BIONOMICS OF PLANT FEEDING MITES OF TEA WITH SPECIAL REFERENCE TO THEIR NATURAL ENEMIES

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled "BIONOMICS OF PLANT FEEDING MITES OF TEA WITH SPECIAL REFERENCE TO THEIR NATURAL ENEMIES" submitted by Shri Kinkar Saha for the award of the degree of Doctor of Philosophy in Agriculture (in Agricultural Entomology) of the Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafied research work carried out under our personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

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INTRODUCTION

INTRODUCTION

At the cross road of this century, tea has established itself little more than a hot beverage. Its beneficial effect on antisensile activity ; immune system and intestinal microflora has elevated its position as health drink. Further studies have revealed its preventive action against coronary heart disorders, modulator of blood pressure and glucose, antiviral and antidental decay. Several polyphenols present in tea acts as antioxidant, anticarcinogen and antimutagen (Zongmao, 1995).

India continues to be the leading producer of tea accounting for about 30% of the global output. It has achieved an average annual production of about 780 million kgs with an export potential of 184 million kgs. The north east India alone accounts for about 75% of the total production with 3.32 lakh hectare under cultivation .

An analysis of the yield/ha of the major tea producing nations over the period 1960 to 1995 shows that India has been lagging behind while Kenya has almost doubled . Its yield. in one hand, the domestic market for tea has been growing faster. On the other, concentrated efforts are required to expand export market to fetch valuable foreign exchange. The need for accelerating the production growth has been felt and an ambitious target of one million tonnes by the turn of the century has been set.

Tea, *Camelia sinensis* grown in N.E. India belongs to two races : i) *Camellia sinensis* - China type ii) *Camellia assamica* - Assam type. The tea ecosystem is a semi-parmanent ecosystem where a tea plant lives for at least 80 years unless destroyed by external agencies. The ecosystem is in a constant state of flux. The dynamics involved are not only the gross morphology of individual trees, qualititive changes occur in the stage of development of the crop but with large variations in the degree of canopy density, the number and species of shade trees present, the depth of litter, amount of dead wood and in the nature of the neighbouring vegetation both from estate to estate and within the same estate throughout the annual cycle. Thus, tea provides niches for a large and diverse fauna and provides suitable conditions for rapid multiplication of pest species.

Tea plants are subjected to the attack of more than a hundred species of pests in N.E. India, the most important of which are insects, mites and nematodes (Das, 1965). Each tea growing region has its own distinctive pests though many species have been recorded from the entire country. The number of pests feedings on tea in given area depends on the length of time for which this crop is grown in that place (Banerjee, 1981).

Tea plants are infested by mites throughout the world. Out of 12 species recorded so far, two spp. viz., *Oligonychus coffeae*(Nietner), red spider mite and *Brevipalpus phoenicis* (Geijskes), scarlet mite are major and *Acaphylla theae*, pink mite and *Calacarus carinatus*, purple mite are minor in nature in N.E. India (Banerjee, 1988). It is evident from the recent records that the red spider mite is on the verge of assuming the status of a key pest on tea. It is difficult to control the pest during the premonsoon period being the peak period of infestation. However, the mite is ammeable to easy control during the second peak period of infestation i.e. during Sept. to Nov. The adults, nymph and larvae of the red spider mite actively feed on upper surface of mature leaves causing reddish-brown spots at the points of sucking, these spots finally coaleses into a large single patch leading ultimately to leaf fall. Severely infested bushes may even be completely defoliatd leading to a huge loss in crop (Das, 1959b). Pink and purple mites are importance as pests both in north and south India. The scarlet mite has a periodic occurrence assuming a important pest status in a cycle of four years (Baptist and Ranawerra, 1955). The incidence of yellow mite, *Polyphagotarsonemus latus* (Banks) is almost negligible in N.E. India. The scarlet mite inhabits the undersurfaces of the leaves, particularly around the petiole, whereas, the purple mite prefers the upper surface of the leaf but the pink mite prefers both surface of the leaves (Banerjee, 1976a, Das and Sengupta, 1958; 1962).

It is estimated that 15-20 per cent of the total crop is lost annually from the ravages of pests in spite of the best effort put through routine conventional control measures possible under these commercial conditions (Anonymous, 1994). The red spider mite alone damages more than 5-15 percent of the total crop in several specific geographical locations like Terai, part of Dooars, foot hills of Darjeeling, North bank (Assam) and Tripura. The peak period of infestation of red spider coincides with the flushes which produce best quality of made tea.

The chemical control is the mainstay to combut the ravages of pests in tea. At present, only five pesticides inclusive of one biocide (neem) are recommended in tea mite control. But the recent global awareness for quality tea free from any chemical residues is further restricting the choice of pesticides between sulphur and neem biocide only. In plantation, it normally takes around 20-25 days to repeat the spray in the same area. Incidentally, none of the chemicals used as acaricide in plantation provides such a long protection necessitating to repeat the spray within 7 to 10 days. The commercial situations in plantation do not permit to undertake frequent spraying thus leaving a vast area under the mercy of god. Therefore, a search for alternatives is needed in mite control in tea.

In order to avoid to much dependance on unilateral control method i.e. chemical control, the concept of Integrated Pest Management (IPM) has got an inroad in pest control in tea. The goal of IPM is to make pest control more efficient by co-ordinating two major components i.e. biological and chemical methods through conservation and augmentation of natural enemies. The semi-permanent tea ecosystem provides a unique opportunity for exploitation of natural regulatory process as envisaged in applied biocontrol measures.

The predaceous mites are most important biocontrol agent of plant feeding mites. Among them, phytoseiids are most widespread and many of them are now used as bio-control agents in a number of agricultural ecosystems and others are important factors in integrated pest management systems (Helle & Sabelis, 1985).

Unfortunately, no detail study has been undertaken to explore the role of predatory mites in natural and applied bio-control of red spider mite of tea. The main objective of this work has to explore the predatory mite complex found in association with red spider mites, to pave the way for their utilisation in the biocontrol of the red spider mite, a key pest of tea.

Chapter - II

REVIEW OF LITERATURE

Review of Literature

2.1 TAXONOMIC CHARACTER OF TETRANYCHID MITES

The Tetranychidae Donnadieu possess long recurved whiplike movable chelae set in the stylophore or fused basal segments of the chelicerae; the fourth palpal segments bears a strong claw; the tarsi I and II and sometimes the tibiae, usually bear specialised duplex setae; the claws possess tenent hairs, and the empodium may or may not have tenent hairs; the female genitalia is the characteristic of the family as well as of the species. Normally there are three pairs of propodosomal, four pairs of marginal, five pairs of dorsal and one pair of humeral setae. Setae may shift, drop out or extra pairs may be added (Tuttle and Baker, 1968).

Tetranychid mites have tactile and chemosensory setae. The tactile setae are pubescent, slender, finely pointed and have thick walls. The chemosensory setae have thin walls in which transverse striations may be evident. The legs have sensory setae other than the duplex setae, on all tarsi, the anterior tibiae and sometimes on the tibia of legs II to IV. Chaetotaxy of the venter is constant within the family, except for the opisthosoma. Females of the higher Tetranychids usually have 2 pairs rather than 3 paris of anal setae, and normally males have 4 pairs rather than 5 pairs of genitoanal setae. Certain genera of the tribe Tetranychidae have the caudal set of the 2 pairs of paraanal setae displaced to appear as a terminal pair of dorsal setae, but these are lacking in some genera (Jeppson et al., 1975).

The dorsal texture of the integument of the body of a tetranychid may be smooth, except for large folds in some of the more generalised form. There may be a development of mediodorsal areas bearing arcolate or punctate impressions on the propodosoma and opisthosoma. The higher tetranychids, however, bear integumentary striations irregular and widely spaced in some species but similar to that of a fingerprint pattern in most. The striae may or may not posses lobes (Grandjean, 1948; Gasser, 1951; Pritchard and Baker, 1955; Tuttle and Baker, 1968).

2.2 FEEDING MECHANISM OF RED SPIDER MITE

The damage to the tea plant is caused by the larval, nymphal and adult mites, which feed on the sap of the leaves and occasionally on the petioles. The red spider mite, *Oligonychus coffeae* (Nietn.) sucks the sap with the help of its pharyngeal pump. A yellowish spot is first formed on the surface at the point of feeding, which subsequently turns brown. Repeated feeding in the vicinity, increases the number of spots, which coalesce and form bigger spots or patches, and in course of time and with the activities of the increasing population, the injury extends to the whole of the leaf surface. The damaged leaves later show coppery brown discolouration, ultimately turning bronze, and may dry up and eventually fall off. The attack is normally confined to the upper surface of older leaves, initially in shallow depressions of the surface, along the mid-rib and veins and, with the margin of the leaves curved over, as it is intensified, the mites spread to the whole of the upper surface, often to the lower surface. In severe infestation, particularly under conditions of drought, both surfaces are found to be more or less equally infested, the attack then extending to young leaves (Das, 1959; Banerjee, 1965, 1979). Harrison (1937) suggested that old leaves, in which the cells are not turgid and the flow of the sap is slow, are preferred by red spider mite, while young leaves in a turgid condition with sap flowing freely are less attacked. He pointed out, however, that the young growth may lose its turgidity under conditions of drought, becoming liable to attack and concluded that conditions tending to reduce the activity of growth of tea bushes are conducive to red spider attack.

2.3 DISTRIBUTION AND ALTERNATE FOOD PLANTS

Red spider mite was first recorded on coffee (Nietner, 1861) and later on tea in Ceylon (Green, 1890). It is widely distributed pest of tea in north-eastern India and occurs in all tea districts under diverse climatic conditions (Das, 1959). It occurs also as a minor pest of tea in southern India (Rau, 1941).

It attacks jute, *Corchorus capsularis* (Misra, 1913, Das, 1948); Misra (1913) also recorded it on cotton, castor, mulberry, orange, indigo, *Triumfetta neglecta, Urena lobata, Hibiscus ficulneus, H. panduriformis* and *H. abelmoschus* as alternative hosts in India.

Andrews (1928) found it on *Tephrosia candida* and *Derris robusta*, as well as on many jungle plants in tea-growing areas of N.E. India. Das (1959) recorded it on *Eugenia* sp., *Litsea* *lancifolia* and *Melastoma malabrathricum*. On tea in Ceylon it normally occurs in small numbers (Hutson, 1921) and has been observed on camphor, *Grevillea, Aristolochia* and *Eugenia cumini* (*jambolana*) (Light, 1927).

It also occurs on tea in other countries, viz., in Indonesia (Bernard, 1909), in Batum, U.S.S.R (Demokidov, 1916), in Transcaucasia (Prostosserdov, 1917), in Formosa (Shiraki, 1920), in South Africa (Tucker, 1926), in Nyasaland (Smee, 1927) and in Indo-China (du Pasquier, 1932-33). In West-Indonesia in addition to tea, it attacks a variety of plants including rubber, coffee, dadap, lamtoro, *Ixora* spp., etc. (Light, 1927).

