Chapter-2

Review of Literature

Mulberry (*Morus* spp.) is the sole food plant of domesticated silkworm, *Bombyx mori* L., and is ravaged by a variety of insect pest and diseases. Though several insect pests of mulberry are well documented, the information on the mulberry mite diversity, symptoms of damage, population dynamics, influence of biotic and abiotic factors, is meager. A preliminary study on mite diversity and effect of mite infested mulberry leaves on silkworm *Bombyx mori* in Kashmir valley showed great threat of phytophagous mites to mulberry leaf quality which correspondingly affects silkworm biological and economic parameters (Dar *et al*., 2011). Keeping in view the importance of this non insect pest of mulberry, a study has been under taken on bio-ecology of mulberry mites in temperate climate of Jammu and Kashmir. Available information related to mulberry mites from various parts of the world is presented in this chapter.

Mites are sub microscopic and tiny creature belonging to subclass Acari of the class Arachnida, phylum Arthropoda and infest a number of plants and animals besides saprophytic life. Mites are the dominant species of Acari present almost in every habitat. They are predacious, parasitic, saprophytes, mycophagous, scavengers *etc*. and are of considerable biological importance. There are more than 300 species of insect and non insect pests infesting mulberry throughout the world (Reddy and Narayanswamy, 1999) causing qualitative and quantitative damage. It has been reported that 30 percent of the mulberry leaf yield gets affected by the pests and the diseases (Devaiah and Kotikal, 1983; Bahu *et al*., 1994). Besides Acari, Lepidoptera, Hemiptera, Coleoptera, Thysanoptera, Orthoptera and Isoptera are the major insect orders known to be the pests of mulberry (Sengupta *et al*., 1990).
The ornamental plants which are grown under protected conditions in India are severely attacked by the *Tetranychus urticae* Koch (Mallik *et al*., 1998). It has been well documented that the phytophagous mites are pests of many agricultural and horticultural crops (Channabasavanna, 1999). The quantum loss due to mite attack is not always easy to determine with accuracy (Banerjee, 1988). Osakabe *et al*.(1990) gave the description of development of *Panonychus ulmi* Koch, on the leaves of Japanese pear, mulberry, Satsuma mandarin, trifoliate orange and kidney bean and reported that mulberry can act as a host to *P. ulmi*. Eriophyid mites are host specific, which have evolved intimate associations with their host plants that enable both host and parasite to survive (Hislop and Jeppson, 1976; Krantz and Lindquist, 1979). It has been observed that leaves of mulberry (*Morus* sp.) trees have reduced water, protein and total amino acid contents when attacked by the mite, *Polyphagotarsonemus latus* Banks (Acari: Tarsenomidae) and the quality and quantity of leaf production for sericulture was seriously affected (Zhang *et al*., 1990).

**Mulberry mite diversity**

*Phytophagous mites*: Mulberry is inhabited by both predatory and phytophagous mites throughout the world. There are five known species of tetranychid mites parasitic on mulberry in Japan (Kishida, 1927; Yokoyama, 1929, 1932, Yokoyama and Ishii, 1934 and Ehara, 1956). It has been reported that the red spider mite, *Tetranychus equatorius* (McGregor) belonging to the family Tetranychidae are known to infest mulberry plants and cause considerable damage to the leaf crop (Khot and Patel, 1956 and Pillai and Jolly, 1986). The comprehensive listing of the economically injurious phytophagous species of mites has been presented by Jeppson *et al*.(1975). Majority of the mites belong to two families, Tetranychidae (spider mites) and Tenuipaldae (false spider mites) and economically significant species are also found in Eriophyidae (Krantz, 1978). Ho (2000) has reported that there are 74 species of spider mites in Taiwan among them ten are major pests and *Tetranychus kanzawai* Kishida is the most important on mulberry. Ehara and Gotoh (1992) gave the descriptions of two new species of *Panonychus mori* Yokoyama, on mulberry and *Panonychus thelytokus* Ehara and Gotoh, on *Ulmus japonina* from Japan. It has been observed that the Carmine red spider mite is one of the serious pests with polyphagy
in agriculture, found to infest the mulberry and more than 100 other hosts in China (Wu et al., 2006).

