CHAPTER II

REVIEW OF LITERATURE
2.0 REVIEW OF LITERATURE

Members of the subclass-Acari, class-Arachnida occupy an important position among Arthropods. They have acquired immense importance in recent years as pest of crops by virtue of small size, high biotic potential, lack of effective natural enemy, capacity to adapt new environment and effect of toxicants. The important plant feeding mite have been grouped mostly under four important families viz., Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae. Present investigations has been carried out on Tetranychid mite, Oligonychus coffeae (Nietner) and its predator Amblyseius coccosocius Ghai and Menon belonging to the family Phytoseiidae. The present review is in no way exhaustive but cares have been taken to cite the most of the phenomena which are pertinent in understanding the work related to the present investigation.

2.1 Taxonomic characters of Family Tetranychidae

According to Tuttle and Baker (1968) members of Tetranychidae family (Acarina) possess long recurved whip like movable chelae set in the stylophore or fused basal segments of the chelae; the fourth palpal segment bears a strong claw; the tarsi B, leg I and II and sometime the tibiae, usually bear specialized duplex setae, empodium may or may not have tangent hairs; female genitalia is characteristic of the family as well as of the species. Normally there are three pairs of propodosomal setae and hysterosoma with 8-13 pairs of setae arranged in different rows like dorsocentral, dorsolateral, humeral, sacral and clunals. Setae may shift, drop out or extra pair may be added. Smith-Mayar (1974) worked on the revision of Tetranychidae of Africa (Acari).
Tetranychidae mites have tactile and chemosensory setae. The tactile setae are pubescent, slender, finely pointed and have thick walls. The chemosensory setae have thin wall with transverse striations. The legs have sensory setae other than the duplex setae on all the tarsi, the anterior tibia and sometimes on the tibia of legs II and IV. Chaetotaxy of the venter is constant within the family except for the opisthasoma (Jeppson et al., 1975). Lee and Lee (1992) contributed on Tetranychid fauna from China.

Baker and Tuttle (1994) reported that the dorsal integument of the body of Tetranychidae may be variously striated, striation pattern of propodosoma is mostly longitudinal. Ventral portion also possesses striae showing variations specially in the opisthosomal region. The number of anal and preanal setae serves as useful tools for separation of species.

2.2 **Taxonomic diagnosis of the Genus - Oligonychus**

Genus *Oligonychus* was first erected by Berlese, 1886. True claws are pad like with a tenant hairs; the empodium is claw like and proxivenral hairs set at right angles to the empodium. The dorsal body setae with few exception are not seen on tubercles. There are 2 pairs of anal setae and a single pair of para-anal setae. Further revision work were done by various workers (Pritchard and Baker 1955; Smith - Mare 1987; Baker and Tuttle 1994).

2.3 **Diagnostic characters of *Oligonychus coffeae* (Nietner)**

The species *O. coffeae* was first recognised by Nietner, 1861. According to him it has 7 tactile setae on
tibia and 3 tactile setae on tarsus I; the proximal members of the duplex setae are very short. Dorsal hysterosomal setae (D4) and latero hysterosomal setae (L4) are equal in length. The aedeagus is bent ventrally at a right angle is not sigmoid and abruptly narrow distally. Later on many workers also diagnosed the species (Pritchard and Baker, 1955; Smith-Mare, 1987; Baker and Tuttle, 1994).

2.4 Biology of red spider mite, *O. coffeae*

2.4.1 Biology of *O. coffeae* under varied ecological condition:

*O. coffeae* are known to pass through egg, larva and two nymphal instar to become adult. The developmental period of the species completed within 12-24 days where 1-2.5 days for larva, 6-11 days for nymphal stages. Total fecundity was reported to be 50-137 eggs at the rate of 6-10 eggs per day per female. The oviposition period varied from 16-26 days and sex ratio was 1:1.01 - 1:2.83 (Das, 1959).

Hu and Wang (1965) studied the duration of life cycle of *Oligonychus coffeae* at a temperature of 22°C and the different life stages took as larva 8 days, protonymphal 4 days, deutonymphal 2-3 days and egg to adult 14 to 15 days. Females laid 40-50 eggs during life time.

Cranham (1966) published an exhaustive review of mite pest of tea and reported that *Oligonychus coffeae* was a most serious pest in North East India. The pertaining works on bionomics of tea red spider published prior to his review were discussed in brief and quoting his 1953 work. He stated that tea red spider did not enter into diapause stage.
Das and Das (1967) observed that pre-oviposition and post oviposition periods of the tea red spider, *Oligonychus coffeae* (Nietner) were inversely related to temperature. At 32°C the female laid an average of 12 eggs per day which reduce to 10.7 eggs per day at 20°C. Eggs failed to hatch at 34°C. Similarly incubation period was 11 days at 20°C but was reduced to 4 days at 30°C and developmental periods were 9 days and 5 days at 20°C and 30°C respectively. Larval mortality was very high at 32°C.

According to Banerjee and Das (1969) a change in light regime, either from light to darkness or vice versa brought a corresponding changes in oviposition. It had influenced specially in the field condition, because at dusk and dawn *Oligonychus coffeae* normally laid maximum number of eggs.

Banerjee (1971) reported maximum activity of red spider mite on tea during warmest period of the year and minimum activity were seen during winter months.

According to Banerjee (1972), rain did not appear to be controlling factor while studying the effect of rain on the population of tea red spider mite. Though the red spider mite migrated to downward zones during rainy season but with cessation of rain they migrated again upward causing reinfestation.

Sadana and Chander (1973) studied the biology of *Oligonychus mangiferus* (Rahman and Sapra) at four different temperatures (20°C, 25°C, 30°C and 35°C), development was maximum at 30°C and was minimum at 25°C.
Gupta et al., (1974) studied the biology of sugarcane red mite, Oligonychus indicus (Hirst) at three different temperatures regimes (25°C, 27.5°C, 30.5°C) and on three different foods (sugarcane, sorghum and maize). Maize was found to be the best food and 30°C was the most favourable temperature because minimum time was taken to complete the life cycle and high fecundity of both fertilized and unfertilized female was recorded on this food and temperature.

Tsai et al., (1989) studied the developmental period of Tetranychus kanzawai Kishida on tea at 15°C, 20°C, 25°C and 30°C. Development was slowest at lowest temperature and fastest at the highest temperature. At 15°C, the egg, larva, protonymphal and deutonymphal periods averaged 16.2, 10.6, 7.4 and 5.2 days respectively in males and 17.1, 10.9, 7.3 and 6.2 days in females. The corresponding periods at 30°C were 3.0, 1.8, 1.1 and 1.3 and 2.5, 2.2, 1.2 and 1.1 days at 15°C adult life span averaged 32.8 days in females and 34.8 days in males, at 30°C it averaged 19.9 and 19.2 days respectively. Average fecundity ranged from 27.8 eggs/female at 15°C to 76.0 at 30°C. The mean generation time ranged from 12.4 days at 30°C to 53.9 days at 15°C.