This species has also been recorded from Transvaal, South Africa, on *Parthenocissus quinquefolia*, from Brisbane, Australia, on *Quisqualis indica*, from Gainesville, Florida, on *Camellia*, and from Richmond, Florida, on *Melaleuca* sp. (Pitchard & Baker, 1955). In South Africa, a red spider was found on tea and described as a new species under the name *Oligonychus merwei* by Tucker (1926) has been found to be identical with *O. coffee* by Pritchard & Baker (1955).

2.4 CROP LOSS ASSESSMENT

An accurate assessment of crop loss is difficult because the intensity of attack varies seasonally depending on climate, attitude and cultural practices. But the loss due to red spider mite, *Oligonychus coffeae* (Nietner), varies between 6 and 11 per cent in the Dooars, and 5 and 7 per cent in Assam (Sen and Chakraborty, 1964).

It is necessary to highlight the magnitude of crop and plant losses in tea plantations due to pests for an appreciation of the importance of pest management programme (Muraleedharan, 1991). More than two decades ago, Cramer (1967) estimated that tea in Asia sustained 8% crop loss through pests. A more recent estimate showed the loss to be anywhere between 6 and 14% (Banerjee 1976). Investigations had shown that 8-17% increase in crop could be obtained following efficient mite control (Rao and Subramanian, 1968). However, a recent study conducted in the Anamallais indicated that the loss due to eriophyid mites would be only around 5% (Muralecdharan and Radhakrishnan, 1989). In SriLanka scarlet and red spider mites are reported to cause 0.56 to 4.99% decrease in yield respectively (Danthanarayana and Ranaweera, 1970). However, in Indonesia scarlet mites could cause a crop deprivation as high as 13% (Oomen, 1981).

According to Awasthi and Venkata Krishnan (1977), 7 to 10% crop loss is caused by red spider mite and the yield increased by 27 million kg/year if the pest was controlled. On the other hand, *Calacarus carinatus* is known to cause losses of 22.7 to 68.0 kg of processed tea/acre in Nilgiri Hills (Rau, 1960).

Ali *et al.*, (1994) estimated the crop losses due to the attack of red spider mite, *Oligonychus coffeae* on tea, which ranged between 6.85-10.88% with a mean average loss of 9.57% during 1988-91 Bangladesh, whereas in neighbouring North-East India the loss was 5%.

2.5 SEASONAL OCCURRENCE

Most of the phytophagous and predatory mites occur in the field throughout the year in tropical climate except, of course, in rainy seasons when the population declines considerably due to washing away of the leaf population and also during the severe winter months when the eggs laying ceases due to dropping down of temperature below the development threshold. Temperature, humidity and light are the important factors influencing the dynamics of mites (Gupta, 1985).

All mite pests show a well marked seasonality in their abundance and distribution on host-plants. They are well adopted to seasonal climatic changes, and such adoptations involved anatomical and behaviourial changes. Temperate species enter into a phase of rest or diapause to avoid extreme cold, but in tropical species diapause is usually absent. However, during the dry period or cold weather the fecundity may decline (Das, 1959).

It is well known that the plant feeding mites belonging to Tetranychidae, show a well marked seasonal variability in their numbers. A number of complex factors influence the dynamics of mite numbers and in situations, climate is considered to be the most important (Moutia, 1958).

2.5.1 Tetranychid Mite :

Spider mites are greatly affected by meteorological conditions viz. temperature, humidity, rainfall, light and wind velocity (Andrewartha & Birch, 1954; Messenger, 1959).

2.5.2 Temperature :

A number of workers have treated temperature as related to tetranychid development, survival or reproduction (Newcomer & Yothers, 1929; Andersen, 1947, Cagle, 1949; Gasser, 1951, Blair & Groves, 1952; Miller, 1952; Kremer, 1956; Tsugawa, Yamada & Shirasaki, 1961; Parent, 1965; Laing 1969). The maximum activity of the red spider mites on tea was recorded during the warmest period of the year and the minimum activity during the winter months-demonstrating non-preference of the mites towards low temperature (Banerjee, 1971; Dhooria, 1986). Low temperature causes reductions in populations and mortality also occurs when temperature starts rising (Mori, 1961).

According to Bodenheimer (1951), the developmental threshold for oriental red mite, *Eutetranychus orientalis* (Klein) was 11°C and the thermal constant, above which temperature development become slower, (26°C). The preoviposition period was up to 1 to 2 days at 23°C or above; 2.5 to 3 days at 20 to 22°C; and 4 to 8 days at 14 to 15°C. The longevity of the adults was about 12 days in summer, 14 to 18 days in the spring and autumn, and upto 21 days during the winter.

The threshold of development of *Tetranychus urticae* was 12°C and the maximum developmental temperature about 40°C. At 30 to 32°C, which was the optimum temperature for development, the incubation period was 3 to 5 days. The developmental stages of the female was 4 to 5 days, the preoviposition period only 1 to 2 days, making a total life cycle period of 8 to 12 days. The average life duration of females of about 30 days, during that time the average number of eggs laid per female was 90 to 110, but a single female deposited more than 200 eggs (Gasser, 1951; Nuber, 1961).

According to Das (1959), the duration of the life cycle of *Oligonychus coffeae* (Nietner) varied with the season depending on the temperature and humidity. The life cycle completed within 9.4-12 days during May-June when the temperature was very high, while it took 28 days in colder months.

The average time required for the development of *Oligonychus platani* (McGregor) from egg to adult in the field was 12.8, 12.1 and 9.8 days during June, July and August respectively, Under constant temperature conditions of 15, 24 and 34°C, the life cycle required 32, 10.2 and 9.6 days respectively (Butler and Abid, 1965).

According to Hu and Wang (1965), the duration of the life stages, of *Oligonychus coffeae* (Nietner) (in days) at constant temperatures of 22°C were : larva 8.0, protonymph 4.0 deutonymph 2 to 3; thus 14 to 15 days were required for development from egg to adult. Females were capable of laying 40 to 50 eggs during their life span.

The pre-oviposition, oviposition and post-oviposition periods of the tea red spider, *Oligonychus coffeae* (Nietner) were reported to be inversely related to temperature. At 32°C the mite layed on an average 12 eggs per day, rising to 10.7 eggs/day at 20°C. Eggs failed to hatch at 34°C. Similarly incubation period of the mite was reduced from 11 days at 20°C to 4 days at 32°C and the duration of developmental stages ranged from 9 days at 20°C to 5 days at 30°C. At 32°C larval mortality was very high (Das & Das, 1967).

Sadana and Chander (1973) studied the biology of *Oligonychus mangiferus* (Rahman & Sapra) at four different temperatures (20°, 25°, 30° & 35°C), development was maximum at 30°C and minimum was at 20°C. Highest mortality was noticed at 20°C and minimum was at 25°C.

Gupta, *et al.*, (1974) studied the biology of sugarcane red mite, *Oligonychus indicus* (Hirst) at five different temperature regimes (25°, 27.5°, 30°, 30.5° and 35°C) and on three different food (sugarcane, sorghum & maize) found that maize was the best food and 30°C was the most favourable temperature because of the minimum time taken to complete the life cycle and high fecundity of both fertilised and unfertilised females on this food and temperature.

Life history parameters of *Tetranychus viennensis* Zacher were investigated at 25±1°C. The total development time was 12.1 days incase of female and 11.9 days incase of male (Tetsuo, 1986).

The duration of development of *Tetranychus kanzawai* Ishida was studied on tea at 15,20,25 and 30°C; development was slowest at the lowest and fastest at the highest temperature. At 15°C the egg, larval, protonymphal and deutonymphal periods averaged 16.2, 10.6, 7.4 and 5.2 days resp., 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 lifespan averaged 32.8 days in females and 34.8 days in males; at 30°C it averaged 19.9 and 19.2 days resp. 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 to 53.9 days at 15°C (Tsai *et al.*, 1989).

2.5.3 Humidity and Temperature :

Humidity alone or in combination with temperature are important factors in spider mite ecology. Extreme arid conditions extended over several days may reduce the number of some tetranychid spp. (Hobza, 1970).

Huffaker (1958) and Huffaker, Shea, and Herman (1963), found that *Eotetranychus sexmaculatus* eggs on oranges (in a laboratory ecosystem study) dehydrated and failed to hatch when humidity fell to 40 per cent at prolonged temperatures of about 27°C.

Das (1959) reported hibernation of red spider mite during the cold weather in the crevices of the bark of the tea bushes and in the soil underneath them . This view was not accepted where it was stated that the mite persisted in all stages of its development on some of the old leaves of tea bushes during the cold weather, only in small numbers on clean pruned tea, but in greater numbers on unpruned or skiffed tea (Das, 1960). Some red spider harboured during the cold weather not only by old leaves but also by 'janams' (Andrews, 1928; Comrie, 1939; Das, 1960).

Nickel (1960) showed that a West Coast stock of *Tetranychus telarius* (=*T. urticae*) developed faster, with higher egg production, under low humidity (25 to 30%) as contrasted with high (85 to 90%). He found the reverse to be true for *T. desertorum*, however Boudreaux (1958) observed reduced egg production and oviposition period and increased mortality of newly hatched larvae under high humidity, in contrast to low humidity, for four species of tetranychids, and postulated that water loss by evaporation determines the amount that the mite can take in by feeding. Thus under low humidities, both intake of nutrients and reproduction will be greater.

Osakabe (1959, 1962 & 1967) found the ranges of temperature and humidity for successful hatching of *Tetranychus kanzawai* to be 15° to 30°C and 40 to 93% R.H. Relative humidities of 20 and 100% had adverse effects on the hatching of eggs, and inhibited development of the immature stages. In the field, however, the population development was not correlated with these atmosphereic conditions.

Rapid build up of red spider populations was observed when the environment was hot and dry, but high humidity was detrimental to the mites. However, eggs of *Oligonychus coffeae* (Nietner) failed to hatch at 17% air humidity, irrespective of temperature 34°C, and the optimum conditions for over 90% hatch were provided by a combination of temperature within a range of 20°C and 30°C and 49% to 94% relative humidity (Das and Das, 1967).

The time taken to complete the life cycle of *Panonychus citri* (McGregor) varied with temperature and humidity. The maximum period in case of mated and unmated females was 14.75 ± 0.21 and 14.75± .20 days, respectively at 23.6 ± 1°C and 64.5% R.H., while the minimum was 12.46 ± 0.27 and 14.29 ± 0.20 days, respectively at 30 ± 1°C and 48.7% R.H. The longevity of adult female and male were 7-11 days and 6-9 days, respectively. The most favourable temperature and humidity were 30±1°C and 48.7% R.H., respectively. The mite remained active in the field during August-March and scarce during hot summer (Maity & Chakraborty, 1977).

The effect of temperature and relative humidity on the development and oviposition of *Tetranychus ludeni* was also studied by Puttaswamy and ChannaBasavanna (1980). Among the five temperatures (20±1°, 24±1°, 27±1°, 30±1° and 32±1°C) and five R.H. (55±3%, 65±3%, 75±3%, 85±3% and 95±3%), the optimum condition for development and maximum survival of eggs were found between 32±1° and 35±1° and 35±1°C and 65±3% and 75±3% R.H. The optimum condition for development of immatures were 30±1° to 35±1°C. The lowest number of eggs was laid at 20±1°C. High humidity (95±3% R.H.) reduced egg production capacity of adults irrespective of temperature ranges. In their another study (Puttaswamy and ChannaBasavanna, 1980a), they found that females took 12.48±0.16 days and males took 11.96±0.38 days to complete the life cycle.

