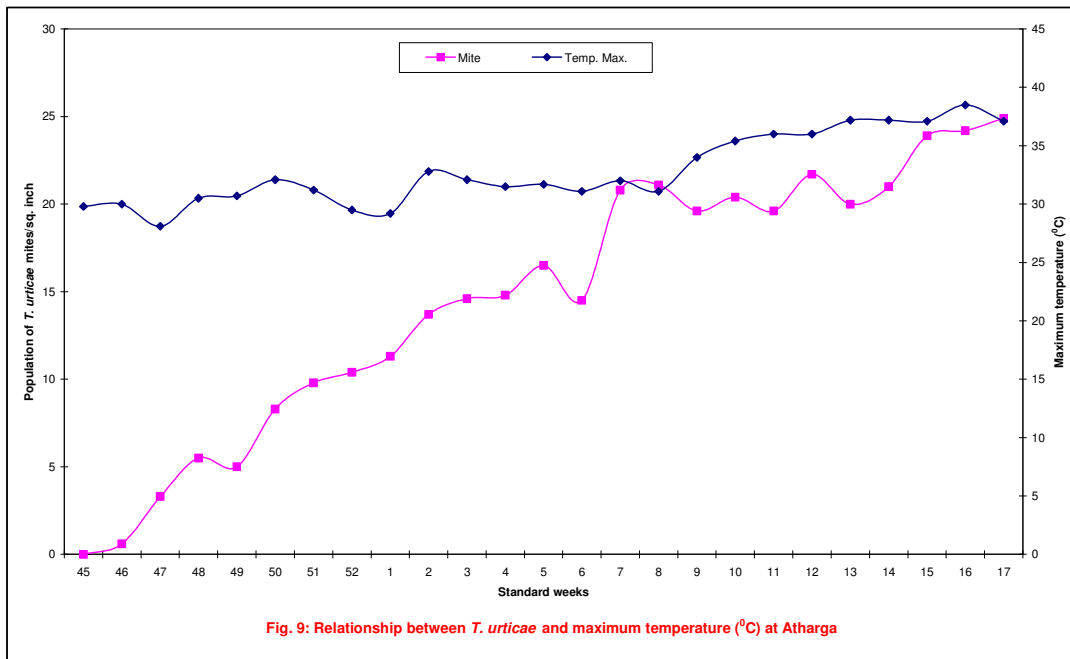
**Fig. 6: Relationship between *T. urticae* and evening relative humidity (%) at Bijapur**



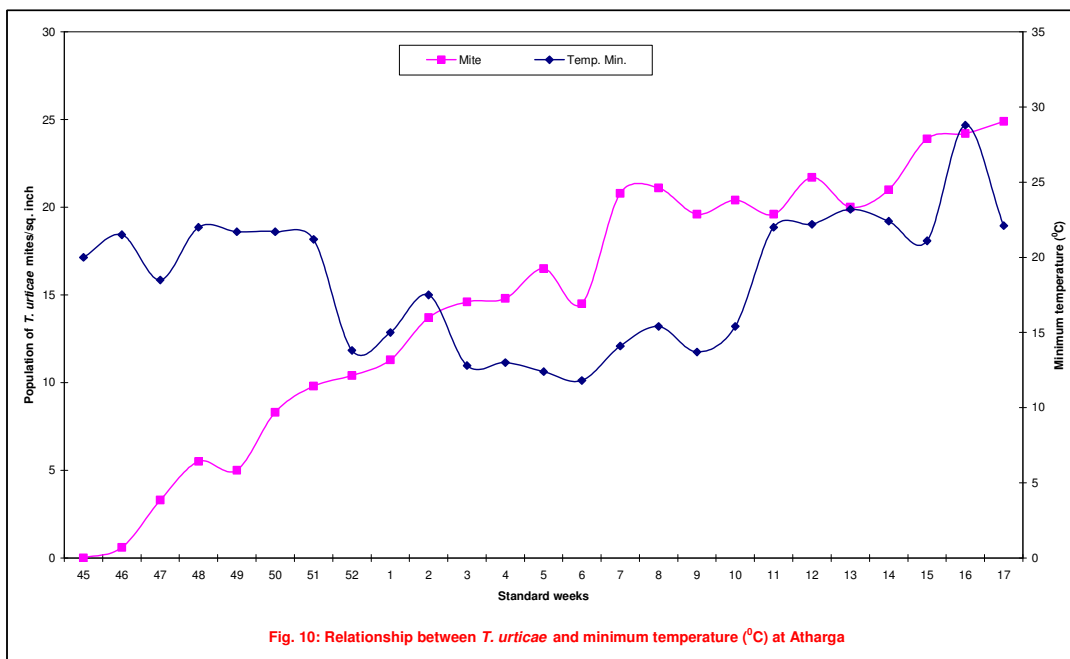
**Fig. 7: Relationship between *T. urticae* and rainfall (mm) at Bijapur**