According to Jose and Shah (1989), the developmental period of the spider mite Tetranychus macfarlanei was influenced by temperature and relative humidity. The low temperature and humidity during the month of December prolonged the duration of the developmental period whereas the relatively high temperature and humidity during June, September and October induced a shorter developmental period. Similarly, fecundity also decreased with the rise of temperature during the different periods under study. The total fecundity (137.97 ± 5.68 eggs) and number of egg laid per day (6.26 ± 0.98) eggs were recorded being maximum during
December (22°C - 29°C and 42% - 76% RH) while during the other months which manifested considerable higher temperature and relative humidity induced lowest fecundity. Likewise the longevity of the spider mite remained higher (39.13 ± 5.93 days for females and 19.90 ± 2.86 days for males) during December compared to the other months.

Ahmed and Sana (1990) attempted to find out the fecundity, duration of life cycle, sex - ratio of Oligonychus coffeae infesting tea in Bangladesh. They observed that the duration of different life stages varied in different months of the years. According to them, the incubation, larval, protonymphal and deutonymphal periods were 3.0-6.5 days, 1-2 days, 1-2 days and 1-2 days respectively. Total life cycle took 6-12.5 days (6 days in August, 12.5 days in January) indicating that the duration of life cycle varied with temperature was reflected in fecundity also as fecundity was 53-57 in January and it was 75 in August. Sex ratio ranged from 1:0.9 to 1:1.3.

According to Muraleedharan (1991), adult female laid 20-25 eggs in her life time and nymphal period took 4-6 days and life cycle was completed in 6-9 days. However at low temperature (20°C) the life cycle might take as many as 12 days. Maximum adult longevity was seen to be 12 days at 28°C.

Senapati and Ghosh (1992) while studying yellow and red spider mite on jute, reported that the longevity of Oligonychus coffeae was 11.3 days and female laid an average 67.33 eggs. The egg, larva, protonymphal and deutonymphal periods were respectively 3.33, 1.25, 1.33 and 6.5 days respectively.
A detailed report on tea mite and their control provided some information on biology of *Oligonychus indicus* and suggested its control measures. According to this studies, the incubation period ranged between 3.5-4.5 days at a constant temperature of 32°C and 4-5 days at 30°C. The duration drastically shortened at lower temperature. The average duration of combined larval and nymphal stages were 4.9, 6.0 and 8.7 days at 30°C, 25°C, 20°C respectively. The longevity of female was 29 days and there were several overlapping generations in a year. (Anonymous 1994).

2.4.2 Life History on different tea clones:

Banerjee (1970-71) attempted to study the inter-clonal variation in the red spider infestation from egg laying capacity of tea red spider on Tocklai clones TV1 to TV19 at 27 ± 3°C with 80% RH in the field. It was found that the egg laying period was prolonged on some clones (TV6, TV7, TV3, TV8, and TV9) and shortened on other clones (TV1, TV5). However the differences were not significant. Differences were also noticed in average daily production of eggs. Possibly, the leaf characteristic of clones had a direct influence on the oviposition period but had no effect on total quantum of egg production.

Banerjee (1971-72) evaluated to Tocklai clones namely TV1, TV2, TV9 and TV12 which were apparently found to be less resistant to pink mite but TV5, TV6, TV7 were less resistant to purple mite. According to the author, Assam tea type was more susceptible to pink mite than the China type. Author also attempted to correlate the monthly mite population in different clones but no relationship could be established.
Banerjee (1977) reported marked variation as regards susceptibilities of clones to mite attack. Clones were found to be different not only in their physiological and morphological attributes but also in their tolerance to mite. The clones which were highly susceptible to red spider mite were TV₁ and TV₇, moderately susceptible were TV₃, TV₂, TV₉ and TV₁₀ and the least susceptible clones were TV₄, TV₅, TV₆, TV₈, TV₁₁ and TV₁₂.

Das (1983) while discussing some basic points of mite control stated that different clones of tea behaved differently to red spider mite attack and the reasons which were attributed to physiological and morphological characters of different clones. He observed that China variety was more susceptible to red spider mite than the Assam hybrid.

Thirugnanasuntharan and Amarasinghe (1990) tested 10 widely planted tea clones grown in mite prone areas in the laboratory to evaluate the susceptibility to Oligonychus coffeae and found that clones MT 18, TRT 2027 were resistant and CY9 and DTI were susceptible varieties. Duration of development varied from (16-21) days in different clones.

Sudoi (1992) assessed 52 Camellia sinensis clones for oviposition and development of red spider mite and determined the number of egg laid, number of eggs that hatched, number of nymphs, length of developmental period and survival rate of adult hood in a growth chamber. A percentage resistant was calculated from survival percentage and development line on the basis of classified clones. According to the author, BBLK, 152, 6/8 and 7/8 clones were classified as resistant while all others were highly susceptible or moderately resistant to the attack of this mite.
Thirty Tocklai TV clones were taken to conduct a laboratory experiment in Tocklai Research Station at 23-25°C and 80% RH for their relative susceptibility to red spider mite by measuring the damage leave. None of the tested clone was free from its attack. Out of the thirty clones, TV₆, TV₅, TV₂, TV₈, TV₁₂, TV₁₃, TV₄, TV₂₂, TV₃₀ and TV₂₆ were moderately resistant (12.5%-25% leaf damage) whereas TV₁, TV₂₇, TV₁₇, TV₂₁ were highly susceptible (above 50% of leave damage). Number of eggs laid by a female were higher on susceptible clones than on those on some of the less susceptible ones. The high yielding clones like TV₂₂, TV₂₆, TV₃₀ and TV₁₄ were tolerant to the pest. (Ann. Report TRA 1995-96).

2.4.3 General studies on tea pest:

Rao (1974) dealt with the tea pests of Southern India, discussed their symptoms of damage and suggested their cultural and chemical control measures.

Sarma (1979) listed the commonly occurring tea pests in India and Sri Lanka and his report included *Oligonychus coffeae* as one of the most important ones. He discussed the various effects of its infestation on tea population.

Pandey and Nandi (1983) surveyed the tea pests of Tripura and found *Oligonychus coffeae* as one of the most important pest.

Sudoi (1988) recorded a Tuckerella as pest of tea in Kenya.
Gupta (1989) provided a detailed account of the tea pests in India and had given keys for their identification.

Mir (1990) reported that *Tetranychus urticae* was a serious pest of tea in Bangladesh and provided information on its biology, nature of damage and control measure.

2.5 Chemical basis of resistance

2.5.1 Role of different Macro and Micro nutrients of tea leaves towards making resistant/susceptible:

It is very important to find out susceptible varieties to increase the plant production and cumulative reduction in mite population. According to Painter (1951) a resistant variety was that, (i) when the plant is not preferred by the pest or 'non preference' (ii) have the power to resist a certain level of infestation. (iii) possesses certain qualities which interfere with the normal development of the pest population and that protect the plant from damage also. This form of resistance lies in the physical or anatomical characters as well as chemical constituents of plants.