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±54.68 eggs) and number of eggs laid per day (6.26±0.98 eggs) were recorded to be maximum during December (22-29°C and 42-76% R.H.) while during the other months which manifested considerably higher temperature and relative humidity induced lower fecundity. Likewise, the longevity of the spider mite remained higher (39.13±5.93 days for female and 19.90±2.86 days for male) during December compared to other months.

The biology of *Tetranychus ludeni* Zacher was carried out in laboratory condition on cowpea leaves at an average temperature of 30.9°C and 33.01°C in combination with each of 75.61 and 77.50 per cent relative humidity, to know the numbers of generation completed by this mite during cropping season. On an average a female laid 116.6±8.08 and 119.40±6.40 eggs. Incubation period ranged from 5.0 ± 0.70 days and 4.60 ± 0.89 days. Larval period varied from 1.90±0.54 days and 1.90±0.65 days. Protonymphal period ranged from 1.30±0.44 days and 1.90±0.41 days. Deutonymphal period was from 1.76±0.53 days and 1.30±0.27 days. The life span of adult female and male ranged from 9.45 ± 0.70 days to 9.60±0.96 days and 5.60±0.92 days to 5.41±0.65 days respectively. The life span was completed in 10.16±0.62 days and 9.60±1.15 days at two different temperatures and relative humidity respectively. The experiment revealed that the mite had shorter life cycle of 9.60±1.15 days at higher temperature of 33.01°C with relative humidity 77.50 per cent than lower temperature (Singh *et al.*, 1989).

In laboratory experiments at 23.5-32°C and 67-90% R.H. *Oligonychus coffeae* was provided with small pieces of jute leaf in petridishes. The longevity of adult *O. coffeae* was 11.3 days. Females laid 67.33 eggs. The egg, larval and proto and deutonymphal periods were 3.33, 1.25, 1.33 and 6.5 days respectively (Senapati and Ghose, 1992).

2.5.4 Rain and Wind

Heavy rains might be expected to cause severe losses, particularly in species that inhabit the upper surfaces of leaves and are not heavy webbers, and the effect may be intensified if heavy rains are accompanied by turbulent wind, which would also tend to expose the lower surface of the foliage (van de Vrie *et al.*, 1972). In Japan, not only the active stages but also the eggs of *Panonychus citri* are swept off by typhoons (Tanaka, 1963).

Blair and Groves (1952) found that *Panonychus ulmi* was not swept off by rain, because all the mites were to be found on the under surface of the leaves, huddled along the midribs and veins.

The red mite *Oligonychus indicus* (Hirst) is prevalent during pre-monsoon months and population dwindles with the onset of monsoon. Khan & Murthy (1956) reported that this mite developed on the leaves of 'Rabi' jowar and 'Ekasali' sugarcane only after the cesation of southwest monsoon rains. Rainfall drastically inhibited its multiplication. The rain affected the population differently on different varieties.

Boyle (1957) demonstrated that *Tetranychus cinnabarinus* was carried by wind but that, in the absence of a ballooning thread, stronger winds were needed than with other tetranychids. Ewing (1914) reported that *Tetranychus urticae* was blown from trees for a considerable distance, but Coghill and Ingram (1962) could find little evidence of wind disposal for *T. urticae* in England. Huffaker and Spitzer (1950) found that strong air currents inhibited buildup of *T. urticae (=T. bimaculatus* Harvey) on young pear trees in a controlled experiment, probably through blowing the mites off or impairing their reproduction.

It has been reported that a moderate rainfall does not adversely affect most tetranychid mites, but heavy and continuous rainfall has been found to be harmful (Das, 1959).

Osakabe (1967) found that the multiplication of *Tetranychus kanzawai* on tea in Japan was remarkably inhibited by rain and, especially, by a combination of rain and wind, which resulted in great reduction. The observed reductions was intensified following the rainy season, because the food quality of the leaves become impaired.

Large numbers of *Tetranychus kanzawai* were carried by wind and were collected at 0.5 to 1.0 meter from the plants. On occassion, the mites were lifted as much as 10 meters into the air. He also found that the number of air-borne mites was correlated with the seasonal population fluctuation on the tea bushes (Osakabe, 1967).

It is important that mites can avoid the direct effect of rain by moving within the plants (Banerjee, 1972), and to an extent, the heavy mite population within the plants results from avoidance to such climatic vagaries on the peripheral parts (Banerjee, 1979). Shade trees can minimize the effect of rainfall by intercepting the rain; otherwise a negative correlation between rainfall and red spider mites exists. (Danthanarayana and Ranweera, 1972).

2.5.5 Light :

The red spider, preferred bright sun, and consequently unshaded tea was more severely attacked than tea under shade trees (Andrews, 1920; Harrison, 1937; Das, 1963; 1965; Banerjee, 1969).

The role of light in mite ecology in significant, yet diverse. Response to light is basically a function of the habitat of the mite. Generally, tetranychids living on the upper surface of the leaf or exposed parts of the plant body, show positive response to light (Banerjee, 1967).

Hueck (1951, 1953) found that winter eggs of *Panonychus ulmi* in the Netherlands hatched less successfully when kept continuously in darkness, in contrast to daylight, at 25°C and 75 per cent R.H. Inspection of unhatched eggs kept in the dark showed that a great proportion contained what seemed to be fully developed larvae whereas this was rarely encountered in eggs kept under daylight. These observations suggest that the development of eggs in the dark was arrested primarily at about the moment of hatching.

This suggestion was supported by the fact that the greatest proportion of eggs hatched during the daylight, and observation of the strong positive phototaxis of the larvae. Hueck (1953) suggested that rupture of the egg shell was performed by the larvae. In view of these facts, it seems likely that light provides a stimulus to the fully developed embryo to break the egg shell.

Das (1963) studied the effect of density of shade and manuring rate on red spider mite, *O. coffeae* in northern India. Infestation developed much less under medium and heavy shade than under light shade or none.

According to Cranham (1966), the reduction of shade tree cover markedly increased the incidence of red spider, *O. coffeae* (Nietner), on tea, but other cultural trends notably higher rates of manuring and changes in pruning practices, had received little attention.

Light greatly influences the egg laying and oviposition rhythm of *O. coffeae*. A change in ligh regime, either from light to darkness or vice versa leads to peak in oviposition, but this flattens out on a constant exposure to light or darkness. These findings have considerable practical significance because under field conditions *O. coffeae* lays the maximum number of eggs at dawn and dusk when a rapid change in the light intensity occurs (Banerjee and Das, 1969).

According to Pande and Nandi (1983) monthly comparisons between shaded and unshaded tea bushes showed that in general the red mite, *O. coffeae* preferred unshaded tea.

2.6 NATURAL ENEMIES OF RED SPIDER MITE

2.6.1 Insect predator :

A large number of predatory insect species of Coccinellidae, Chrysopidae, Staphylinidae have been recorded from red spider colony infesting tea (Das, 1959; 1960;1965;1974;1979; Ananthakrishnan, 1960;1992; Banerjee,1967;1977; Rao *et al.*,1970; Sarma 1976; Helle and Sabelis, 1985). The larvae and adults of the Coccinellids i.e. *Stethorus* sp., *Verania vinetata, Scymnus* sp. *Jauravia* sp. were reported to feed on all stages of the red mite keeping the pest under considerable control. *Chrysopa* was occasionally found feeding on active stages of the mite, and the larvae and adults of a small staphylinid beetle also attack the red mite (Das, 1959; Anonymous, 1994).

The report of *Stethorus gilvifrons* predating indiscriminately on eggs, nymphal stages and adults of *Oligonychus coffeae* in the field at the rate of 900 eggs, 250 nymphs and 74 adults of red spider mite is available from the work of Banerjee (1967). He made further observation on this insect predators of red spider and opiond nut in spite of such a high feeding rate, *S. gilvifrons* fails to effectively control red spider populations because of their low numbers and extremely sparse distribution in the field , indeed it is rarely seen in the late and early part of the year when mite population is low and can be effectively controlled (Banerjee, 1977), Rao *et al.*, (1970) identified several species of Coccinellidae, one species each of staphylinidae (*Oligota* sp.), Anthocoridae (*Orius* sp.), Chrysopidae(*Chrysopa* sp.) and Thripidae (*Scolothrips* sp.) predating on nymph and adult of *Oligonychus coffeae*.

2.6.2 Predatory mite :

Many of the predatory mites belonging to the families Phytoseiidae, Stigmaeidae, Bdellidae, Cunaxidae, Tydeidae and Cheyletidae are known to be efficient predators of phytophagous mites (Chaudhuri *et.al.*, 1974; Ueckermann and Smith -Meyer, 1987).

Rao *et.al.*, (1970) reported some undetermined species of Erythraeidae, Stigmaeidae, Anystidae and Cheyletidae feed on *Oligonychus coffeae*. Muraleedharan and Chandrasekharan

(1981) found *Amblyseius herbicolus* to be an important predator of red mite in South India. The number of predatory species of other families viz. Bdellidae, Tydeidae and Ascidae was so poor that they hardly exerted any influence on their prey population.

Gupta (1989) reported twenty one species of predatory mites in associated with tea plants in India during survey made in different tea gardens in north east India and North Bengal during 1983-1985. He reported four species of Phytoseiidae, three species of Stigmaeidae and one species of each of Bdellidae, Anystidae, Eupodidae, Cunaxidae, Tydeidae and Opiidae for the first time on tea plants. Among the predatory species, *Amblyseius herbicolus* and *Agistemus* sp. were very common and most active praying on nymphs and eggs of *O.coffeae*.

Anonymous (1994) further recorded three species of predatory mites viz., *Agistemus* sp, *Exothoris caudata* and *Cunaxa* sp. to predate on red spider. One exotic species of predatory mite, *Phytoseiulus persimilis* introduced in India for the control of *T.urticae* was recorded to feed on all the stages of red spider expect egg stage.

2.7 ECOLOGICAL NICHE OF RED SPIDER MITE

The bushes along the main roads, particularly those which become covered with dust, are severly attacked by red spider. The attack is most serious on two or three rows along the road and the degree of attack gradually decrease as the distance from the road increases. This increase appears to be mainly due to the presence of more laterals carrying more mites on the first row by the side of the road (Das, 1960). He also concluded that adults and larvae of coccinellid predators were virtually absent on a few rows (first to fourth) from the road-side which remain almost completely covered with dust, as compared with the inner rows (eight to ninth) which are away from the road and are less covered with dust. Fleschner (1958) recorded a higher population of mites on terminals of *Citrus* plants treated with talc, road dust and zinc-deficiency spray material, and he concluded that this increase was due to a direct stimulating effect of inert residues on mites. Adverse effect of dust on predatory mite and stimulating effect of inert material on red spider mite as indicating by various authors (Muraleedharan, 1991; Anonymous, 1994).