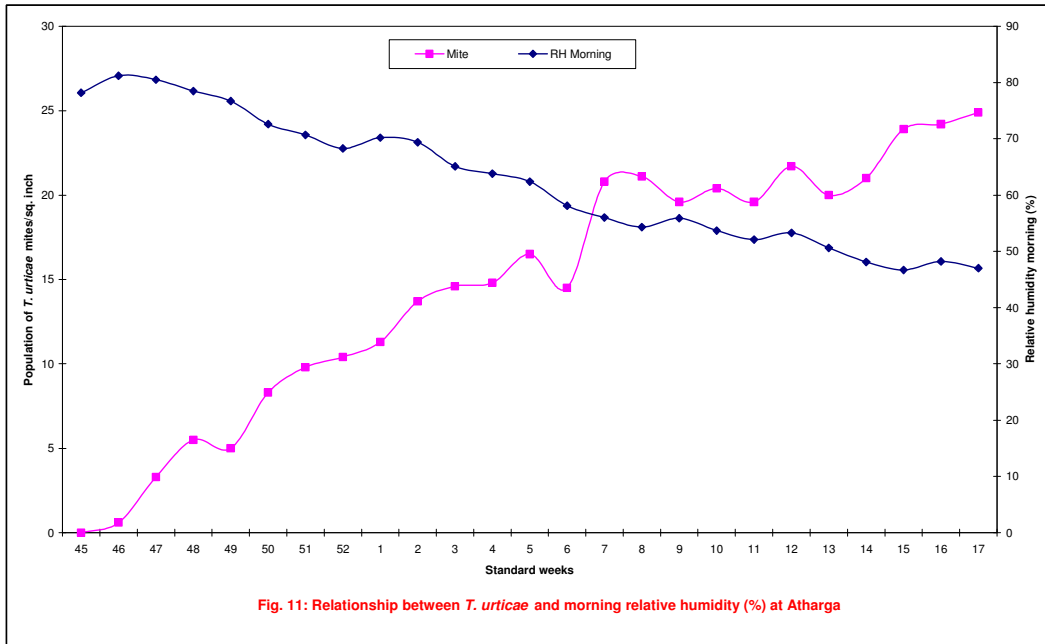
**Fig. 8: Relationship between *T. urticae* and predatory mites at Bijapur**



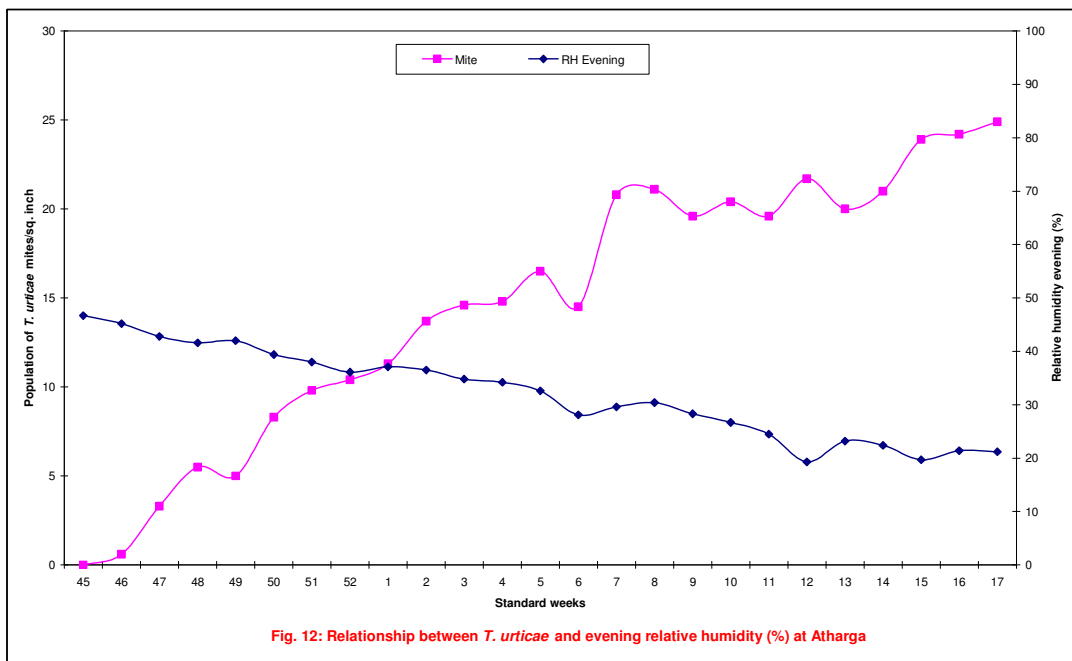
**Fig. 9: Relationship between *T. urticae* and maximum temperature (0C) at Atharga**