The bud mite, *Aceria mori* Keifer (Eriophyidae: Acari) has been reported on mulberry in Italy (Castagnoli, 1980) and has been also reported on mulberry from Tamil Nadu. All the stages of mites may be seen within the bud scales and infested buds usually dry out (Mohanasundarum and Sivagami, 1983). *Eutetranychus orientalis* Klein, has been reported as a new record of on mulberry from Nilgiris infesting the tender mulberry leaves of the M5 variety and sucks the sap from the ventral side of leaves (Thiagarajan et al., 1994). Castagnoli (1980) reported the *Leipothrix moraceus* Castagnoli, as a new pest of mulberry and found that it overwinters between the scales of the lateral buds.

Fifteen species of mites belonging to families Tetranychidae and Eriophyidae have been reported to occur on mulberry worldwide and cause considerable damage to the leaves (Kotikal, 1982; Sengupta et al., 1991 and Narayanswamy et al., 1996). Among seven species of tetranychids (red spider mites) reported from India, *Tetranychus equitorius* and *Tetranychus ludeni* have been commonly found in many mulberry gardens (Table 1). *Polyphagotarsonemus latus* Banks has been recently reported from mulberry gardens of Tamil Nadu (Chauhan et al., 2002). *Polyphagotarsonemus latus* affects the young topmost and tender leaves closer to the apical bud (Chauhan et al., 2002 and Rajalakshmi et al., 2009). The said mite has been found to attack more than 250 species of plants and cause a severe disease in chilli called “Murda disease” (Nair, 1986) and a sporadic pest on tea plants in Nilgiris and elsewhere in India (Das, 1965). *Tetranychus* species has been reported to inhabiting mulberry throughout the Kashmir valley (Khan and Nighat, 1991). Yousuf and Chouhan (2009) recorded seven species of mites belonging to genus *Tetranychus* namely *T. hydrangea* Pritchard and Baker, *T. ludeni* Zacher, *T. neocaledonicus* Andre, *T. urticae*, *T. sayedi* Baker and Pritchard, *T. fijiensis* Hirst and *T. macfarlanei* Baker and Pritchard infesting forest trees in northern part of India among them *T. urticae* has been reported from mulberry (*Morus alba*). Four mite species comprising of *Tetranychus* sp. and *Panonychus* sp. are phytophagous and *Euseius* sp. and *Agistemus* sp. which are predatory in nature have been known to inhabit mulberry
<table>
<thead>
<tr>
<th>Mite species</th>
<th>Location (State/Country)</th>
<th>Important finding/ remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eotetranychus suginensis</em></td>
<td>Yokoyama, Japan</td>
<td>New record and incidence was severe in the Summer–Autumn rearing season</td>
<td>Ayuzawa et al., 1972</td>
</tr>
<tr>
<td><em>Panonychus citri</em> McGregor</td>
<td>Japan</td>
<td>New record and incidence was severe in the Summer–Autumn rearing season</td>
<td>Ayuzawa et al., 1972</td>
</tr>
<tr>
<td><em>Tetranychus kanzawai</em> Kishida</td>
<td>China</td>
<td>New record, completes 10 generations per year, infestation was severe in the Summer–Autumn rearing season</td>
<td>Ayuzawa et al., 1972; Ho 1990</td>
</tr>
<tr>
<td><em>Tetranychus truncates</em> Ehara</td>
<td>Thailand</td>
<td>New record</td>
<td>Sinchaisri and Isarangkul, 1973,</td>
</tr>
<tr>
<td><em>Tetranychus bimaculatus</em> Harvey</td>
<td>Japan</td>
<td>New record Completes 20 generations per year. Suck sap from leaves and make them pale green and sometimes shrink in size.</td>
<td>Yokoyama, 1975</td>
</tr>
<tr>
<td><em>Tetranychus telerius</em> Linnaeus</td>
<td>India</td>
<td>New record and one generation completed in 18–40 days</td>
<td>Rangaswami et al., 1976</td>
</tr>
<tr>
<td><em>Tetranychus equitorius</em> McGregor</td>
<td>India</td>
<td>New record, total development period occupies 10 days, population maximum during March, April and May–June. From June on words considerable reduction up to August and remains at lower level in January–February</td>
<td>Rangaswami et al. 1976; Pillai and Joly 1986; Sengupta et al., 1990</td>
</tr>
<tr>
<td><em>Tetranychus ludeni</em> Zacher</td>
<td>India</td>
<td>New record, total development period of 9–10.25 days by female and 9.00 to 10 days by male.</td>
<td>Puttaswamy et al., 1980; Nangia et al., 1990</td>
</tr>
<tr>
<td><em>Leipothrix moraceus</em> Castagnoli</td>
<td>Italy</td>
<td>New record and overwinters between the scales of the lateral buds.</td>
<td>Castagnoli, 1980</td>
</tr>
<tr>
<td><em>Tetranychus neocaledonicus</em> Andre</td>
<td>Dharwad, Karnataka, India</td>
<td>New record total development period 10.14 days and adults live about 23.55 days. Population maximum during December, low in the May and nil during February, March and April</td>
<td>Puttaswamy and Channabasavanna 1981; Kotikal, 1982</td>
</tr>
<tr>
<td><em>Aceria mori</em> Keifer</td>
<td>Tamil Nadu, India</td>
<td>New record, infested buds dry out and consequently auxiliary shoot and leaf production is severely affected</td>
<td>Mohanasundaram and Sivagami, 1983</td>
</tr>
<tr>
<td><em>Eutetranychus orientalis</em> Klein</td>
<td>Dharwad, Karnataka India</td>
<td>New record and population is minimum during middle of November and maximum during middle of March</td>
<td>Birader, 1989</td>
</tr>
<tr>
<td><em>Tetranychus urticae</em> Koch</td>
<td>Dharwad, Karnataka India</td>
<td>New record</td>
<td>Birader, 1989</td>
</tr>
<tr>
<td><em>Tetranychus cinnabarinus</em> Biosdual</td>
<td>China</td>
<td>New record</td>
<td>Huang, 1989; Wu and Tian, 1993</td>
</tr>
<tr>
<td><em>Panonychus mori</em> Yokoyama</td>
<td>Japan</td>
<td>New record</td>
<td>Ehara and Gotoh, 1992</td>
</tr>
<tr>
<td><em>Panonychus ulmi</em> Koch</td>
<td>West Bengal, India</td>
<td>First report from mulberry, causing damage to leaf yield</td>
<td>Karmakar et al., 1998</td>
</tr>
<tr>
<td><em>Polyphagous tarsonemus latus</em> Banks</td>
<td>Nilgiris, India</td>
<td>New record, life cycle, seasonal occurrence and control measures are studied</td>
<td>Chauhan et al., 2002; Rajalakshmi et al., 2009.</td>
</tr>
</tbody>
</table>
plantation in Kashmir valley (Dar et al., 2012a).