2.8 EFFECT OF PRUNING ON TEA MITES

The red spider mite, *Oligonychus coffeae* prefers mature leaves, and young leaves are not normally attacked, but in severe outbreaks when the growth of the bushes is checked, particularly under conditions of drought, both young and mature leaves may be equally attacked (Harrison, 1937; Das, 1959). Harrison (1937) also concluded that, tea left unpruned (skiffed) and carrying much old leaf and 'banjhi' (dormant shoot apex) growth was especially susceptible to attack by red spider. Harrison (1937) also observed that though early pruned tea is badly attacked by red spider, it is only that which has not been properly cleaned out that sufferes, severely, whereas the bushes which have been properly cleaned out by removing all 'banjhi' growth along with much of the old leaves are, however, less effected.

Andrews (1928) observed that all processes which tend to bring about retention of poor and old wood in the bushes for a shorter or longer period caused an increase in the prevalence of red spider. Harrison (1937), from the results of observations on the red spider, *Oligonychus coffeae* incidence in relation to style of pruning came to the conclusion that the tea that has been 'stick-pruned' is considerably less attacked by red spider than that receiving a lighter form of cleaning out, and the removal of banjhi growth of the previous season appears to be, as far as pruning operations are concerned, the chief factor in controlling red spider. Woodford (1947) observed that red spider attack was associated with the degree to which the bushes were cleaned out, the more branches removed, the less the attack. He added that the length of one year wood left at pruning was also associated with red spider attack. The least red spider occurred on the bushes pruned at the old pruning level, but the incidence of red spider did not increase with increasing amount of one year wood.

Das (1960) concluded that in pruning, a great many of the old leaves (including janams) are removed from bushes, and, concomitantly, the red spider. Pruned tea was, therefore, less attacked than unpruned tea or skiffed tea in which comparatively more leaves are left on bushes. Early pruned tea was, however, more subject to red spider attack than late pruned tea, but there is little difference between early and late cleaning out and also between early and late skiffing, in their effect on the degree of red spider attack.

Pruning is an important cultural operation which affects the incidence of mites in tea fields. Das (1965) noted that in north-east India pruned tea was considerably less attacked by red spider mites, than the unpruned or skiffed fields. Oomen (1982) found that during the first two years of the pruning cycle, scarlet mite populations multiplied slowly and more or less exponentially, but during the third and fourth years the average population growth levelled off. According to Radhakrishnan *et al.* (1991), the population density of pink mites was higher in fields during 2nd and 3rd years, in comparison to first years.

2.9 BIOLOGY OF PREDATORY MITE

The phytoseiid mites pass through four developmental stages viz., egg, larva, protonymph and deutonymph. The larva has 3 pairs of legs and all postlarval 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 life cycle in Phytoseiidae is normally brief in comparison to tetranychid mites under identical conditions and takes 6-7 days and species of *Phytoseiulus* Evans takes still lesser time. However, if the temperature is very low, the developmental period may be prolonged. On the other hand, high temperature may be detrimental for development (Gupta, 1985).

The preoviposition period in most phytoseiids is very low (24-30 hrs.) but under optimum condition it requires 3-5 days. Putman (1962) obtained a mean pre-oviposition period of *Typhlodromus caudiglans* Schuster 9.2 and 16.3 days at 16°C and 14°C, respectively, while Dosse (1957) reported 15 days as the mean preoviposition period for females of *Typhlodromus pyri* when held at 25-26°C after being collected in the field in March. Regarding oviposition, in most of the species, the maximum production is 2.5 eggs/day at winter temperature with abundant food.

Bravenboor and Dosse (1962) and Force (1967) reported the temperature between 25 to 30°C and 20°C respectively, as optimum for *Phytoseiulus persimilis* Athias-Henriot to control *Tetranychus urticae* Koch, efficiently.

According to Borthakur (1981), the lowest density of tyedids, *Pronematus* sp. observed was 1.5 mites/leaf during January-February and the hgihest was 6 mites/leaf in August-September. The female predators oviposited over a period of 15 days (laying upto 20 eggs each in August-September) and the eggs hatched in 3-4 days in summer and 5-7 days in winter. The total duration of the development cycle was 20-25 days in summer and 28-32 days in winter.

According to Sharma and Sadana (1984), the rate of development of *Amblyseius finlandicus* (Oudemans) was studied at temperatures 20, 25, 30 and 35°C on the leaves of citrus. The most suitable temperature was found to be 25°C as at this temperature the total developmental period was quite short with no mortality, longer oviposition period and higher fecundity. The highest mortality was observed at 35°C.

The rate of development of *Neocunexa* sp. was studied at temperature 20 and 30°C and relative humidity (RH) 30, 60 and 90% on the leaves of pineapple. The most suitable temperature and RH were found to be 30°C and 90% as at this stage fecundity and survival in egg stage were higher. The duration of incubation period was maximum (8.50 days) at 20±1°C and 60% RH and minimum at 30±1°C and 60% RH. The total developmental period decreased with the increase in temperature. It was maximum at 20±1°C and 60% RH (Das *et al.*, 1987).

The biology of *Euseius mesembrinus* was studied laboratory conditions while being fed pollen of ice plant, *Malephora corcea* (Jocq). The developmental time for immatures stages at 18,22,26 and 30°C was 11.50, 7.47, 4.54 and 4.40 days, respectively. Eggs, hatched but mortality in other stages was high at 34°C. The intrinsic rate of natural increase was 0.146, 0.250 and 0.246 at 22, 26 and 30°C. The optimum temperature for the phytoseiid to develop and increase on ice plant pollen was in the range of 26-30°C (Abou-Setta and Childers, 1987).

2.10 CHEMICAL CONTROL

The importance of chemical method of pest control in plantation crops at large and tea in particular had been emphasised by several workers (Venkata Ram, 1974; 1980; Muraleedharan, 1984; 1989). The chemical method of pest control involves costly inputs like pesticides, fuel, labour and spraying equipment. The correct choice of pesticides, their dosage, timing and method of application are of paramount significance for the success of pest control. The misuse of pesticides and improper excution of pest control technology may result in crop loss, pesticide resistance, secondary pest outbreaks, pest resurgence, health hazards and environmental pollution (Muraleedharan, 1991).

Most of the first generation pesticides which fall under organochlorinated groups are very 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 causes resurgence of mites.

After the first generation pesticides the second generation pesticides i.e. the organophosphate and carbamate compounds have shown their magical power. But most of the organophosphorus compounds are highly toxic to humans, animals, honeybees and phytotoxicity may results in some crops and responsible for rapid appearance of resistance population of pests after its perennial application. Perennial application of carbamate also causes group resistance to insects and mites. When carbamates (except carbaryl) are ingested into human and animal organisms even in small doses exhibit embryotoxic and mutagenic action. There has also been noted the appearence of cross resistance to organochlorine, carbamates and organophosphorus compounds (Matsumura, 1976).

After the second generation, the third generation pesticide the synthetic pyrethroids like cypermethrin, fenvalerate, deltamethrin, _-cypermethrin have come into the market and became the most useful pesticide for its quick knock-down effect. But now their use in agricultural field have gradually limited because they are responsible for resurgence of some pests particularly the white fly on cotton and mites on different crops (Williams, 1967).

The fourth generation pesticide includes pheromones, attractants and repellants. They are not as useful as 1st, 2nd, & 3rd generation the pesticides. Moreover, due to non-availability of proper formulation these are not used in mass scale in pest management programme. However, these are useful for trapping pest spp. for monitaring our purpose (McEwen and Stephenson, 1979).

Chitin inhibitors, the fifth generation pesticides and according to sequence are the latest. All compounds belonging to these group developed as metabolic disruptors and molt inhibitors. Since the large site of action for these chemicals is known and susceptible to disrupt only in certain species, these materials are thought fewer serious deleterious effects on non target species. The acute toxicity of these compounds to vertebrates is very low because of the absence of the cuticular target site in vertebrates. Since they affect more than one aspect of development and physiology of a species, they could be effective against those which are resistance to pesticides. Moreover, they are highly biodegradable and so non-persistant and non-polluting and have so far not been found to be toxic to man, animal and plant. In this respect, chemistry of those compounds have widely accepted throughout the world and have got tremendous success in the pest management programme in the field of agriculture (Srivastava, 1988).

2.10.1 Chemicals control of plant feeding mite :

Chemical control of plant feeding mites has entered into a dynamic stage after a slack period of two decades. Problems 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 phages of chemical era viz., inorganic compounds use of oils, organic compounds, synthetic organic compounds and finally entered into a synthetic pyrethroid era. As of now, microbial pesticides appear to have more potentiality as acaricide.

SULPHUR :

Sulphur and sulphur containing compounds were probably the earliest acaricides being used until 1920. It is highly effective against eriophyoids, tenuipalpids as well as against majority of tetranychids of the genera *Oligonychus, Eutetranychus* and *Eotetranychus*. However, it has a decreased effectiveness against tetranychid mites of the genera *Tetranychus* and *Panonychus* (March, 1958; Mistric, 1957).Sulphur has been used for mite control on tea for over 60 years. In northern India it has been widely used in the form of lime sulphur at 2.5 per cent concentration applied as a full foliage spray; this is not ovicidal and at least two well-timed applications are required. With a week's interval between spraying and plucking, lime-sulphur does not cause taint off-favour of made tea under the conditions in northern India, although it does in southern India and Ceylon (Cranham, 1966).

Sulphur has many advantages for use as an acaricide. It is not toxic to the applicator or to those who consume crops on which it is applied. After application it releases vapors that are toxic to many mite 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 hot weather, yet in effective when applied during cool weather (Jeppsonet *et al.*, 1975).

PETROLEUM OILS:

Use of petroleum oils in the control of mites also started in the year 1920. The effectiveness of these oils 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 extensive 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 phytotoxic nature i.e. scorching and other forms of plant damage (March, 1958).

In some oil preparations like the summer oils, phytotoxicity has been greatly reduced by chemical modifications and refinements. It is basically used to control the eggs of red spider mites on the twigs and foliage of fruit trees. Summer oils are also used to control tetranychids like *Panonychus, Tetranychus* and *Bryobia* on fruit trees. But they are not effective in the control of eriophyids i.e. the bud mites or tetranychids that live on the under surface of leaves. One advantage of mineral or petroleum oils is that mites do not easily develop resistance to them (Jeppson *et al.*, 1975).