**Fig. 10: Relationship between *T. urticae* and minimum temperature (0C) at Atharga**



**Fig. 11: Relationship between *T. urticae* and morning relative humidity (%) at Atharga**



**Fig. 12: Relationship between *T. urticae* and evening relative humidity (%) at Atharg**

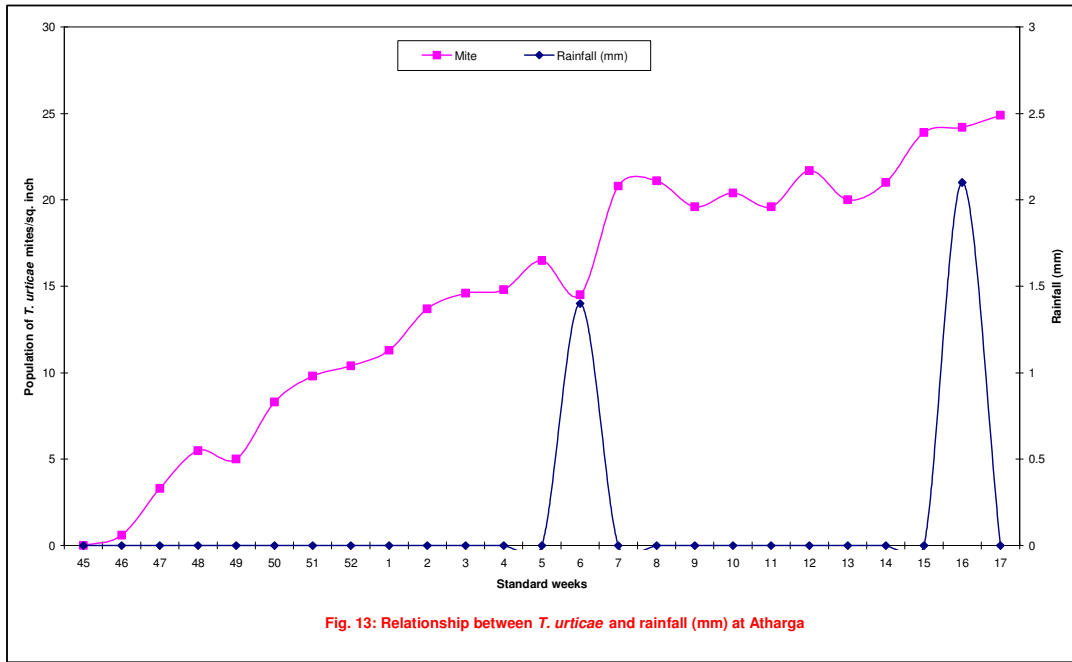


Fig. 13: Relationship between *T. urticae* and rainfall (mm) at Atharga

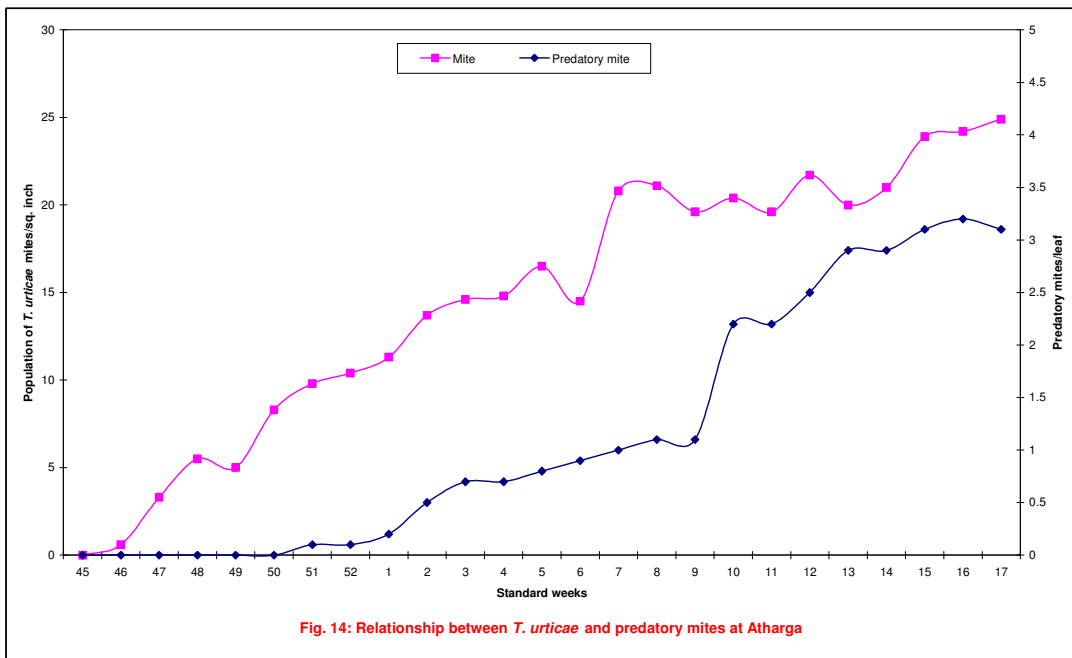


Fig. 14: Relationship between *T. urticae* and predatory mites at Atharga

Thus a host dependant density pattern of incidence was evident for phytoseiid mite in Bijapur where highest population mean ( $3.23 \pm 0.7$  per leaf) was noticed. As the grape itself is recently relishing host for *T. urticae* the association of predatory mite has not been much pronouncing in present study (Fig 2). However, mites were never devoid of phytoseiid or predatory complex in any crop (Gupta and Gupta, 1985). Different phytoseiid mites (Anon.,2000c) *Viz.*, *Amblyseius lorgonsis*, *A. alstoniae*, *A. finlandicus*, *Phytoseius roseus* have been reported as the predatory mites of *T. urticae* and other spider mites particularly in brinjal. According to Shibao *et al.* (2004) and Duso and Vettorazzo (1999) *Amblyseius andersoni*, *Phytoseius finitimus*, *Euseius sojanesis*, *A. eharari* have been observed as promising predatory mites in grape ecosystem of Netherlands. The *Euseius sp.* observed in present study is probably a recent appearance as there are no such reports with respect to predation on *T. urticae* and other mites in any crops. However, *Euseius kodekenalensis* has been recorded long back in South India (Gupta, 1978). Two spotted mite *Teranychus urticae* being polyphagous pest its predator *Euseius sp.