**Predatory mites:** Predatory mite act as natural enemies and have a regulatory effect on population of different species of phytophagous mites besides insect pests. Outbreak of mites during different seasons is due to the absence of natural enemies besides host plant and climatic factors. Predatory mites have been so far recorded on tetranychids, and a little is known about predators of eriophyids (Banerjee 1988). Gupta (1980) has studied 16 phytoseiid species belonging to four genera from Jammu and Kashmir. *Typhlodromus kashmiricus, T. mori, T. transittans, T. neosoleiger and Phytoseius (Dubininellus) wainsteini,* of which five were new species of which *T. mori* and *T. transittans* have been reported from mulberry. *Amblyseius potentillae* Graman and *Phytoseius corniger* Wainstein have been recorded for the first time from India. Dar et al. (2012a) recorded the *Agistemus* sp. and *Euseius* sp. mite species from mulberry gardens of Kashmir, India (Table 2).

It has been observed that among predatory mites, phytoseiids are major predators of phytophagous (plant feeding) mites and are regarded as the most important enemies of spider mites (Helle and Sabelis, 1985). These predatory mites feed on phytophagous mites of families Tetranychidae, Tenuipalpidae and Tarsonemidae and also on insects like aphids, thrips, whitefly and their eggs. Predatory mites belong to families viz., Phytoseiidae, Stigmaeidae, Cunaxidae, Chyletidae and Bdellidae (Jeppson et al., 1975; Evans, 1992). Shih (1985) used *Amblyseius womersleyi* Schicha, against *Tetranychus kanzawai* and evaluated them on the basis of the population density of spider mites.