DINITROPHENYL ACARICIDES :

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

SYNTHETIC PESTICIDES :

With the rapid development of new synthetic pesticides in the late forties, several chlorinated hydrocarbon compounds come as potential acaricides. Several insecticides, namely DDT, BHC, endrin, dieldrin etc. were tested to explore their potentiality as acaricides but none other than endrin was found suitable aginst mite species. However, during these periods some of the chemicals viz. ovex, aramite, dimite etc. received attention for their acaricidal properties and were extensively used throughout the world for the control of tetranychid mites for a limited period because the repeated applications of these chemicals resulted resistance in mite species (Smith, 1960). Neither aramite nor ovex were effective in controlling eriophyoid, tarsonemid or most-brevipalpid mites. Aramite is most toxic to the active mite stages (Ebeling and Pence, 1954), but residues are sufficiently persistent to kill mites that develop from eggs present at the time of treatment. Residues of aramite and ovex penetrate through leaves of many plants sufficiently that mites living on the side opposite to the deposite are killed by the translocated chemical (Ebeling and Pence, 1954; Cooke, 1964). The discovery of acaricidal properties in dicofol in the year 1952 is a land mark in the history of chemical control of mites. The product has undergone extensive field trial throughout the world and has proved its superiority over most acaricides by virtue of its toxic nature to all mite stages of not only the family Tetranychidae but also against Tenuipalpidae and Tarsonemidae (Kirby and Tew, 1952; March, 1958). Other advangates provided by this acaricide are that mite population resistance to OP compounds and to other chlorinated hydrocarbon acaricides, did not show cross resistance to it (Hoyt and Kinney, 1964). In India the evaluation of effectiveness of dicofol against mite species began in early sixties.

Dicofol has emerged as a nontainting acaricide, effective against all of the mite pests on tea (Ananthakrishnan, 1963; Cranham, 1963; Mukerjea, 1963; Banerjee, 1979). It has a good knockdown effect, but acts mostly on the adult stages of mites. It is effective in low-volume applications through a knapsack mist-blower; even against scarlet-mites on the under surfaces of mature leaves (Ananthakrishnan, 1964; Cranham, 1963). At present, it is the only acaricides which is extensively used for the control of a variety of mite species (Nageshchandra and Sannaveerappanavar, 1983). The field evaluation of tetradifon was started in 1954, it acquired a 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; Mukerjea, 1962; Overmeer, 1967).

Later, tetradifon was found to be highly effective for red spider control in northern India (Das, 1963; Mukherjee, 1962), with a good ovicidal action, and often effective with one low dosage application. It is fairly good for control of purple mite (Anathakrishnan, 1963; 1964), and yellow mite (Cranham, 1963), but ineffective against scarlet mite (Cranham, 1963; Mukerjea, 1963; 1964).

Tests at Tocklai indicate that tetradifon is superior to dicofol for the control of red spider mite and has a better residual action (Mukarjea, 1964).

In the year 1960, Binapacryl appeared as a potential acaricide after red spider mites developed resistance to the available chlorinated hydrocarbons and OP acaricides. But the acaricide was allowed to phase out gradually due to its relative ineffectiveness against injurious mite species. During these periods several representatives of new acaricides, viz., morestan and fentin hydroxide (plictran and galecron) appeared in the pesticide market. But the potentiality of these acaricides has not been fully explored till today. In India, most of the acaricides were introduced during the late sixties to early seventies and several fields trials were conducted to evaluate their acaricidal properties against important mite species (Saradamma *et al.*, 1979, Thimmaiah and ChannaBasavanna, 1979).

Field evaluation of OP acaricides started in 1946 (Dean and Newcomer, 1948; Huckett, 1948; Kirby and Tew, 1952; Hofmaster and Greenwood, 1953; March, 1958; Smith, 1960; Mukerjea, 1962). Tetraethyl pyrophosphate (TEPP) was used to provide immediate reduction of active mite under field condition. Since repeated treatments were necessary, its use was limited. Parathion, on the otherhand, was used extensively in the control of mites which were not satisfactorily controlled by sulphur, particularly belonging to the genus *Tetranychus*. But after two or three years of extensive use of parathion, mite population developed sufficient resistance to parathion as well as cross resistance to other pesticides. To overcome these resistance problem, other OP compounds and several other acaricides viz., ethion, carbophenthion etc. appeared in mid fifties came in the picture of mite control.

Mukarjea (1967) stated that ethion 47% (1:500) highly effective against all types of phytophagous mites which include red, pink, purple and scarlet mites. Ethion is not phytotoxic and is a safe compound to handle. It has a good ovicidal property and acts on both of developing stages and adult mites (Banerjee, 1971). During the last two decades many OP and carbamate compounds were evaluated to ascertain their potentiality as acaricides. But most of these have been less toxic to OP resistance than the susceptible mite strains and only a few of the compounds that were equally toxic to both strains were subjected to repeated treatments in the field, developed measurable resistance within two to four applications (Brown, 1964; Herne, 1967; Nomura *et al.*, 1965). It has also been reported that some of the compounds namely diazinon, endosulfan and carbaryl which are primarily insecticides, have been most useful in keeping bud mites on deciduous fruits and ornamental plant under control. Similarly zineb, a fungicides has been used extensively against the citrus rust mite, but is not effective in the control of bud mites (Jeppson *et al.*, 1975).

It is revealed from the available literatures that several pesticides have been tested against tenuipalpid mites and chlorobenzilate, dicofol and sulphur are highly effective in controlling them (Morishita, 1954; Hernera-Villamil, 1958; Raikov and Nachev, 1965, Sarkar, 1984). Organophosphate and carbamate pesticides are not generally effective against this group of mites.

A perusal of available literature on the chemical control of eriophyoid mites reveals that sulphur compounds, diazinon, chlorobenzilate, carbaryl and dicofol have been found to be most effective in the control of eriophyoid mites. The descending order of the efficacy of pesticides on eriophyid mites are sulphur followed by dicofol, chlorobenzilate, diazinon, carbaryl and so on (Dippenaar, 1958; Jeppson *et al*, 1975; Merwe and Coates, 1965; Pritchand, 1957).

For the control of scarlet mite of tea, *Brevipalpus phoenicis*, sprays, preferably containing emulsion concentrates of 50% ethion, 18.5% dicofol (Kelthane), 40% binapacryl (Morocide) or 20% carbophenothion (Trithion) or a wettable powder of 25% quinomethionate (Morestan), all of which are very effective against *B. phoenicis*; should all be applied at the rate of 1.25 lt in 100-200 lt water/ha by mid-December, again four weeks later and a third time in March, this should normally reduce mite populations below the critical level, but extra applications may be necessary immediately after pruning or it mites reapper in patches of the field during the season (Banerjee, 1971).

According to Banerjee (1978), among contact acaricides, ethion is rated as giving very good control of all the species viz. *Oligonychus coffeae, Brevipalpus phoenicis, Acaphylla theae, Calacarus carinatus*, dicofol good or very good control, tetradifon very good control of *O. coffeae*, fairly good control of *A. theae* and *C. carinatus* but none of *B. phoenicis* and chlorobenzilate (Akar) good control of *B. phoenicis* and fairly good control of the other 3 species. The systemic acaricides thiometon and dimethoate are rated as giving moderate control of all the species. All the acaricides are normally applied at a 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 of 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. According to Das (1983), tetradifon is generally the most effective acaricide against *O. coffeae*, and dicofol and ethion against the other mite, all compounds being applied at 1 lt in 200 lts of water using a low-volume sprayer or at 1 lt in 400 lts using a high volume sprayer. *O. coffeae* and *B. phoenicis* generally need 4-6 treatments, while 2-3 sufficient for *C. carinatus* and *A. theae*.

Field evaluation of different acaricides for the control of *Brevipalpus phoenicis* on tea in kenya revealed that all the tested acaricides, namely flucythrinate, dicofol , omethoate, dimethoate and permethrin were effective in controlling the mite. However, significant yeild increases were obtained in flucythrinate and permethrin treated plots compared with the other acaricides (Sudoi, 1990).

SYNTHETIC PYRETHROIDS :

Various types of insecticides including old and new synthetic insecticides are being used to control mites. The third generation pesticides like synthetic pyrethroids have received special attention for their effectiveness in controlling the tissue borer as well as due to short residual and low mammalian toxicity. Synthetic pyrethroids are highly toxic to mite predators. As a result the out breaks of plant feeding mites are regular phenomenon on vegetables where synthetic pyrethroids are applied at regualr intervals (Babu & Azam, 1982, Basha *et al.*, 1982).

Bhumannavar and Singh (1986) studied the performance of some new chemicals for control of oriental red mite (*Eutetranychus orientalis*) and concluded synthetic pyrethroids viz. fenvalerate and permethrin at the rate of 0.05% giving effective control of mite for more than 21 days.

Pokrakar and Yadav (1986) found fluvalinate (0.012-0.006%) was most effective, followed by fenpropathrin (0.015%) in controlling *Tetranychus urticae* on rose.

According to Sannaveerappanavar and ChannaBasavanna (1986) studied the performance of three pyrethroids against all the stages of *Tetranychus ludeni*. Of the three pyrethroids, cypermethrin (0.01 and 0.005%) recorded the highest mortality (91.72 and 89.56% respectively) while fanvalerate and permethrin were relatively less toxic.

The susceptibilities of 6 strains of *Tetranychus kanzawai* collected from 5 tea-producing districts of Japan to 4 pyrethroid insecticides and 4 acaricides were examined in the laboratory. Large regional differences in susceptibilities to pyrethroids were found, and fluvalinate and bifenthrin had low acaricidal activities against all strains tested. Strains with low susceptibility to acaricides generally had low susceptibilities to pyrethroid insecticides (Ohtani, 1988).

2.10.2 MISCELLANEOUS CHEMICALS :

Various new compounds are extensively used around the world in the control of plant feding mites. As most of these compounds are not registered in our country and *Oligonychus coffeae* is a specific pest of oriental region, very limited information are available on their toxicity against red spider mite of tea.

Acrinathrin, a novel miticide for crop protection was discovered by Agrochemicals and biological researchs of ROUSSEL UCLAF, belonging to the new chemical group of non pyrethric esters. Acrinathrin showed a very low mammalion toxicity. It acts by contact and ingestion and showed good acaricidal properties especially against Tetranychidae (Heller *et.al.*, 1992). In poland single spray of acrinathrin was effective to control *Tetranychus urticae* and *T. cinnabarinus* on cucumber and tomato. In all cases, fourteen days after treatment, more than 98% mortality of the motile stages was obtained (Szwejda, 1993;1994).

The studies undertaking in the other parts of the world revealed that fenazaquin, a new acaricides was highly effective in the control of *Tetranychus urticae, Panonychus ulmi* on strawberries and apple respectively (Fitzgerald *et.al.* 1992; Pollak *et.al.*, 1992; Solomon *et.al.* 1993) . They suggested that fenazaquin could be used in IPM of strawberries and apple without damaging natural enemies.

Bromopropylate has attracted world wide attention for its excellent properties in the control of *Polyphagotarsonemus latus* infesting citrus, tea, sweet pepper, *Acalitus essigi* on blackberry leaves, *Tetranychus cinnabarinus* in strawberries, eriophyid mite on cocoa and *Aculus schlechtendali* on apple orchard (Marabad *et.al.* 1983; Hugen and Chaupin, 1986; Fourie,1989; Labanowska & Suski, 1990; Jesus Soria *et.al.*, 1991; Vogl, 1992; Yigit and Erkilic, 1992).

Scanty information are also available on the excellent efficacy of amitraz against plant feeding mite . It is widely used in the control of *Polyphagotarsonemus latus, Tetranychus ludeni, T.urticae, T.cinnabarinus* on cotton, chilli, pea bean, apple respectively in different parts of the world (Carvalho *et.al.* 1983; Sannaveerappanavar and ChannaBasavanna, 1986; Rajasri *et.al.*, 1991; Cheng and Pan, 1994).