The work on this aspect had some limitations. Hukusima (1958) worked on this aspect. According to him, with the increase of nitrogen contents in the leaves of mite produced more offsprings than those which were growing in nitrogen deficient soil. Contrary to Hukusima's dissertation it has also been reported that alternation of the nitrogen level, does not affect directly to the acceleration of mite generation.
Breukel and Post (1959) reported that *Panonychus ulmi* (Koch) when fed on apple, showed a positive relation between nitrogen contents and the number of mites present on leaves. Huffacker et al., (1969) also reported that a high level of fertilizer and excess of soluble elements like magnesium and calcium were conducive to mite population.

Mineral nutrition of a plant can have a large impact on the population dynamics of spider mites (Van de Vrie et al., (1972).

Banerjee (1975) showed nitrogen had no effect on the population of *Oligonychus coffeae*. On the other hand due to infestation of *Oligonychus coffeae*, depletion of nitrogen, phosphorus and potassium of leaf took place. Depletion level depended on the density of mite numbers. Jeppson et al., (1975) showed that besides nitrogen, other elements viz. potassium, phosphorus, calcium, magnesium, zinc and cobalt had some influence on mite nutrition and that observation was supported by Suski and Badowaska (1975).

Herbert and Butler (1973) observed that important changes in chemical composition of host plant took place specially in respect of minerals. The former author also observed that decrease in potassium was caused damaging of leaves while the latter worker did not observe any such change in respect of sodium, calcium and potassium.

Uthamasamy et al., (1976) found that adequate amount of phenolic substances, sugars and minerals in brinjal leaf increased the population of *Tetranychus cinnabarinus* (Boisduval). According to Banerjee (1977), increase of zinc content caused abundance of mite population. On the other hand Jhonson and Campbell (1982) did not find any
correlation between potassium, magnesium, manganese, zinc and iron and population of *Tetranychus urticae*.

Manjunatha and Puttaswamy (1983a) observed the relationship between the biochemical principles of the host plant and the rate of development of plant feeding mite. They found that amino acid had a positive correlation with the rate of population of mites while a negative correlation was observed with total sugar and phenol. In another study Manjunatha and Puttaswamy (1983b) reported that excess amount of nitrogen enhanced the rate of population of *Tetranychus neocaledonicus* Andre.

Sarkar (1984) attempted to show a correlation between the physical and chemical basis of resistance in coconut infested *R. indica* (Hirst) and *Tetranychus filiensis* Hirst. According to him, the length, thickness, depth of midribs groove of coconut leaf did not play any role in inducing the mite population.

Sharma et al., (1985) studied the effect of foliar spray of micronutrients on tea and its effect. It was found that it played an important role in the growth of tea. Zinc sulphate induced rapid build up of mite population. Tea leaves treated with zinc sulphate, manganese sulphate and folic acid recorded lowest population of *Oligonychus coffeae*. The succulent growth promoted by zinc was responsible for high incidence of *Oligonychus coffeae* on tea.

In case of the two spotted spider mite, on bean leaves, fecundity increased with the increase of nitrogen level (Gregory, 1989).
Xu et al., (1996) reported that leaves of resistant tea varieties had higher contents of total amino acids, theanine, glutamic acid, aspartic acid, caffeine and lower content of reducing sugar, water soluble sugars. There were stronger glutamate dehydrogenase and phenylalanine amonialyase activities in shoots of resistant varieties.

2.5.2 Biochemical changes in leaves due to mite infestation:

Zukova (1963) observed reduction in activity of amylase proteolytic enzyme and reduction of protein content due to feeding of Tetranychus telarius.

Avery and Lacey (1968) found correlation in leaf injury by Panonychus ulmi and decrease in level of auxin.

Van de Vrie et al., (1972) provided data indicating reduction in chlorophyll content in apple leaves due to the attack of Panonychus ulmi while some authors like Poskuta et al., (1975), Sances et al., (1979) and Kolodziej et al., (1975) reported that only minor changes in chlorophyll content was evidenced due to mite attack. Reduction in chlorophyll content by Panonychus ulmi was also reported by Ploude et al., (1983).

Hall and Ferree (1975) reported that the mite attack caused reduction of photosynthetic rate as much as 43% in apple.

Keilkiewiez (1981) observed the increase in the levels of phenolic compounds in strawberry leaves due to infestation of T. urticae.
De. Angelis et al., (1983) reported increase of soluble sugar in damaged leaves and explained that it was because of decrease in starch synthesis.

Ploude et al., (1983) studied the effect of feeding by Panonychus ulmi on chlorophyll level of apple.

Sumangala and Haq (1995) studied the effect of feeding of Eutetranychus orientalis on chlorophyll depletion in Eichornia crassips in Kerala. Estimation of the depletion of chlorophyll content in infested leaves recorded depletion to the plants in the fields. A severe chlorosis was observed because of feeding and the infested plant ultimately collapsed.

Goel and Sadana (1995) stated that the feeding of Brevipalpus phoenicis caused reasonable changes in the levels of different biochemical components in leaves of host and non host. The qualitative analysis of biochemical components viz. total sugar, reducing and non reducing sugar, protein, phenol, free amino acid, nitrogen, sulphur, phosphorus, sodium, potassium in the leaves of different hosts viz. Kakgi Nebu, Banarasi Nebu, grape fruits, guava, papaya and banana due to feeding of Brevipalpus phoenicis revealed that host plant contained significantly higher amount of starch, free amino acid, nitrogen, sodium and sulphur as compared to non host plants. There was no significant difference in the amount of total sugar, reducing sugar, non reducing sugar, lipids, phenol in both host and non host plants.

Chatterjee and Gupta (1995) studied the effect of feeding by Tetranychus on the inorganic and organic compounds in leaves of spongy gourd (Luffa acutangula). In all
the cases a marked difference was noticed in the contents of mineral, organic and inorganic components because of mite feeding. However, the author failed to ascertain whether the decrease of these chemicals was because of reduced uptake by roots from soil or it was because of damage cells due to mite feeding.

Kennedy and Waterkeyn (1995) studied the phytohistology of injuries caused by mites and attacked protoplasm of punctured cell which coagulated and the cells accumulated phenolic compound. Parenchyma cells near the punctured cells inflated at the expense of cell vacuoles resulting in thickening of cells. There was a significant loss of chlorophyll production and respiration.

Ravi et al., (1995) studied the effect of feeding by E. orientalis on Cassia, chilli and jasmine leaves. The author observed that the mite feeding caused direct mechanical damage in upper pallised parenchyma and lower pallised parenchyma causing reduction in thickness of leaves. In case of chilli, the mite feeding caused reduction of leaf thickness of protein and RNA content. In case of jasmine leaves the major tissues were causing reduction in thickness.