It has been observed that the influence of diet on the life history and predatory capacity of *Amblyseius zaheri* Yousef and El-Brolossy (Acari: Phytoseiidae) has an important role in their development. The predatory mite was able to develop and reproduce when fed on nymphs of the two spotted spider mite, *Tetranychus urticae* Koch; nymphs of the citrus brown mite, *Eutetranychus orientalis* Klein; eggs of scale insect and nymphs of the whitefly (Rasmy et al., 2003). Rai and Singh (1999) have explained the biology of *Agistemus industani* (Acari: Stigmaeidae), with the prey mite, *Tetranychus ludeni* on mulberry. It has been observed that the *A. industani* fed
voraciously on the eggs of the *T. ludeni* in the field. Fertilized female of *A. industani* produces female and male progeny in the ratio of 3:1. Longevity of the female has been found to be between 23 to 46 days and that of male was 23 to 48 days. Feeding rate of *A. industani* female was three times higher than that of male. Per day egg laying tripled after the consumption of 15 eggs per day.

Khan and Afzal (2005) have studied the effect of different prey species on the biology of stigmaeid mite, *Agistemus buntex* Chaudhri which completed its life stages in 9.00 days when fed on *T. urticae* as compared to 15.33 and 10.00 days when fed on *P. citri* and *E. orientalis*, respectively. Female laid 40 eggs when feed on *T. urticae*, whereas upon feeding on *P. citri* and *E. orientalis* it reduce to 24.3 and 27.6 eggs, respectively.

Pest Control of India Limited has initiated steps for making availability of *Amblyseius tetranychivorus* as one of the promising indigenous predatory mites on commercial scale but, could not sustained (Krishnamoorthy, 1982). Maketon et al. (2008) has studied twelve entomopathogenic fungi for controlling broad mite (*Polyphagotarsonemus latus*) in mulberry and found that *Metarhizium anisopliae*, CKM-08 was the most virulent strain in controlling both larvae and adult broad mites.

Gosh et al. (2001) has studied the predatory potential of *Amblysisus tetranychivorus* against the spider mite, *T. urticae* under laboratory and polyhouse conditions. Predatory potential of male and female *A. tetranychivorus* was found to be about 1.9 and 3.6 preys per day respectively. The predator works more effectively at low than high prey population levels. Naher and Haque (2007) have observed the predation efficiency of adult female, *Phytoselius permilis* on adult *T. urticae* as a process of biological control. An adult female *P. permilis* consumed 6.47 *T. urticae* per day and highest prey consumption (19.00) was found on the second day and lowest (1.0) was found on fourth and sixth day.

**Damage Symptoms and Economic loss to mulberry**

Blair and Groves (1952) observed that the mites mostly prefer ventral side of the leaves along the midrib, veins and veinlets. They puncture the plant cells with
### Table 2: Glimpses of literature on predatory mites recorded in mulberry ecosystem

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<tbody>
<tr>
<td><em>Phytoseius persimilis</em></td>
<td>China</td>
<td>Natural enemy of <em>T. urticae</em></td>
<td>Laing, 1968</td>
</tr>
<tr>
<td><em>Amblyseius bibens</em></td>
<td>Madagascar</td>
<td>Natural enemy of <em>T. urticae</em></td>
<td>Blomers and Van-Etten, 1975</td>
</tr>
<tr>
<td><em>Amblyseius largoensis</em></td>
<td>India</td>
<td>Natural enemy of <em>E. orientalis</em></td>
<td>Gupta, 1976</td>
</tr>
<tr>
<td><em>Amblyseius ovalis</em></td>
<td>India</td>
<td>Natural enemy of <em>T. cinnabrinus</em></td>
<td>Gupta, 1976</td>
</tr>
<tr>
<td><em>Amblyseius womersleyi</em></td>
<td>Taiwan</td>
<td>Natural enemy of <em>T. kanzawai</em></td>
<td>Shih, 1985</td>
</tr>
<tr>
<td><em>Amblyseius longispinosis</em></td>
<td>Taiwan</td>
<td>Natural enemy of <em>T. kanzawai</em></td>
<td>Lo <em>et al.</em>, 1990</td>
</tr>
<tr>
<td><em>Amblyseius herbicolus</em></td>
<td>Taiwan</td>
<td>Natural enemy of <em>T. kanzawai</em></td>
<td>Lo <em>et al.</em>, 1990</td>
</tr>
<tr>
<td><em>Agistemus industani</em></td>
<td>India</td>
<td>Feed voraciously on eggs of the <em>T. ludeni</em></td>
<td>Rai and Singh, 1999</td>
</tr>
<tr>
<td><em>Cheletacarus gryphus</em></td>
<td>Hisar, Haryana, India</td>
<td>New record</td>
<td>Putatunda <em>et al.</em>, 2002</td>
</tr>
</tbody>
</table>