2.10.3 Effect of Biocides on Mite Pest :

Due to high cost, ecological hazards, and many other undesirable effects search is on for move safer pesticides. Maximum attention has been paid on botanical pesticides. Plant extracts provide several advantages in pest management as they are economical, do not possess much mammalian toxicity and impart minimum disturbance to the ecosystem (Tewari & Krishnamoorthy, 1985). The neem tree contains promising pest control substances, found effective against many economically important pests. The extracts have generally been found safe even beneficial for mammals and the environment (Ahmed & Grainage, 1986) and have little effect on predatos and parasitoids of pest spp. (Saxena, 1983).

Mansour *et al.*, (1987) compared the efficacy of different neem seed kernel extracts on the predatory phytoseiid *Phytoseiulus persimilis* and on the phytophagous tetranychid *Tetranychus cinnabarinus*. All the extracts tested were more toxic to the pest than to the predator. The toxicity indexes of LC50 *P. persimilis* : LC50 *T. cinnabarinus* were 3 for methanol, 4 for ethanol, 23 for acetone and 58 for pentane extracts. The EC50 for fecundity reduction was similar in the 2 species.

Pande, Majumdar and Roy (1987) studied the bioefficacy of two solvent extractions of neem (*Azadirachta indica*) leaf at six conc. i.e. 0.05, 0.1, 0.5, 1.0, 1.5 and 2.0 per cent against *Tetranychus neocaledonicus* Andre, an important pest of okra in Tripura. The ethyl alcohol leaf extract gave higher mortality as compared to petroleum ether extract. Although per cent kill increased with the increase in the concentration, no significant differences were observed among three higher conc. 1.0, 1.5 and 2.0 per cent.

The studies undertaken by Mansour *et al.*, (1993) on the relative efficacy of three commercial formulations of neem seed kernel extracts, namely Margosan-o, Azatin and RD9-Repelin, on a phytophagous mite, *Tetranychus cinnabarinus* a predacious mite *Typhlodromus* *athiasae* and a species of predatory spider *Cheiracanthium* revealed that none of the formulations was toxic to the spider. Margosan-o and Azatin were also not toxic to either of the mite spp. while RD9-Repelin was highly toxic to both of them. Similar studies on other commercial formulation of neem of the botanical insecticides like Neemark (0.5%), Repelin (1.0%), Margocide (CK 0.1%) and Margocide (OK 0.8%) against *Tetranychus cinnabarinus* and *T. macfarlanei* in brinjal, okras and Indian ben (*Lablab purpureus*) indicated that these formulations were as effective as conventional pesticides but efficacy varied widely depending on the host plants used in the experiment (Patel *et al.*, 1993).

2.10.4 Effect of Microbial Pesticides on Mite Pests :

Avermectin are natural compounds produced by soil actinomycete, *Streptomyces avermitilis*. The most important commercial use of abamectin (avermectin B1) is as acaricide. They are known to be effective against a wide range of mite pests such as eriophyids, tetranychids, tarsonemids and tenuipalpids. It provides excellent initial and residual control of immature and adult mites on a number of crops (Muraleedharan, 1993). Several workers reported the excellent efficacy of abamectin in mite control. It was widely used in the control of *Polyphagotarsonemus latus, Tetranychus cinnabarinus, Acaphylla theae Calacarus carinatus, Eriophyes discoridis, Aculops lycopersici* on castor, cotton, chilli, tea, tomato and cucumber, respectively in different parts of the world (Huengens and Degheele, 1986; Donatoni, *et al.*, 1988; Brits and Vickers, 1990; Rangel, *et al.*, 1990; Zie *et al.*, 1992; Muraleedharan, 1993; Szwejda, 1994).

Bacillus thuringiensis the other best known and most widely used pathogon, produced a toxin that effects any different spp. of Lepidoptera. A few studies have been made of the effect of *B.t.* on spider mites. The result of these studies made clear that the spore crystal complex of *B.t.* has no effect on spider mite. The ß-exotoxin, on the other hand, possessed a clearly toxic action towards several spp.of Tetranychidae (Kreig, 1968; Hall *et al.*, 1971) . The bneneficial effect sometimes observed on spider mite populations of *B.t.* formulations is attributed ot the presence of by-products in the formulations, and not to the action of the bacterium or of its metabolic products (Helle & Sabelis, 1985).

2.10.5 Effect of pesticidal treatment on predatory mites:

It has been reported that most of the chlorinated hydrocarbons and their relatives are toxic to predatory mites. However, a few of the predatory mites are tolerant to these pesticides. Dieldrin is moderately toxic, endosulfan is relatively non-toxic and some specific acaricides such as dicofol and tetradifon have low toxicity to most of the phytoseiid mites. The OP compounds such as parathion and malathion are highly toxic to predacious mites. Similarly, the carbamates reduce population, of predatory mites (Jeppson, Keifer and Baker, 1975).

Croft and Jeppson (1970) observed that four strains of *Typhlodromus occidentalis* Nesbitt exhibited wide difference in tolerance against four compounds namely, carbaryl, dicofol, oxythioquinox and omite. Jeppson *et al.*, (1975) while working on the relative toxicity of pesticides to adult predacious phytoseiid mites reported that *T. occidentalis* was more resistant to many of the pesticide than *Panonychus citri* (McGregor) but other four species of predacious mites were more susceptible to pesticides than *P. citri*.

According to Stamenkovic and Peric (1984), low toxic pesticides tested against *Phytoseiulus persimilis* were tetradifon, cyhexatin, phosmate, malathion, endosulfan, dodine and their mortality value ranged between 30-69%. Highly toxic pesticides were bromopropylate, carbaryl, dimethoate, phosphamidon, permithrin, omethoate, fenvalerate, cypermethrin and their mortality value ranged between 70-100%.

Direct application of cypermethrin, flucythrinate and fenvalerate was moderately toxic to the adult females of *Amblyseius gossipi* El-Badry, while cyfluthrin was highly toxic. The most toxic compounds were pyridaphenthion and methamidophos, while the least toxic was dicofol (Abou-Awad & Banhawy, 1985).

The susceptibility of adult females of the predatory mite, *Amblyseius longispinosus* of 2 strains in Japan to various pesticides was determined in the laboratory. A strain derived from tea plants was resistant to most insecticides, whereas a strain from wild plants was not. The genetics of resistance to methomyl and methidathion were investigated by selecting for resistance, resistance to methidathion was mainly due to a single completely dominant major gene while that to methomyl was mainly due to a single incompletely dominant major gene (Hamamura, 1987).

The susceptibility of the predatory mites, *Amblyseius longispinosus* to permethrin (20% w.p.) was investigated by the leaf disc spray method. Among 11 strains, the LC-50S for Hiranuma (1), Ide(1) and Minamihara strains were 301.9, 66.5 and 8.8 ppm, resp., in the tea plantation in Japan where the most resistant strain [Hiranuma (1)] was collected following at least six round of application of synthetic pyrethroid insecticides for 4-5 years begining 1987 (Mochizuki, 1990).

During 1988-89, a population of the predatory mite *Amblyseius longispinosus* from tea fields in eastern Shizuoka Prefecture, Japan, was found to exhibit multiple resistance to organophosphorus (methidathion), carbamate (methomyl) and synthetic pyrethroid insecticides (cypermethrin, fenvalerate and fluvalinate). However, fenpropathrin and permethrin emulsifiable concentrates at field rates were highly toxic to the predators, although a wettable powder formulation of permethrin was not toxic (Mochizuki, 1992).

According to Pollak *et al.*,(1992) in trials on potted ornamentals and strawberries in the UK, fenazaquin (as a 200g/lt SC formulation at 0.1 & 0.2 lt/ha and 200 or 1000 lt/ha) against adults of *Phytoseiulus persimilis* was recorded. The least mortalities in contact and persistance tests were 76 & 26%, 1 and 2 days after application, resp., with 0.5 lt/ha at 200 lt/ha.

The results of short term toxicity tests carried out in the laboratory using plum leaf disc bioassays suggested that fenazaquin could be used in IPM of apple to control *Panonychus ulmi*, without damaging its natural enemy, the predatory mite *Typhlodromus pyri* (Fitzgerald *et al.*, 1992).

According to Solomon *et al.*, (1993) fenazaquin, a new acaricide at 100 & 200 ppm a.i., initially reduced numbers of the predator mite *Typhlodromus pyri*, but by 45 days after treatment, numbers of the predatory had recovered. Thus fenazaquin was shown to be a promising candidate for use in IPM programmes in apple.

Chapter - III

MATERIALS AND METHODS

MATERIALS AND METHOD

For the purpose of investigations, several materials and methods were used and these are given below :

3.1 SITE OF INVESTIGATION

Several sites comprising of tea estates located in the states of West Bengal, Tripura and Assam were choosen. Most of the studies were confined to Experimental Station, TRA, Nagrakata; Dalgaon T.E., Debpara T.E., Karballa T.E., Nagrakata T.E., Grassmore T.E., Nayasaylee T.E., Hilla T.E., Saylee T.E. in Dooars; Newchamta T.E., Gangaram T.E., Mohurgung and Gulma T.E., Hansqua T.E., Matidhar T.E. in Terai; Castleton T.E., MontiViot T.E., Jungpana T.E. in Kurseong; Bennockburn T.E. in Darjeeling; Durgabari T.E., Kamalasagar T.E., Kalachara T.E. in Agartala; Addabarie T.E. in Tejpur; Keyhung T.E. in Tinsukia. In addition, some prelimary studies were also initiated at the Experimental Tea orchard developed within the University campus at Gayeshpur, Mohanpur, West Bengal.

3.2 MATERIALS

3.2.1 Plant species/cultivar used :

Experiments were carried out either on broad leaved "Assam type" of tea plant *Camellia assamica* (Masters), *Camellia assamica* sub sp. *lasiocalyx* (Planchon ex Watt) Wight or on short leaved "China type" of tea plant *Camellia sinensis* (L). O. Kuntze depending upon the type of experimentations. Nine Tocklai released standard clones for plains viz. TV_1, TV_9, TV_{11}, TV_{12}, TV_{16}, TV_{17}, TV_{20}, TV_{27}, TV_{28} and seven yield clones, namely, TV_{18}, TV_{19}, TV_{22}, TV_{23}, TV_{25}, TV_{26}, and TV_{29} were choosen to suit the purpose of studies. The age of the clones varied between 7-15 years in single hedge plantation. The spacing between plants and row were 60 and 90 cm, respectively. The shade trees were mostly comprised of *Albizzia chinensis, Albizzia lebbek* and *Acacia lenticularis* (spacing 12 x 12m).