Chattapadhyay (1998) studied the effect of Tetranychus ludeni on leaves of brinjal and consequent changes in the minerals, organic and inorganic compounds. The author observed significant depletion in respect of Ferrous, Zinc, Silicon, Copper, Calcium, Manganese, NO₃ and NO₂ in infested leaves as compared to the healthy leaves. However, mite feeding caused increase of phenolic compounds. Reduction of reducing and non reducing sugar and chlorophyll was also quite high. In other studies moderate decrease in total carbohydrate, reducing and non reducing sugar content in
infested plants suggested that mite feeding disturbed carbohydrate metabolism while heavy loss of chlorophyll reduced physiological activities of plants.

2.6 Life table studies of *O. coffeae* on China and Assam type of tea leaves

Life table is a record of events in the life of a population. To study the life table different components i) net reproductive rate (*R₀*) ii) mean generation time (*T*) iii) innate capacity to increase (*rm*) iv) finite rate of increase (*λ*) are needed.

So far as the author is aware of, barring one reference (Banerjee, 1974) on *Oligonychus coffeae* (Nietner) practically no attempt has ever been made by others as to construct the life table of any tea pest or any other predatory mite associated with tea pest. Hence, the review which is provided here is based on pertaining works with regard to other mites, both phytophagous and predatory ones available on other crops.

2.6.1 Net reproductive rate (*R₀*) :

Laing (1969) made an interesting study on the life history and life table of *Tetranychus urticae* Koch on strawberry leaflets. According to him net reproductive rate was 30.93 times at 15 to 28.3°C.

Gutierrez and Chazeau (1972) reported *R₀* being 51.57 times at 25-35°C and 50-70% RH.

Shih et al., (1976) worked on *Tetranychus urticae* and found that the net reproductive rate was 97.4 times at
27°C and 95% RH. Ho and Lo (1979) worked out the net reproductive rate on different temperatures viz. 20, 25, 30 and 35°C. According to them net reproductive rate was 37.81, 64.32, 49.91 and 22.66 times respectively on these temperatures.

Shih et al., (1978) reported $R_0$ as 44.74 for Tetranychus kanzawai at 27°C±2°C and 65 ± 3% RH. But $R_0$ was recorded to be 41.99 times at 27±2°C and 65±5% RH for Tetranychus cinnabarinus (Shih and Shieh, 1978). Herbert (1981) studied $R_0$ for Tetranychus urticae on apple as 20.8387, 38.4359 and 58.0357 times at 15, 18, and 21°C respectively while for the same species on cotton it was found to be 74.84 and 47.60 at 23.9 and 29.4°C respectively (Carey and Bradley, 1982). Jose (1983) worked out $R_0$ as 31.23 times for Tetranychus macfarlanei on cotton at 30°C and 57.55% RH.

Mallik and ChannaBasavanna (1983) studied the life history of Tetranychus ludeni and its predator Amblyseius longispinosus. Mallik and ChannaBasavanna (1983) reported that the $R_0$ as 123.73 times for Tetranychus ludeni on French bean at 27±0.5°C. It was also reported that $R_0$ of T. ludeni and A. longispinosus were 53.27 and 15.53 respectively at 27±0.5°C in the laboratory. Rai et al., (1990) studied the life table on Tetranychus macfarlanei. It was found that $R_0$ was 30.3744 times at 29.69°C and 87.3% RH on okra. Tetranychus ludeni when reared on Phaseolus vulgaris gave the $R_0$ as 77.42 times (Morros and Aponte, 1994).

2.6.2 Mean generation time (T):

Laing (1969) studied the mean generation time for *Tetranychus urticae* which was 24 days at 15 to 28.3°C, while it was found to be 13.6 days at 27°C and 95% RH. (Shih et al., 1976). Gutierrez and Chazeau (1972) recorded mean generation time as 12.3 days at 25 to 35°C and 50 to 70% RH for *Tetranychus neocaledonicus*. According to Ho and Lo (1979), the mean generation time was 18.12, 18.42, 9.78 and 9.52 days at 20, 25.30 and 35°C and 40 to 65% RH respectively. Saito (1979) recorded mean generation time for *Tetranychus urticae* as 16.16 days at 25°C and 52% RH. Shih and Shieh (1978) found mean generation time 11.72 days for *T. cinnabarinus* at 27±2°C and 65±5% RH and 9.76 days for *T. kanzawai* at 27±2°C and 65±3% RH which was supported by Shih et al., 1978.

Herbert (1981) recorded the mean generation time (T) of *T. urticae* on apple as 43.9615, 23.3672 and 10.9082 days at 15, 18 and 21°C respectively, while for the same species, on cotton it was 19.17 and 13.17 days at 23.8 and 29.4°C respectively (Carey and Bradley, 1982). Mallik and ChannaBasavanna (1983) studied that mean generation time (T) 15.53 days for *T. ludeni* when reared on french bean. For *T. macfarlanei* on cotton 'T' was 21.88 days at 30°C and 57.50% RH. (Jose, 1983). According to Rai et al., (1990) mean generation time (T) of the same species on okra was found to be 12.037 days at 29.67°C and 87.30 RH. Morros and Aponte (1994) showed that mean generation time of *T. ludeni* was 19.63 days when reared on *Phaseolus vulgaris*. The mean generation time was 8.26 days in *Phaseolus persimilis* when reared on bean leaves (Kilincer et al., 1996). According to Aponte and McMurty (1997), recorded shortest mean generation time of 18.38 days in *O.*
perseae when reared on Hass leaves. According to Chauhan and Sharma (1998), mean generation time of T. ludeni was of 23.86 days when reared on P. minima L.

2.6.3 Intrinsic rate of natural increase (rm):

Laing (1969) recorded intrinsic rate of natural increase (rm) of Tetranychus urticae which was 0.143 at 15 to 28.3°C and 0.336 at 27°C and 95% RH (Shin et al., 1976), 0.254 at 25°C and 52% RH (Saito, 1979). Ho and Lo, 1979 found out the rm value being 0.117, 0.226, 0.40 and 0.237 of the same species at different temperatures viz. 20, 25, 30 and 35°C respectively. The value for T. kanzawai was found to be 0.380 at 27±2°C and 65±3% RH as reported by Shih et al. (1978). Shih and Shieh (1978) reported that the rm was 0.318 at 27±2°C and 65±5% RH for T. cinnabarinus. Herbert (1981) studied the rm of T. urticae on apple leave as 0.0691, 0.1562 and 0.3723 at 15, 18 and 21°C respectively. For the same species on cotton it was recorded to be 0.219 and 0.293 at 23.8 and 29.4°C respectively (Carey and Bradley, 1982). The rm for T. ludeni on French bean was observed to be 0.310 at 27±5°C (Mallik and ChannaBasavanna, 1983). The rm for T. macfarlanei on cotton was recorded to be 0.627 at 30°C and 75% RH (Jose, 1983). But rm value for the same species on okra leaves was found to be 0.2836 at 29.67°C and 87.30% RH (Rai et al., 1990). Kilincer et al., (1996) showed that in case of Phytoseilus persimilis on bean leaves, the intrinsic rate of natural increase, (rm) was 0.399 female/female per day. Aponte and Mcmurry (1997) worked out life table of O. perseae on Hass avocado leaves, Persia americana at different temperatures and reported that rm value was highest (0.144) at 30°C. According to Chauhan and Sharma (1998) intrinsic rate of natural increase of Tetranychus ludeni was 0.128 when reared on Physalis minima. L.
2.6.4 The finite rate of increase ($\lambda$):

Ho and Lo (1979) studied life table of $T. urticae$ at different temperatures. The value of $\lambda$ was 1.124, 1.254, 1.492 and 1.387 individuals/female/day and the number of days required for the population to double was 5.92, 3.07, 1.73 and 2.92 days at 20, 25, 30 and 35°C and 45 to 65% RH, respectively. Herbert (1981) recorded $\lambda$ of $T. urticae$ on apple as 1.0715, 1.1690 and 1.4511 females/female/day at 15, 18 and 21°C respectively.