their stylet which leads to sap exudation from the leaves. Avery and Briggs (1968) found that the phytophagous mites puncture the plant cells with their stylets to a depth of 70 to 120 μm. Both nymphs and adults mites insert their stylets into leaf tissue and suck the sap. The affected portion of the plant turns grayish white and ultimately withers (Ayuzawa *et al.*, 1972). *Tetranychus bimaculatus* sucks the sap from the adaxial leaf surface due to which leaves become yellowish green or pale green in colour and sometimes shrinks in size, the affected leaves become nutritionally poor (Yokoyama, 1975).

Mulberry plants infested by *T. equitorius* present a sickly appearance and the lightly infested leaves have pale spots throughout the leaf blade. During the severe infestation, the entire leaf appears rusty and light green in colour and later dries up. It was observed that under surface of the mite infested leaf shows silken threads spun across them, under which the mites crawl and also fasten their eggs (Rangaswami *et
Puttaswamy et al. (1980) reported that, the mulberry leaves infested by *T. ludeni* shows white specks at the place of feeding. With the increase in intensity of feeding, the specks increase in number and gradually coalesce with one another, finally producing large patches. Nangia and Nagaeshchandra (1990) found that the leaves infested with *T. ludeni* have very low biochemical composition than non-infested leaves and all the cocoon and larval characters of *B. mori* were highly affected. Dar et al. (2011) investigated that the mulberry leaves of Goshoerami variety infested with *Tetranychus* sp. and *Panonychus* sp. were low in chlorophyll, protein and carbohydrate content and affect all the biological as well as cocoon parameters of *B. mori*.

The bud mite, *A. mori* lives in the bud scales of the apical bud and caused discolouration and premature fall of shoots and occasionally premature fall of older leaves (Castagnoli, 1980). It has been observed that the *Leipothrix moraceus* overwinter in the bud scales and during the growth period of mulberry fed on the leaves and young twigs, causing them to turn brown.

Tikader et al. (1998) have reported the infestation of *Tetranychus* sp. on young shoots of mulberry in Tamil Nadu. It has been observed that the top leaves become pale green in colour and subsequently shrink in size. The mite infested leaf is poor in nutrition contains less moisture and are not suitable for silkworm rearing. Chauhan et al. (2002) observed that as a result of feeding by the *P. latus* leaves turn rough, corky and losses its normal green colour and becomes dull whitish green. Mulberry plantation in Kashmir valley of India is severely affected by *Tetranychus* sp. and *Panonychus* sp. of mites and cause damage to mulberry leaf yield as well as cocoon and larval characters of *B. mori* (Dar et al., 2011). A preliminary study on damage assessment in mulberry revealed that mite infestation followed a typical bell shaped curve which started with 25 percent in the beginning of the study to reach 62 percent during August end from where started declining to reach a low of 18 percent by October end which coincided with initiation of leaf senescence (Dar et al., 2012b).
Biology:

The typical life cycle of mites consists of five stages, egg, larval stage with three pairs of legs, two nympha1 stages (protonymph and deutonymph) with four pairs of legs and adult stage with four pairs of legs. Brief description on life history of some of the mites infesting mulberry is presented below.

*Tetranychus bimaculatus*: The red spider mite adult measures 0.5 mm in length and is more or less oval in shape. Male is usually tapering posteriorly, red in colour and many dark purple areas are seen translucently through the skin of the body. It repeats its generation for about 20 times per year (Yokoyama, 1975) in Japan.

*Tetranychus kanazawai*: The female imago of *Tetranychus kanazawai* is oval or ellipsoidal, 0.4 to 0.5 mm long while the male imago is spindle shaped and 0.3 to 0.4 mm long. Both the sexes are red in colour and complete more than 10 generations per year. It hibernates in the larval state under the fallen leaves, cracks of the stem, etc. during winter season (Ayuzawa et al., 1972) in Japan.

*Tetranychus equitorius*: The adult female of red spider mite lays 45 to 140 eggs on the ventral surface of the leaf as well as in webs. Newly emerged larvae are light amber in colour and the larval, protonymph and deutonymph periods occupy about 2 days each. The total developmental period of this mite occupies 10 (Pillai et al., 1980) days under tropical climate of West Bengal, India.