* observed in the present study may be in more abundance in other hosts (brinjal, chilli etc.) which have lesser pesticide pressure. Such phenomenon is common (Pozzebon *et al.*, 2005) with respect to predatory and phytophagous mites. Predatory mite *viz.*, *Euseius vignus* and *E. insanus* have been reported as dominant species in both vineyards and surrounding vegetation in Jammu valley (Rathar, 2006). Thus association of mites belonging to *Euseius* genera is there in Indian grape ecosystems. In the near future it could be dominating in Karnataka also. If it happens so it is likely that *Euseius sp.* excise an appreciable natural control or it may emerge as good bio-control agent candidate for inundative release as *Euseius* genera has better predacious characters. This conclusion is stemming on the fact that *Euseius finlandicus* is potential bio-control of *T. urticae* (Abdallah *et al.*, 2001) and its intraguild dominance amongst other predator (of *T. urticae* itself) is evident as per Raquel *et al.* (2010). Besides, *Euseius hibisci* has been a well accepted bio-control agent against *T. urticae* in strawberry orchards based on a prey stage preference and functional response studies in Mexico (Mohammed *et al.*, 2004).

### 5.1.3 Population dynamics of *T. urticae* and predatory mites in grape

Survey and surveillances information helps in understanding the bionomics of pests in the better way and to develop suitable management strategies. Hence fixed plot seasonal studies were carried out at Bijapur (Tq / Dt: Bijapur) and Atharga (Tq: Indi, Dt: Bijapur) selecting commercial Thompson seedless vineyards. The garden was six year old at Bijapur and nine years old at Atharga.