According to Mallik and ChannaBasavanna (1983) the finite rate of increase for $T. ludeni$ on French bean was 1.3638 females/female/day at 27 ± 5°C. Jose (1983) recorded $\lambda$ for $T. macfarlanei$ on cotton to be 1.886 females/female/day at 30°C at 57.50% RH whereas Rai et al., (1990) studied the $\lambda$ for $T. macfarlanei$ on okra was 1.328 females/female/day at 29.67°C and 87.3% RH. Tetranychus ludeni gave the finite rate of natural increase was 1.1874 individuals/female per day when reared on Phaseolus vulgaris (Morros and Aponte, 1994). In case of O. persimilis on bean leave, the finite rate of natural increase was 1.372 females/female per day (Kilincer et al., 1996). The value of $\lambda$ of $T. ludeni$ on Physalis minima L. was 1.14 females/female per day (Chauhan and Sharma, 1998).

2.7 Biology of Predatory Mite

Four developmental stages are observed in the Phytoseiid mites viz. egg, larva, protonymph and deutonymph. The larva has 3 pairs of legs and all post larval stages have 4 pairs of legs in some species, males may not exhibit deutonymphal stages as is seen in Amblyseius finlandicus (Oud) (Ballard, 1954).
The preoviposition period in most Phytoseiid is very low (24-30 hrs.) but under optimum condition it takes 3-5 days. It was reported that the mean preoviposition period for female of *Typhlodromus pyri* was 15 days when held at 25 to 26°C after being collected in March. Regarding oviposition in most of the species, the maximum production is 2.5 eggs per day at winter temperature with abundant food (Dosse, 1957). According to Putman (1962) the mean preoviposition period was 9.2 and 16.3 days at 16°C and 14°C respectively in case of *Typhlodromous caudiglans* Schuster.

Sharma and Sadana (1984) studied the biology of *Amblyseius finlandicus* (Oudemans) at different temperatures viz. 20°C, 25°C, 30°C and 35°C on the leaves of citrus. at 25°C it was observed that the developmental period was quite short with no mortality, longer oviposition period and higher fecundity. So, 25°C was the suitable temperature for their development.

As per Gupta (1985), the developmental period was short in case of Phytoseiid mite in comparison to that of Tetranychid mite. Under favourable condition, it took 6-7 days to complete the life cycle. Life cycle will be prolonged at low temperature while very high temperature might be detrimental for development.

Borthakur and Das (1987) while surveying the predatory mites associated tea pests in the North East India, recorded *Agistemus* sp. which was found to be most common in the field and studied its biology in the laboratory.

Das et al., (1987) studied biology of *Neocunexa* sp. at different temperatures of 20°C and 30°C and RH 60 and
90% on leaves of pine apple. It was found that at 30°C temperature and 90% RH, the fecundity was highest with high hatching percentage. The duration of incubation period was maximum 8.5 days at 20±1°C and 60% RH and minimum at 30±1°C and 60% RH. The developmental period decreased with the increase of temperature.

Chen (1988) provided information to the farmers regarding rearing of *Amblyseius longispinosus* (Evans) for control of *Oligonychus coffeae* (Nietner) and *Tetranychus kanzawai* infesting tea in Taiwan.

Hsiao (1988) studied biological control of tea pests in Taiwan and reported that *Amblyseius californicus* and *Amblyseius longispinosus* were potential predator of *Tetranychus kanzawai*.

Suzuki and Kobayashi (1992) studied the seasonal occurrence of *Amblyseius longispinosus* (Evans) on tea plantations in Shizuoka (Japan).

### 2.7.1 Prey-Predator Interaction:

Herbert (1962) reported that at 1:5 and 1:12 ratios between *T. tyri* and *B. arborea*, two peaks of prey population at higher ratios obtained during 7th and 11th weeks with 100 and 900 times increase providing predator as ineffective biocontrol agent.

Banerjee (1967) reported that *Stethorus gilvifrons* fed voraciously the eggs, nymphal stage, adults of *Oligonychus coffeae* at the rate of 900 eggs, 250 nymphs and 74 adults in her life time.
Mukherjee (1975) while investigating the attributes of a good predators for controlling tea pests and reported that higher fecundity, shorter developmental period as compared to that of the prey along with good dispersal rate and capability to adapt to different ecological conditions being most important.

Under laboratory condition, Puttaswamy (1978) reported ability of *A. tetranychivorous* to control *T. ludeni* population at the ratio of 1:10, 1:50.

Mallik (1975), studied interaction between *Amblyseius longispinosus* (Evans) and *Tetranychus ludeni* Zacher at 1:4 and 1:10 ratios, reported that at 1:4 ratio after 5th day, there was decline in prey population followed by decline in predator population after a peak attaining on 6th day.

It was reported that prey-predator interaction was maintained at 1:1, 1:4, 1:6, 1:8, 1:15, 1:20, 2:3, 2:5 and 2:6 ratios. Out of these ratios 1:1 ratio, the prey population reached peak on 3rd week and by the end of the 6th week the predators completely eliminated the prey population (Anonymous, 1987).

Mallik et al., (1989), in their studies on interaction of *T. ludeni* with *A. longispinosus* and *A. tetranychivorous* at 10:1 in laboratory, reported that *A. longispinosus* preferred eggs followed by younger immature stages whereas *A. tetranychivorous* preferred adults and older younger stages. Total time taken to eliminate prey population by both predators together or any one of them was same. The mathematical model developed for the number of different steps of prey and predator based on different equation.
Sannigrahi and Mukhopadhyay (1992) evaluated predatory efficiency of *Geocoris octopterus* at temperature of $27^\circ C \pm 1^\circ C$ and $80 \pm 10\%$ RH with three common tea pests. It was reported that predation gradually increased up to 4th instar on *Scirtothrips dorsalis*, up to the 2nd instar on *Oligonychus coffeae* and up to the adult stage on *Euproctis latisfascia*. Mortality of the immature stages of the predator was high when reared on these prey species.


2.7.2 Effect of chemicals on predatory mite:

Muraleedharan et al., (1988) listed the enemies of tea pests in Southern India reported that widespread use of dicofol and sulphur caused elimination of natural enemies in the field.