*Tetranychus telarius*: Rangaswami et al. (1976) studied the life history of *T. telarius* and observed that a gravid female lays 2 to 10 eggs per day and a total of 70 to 75 eggs over a period of 20 days. Eggs are very minute, spherical in shape and are attached to the under surface of the leaf, within the web. The young larvae are pink in colour, later they moult into protonymph, deutonymph and to adult. The female moult thrice while the male mouls twice, one generation is completed in 18 to 40 days.

*Tetranychus ludeni*: Adult of *T. ludeni* lays on an average of 52.72 eggs on the lower surface of leaves. The total developmental period occupied 9.00 to 10.25 days by female and 9.00 to 10.00 days by male. Males are longer than the females and the
mating takes place immediately after the emergence of females and the duration of mating is 1 to 2 minutes. Gravid females produce progeny consisting of both sexes, where as only males are produced by the unmated female (Puttaswamy et al., 1980).

_Tetranychus neocaledonicus:_ It has been observed that the gravid females of _T. neocaledonicus_ lay on an average, 185.33 eggs during the ovipositional period of 20.17 days. The total development is completed in 10.14 days and the adult live for about 23.55 days (Puttaswamy and Channabasavanna, 1981).

_Polyphagotarsonemus latus:_ It has been reported that the _P. latus_ completes its life cycle on mulberry by passing through egg, nymph, quiescent and adult. The eggs are oval, oblong, flattened below and translucent having incubation period of about 43.23± 10.81 hours. Nymphs are pear shaped and take 32.97 ± 7.31 hours to reach the quiescent stage. The quiescent stage lasts for 23.63 ± 2.63 hours. Males emerge earlier than the females and wandered by carrying female quiescent on its back (Chauhan _et al._, 2002).

**Seasonal incidence and abundance**

Mite pests show a well marked seasonal behavior in their abundance and distribution on host- plants. They are well adapted to seasonal climatic changes and such changes involve anatomical and behavioral changes. Temperate species enter into diapauses to avoid extreme cold, but in tropical species diapauses is usually absent. However, fecundity declines during the dry season or cold weather (Das, 1959). Ho _et al._ (1989) have found that the _T. kanazawai_ population on mulberry almost tripled each week in autumn in Taiwan region of China. Slower rate of _T. kanazawai_ infestation is observed in the spring season, while in summer the incidence is very negligible. Karmakar _et al._ (1998) reported that mean population of _P. ulmi_ attain peak during the second fortnight of March (19.74 mites/leaf) on mulberry gardens of West Bengal.

In Japan, incidence of _T. kanzawai_, _Panonychus citri_ and _Eotetranychus suginamensis_ on mulberry is severe in the summer- autumn rearing season when it is dry (Ayuzawa _et al._, 1972). Damage due to red mite, _T. bimaculatus_ is also more
during dry season in Japan (Yokoyama, 1975). Population of *Tetranychus truncates* increases tremendously at the end of wet season in Thailand and overwinters in the egg stage (Sinchaitsri and Isarangkul, 1973). In India, population of *T. equitorius* on mulberry is maximum during March- April and May- June. There was a reduction in mite population during August and which remained at a lower level up to January-February. The sudden fall in mite population from August onwards was attributed to the heavy rain fall (Pillai et al., 1980). Population was also higher during hot season in Tamil Nadu (Pillai and Jolly, 1986). High temperature (28 to 33 °C) coupled with low humidity (45- 50%) favoured breeding over low temperature (25.5 to 27 °C) and high humidity (85 to 90%) coupled with heavy rain fall affected the population of *T. equitorius* (Pillai et al., 1980). The distribution, biology and feeding behavior of the predatory mite, *Agistemus industani* were studied with *Tetranychus ludeni* being the prey mite of the mulberry leaves by Arbabi and Singh (2002).

Population of *T. kanzawai* had two peaks, early June and late August in mulberry field in Japan (Kakimoto et al., 2004). Rajalakshmi et al. (2009) reported that the average maximum temperature of 24-25 °C and above, with relative humidity of around 70 percent and above, favoured the multiplication of mites and hence the total population shot up very fast in May/June. From October onwards average minimum temperature fell below 20 °C and hence the population starts reducing.