The first incidence of mite was observed during 48<sup>th</sup> standard week (November) with the low population of  $0.6 \pm 0.1$  mites per square inch of leaf. The population gradually increased to  $25.5 \pm 0.9$  and remained at higher level till end of the season. During this period the population ranged from  $0.62 \pm 0.1$  to  $25.5 \pm 0.9$ . However, the seasonal mean incidence was  $13.7 \pm 7.8$  per square inch in Bijapur. The seasonal dynamics of mites in Atharga was similar to that of Bijapur. The mean incidence was  $14.6 \pm 7.5$  per square inch with range of  $0.62 \pm 0.1$  to  $24.9 \pm 1.4$ . The maximum mite activity was found from 15<sup>th</sup> to 17<sup>th</sup> standard week ( $23.9 \pm 0.7$  to  $24.9 \pm 1.4$ ) and prevailed till the season end (Fig 3 to 7 and Fig 9 to 13).

At both the places activity of predatory mite *Euseius sp.* was depending on its prey density. The first incidence of predatory mite was observed at 52<sup>nd</sup> and 51<sup>st</sup> standard weeks at Bijapur and Atharga with  $0.1 \pm 0.3$  and  $0.13 \pm 0.3$  per leaf respectively. Maximum activity of predatory mites was observed during 15<sup>th</sup> and 17<sup>th</sup> standard week at both the places. The highest incidence of predatory mites recorded at Bijapur was  $3.4 \pm 0.9$  (15<sup>th</sup> SW) and  $3.1 \pm 1.3$  mites per leaf in Atharga (Fig 8 and 14).

Thus the incidence of phytophagous mites in grape started from November and reached peak by December. The mites activity was persisting till the harvest of crop i.e March. During all these months the prevailing temperature was high in the study locality as well as surrounding areas (Appendix II). Chandra Sekhar *et al.* (2008) also observed higher incidence of mites during high temperature (March / April 2005) in grape ecosystems of Andhra Pradesh. According to Dhar *et al.* (2000) mite population reached peak when temperature was about  $31.3^{\circ}$  C on okra. Thus from available reports it is clear that mite incidence likely to be highest in high temperature regimes. This was evident in the present investigation also.

## 5.2 Biology of *T. urticae* infesting grapes

Studies on biology of red spider mite on grapevine revealed that most of the egg laying by mite was confined to the area nearer to mid rib and lateral veins on the under surface of leaf. Freshly laid eggs were spherical, smooth and translucent white. The larva was whitish in colour with prominent red simple eyes and with three pairs of legs.

The larval stage was followed by a quiescent stage (Quiescent I). The newly emerged protonymph was amber in colour and the later stage protonymph was brownish in the beginning. Later it turned to dark brown and it was slightly larger than larva and easily distinguishable by the presence of four pairs of legs. The protonymphal stage was followed by quiescent stage (Quiescent II). After protonymphal stage the mite passed to deutonymphal stage, which resembled to protonymph in all characters except bigger in size. After deutonymphal stage, the pest immediately entered into a quiescent stage (Quiescent III). The total developmental period from egg to adult stage was averaged to  $12.55 \pm 0.82$  days. The observations of *T. urticae* reared on grapes (Thompson seedless) in the present study are in accordance with Chandra Sekhar *et al.* (2008) and NRC Pune reports (Anon., 2008). However, slight variations in individual life stages were evident which is a common phenomenon. The fecundity observed in present study is comparatively lesser than observations of Chandra Sekhar *et al.* (2008) and more than that of NRC Pune report (Anon., 2008). However, in the comparative account the present study revealed low fecundity  $55.5 \pm 4.5$  and shorter female longevity 12.8 on mulberry host. The total developmental period and ovipositional period were also less for *T. urticae* reared on mulberry compared to grape (Table 10 and 11).

Thus, the grape appears to be a better host for *T. urticae*. The biological variation in pest performance among the different host is a known phenomenon though each host supports the survival and perpetuation to considerable extent. Thus, the pest like *T. urticae* appears to be polyphagous infesting many crops. For instance Mayer (1974) and Liu (2000) observed chilli and otello corn as better hosts for *T. urticae*. Tomatoes have total developmental period closer to grape host for *T. urticae* as per Chahine *et al.* (1994). Similarly, apples also support *T. urticae* biology in a very close fashion to grapes (Czajkowska, *et al.* 1995). Though, brinjal is a good host for *T. urticae* with biological parameter similar to grapes (except fecundity) the differential response among brinjal cultivars themselves was also evident in (Vora, 1994). Hence grape appears to be a good host for two spotted spider mite and differential response would be possible among cultivars.