Mochizuki (1992) studied the effect of certain chemicals on the development of resistance on *Amblyseius longispinosus* (Evans) and reported that resistance was developed against organophosphorus compounds and carbamates but synthetic pyrethroids viz. fenpropathrin and permethrin were highly toxic to the predators while wettable sulphur was not that toxic.

Borthakur et al., (1995) evaluated toxicity of endosulphan (35 EC), ethion (50 EC), acephate (75 SP) in the laboratory against some predators of *Oligonychus coffeae*. Endosulphan was found to be harmless against *Agistemus* sp. but was toxic to *Stethorus gilvifrons* and *Chrysoperla car-
Acephate was harmful to *Stethorus gilvifrons* and *Chrysoperla carnea*.

### 2.7.3 Diversity of natural enemies:

Rao et al., (1970), while surveying the natural enemies of phytophagous mites and flushworm, reported some predatory insects belonging to families Coccinellidae, Staphylinidae, Anthocoridae, Chrysopidae and Thripidae as well as some undetermined species of Erythraeidae, Stigmaeidae, Anystidae and Cheyletidae feeding upon *Oligonychus coffeae*. Two exotic predators brought from Australia against this mite failed to establish. Similarly a virulent strain *Bacillus thuringiensis* also was found to be ineffective against *O. coffeae*.

Das (1979), while listing the parasites and predators of tea pests in North East India, enumerated the predators of tea red spider mite which were *Venaria vincta* and *Stethorus gilvifrons*. Besides these some undetermined species of Chrysops and gall midges were also reported.

Muraleedharan et al., (1988) published a detailed list of natural enemies of all the important tea pests with the groups to which they belonged, life stages of pest upon which they attacked and cited the relevant references. So far as the predators of red spider mites are concerned, there were as many as fifteen predators of which two belonged to Phytoseiidae, eight to Coccinellidae, one each to Staphylinidae, Anthocoridae, Chrysopidae, Coniopterygidae and Thripidae. Among these, *Phytoseiulus persimilis* was the exotic one, while the others were indigenous. It was also pointed out that the predator population in the field was quite low and wide spread use of dicofol and sulphur caused
elimination of most of the natural enemies.

Gupta (1989) reported 21 species of predatory mites associated with tea plants in India of which four species belonged to Phytoseiidae, three to Stigmaidae, one species each to Bdellidae and Opididae were most common Amblyseius herbicolus (Chant) and Agistemus sp. were reported to feed actively upon nymphs of Oligonychus coffeae.

Lo, et al., (1990) while investigating the predatory mite for control of red spider mite on tea along with other agricultural pests, reported Amblyseius longispinosus (Evans) as the most effective predator.

Sudoi, et al., (1991) made studies on the predacious mite which could be used for biological control in Kenya and reported one exotic Phytoseiid species (Neoseiulus idaeus) and an indigenous Phytoseiid mite found feeding on Oligonychus coffeae but did not prefer Brevipalpus phoenisi-sis, the tea scarlet mite. The indigenous Phytoseiid was more voracious feeder than the exotic one.

Three species of predatory mites namely Agistemus sp., Exothoris sp. and Cunexa, predating upon Oligonychus coffeae, Phytocoelus persimilis. Athias-Henriot, introduced in India was reported to feed upon all stages of spider mite (Anonymous, 1994).

The surveyed natural enemies of the tea red spider are 7 species including Amblyseius longispinosus (Neoseiulus longispinosus), A. eharai, Anystis baccarun, Agistemus fleschneri, Orius sauteri, Oligota yasumatsui and Scolo-thrips sp. (Lee et al., 1995).
Several workers had emphasized on the chemical method of pest control in plantation croplike tea (Venkataram, 1974, 1980, Muraleedharan, 1984, 1989). Chemical control is costly because of several factors like pesticides, labour fuel and spraying equipments. The correct choice of pesticides, their dosages, timing and method of application are of highest significance for the success of paramount control. So, the improper use of pest control technology may result in crop loss, pesticide resistance, secondary pest outbreaks, pest insurgence, health hazards and environmental pollution (Muraleedharan, 1991).

Chemical control of tea had been initiated by pesticides belonging to different groups, namely natural, synthetic and of microbial origin which were tested from time to time.

The organochlorinated group of first generation pesticides are much toxic due to their large accumulation in the nature as well as systemic accumulation in man and animal fat bodies which may pose a great hazard and cause resurgence of mites.

Organophosphorus and carbamates are the 2nd generation pesticides. It is very effective against mite but it is highly toxic to human, animals and honeybees and phytotoxicity may result in some crops and responsible for rapid appearance of resistant population of pests after its perennial application. Perennial application of carbamate also causes group resistance to insects and mites. When carbamates (except carbaryl) are injected into human and animal organisms even in small doses results into embryonic and mutagenic action (Matsumura, 1976).
Synthetic pyrethroids are the 3rd generation pesticides. Cypermethrine fenvalerate, deltamethrin etc. belong to this group and are very effective having quick knock down effect. William (1967) reported that now-a-days their use in agriculture is very limited, because they are responsible of rising of some pests particularly the white fly on cotton and mites on different crops.

Pheromones, attractants and repellants are regarded as fourth generation pesticides. Moreover due to non-availability of proper formulation these are not used in large scale in pest management programme. These are useful for trapping pest spp. for monitoring our purpose (Mc Ewen and Stephenson 1979).

Chitin inhibitors are not only the latest being the 5th generation pesticides. All compounds under this group, inhibit the moulting and disrupt the metabolic path way. The toxicity of the chemicals is very low. It is very effective against those which are resistant to pesticides. Moreover, they are highly biodegradable and so non resistant and non polluting and less toxic to man and plant. Due to these chemistry of those compounds, got world acceptance and achieved tremendous success in pest management programme (Srivastava, 1988).

2.8.1 Chemical control of plant feeding mite:

Chemical control of plant feeding mites has entered into a dynamic stage after a slack period of two
decades. Problem related to chemical control of mites may be viewed from two angles:-

i) capability of rapidly developing resistance in mite against a wide variety of toxicants.

ii) difference observed among closely related mite species in their physiological susceptibility to acaricides.

Therefore, chemical control of mites deserves special attention. The history of chemical control of mite is not too old. It passed through different phases of chemical era viz. inorganic compounds, use of oils, organic compounds, synthetic organic compounds and finally entered a synthetic pyrethroid era. As of now, microbial pesticides appear to have more potentiality as acaricides.

2.8.2 Sulphur:

Sulphur and sulphur containing acaricides being used until 1920. It is highly effective against Eriophyoids, Tenuipalpids against majority of the Tetranychid mites, Oligonychus, Eutetranychus and Eotetranychus (March, 1958; Mistrlic, 1957). Sulphur has been used in mite control on tea since 60 years. It is used in the form of lime sulphur at 2.5 percent concentration applied as a full foliage in the Northern India. Lime does not cause taint of flavour of made tea if there is a week interval between spraying and plucking (Cranham, 1966).
According to Muraleedharan and Haran (1991) lime sulphur was very effective to control red spider mite. It was also supported by Rattam (1992).