Mites inhabiting mulberry show well marked host specificity. The divergence of the northern and southern populations of *Panonychus mori* Yokoyama in Japan was studied by Osakabe (1993). It was found that the northern population of *P. mori* developed on mulberry, but not on pear or kidney bean on which southern population of *P. mori* developed well. Saber and Rasmy (2005) have reported the influence of the plant leaf surface on the development, reproduction and life table parameters of the predacious mite, *Agistemus exsertus* Gonzalez (Acari: Stigmaeidae). It has been observed that smooth, glabrous pear leaves accelerated the development of *A. exsertus* and reported a shortest mean generation time. Slightly rough, hairy leaves of mulberry were the most suitable surface for oviposition of the predator. They exhibited the highest fecundity and net reproductive rate. On the other hand, leaves of rough
pubescent apple and scabrous, bristly lantana were the least suitable surface for oviposition of *A. exsertus* and they show the least fecundity and net reproductive rate.

Nangia *et al.* (1993) observed the growth and development of *Eotetranychus suginamensis* Yokoyama, on six varieties of mulberry and found that *E. suginamensis* could be breed on all the six varieties of mulberry, but *S₅₄* proved to be better substrate for development as shown by the values recorded for the demographic parameters. The relative abundance and biology of European red mite, *P. ulmi* infesting mulberry cultivars was observed by Karmakar *et al.* (1998) in West Bengal. It was observed that among the cultivars of mulberry observed the cultivar local was found to be highly susceptible to *P. ulmi* (49.52 mites/leaf) and cultivar KPG-11 was least susceptible (3.89 mites/leaf). Gotoh and Gomi (2003) suggested that mulberry is a good host plant for *Tetranychus kanzawai* when compared its performance on other plants like, tea, hydrangea and Japanese pear.

Phytophagous mites under study:

*Tetranychus turkestani*: The strawberry spider mite, *Tetranychus turkestani* Ugarov and Nikol. is a widespread pest of many agricultural crops including cotton, beans, cucurbits, alfalfa, soybean and sugar beet (Jeppson *et al.*, 1975; Kamali *et al.*, 2001; Zhang, 2003 and Khanjani, 2005). Feeding and web production affect the quantity and quality of yield (Jeppson *et al.*, 1975 and Sohrabi and Shishehbor, 2008). This mite species feed on the epidermis and puncture parenchyma cells, leaving light-colored stipples on the leaf surface and interfering with photosynthesis. At high population levels, massive brownish yellow rots can be seen on upper leaves until leaves wither and defoliate finally (Kuang 1986 and Wang *et al.*, 1999). So far, many aspects of the biology and ecology of this spider mite species have been well known, including developmental threshold temperature and effective thermal summation, developmental and fecundity, influence of temperature, photoperiod and host plants (Fan *et al.*, 2000 and Guo, *et al.*, 2013). Even though mulberry has been used as a laboratory host in most mite studies, the influence of mulberry as a host and mite as a pest are little known. Total development duration of *T. turkestani* females from egg to adult was 16.14 ± 0.19 days at temperature of 20 °C. The lower thermal thresholds for
the development of *T. turkestani* were calculated to be 11.89 and 12.21 °C for female and male mite, respectively. Sixteen species of phytophagous mites were recorded from Stone fruit plants by Rather (1988) among them *T. urticae, T. cinnabarinus* and *T. kanzawai* have been reported from *Prunus persica* L. in Ganderbal Srinagar, of Jammu and Kashmir.

**Panonychus ulmi:** Commonly known as the European red mite, *P. ulmi* was found in many parts of the world. It is a major pest of apple, pear, and plum in Europe, USA and Japan. In India, *P. ulmi* has however recorded from peach, plum, apple, wheat, fig, hibiscus, tomato and Ivy from Jammu and Kashmir and from apricot in Himachal Pradesh, but has no reports on damage nature and extent (Kumar and Bhalla, 1993). It has been reported for the first time as a serious pest of mulberry in the Terai zone of West Bengal, India during the late 1990’s. Total developmental period from egg to adult emergence on an average was 9.10 days. It was found on various cultivars of mulberry. Development of *P. ulmi* on the leaves of Japanese pear, mulberry, satsuma mandarin, trifoliate orange and kidney bean (*Phaseolus vulgaris* L.) was investigated in the laboratory at 20 and 25 °C. Higher maturity was observed on mulberry (97.2%) than the leaves of other plants, thus indicating the mulberry as a good host for this mite (Osakabe et al., 1990). Rather (1988) studied plant mites associated with stone fruits in subtropical, temperate and cold-arid zones of Jammu and Kashmir and found 16 species of phytophagous mites among them *P. ulmi* was observed feeding on *Prunus persica* in Ganderbal, Srinagar, J and K.