3.2.2 Mite species:

The major spp. of plant feeding mites included in these studies were red spider mite, *Oligonychus coffeae* (Nietner) scarlet mite, *Brevipalpus phoenicis* (Geij.), *Brevipalpus obovatus* Donnadieu, pink mite, *Acaphylla theae* (Watt), and purple mite, *Calacarus carinatus* (Green). These mites were collected from the infested plants and were identified by the curtsy of Dr. S.K. Gupta, A.D., Zoological Survey of India, Calcutta. Several species of predatory mites and insects were also collected during the rapid roving survey from different locations and these were classifed according to the field key in Table 1A,1B and 1C. Further conformations to reveal their identity the specific level were done with the help of Dr. S.K. Gupta, ZSI Calcutta.

3.2.3 Apparatus used for residue analysis:

i) Remi automix blender

ii) Rotary vaccum evaporator

iii) Hewlett Packard Gas Chromatograph Model 5890A with ECD coupled with 3392A integrator.

iv) Buchner funnel

v) Mechanical shaker

3.2.4 Chemicals :

The list of the chemicals which were used to test their efficacy against plant feeding mite along with the adverse effect on predatory mites in next page :

Sl. No.	Chemical Name	Group	Formulation	Trade Name	Source
1.	Neem Oil	Botanical	300 ppm Aza.	Bioneem	BICCO.
2.	Azadirachtin enriched formulationl	Botanical	10,000ppm Aza.	Neemazol-F-1%	E.I.D.Parry(I) Ltd. Madras
3.	Neem Kernel	Botanical	1500ppm Aza.	Neemgold	SPIC, Madras
4.	Wettable Sulphur	Inorganic	80%WP	Sulfex	M/s Excel Industries Ltd. Bombay
5.	Colloidal Sulphur	Inorganic	'52'S	Microsul	Stoller Enterprises,INC.USA
6.	Liquid Sulphur	Inorganic	'20'S	Microsulf	Micro Organics (India,M.P.)
7.	Dicofol	Organochlorine	18.5% EC	Kelthane	M/s INDOFIL Chemicals Ltd., Bombay
8.	Endosulfan	Organochlorine	35% EC	Endocel	M/s Excel Industries Ltd. Bombay
9.	Bromopropylate	Chlorinated group	50% EC	Neoron	CIBA-Geigy,Basel, Switzerland
10.	Dichlorvos	Organophosphorus	76% EC	DDVP	M/s National Organic Chemicals Industries Ltd., Bombay
11.	Monocrotophos	Organophosphorus	36% SL	Monocil	M/s National Organic Chemicals Industries Ltd., Bombay
12.	Phosphamidon	Organophosphorus	85% EC	Cildon	M/s National Organic Chemicals Industries Ltd., Bombay
13.	Ethion	Organophosphorus	50% EC	Mit-505	M/s Rallis India Ltd. Bombay
14.	Acrinathrin	Synthetic Pyrethroid	15% EC	Rufast	M/s Hoechest & Schering Agr. Ltd., Bombay
15.	Cypermethrin	Synthetic Pyrethroids	10% EC	Ripcord	M/s National Organic Chemicals Industries Ltd., Bombay
16.	α-cypermethrin	Synthetic Pyrethroids	10% EC	Alpaguard	M/s Gharda Chemicals Bombay
17.	Fenazaquin	Quinazolin	10%	Fenazaquin	M/s Dow Elanco,
18.	Amitraz	Formamidine	20% EC	Mitac	M/s Hoechest Schering Ag r. Ltd., Bombay
19.	*Bacillus thuringiensis*	Microbial	Oil Formulatia	Delfin	M/s Sandoz India Ltd., Bombay
20.	*Streptomyces avermitilis* (Abamectin)	Microbial	1.8% V/V	Vertimec	M/s MSD AGVET. (Merck Sharp & Dohme B.V.) Waarderweg. -39 2031 BN, Haar teem/netherlands

Table 1.A : FIELD KEY FOR IDENTIFICATION OF MAJOR FAMILIES (AND SOME SPECIES) OCCURING ON TEA IN INDIA

Tea mites

- Body whitish, tiny (1/5 mm) worm like with only 2 pairs of anteriorly placed legs. **Fam : Eriophyidae**
- Body rounded or oval, 1/2 mm size, never elongated or worm like, normally with 4 pairs of legs.
  - Soft body, rounded or oval, pear shaped or convex or flat, brightly coloured or glossy with 3-4 pairs of legs, may live in colonies but may or may not be covered with webs, mostly slow moving **Phytophagous mites**
    - Body brightly coloured, size reasonably big, can be seen in naked eye, slow moving.
      - Body flat, oval, scarlet or brightly coloured mostly on undersurface of leaves, colonies never covered with webs **Fam : Tenuipalpidae**
      - Body convex, red or brownish red normally on under surface or leaf but may be on upper surface of leaf, colonies normally covered with webs. **Fam : Tetranychidae**
    - Body white glossy, tiny, fast moving **Fam :Tarsonemidae**
  - Body whitish or deep brownish slow moving often associated with fungus. **Fungus associated mites.**
    - Body highly convex, deeped sclerotised and brownish. **Fam : Oribatulidae**
    - Body mostly whitish or creamish, posterior part of the body often having long whip like setae. **Fam : Acaridae**
  - Body rounded or oval, usually white, creamish or brownish or brick reddish, mostly isolated, not in colonies, usually fast moving, prefer protected places in angles of veins, always with 4 pairs of legs. **Predatory mites**
    - Body oval or pear shaped whitish , creamish or light brownish, fast moving, mostly live within angles formed by veins, sometimes within , spider mite colonies.
      - Body pear shaped, tiny, difficult to locate in naked eye, very fast moving often the mites move away very fast or jump with a slight disturbance (200-250 micrones) **Fam : Tydeidae**
      - Body round or oval resonably big (over 300 micrones) and easily visible with naked eye.
        - Body whitish or brownish fast moving either isolated or in spider mite colonies in a no. of setae or dorsal shield normally less than 20 pairs. Normallly very voracious feeders. **Fam : Phytoseiidae**
        - Body normally more than 400 micrones, deep brownish, slow moving, body with or over 30 pairs of setae, occasional predators. **Fam : Ascidae.**
    - Body variously coloured
      - Dorsal surface of body with black S-shaped line , body yellowish or orange, mostly remain in cravices form by the main veins with leaf lamina, sometimes show predatory behaviour **Fam : Cheyletidae**
      - Dorsal surface of body with no such S-shaped black line.
        - Body reddish or black yellowish often run fast or jumped when disturbed.
          - Body reddish or yellowish size of above 450-500 microns, mostly found within the angle forms by veins or near the leaf margin and often sink jump, often the prey mites which is often Tetranychidae and Tenuipalpidae. The pedipalp is curved inward often found with claw which devices for capturing prey. **Fam : Cunaxidae** (*Cunaxa setirostris*)
          - Body reddish, size above 500 microns, slow moving, pedipalp ilboard terminating with whip like setae and this devices for capturing prey. **Fam : Bdellidae** (*Bdella maldahaensis*)
        - Body yellowish or reddish, slow moving or make whirling movement.
          - Body much bigger some what triangular with long setae appears to be radiating from the body, makes whirling movement and often fall down from the leaves as soon as disturbed. **Fam : Anystidae**(*Walzia* sp)
          - Body reddish, thickly clothed normally slow moving. **Fam : Erythraeidae**
          - Body normally yellowish and way looked reddish after consuming prey, slow moving with tiny needle like chelicerae. **Fam : Stigmaeidae.** (*Agistemus fleschneri A.exsertus A.terminalis*).

*Based upon Gupta *et al*., 1995.

Table 1.B : FIELD KEY FOR IDENTIFICATION OF PHYTOPHAGOUS SPECIES OCCURING ON TEA IN INDIA

PHYTOPHAGOUS SPECIES

- Body worm like tiny with 2 pairs of legs.
  - Robust body with 5 longitudinal waxy ridges on dorsal surface, body deep purplish, infested leaves become bronzy with dusty waxy covering of cast skin on the upper surface of leaves. ***Calacarus carinatus*** (Plate No. 4-6)
  - Occur on both surface of leaf, thin body without longitudinal waxy ridge, attacked leaf turn pale, often leathery with veins and margins turn pinkish, ***Acaphylla theae*** (Plate No. 7)
- Body rounded oval with 4 pairs of legs.
  - Body tiny , convex , glossy, fast moving, males often carry female deutonymphs in their chelicerae occur on undersurface of leaf and the infestation mainly tea plants in nursery and the infested apical leaf turn bronzy. ***Polyphagotarsonemus latus*** (Plate No. 9)
  - Body not tiny reasonably big either flat, pear shaped or round convex, either scarlet or reddish brown
    - Body flat, pear shaped, scarlet, occur on undersurface of leaves, light brown to dark brownish spot appear on the infested leaves. ***Brevipalpus*** **spp** (Plate No. 8)
      - Body bright to dark red, dark spots if present not distinct.
        - Body normally bright red dark spots if present not distinct, damaged leaves show reddish spots, the species occur only very rarely. ***B. deloniae***
        - Body dark red, dark spots if present not visible distinctly, damage leaves show yellow spots initially but turn brown at later stage. ***B. obovatus***
      - Body dark red with distinct black or yellow spots, attacked portion produces yellow to brown spots on leaves. ***Brevipalpus phoenicis***
    - Body reddish brown or bright crimson dorsally, purplish ventrally, occur only on the upper surface of the leaves , the damage leaves show bronzing or yellowing. ***Oligonychus coffeae*** (Plate No. 1-3)

*Based upon Gupta *et al*., 1995.

1.

2.

3.

PLATE NO. 1 **Adult female of red spider mite, *Oligonychus coffeae***

PLATE NO. 2 **Adult male of red spider mite, *Oligonychus coffeae***

PLATE NO. 3 **An overall view of damage by tea red spider (*Oligonychus coffeae*) in tea plantations**


4.

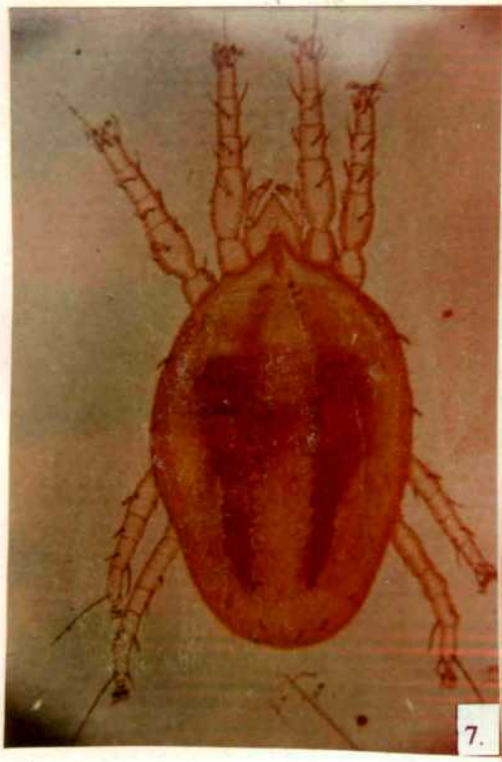

5.


6.