### 5.3 Management of grape mites using synthetic acaricides and biorationals

With an aim to generate information on the management options for mites infesting grapes a field experiment was conducted at Toravi during 2012-13. A total of thirteen different acaricides comprising of synthetic compounds, neem based product and fungal pathogens were evaluated in comparison with untreated control on Thompson seedless variety. The first round treatments were imposed during last week of December where in population ranged from 165.33 to 193.33 mites per four leaves in experimental unit which was statistically uniform (Table 12). All together three sprays were given. The observations were made at a day before as well as one, five and ten days after every spray.

Among different treatments hexythiazox 5.45 EC appeared to be the best treatment in containing the mite incidence successfully. Though many acaricides were on par with hexythiazox at one DAS, only abamectin and propargite could maintain the comparative efficacy with it in all observations. The population was brought down to 56.32 per four leaves from 185.21 in 10 DAS when hexythiazox was applied @ 1.5 mL per liter. Similarly, suppression was from 187.5 to 61 in abamectin 1.9 EC treatment @ 0.5 mL per liter. Even 2<sup>nd</sup> and 3<sup>rd</sup> spray (Table 13 and 14), the bio-efficacy of these compounds remained superior over the rest. Finally the population observed in hexythiazox and abamectin treatment at 10 days of 3<sup>rd</sup> spray was 3.7 and 8.00 per four leaves respectively. The treatments *viz.*, spiromecifen 240 SC (0.5 mL/Liter), propargite 57 EC (2 mL/Liter) were next best treatments with 12.35 and 12.67 mites per four leaves at 10 DAS of 3<sup>rd</sup> spray. Conventional acaricides *viz.*, dicofol 18.5 EC, ethion 50 EC could not be considered as effective based on the persisting populations of mites in these treatments. This holds good even for sulphur 80 WP a compound known for acaricidal activity. However, fenazaquin 10 EC had a fairly good effect against grape mites. The efficacy of fungal bio-agents *H. thompsonii* and *V. lecanii* was on par with efficacy of dicofol/ethion/sulphur in suppressing mite incidence. Thus, reliance on these two bio-agents as sole treatments was not defensible as per the results of present study. However, the scope for using them at still higher dosages or with strains of better pathogenesis still remains as a choice. Such considerations holds good for neem product (neemazal 3000 ppm) also which had significantly lower bio-efficacy than fungal bio-agents. Dicofol, sulphur and ethion have been considered as effective against *T. urticae* and other phytophagous mites in grape and different crops (Kumar and Sharma, 1991., Rai *et al.*, 1995. and Patel *et al.*, 1993). The poor performance of these compounds in the present study may be due to development of resistance in *T. urticae* as they are being used since long against these mites in different crops.

The superiority of hexythiazox is in confirmation with the investigations of Keena *et al.* (1991) against *Tetranychus* sp. in laboratory and Ma-Shue *et al.* (1998) against *T. urticae* on apple. However, its efficacy on grape is not reported in literature presently. The effectiveness of abamectin in reducing the mite population has been reported by Karmate and Chandele (1997) in different crops. Recommendations from NRC, Pune (Anon., 2008) and IIHR, Bangalore ([www.iihr.ernet.in](http://www.iihr.ernet.in)) also include dicofol, fenpyroximate, difenthrion, sulphur, abamectin, azadirachtin for management of grape mites at variable pre-harvest interval for harvest safety in terms of residues. In the present study these chemicals have been used in the dosages recommended by these institutions. Chandra Sekar *et al.* (2008) also considered abamectin as a best treatment against mites in grapes followed by difenthrion, fenazaquin and spiromecifen. Further, propargite 57 EC has been reported as most effective treatment in containing *T. urticae* incidence in grapes (Thompson seedless) at Bijapur itself (Karabhantanal *et al.*, 2012) recently. The efficacy of abamectin and poor performance of dicofol is also evident in this report. The bio-efficacy of abamectin, fenazaquin and propargite observed in present study is in agreement with reports of Mani *et al.*(2003), Anand Kumar (2002), Singh *et al.*(2004) and Roopa (2005) against different phytophagous mites. Thus acaricides of recent origin as well as different chemistry preferably with IGR action have rendered better suppression of *T. urticae* in grape compared to old and conventional chemicals.