**Predatory mites under study**

**Euseius** sp.: Predaceous mites in the family Phytoseiidae are important natural enemies of several phytophagous mites and other pests on various crops (Bounfour and McMurtry, 1987 and McMurtry and Croft, 1997). Genus *Euseius* was erected by Wainstein in 1962 and he designated *Euseius finlandicus* Oudemans as its type species. Members of the genus *Euseius* Wainstein are predaceous mites which occur on a wide range of plants in association with phytophagous mites and insects. *Euseius alatus* DeLeon effectively feed on *Oligonychus mangi* (Rahman and Sapra) infesting mango plants (Moraes and McMurtry, 1983), *Euseius vignus* proved very effective against *Tetranychus turkestani* (Ugarov and Nikol.), *Tetranychus urticae* (Koch) and
Brevipalpus pulcher (Rishi and Rather, 1983). Chaudhri and Akbar (1985) found Euseius relictus Chaudhari as a good predator of Bryobia praetiosa Koch on apple in Pakistan. A good amount of taxonomic work on this genus has been conducted in the world by DeLeon (1966), Denmark and Muma (1970), Muma and Denmark (1970), Gupta (1978), Denmark and Andrews (1981), Moraes et al. (1982), Moraes and McMurtry (1983), Congdon and McMurtry (1985), McMurtry and Moraes (1985, 1989, 1991) and Walter (1999). Euseius scutalis was first described in Algeria as Typhlodromus scutalis by Athias-Henriot (1958). It was classified as T. (Amblyseius) rubini (Swirski and Amitai, 1961) in Israel. Euseius scutalis was reported to be a common phytoseiid mite in Middle East countries (Lebanon, Iran, Egypt, Israel, Jordan) and North Africa on a variety of host plants including Citrus spp. (Porath and Swirski, 1965 and Bounfour and McMurtry, 1987). Previous studies have shown that E. scutalis is not only a predator of spider mites, but also feeds on eggs and immature stages of whiteflies (Meyerdirk and Coudriet, 1986; Çobanoglu, 1989; Yildiz, 1998 and Nomikou et al., 2001). Fourteen species of predatory mites have been reported from stone fruit plants in various agro climatic Zones of Jammu and Kashmir among them E. insanus Khan and Chaudhari on Prunus armeniaca L. from Mendhar, and E. Vignus Rather and Rishi on Juglans regia L. from Tangmarg (Rather, 1988). Rather 2008, found that these two species also occurred in vineyards and surrounding vegetation in Jammu and Kashmir. Both these species along with Agistemus herbarius (Kuznestov and Wainstein) were seen actively feeding upon eggs and nymphs of spider mites.

**Agistemus industani:** The family Stigmaeidae includes potentially important predacious mite species found throughout the world on many crops including apple, citrus, grapes, tea, tomato, fig, cotton, sweet potato and potato (Nelson et al. 1973; Childers and Enns, 1975; Muma, 1975; Santos and Laing, 1985; Sepasgosarian, 1985; Thistlewood et al., 1996; Searle and Smith Meyer, 1998 and Villanueva and Harmsen, 1998). Some stigmaeid species may play a significant role in controlling phytophagous mites and scale insects in North America, Europe, Africa, and Asia (Rasmy, 1975; Krantz, 1978; Childers, 1994 and Childers et al., 2001). Few biological studies with Agistemus spp. have been conducted (Zaher and El-badry, 1961; Hanna et al., 1980; Hafez et al., 1983; Osman and Zaki, 1986 and Yue and
Childers, 1994). Distribution, biology and feeding behavior of the predatory mite *A. industani* have been studied with *T. ludeni* being the prey mite on mulberry leaves. This predator was observed feeding voraciously on eggs of prey in the field. The total developmental period of a female predatory mite fed on eggs of *T. ludeni* varied from 11 to 17 days but it was 10-16 days in case of the male. The longevity of the adult female varied from 23 to 46 days, whereas the male lived 23-48 days. The feeding rate of the female predator was three times higher than that of the male. On an average its egg laying per day was tripled after consumption of 15 prey eggs. The male predator consumed nearly 6 eggs per day (Arbabi and Singh, 2002).