Now a days micronised form of sulphur is used against plant feeding mite and it has good effect on red spider mite also. It was reported that red spider mite was treated with microsulf @ 1:300, ultraself @ 1:200 and sulfex @ 1:200 and was observed that microsulf gave the good response giving 86.1% adult mortality of *O. coffeae* (Ann.Report 1996-97).

Jeppson et al., (1975) reported that sulphur has some advantage used as an acaricides. It is non toxic to applicator or to those who consume crops on which it is applied. After application it releases vapour that are toxic to many species. sulphur is also relatively inexpensive, is available in most areas and may be formulated with many other pesticides. It is phytotoxic to many plant species when applications are made during the hot weather, yet ineffective when applied during cool weather.

2.8.3 Mineral Oil :

Petroleum based oils are used in the control of mite also started in the year 1920. The effectiveness of this oil against mites as well as against some important insect pests and the inability of mite population to develop resistance to these oils has resulted in its exhaustive use over a long period inspite of the rapid development of new acaricides. But its application received a set back after the discovery of its pytotoxic nature i.e. scorching and other forms of plant damage (March 1958).
It is basically used to control the eggs of red spider mite on the twigs and foliage of fruits trees. Summer oils which are less phytotoxic, used to control tetranychid mite like *Panonychus* spp. *Bryobia* spp. and some bud mites. Main advantage of this pesticide is that long term use of this pest does not develop the resistant power to mite against this chemical (Jeppson et al., 1975).

2.8.4 Dinitrophenyl Acaricides:

With the development of dinitrophenyl (DN) acaricides, the first use of organic acaricides in the control of mite came into picture. The application of DN acaricides possess several complications like phytotoxicity during hot weather and effectiveness during cold weather, short residual toxicity, ineffectiveness in killing immature and mature stages of mites (Boyce et al., 1939).

2.8.5 Synthetic pesticides:

In late forties, several chlorinated hydrocarbon compounds came as potential acaricides with the rapid development of new synthetic pesticides. Several insecticides namely DDT, BHC, endrin, dieldrin etc. were tested to explore their potentiality as acaricides but none other than endrin was found suitable against species. However, during these periods some of the chemicals viz. ovex and aramite have been used extensively throughout the world for the control of tetranychid mite for a limited period because repeated application of this chemicals resulted to resistance in mite species (Smith 1960). Out of the above said synthetic pesticides aramite is most toxic to the active stages of mite (Euling and Pence 1954).
But residues are sufficiently persistant to kill mites that develop from egg present at the time of treatment. Residues of aramite and ovex penetrate through leaves of many plants sufficiently that mite living on the side opposite to the deposit are killed by translocated chemicals (Ebeling and Pence, 1954; Cooke, 1964).

The discovery of acaricidal properties in dicofol in the year 1952 is a landmark in the history of chemical control of mites. Dicofol emerged as a effective acaricide against all types of mite pests on tea (Ananthakrishnan, 1963; Cranham, 1963; Mukherjea, 1963; Banerjee, 1979). It has a good knock down effect but acts mostly on adult stages of mites. It is effective in low volume applications through a knapsack mist blower even against scarlet-mite on the under surface of the mature leaves (Cranham, 1963; Ananthakrishnan, 1964). It is only acaricides which is extensively used for the control of a variety of mite species (Nagesh Chandra and Sannaveerappanavar, 1983).

Dicofol was very effective against red spider mite (Sudoi, 1990; Muraleedharan, 1991). Dicofol acts as an effective acaricide against tea pests. Rattam (1992) reported that dicofol in 1:200 at low volume sprayer were good, giving high mortality on tea mite. It was good because of showing ovicidal effect also giving 90% mortality.

The field evaluation of tetradifon was started in 1954, it acquired an important position till today in the control of tetranychid mites on tea by virtue of its highly toxic nature to the egg and larval stages but its use has been restricted to a great extent due to its relative ineffectiveness in the control of Brevipalpus, Eriophyoid and Tarsonemid mites (March, 1958; Mukherjea, 1962; Overmeer, 1967).
Mukherjea (1962) also found tetradifon was effective against tea mite. It had good ovicidal action and found effective at low dose. It is fairly good for control of purple mite (Ananthakrishnan, 1963; 1964) and yellow mite (Cranham, 1963) but ineffective against scarlet mite (Cranham, 1963; Mukherjea, 1963; 1964).

Mukherjea (1964) proved that tetradifon was superior to dicofol for the control of red spider mite and has a better residual action.

It was observed that in spite of the presence of favourable conditions conducive to rapid multiplication of Oligonychus coffeae, timely monitoring and judicious application of dicofol kept the tetranychid below the economic injury level and minimized crop loss. (Ali et al., 1994).

Field evaluation of organophosphorus acaricides started in 1946 (Dean and Newcomer, 1948; Huckett, 1948; Kirby and Tew, 1952; Hofmaster and Greenwood, 1953; March, 1958; Smith, 1960; Mukherjea, 1962), Tetraethyl pyrophosphate (TEPP) was used to provide immediate reduction in active stage of mite in field condition. The mites which were not satisfactory controlled by sulphur treated with parathion, gave good control belonging to the genus Tetranychus. But by repeated application of parathion, mites were resistant to it as well as cross resistant. To avoid this problem other organophosphorus acaricide compounds and several acaricides viz. ethion, carbophenthion dimethoate, folimate etc. appeared in mid-fifties to control the mites.

Mukherjea (1967) reported that ethion 47% (1:500) was highly effective against all type of tea mite. It was not phytotoxic and also safe to handle. Its ovicidal action
was shown by Banerjee, 1971. During the last two decades organophosphorus acaricides carbamate compounds were evaluated to ascertain their potentiality as acaricides. But most of these have been less toxic to organophosphorus acaricides resistance than the susceptible mite strains and only a few of the compounds that were equally toxic to both strains were subjected to repeat treatments in the fields, developed measurable resistance within two of four application (Brown, 1964; Herne, 1967; Nomura and Nakagoshi, 1965). Some primary insecticides like diazinon, endosulfan and carbaryl were used as a controlling measure of bud mites on deciduous fruits and ornamental plants under control. On the other hand zineb a fungicide has been used extensively against the citrus rust mite, but is not effective in the control of bud mites (Jeppson et al., 1975).

Banerjee (1977) reported that application of DDT (50% WP) @ 0.1% increased the fecundity of *O. coffeae*:

Banerjee (1978) stated that ethion, as a very good pesticides against *O. coffeae* on tea while thiometon and dimethoate were rated as giving moderate control. All the acaricides are normally applied at dilution rate of 1 part toxicant to 200 parts of water and are usually applied only once, but if subsequent applications are necessary their timing should be determined by the duration of the life cycle and the species concerned. Ethion, dicofol and tetradifon, of which the acceptable tolerance levels are known may be applied on tea under plucking, but after treatment with the others at least one plucking round of leaves must be discarded.