With respect to yield, significantly highest yield (355.71 q/ha) has been harvested from hexythiazox treatment followed by 337.81, 320.11 and 316.15 q/ha from abamectin, propargite and spiromecifen sprayed plots respectively (Table 15). Diafenthiuron and fenpyroximate remained on par with abamectin in terms of yield. All other treatments also rendered significant yield advantage over untreated control despite their lower bio-activity. The studies of Chandra Sekar *et al.* (2008) endorse the present study in terms of yield also. The present study is restricted to bio-efficacy and yield advantage in protecting grapes against mite incidence. The attention has to be given to residue issue also.

#### Future line of work

- Comparative biology of *T. urticae* in different grape cultivars.
- Long term seasonal incidence studies of grape mites in Bijapur district to develop a forecasting model.
- Studies on resurgence of mites in grapes.
- Screening of virulent pathogens and other botanicals for acaricidal property against grape mites in integrated way.

## SUMMARY AND CONCLUSIONS

Results of investigation on different aspects of bio ecology and management of mites infesting grape are summarized and concluded below.

Roving survey was conducted throughout Karnataka covering North Karnataka (Bijapur, Belgaum, Bagalkot and Koppal districts) and South Karnataka (Bengaluru and Chikkaballapur districts) predominantly grape growing areas for incidence of mites and their natural enemies. *T. urticae* was the species of mite infesting grapes. The maximum infestation of mites was observed in Northern Karnataka with mean population of  $18.41 \pm 2.4$ ,  $12.0 \pm 1.8$ ,  $11.7 \pm 0.2$  and  $7.5 \pm 0.8$  per sq inch leaf area in Bijapur, Belgaum, Bagalkot and Koppal districts respectively. So northern parts of Karnataka are likely to be endemic for grape mites in the state. A predatory mite *Euseius sp.* found to be associated with *T. urticae*.

The incidence of mites at Bijapur and Atharga commenced from 47<sup>th</sup> and 45<sup>th</sup> standard week of November 2012 and continued up to 15<sup>th</sup> and 17<sup>th</sup> standard week of April 2013 respectively. The correlation studies on population of *T. urticae* was significantly and positively correlated with maximum and minimum temperature, where as negatively correlated with relative humidity and non significant with rainfall.

Biology of *T. urticae* recorded varied with respect to different life stages viz., egg period ( $4.02 \pm 0.2$ ), larval ( $2.08 \pm 0.1$ ), quiescent I ( $0.76 \pm 0.07$ ), protonymph ( $1.99 \pm 0.15$ ), quiescent II ( $0.81 \pm 0.06$ ), deutonymph ( $2.01 \pm 0.12$ ) and quiescent III ( $0.88 \pm 0.07$ ) days respectively. The total developmental period completed within  $12.55 \pm 0.82$  days. Pre-oviposition, oviposition and post-oviposition periods were  $10.99 \pm 0.13$ ,  $10.54 \pm 0.26$  and  $2.57 \pm 0.16$  days respectively. The male longevity lost for  $8.63 \pm 0.3$  days and whereas female of  $15.09 \pm 0.56$  days. Average fecundity was  $66.53 \pm 4.93$  eggs per female.

Among different synthetic acaricides and biorationals tested, hexythiazox 5.45 EC (1.5 mL/L), abamectin 1.9 EC (0.5 mL/L) and propargite 57 EC (2.0 mL/L) were highly effective followed by, spiromecifen 240 SC (0.5 mL/L) in reducing *T. urticae* mites on grapes and rendering higher yields. In terms of yield highest fruit yield was harvested from hexythiazox 5.45 EC (1.5 mL/L) treatment ( $355.81$  q/ha)

These results of present investigation on bioefficacy of acaricides and biorationals would help in management of mites *T. urticae* infesting grape orchards in Karnataka.

### Conclusions

- Phytophagous mite *Tetranychus urticae* is an established pest in North Karnataka vineyards.
- The largely grown grape cultivar Thompson seedless supports incidence and pestiferousness of phytophagous mite *Tetranychus urticae*.
- Hexythiazox, abamectin, propargite and spiromecifen are promising acaricides for management of grape mite.