Das (1983), while discussing some basic points in
mite control found that tetradifon was effective on red spider mite. Apart from tetradifon, dicofol and ethion one litter in 200 litters water using a low volume sprayer or one litter in 400 litters using high volume sprayer had effective control on O. coffeae. In case of tetradifon, effectiveness was slow in the beginning but increased progressively. Dicofol and ethion had quick knock down effect.

Ethion, dicofol, dimethoate, thymeton 1:200 at low volume sprayer were good giving high mortality. The former two were good because of showing ovicidal effect also giving 90% mortality (Anonymous, 1994).

2.8.6 Synthetic pyrethroids:

The third generation pesticides like synthetic pyrethroids have received greater attention for their effectiveness in controlling the tissue borer as well as due to short residual effect and low mammalian toxicity. Synthetic pyrethroids are highly toxic to predatory mite. So outbreaking of plant feeding mites are regular phenomenon on vegetable where synthetic pyrethroids are applied at regular interval (Basha et al., 1982).

Pokrakar and Yadav (1986) studied that fluvalinate (0.012-0.006%) was most effective followed by fenpropathrine (0.015%) in controlling Tetranychus urticae on rose.

Sannaveerappanavar and ChannaBasavanna (1986) studied the activities of three pyrethroids against all the stages of Tetranychus ludeni. Out of these three, cypermethrin 0.01% and 0.005% recorded the highest mortality (91.72 and 89.56% respectively) while farvalerate and permethrine were relatively less toxic.
Acctamiprid (NI-25) is a new systemic insecticide suitable for controlling insect pests belonging to order Hemiptera, Thysanoptera, Lepidoptera, Coleoptera and Isoptera (Matsuda and Takahashi, 1996). It showed good effect on aphid also (Pasqualini and Vergnani, 1997).

2.8.7 Effect of botanical pesticides on mite:

To avoid high cost, health hazard and many other undesirable effects, search is on for more safer pesticides. According to Tewari and Krishnamoorthy (1985) plant extract provide several advantages in pest management as they are economical do not possess much mammalian toxicity and less effective in ecosystem. Ahmed and Grainage (1986) showed that neem tree contains promising pest control substances, found effective against many economically important pests. The residual effect of neem extract is very low and safer for mammals and the environment.

Extract of neem karnel were tested on both prey and predatory mite. All the extract which are tested on prey were more toxic than the predator (Mansour et al., 1987).

Pande et al., (1987) studied the bioefficacy of two solvent extraction of neem (Azadirachta indica) leaf at six concentration i.e 0.05, 0.1, 0.5, 1, 1.5 and 2 percent against Tetranychus neocaledonicus Andre, and important pest of okra in Tripura. The ethylalcohol leaf extract gave higher mortality as compred to petroleum ether extract. Although killing percentage was increased with the increase of concentration no significant differences were observed among three higher cone 1, 1.5 and 2 percent.
Mansour et al., (1993) studied on the three formulations of neem seed kernel extracts namely Margosan-O, Azatin and RD9 - Repelin, on a phytophagous mite *Tetranychus cinabarinus*, a predacious mite *Typhlodromous athiasae* and a species of predatory spider mite *Cheiracanthium* revealed that none of the formulation was toxic to the spider. Out of these three RD-9 - Repelin was highly toxic to both of them. Similarly other formulations of neem of botanical insecticides like Neemark (0.5%), Repelin (1%), Margocide (CK 0.1%), Mangecide (OK 0.8%) against *Tetranychus cinabarinus* and *T. macfarlanei* in brinjal, okras and Indian bean (*Lablab purpureus*) was very effective as conventional pesticides but efficacy depends on the host plant used in the experiment (Patel et al., 1993).

Bisen and Ghosh Hazra (1995) tested neem oil, neem seed kernel powder with different sprayers against some pest of tea and reported that neem oil and liquid soap at 1% cone. Neem oil (1%) with teapol (2%) were quite effective against sucking pests. The cost-benefit ratio were 1.2:13 and 1:10 respectively.

According to Bezbaruah et al., (1996) *Oligonychus coffeae* was exposed to 1,3,5 and 7% Biomix-2 in petridishes. Exposure to 3.7% Biomix-2 for 24 hours introduced 100% mortality of *O. coffeae*.

Stark et al., (1997) found out the effect of azadirachtin on the reproduction potential of two mite species viz. *Tetranychus urticae* and *Iphiseius degenerans*. It was recorded that *I. degenerans* was much more susceptible to neemazal than *T. urticae*.

It was reported that 0.03% neem seed oil product
as a contact poison for mite was effective on *O. coffeae* (Sudoi, 1998).

2.8.8 **Effect of Microbial pesticides:**

Spinosad is a new broad spectrum insect control product introduced by DOW Agroscience, 1997, that is a naturally occurring mixture of 85% spinosyn A and 15% spinosin D. Spinosad are produced by the soil actinomycetes *Saccharopolyspora spinosa*. It had been used to control the *Spodoptera exigua*, predaceous mite (Hendrix et al., 1998), hemipteran insects (Boyd and Boethal, 1998) and thrips (Khan and Morse, 1998).

2.8.9 **Effect of insect growth regulator (IGR) compound:**

Flufenoxuron is one of the IGR compounds. It is under the class of benzophenyl ureas resulting in moulting disruption. The insecticidal activity of the benzophenyl ureas analogs was discovered around 1970 by the Philips Duphor company. Ishaya and Casida (1974) showed an increase in chitinage to result in the moulting disruption symptoms when worked on the effect of diflubenzuron on housefly. According to Becker, 1978 and Clarke et al., 1977 in Orthopteran the peritrophic membrane formed in the presence of diflubenzuron had a reduced amount of chitin.

Tarborrelli et al., 1995 studied that Flufenoxuron 50 DC appears to be an innovative insecticide because it was active against Lepidoptera, Leaf hopper, Hemiptera and Phytophagous mites. This product gives a rapid knock down effect and gives excellent control of a wide range of pests in top fruits and vineyard.
According to Paik et al., 1996 Flufenoxuron was less toxic to predatory mite (Amblyseius womersleyi). Fecundity, sex ratio of the progeny were not significantly affected when it was used to control the spider mite Tetranychus urticae.

According to Goka et al., 1998 reported that, T. okinawanas was examined by 14 acaricides including Flufenoxuron but it was highly susceptible to 13 of the acaricides and resistant to Flufenoxuron.

Flufenoxuron was used as different doses (0.5, 1.0, 1.5 and 2 ml/litre) on two spotted spider mite Tetranychus urticae. It was reported that it gave effective control on Tetranychus urticae. The most effective dose was 1.5 ml/litre, which gave more than 90% mortality of the pest. Although the action of Flufenoxuron was slow, it was not toxic to rose plants and safe to the predatory mite Amblyseius sp. (Rani and Mohan, 1998).