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### Appendix 1: Composition of Hoyer's medium

Sl. No.	Content	Quantity
1	Distilled water	50 mL
2	Gum arabic	30 g
3	Chloral hydrate	200 g
4	Glycerol	20 mL

### Appendix 2: Materiological data of Bijapur and Atharga

SW 2012/ 13	Bijapur					Atharga				
	Temp max. (°C)	Temp min (°C)	RH Max. (%)	RH mini (%)	Rainfall (mm)	Temp max. (°C)	Temp min (°C)	RH Max. (%)	RH mini (%)	Rainfall (mm)
<b>2012</b>										
45	0	0	0	0	0	29.8	20	78.2	46.7	0
46	0	0	0	0	0	30	21.5	81.2	45.2	0
47	29.9	15.9	81.7	45.1	0	28.1	18.5	80.5	42.8	0
48	30.3	16.7	79.3	44.9	0	30.5	22	78.5	41.6	0
49	30.3	16.7	82.1	42.3	0	30.7	21.7	76.7	42	0
50	32.2	14.4	80.4	29	0	32.1	21.7	72.6	39.4	0
51	29.9	12.6	79.6	31.7	0	31.2	21.2	70.7	38	0
52	29.4	14.2	77.1	38	0	29.5	13.8	68.3	36.1	0
<b>2013</b>										
1	32.7	17.9	70	32.4	4.2	29.2	15	70.2	37.1	0
2	30.7	13.6	71.9	30.3	0	32.8	17.5	69.4	36.5	0
3	31.4	12.8	69.1	24.6	0	32.1	12.8	65.1	34.8	0
4	31.3	15.5	67.9	28.6	0	31.5	13	63.8	34.2	0
5	31.6	16.4	68	29.7	0	31.7	12.4	62.4	32.6	0
6	32.7	18.3	68.6	31	0	31.1	11.8	58.1	28.1	1.4
7	32.5	18.2	70.7	30	8.6	32	14.1	56	29.6	0
8	33.6	17	64.3	26.4	0	31.1	15.4	54.3	30.4	0
9	34.4	17.2	44.6	17.3	0	34	13.7	55.9	28.3	0
10	35.3	20	61.1	24.9	0	35.4	15.4	53.7	26.7	0
11	36.5	19.7	53.7	23.3	1.4	36	22	52.1	24.5	0
12	36.8	20	45.6	18.6	0	36	22.2	53.3	19.3	0
13	37.9	23.8	49.3	21.6	0	37.2	23.2	50.6	23.2	0
14	38.9	22.2	45.3	16.7	0	37.2	22.4	48.1	22.4	0
15	39.5	25.3	50.3	22.9	0	37.1	21.1	46.7	19.7	0
16	0	0	0	0	0	38.5	28.8	48.2	21.4	2.1
17	0	0	0	0	0	37.1	22.1	47	21.2	0

# BIO-ECOLOGY AND MANAGEMENT OF GRAPE MITES

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2013

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## ABSTRACT

Bioecology and management studies on two spotted spider mite *Tetranychus urticae* Koch infesting grapes were carried out during 2012-13.

From roving survey it was evident that in Northern Karnataka mite incidence was severe with mean population of  $18.41 \pm 2.4$ ,  $12.0 \pm 1.8$ ,  $11.7 \pm 0.2$  and  $7.5 \pm 0.8$  per sq inch of leaf in Bijapur, Belgaum, Bagalkot and Koppal districts respectively. In Southern Karnataka population was negligible.

Seasonal dynamics studied revealed maximum incidence of mites during 15<sup>th</sup> and 17<sup>th</sup> standard weeks with population of  $25.5 \pm 0.9$  and  $24.9 \pm 1.4$  at Bijapur and Atharga, respectively. The predatory arthropods observed were coccinellid beetle and predatory mite, *Euseius sp.* There was positive and significant correlation between mites and temperature where as negatively significant negative relation with relative humidity.

In laboratory study the fecundity of *T. urticae* reared on grape leaves was  $66.53 \pm 4.93$  eggs/female. The female and male longevity was  $15.09 \pm 0.56$  and  $8.63 \pm 0.30$  days respectively. The period occupied by young stages was  $12.55 \pm 0.82$  days.

Bio-efficacy studies showed that hexythiazox 5.45 EC (1.5 mL/ L), abamectin 1.9 EC (0.5 mL /L) and propargite 57 EC (2.0 mL /L) as highly effective acaricides against grape mites. With three sprays the mite incidence reduced from 185.21 to 3.67 per four leaves from hexythiazox application which rendered 355.81 quintal per hectare grape berry yield. From abamectin spray the population suppressed from 184.50 to 8.00 per four leaves where in the yield was 337.81 quintal per hectare.