PLATE NO. 4 **Adult of purple mite, *Calacarus carinatus***

PLATE NO. 5 **Different types of grading of damage by Purple mite, *Calacarus carinatus***

PLATE NO. 6 **Casts skin of Purple mite, *Calacarus carinatus***



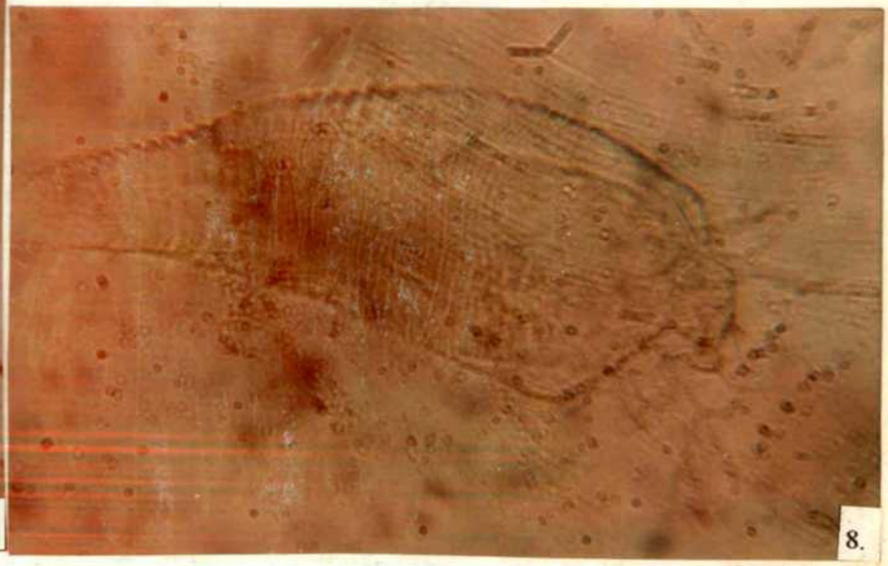


PLATE NO. 7 **Adult of false spider mite, *Brevipalpus* spp.**

PLATE NO. 8 **Adult of pink mite, *Acaphylla theae***

PLATE NO. 9 **Damage symptom caused by Yellow mite, *Polyphagotarsonemus latus***

Table 1.C : **FIELD KEY FOR IDENTIFICATION OF SOME MAJOR SPECIES OF PHYTOSEIIDAE OCCURING ON TEA IN INDIA**

PHYTOSEIIDAE

- Body with 2 pairs of long whip like posterior setae easily visible with naked eye.
  - Body whitish but may turn reddish after consumption of red spider mites. ***Amblyseius largoensis***
  - Body slightly brownish, elongated, large, fast moving very actively feed on red spider mites and scarlet mite. ***A. herbicolus***
- Body without such whip like posterior setae.
  - Body whitish, slow moving, some body setae thick, long, serrate. ***A. multidentatus***
  - Body whitish or brownish, fast moving, body setae mostly short, never long and serrate.
    - Some of the body setae reasonably longer, though some are very small , fairly active and whitish or brownish colour.
      - Body whitish and active. ***A. alstoniae, A. coccineae, A. cocosocius, A. pruni***
      - Body brownish, slow moving. ***A. longispinosus, Typhlodromus homalii, T. darjeelingensis***
    - Most of the body setae minute, very active and efficiently feeds on spider mites and scarlet mites, body mostly oval. ***A. ovalis***

*Based upon Gupta *et al.*, 1995.

3.2.5 Reagent used for residue analysis:

i) Dicofol were supplied by M/s INDOFIL Chemicals Ltd., Bombay.

ii) Acrinathrin were supplied by M/s Hoechest & Schering AgrEvo. Ltd., Bombay

iii) n-hexane (A.R. Grade), E. Merck India Ltd.,

iv) Diethyl ether, E. Merck India Ltd.,

v) Anhydrous sodium 8 sulfate, E. Merck India Ltd.,

vi) Florisil (Spectrochem, 60-100 mesh).

vii) Sodium chloride

viii) Acetonitrile

ix) Ethyl acetate

3.3 METHOD

3.3.1 Collection and preservation:

Mite infested leaves were sampled periodically to obtain plant feeding and predatory mites adopting various modes of collection by fine brush, jarking method etc. Subsequently, these specimens were preserved in 70% alcohol or in A.G.A. solution (8 part 70% ethyl alcohol + 1 part glacial acetic acid + 1 part glycerin) for prolonged preservation.

3.3.2 Taxonomic observations:

permanent slide mounts of collected materials were made in Hoyer's media (distilled water 50g, gum arabic 30 g, chloral hydrate 20 g and glycerine 20g) after prior treatment of individuals of certain species in lactic acid for 24 hrs., for subsequent microscopic observations.

3.3.3 Survey of plant feeding mites and their natural enemies in tea growing areas of N.E. Region:

Rapid roving surveys were conducted in different tea gardens in the Dooars, Terai, Kurseong and Darjeeling (West Bengal), Agartala (Tripura); Tinsukia, Tejpur and Cachar(Assam) during July 1993 to March 1996. Attempts were made to study the functional relationships within a given tea ecosystems involving mainly plants and mites. Several characteristics of the community such as species diversity, their dominance and ralative abundance were measured. The diversity of predatory and phytophagous mites in two tea ecosystem viz. West Bengal and Tripura were studied following the Shannon-Wiener diversity index (D) based on the number of species among a total number of individuals of all the species present. The closeness of the association expressed as V_{AB}. An index of frequency of occurrence together was calculated as J_{AB} (Michael, 1984). The relative distribution of predators and prey in upper, middle and lower segments of tea bushes as well as on different colnes was studied based on their number on five leaves of each of the fifty random bushes old. The data collected on relative distribution of prey and predator were expressed in ratio. (Table 19 to 27)

3.4 EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE DEVELOPMENT, LONGEVITY AND FECUNDITY OF TEA RED SPIDER MITE, *Oligonychus coffea*

This study was taken up at three different combinations of temperatures and relative humidities, viz. 26.0°C + 71.60% RH, 30.5°C + 76.5% R.H. and 33.2°C + 79.85% R.H. under laboratory condition at Bidhan Chandra Krishi Viswavidyalaya and the stock culture was obtained from the heavily infested tea plants maintained at the adjoining nursery. For studying biology, the adult females were released on excised tea leaves kept on wet cotton swab in petridish of 5 cm diameter and the females were allowed to lay eggs on the excised leaves. Before release of the mites, it was ensured that all unwanted organisms were removed from the leaves by thoroughly brushing the leaves and examining those under stereobinocular microscope. On the following day, 5-10 eggs were seen on each of the excised leaves and thus 40-50 freshly laid eggs were available and all belonged to the same age. Thereafter, observations were recorded under stereobinocular microscope at 12 hourly intervals until the eggs hatched. After hatching, the larvae emerged and each of them was kept in a separate petridish for recording further observations regarding duration of different stages, fecundity, longevity etc. Whenever necessary, the old leaves were replaced with fresh ones. For determining the fecundity of unfertilized females, the female deutonymphs, before moulting into adults were kept separately without allowing it to mate with the female while for determing the fecundity of fertilized female, each female deutonymph was kept with a male allowing it to fertilize it. Thus for fecundity two sets of petridishes were maintained. Measurement of different life stages were recorded and all the data was subjected to statistical analysis (Table 6 & 6A).

3.5 ECOLOGY OF PLANT FEEDING AND PREDATORY MITES UNDER FILED CONDITION

3.5.1 Seasonal incidence of *O. coffeae* and its predatory mites:

Observations were recorded from January 1994 to December 1995 on 10 years old tea bushes at the Debpara Tea Estate (Dooars), Jalpaiguri, West Bengal. The experimental area consisted of 200 bushes (Clone -TV_1) planted at a spacing of 60 cm x 90 cm between plants and rows. The experimental site was marked in the previous year (1993), so that the area remained free from pesticidal application. To record the mite population, ten bushes were selected randomly and from each bush, fifteen leaves were again choosen at random within the bush cAnopy, down upto 10-30 cm. The number of mites/leaf was counted with the help of high power hand lens(10x). The data on mite population collected weekly were summarised in monthly population mean and have been presented in Table 7 to 11. The data on important weather parameter such as temperature, relative humidity, rainfall, sunshine and wind velocity were collected from the Meteorological observatory located nearby (TRA, Nagrakata).

Simple and multiple correlations between weather parameters and seasonal abundance of the mite populations as well as correlation between the population dynamics of predators and the mite pest were worked out as outlined by Snedecor and Cochran (1967).

3.5.2 Spatial pattern of plant feeding and predatory mite in tea bush :

Experiments were designed in RBD with three replications at two location in the Central Dooars (Nagrakata and Debpara) to study the distribution pattern of plant feeding and predatory mite in tea bush in a block of two months starting from January to June to represent off, build up and peak period of infestation Table 12 to 17. Forteen Tocklai released clones were choosen from each of the two gardens in unshaded area which are considered as suitable ecological niche of red spider mite. Tea bushes out of hundred were selected randomly for each of the forteen clones to sample mite population. The average height of the tea bushes was 30 to 90cm. tea bushes were selected at random and each bush was divided into three segments to represent upper (top to 20 cm.), middle (20-40) and lower (40 - ground level). Periodic observations at an interval of 15 days were taken to count the number of plant feeding and predatory mite present in ten random leaves. Such records were collected from each of the three segments. The data collected over six months at two locations were then presented as pest : defender ratio (red spider : predatory mite).

Attempts were also made to reveal the spatial pattern of different spp. of predatory mite in tea bush. For this purpose predatory mites collected from the three segments of tea bush were identified and their pattern of distribution have been presented in Table 18.

3.5.3 Ecological niche of red spider mite :

For the purpose of investigation, ten groups of five bushes each were selected at random in each of the row listed in Table 28. form the side of the main road. The observation were recorded during early part (January-February) and the middle part of the year (May-June) to represent off and peak periods of red spider infestation. The experiment was conducted at the Debpara T.E., Central Dooars, W.B. in a section having moderate shade status. Samplings were done at periodic intervals (15 days) to collect plant feeding and predatory mites present on ten marked leaves inside the bush from each of the mites specimen thus collected were revealed under a bionocular microscope and the data was transformed into ratio between plant feeding and predatory as presented in Table 28.

3.5.4 Effect of pruning cycle on relative abundance of plant feeding and predatory mites in tea bushes :

The experiments were conducted at central Dooars, W.B., in Debpara T.E. on Assam type while Assam and China types were included in the studies undertaken at Castleton T.E., Kurseong. The observations coincided with the off (January '94) and peak (May'94) of red spider infestation in tea. There were 100 bushes in each of the four treatments (pruned, unpruned, light skiffed, deep skiffed), out of which five bushes was selected at random. Again five leaves were marked randomly on each of the five bushes selected previously. Counts of the mites were taken periodically at an interval of 15 days and the data were transformed into ratio between plant feeding and predatory mites (Table 29 to 31) . The ratio was based on two groups of predatory mite vs. red spider mite during the off and peak season of red spider infestation.

3.6 INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF THE PREDATORY MITE, *Amblyseius coccosocius*

The predatory mite, *Amblyseius coccosocius* was collected from alternate host plant (mango) and mass cultured in laboratory on tea leaf dises kept on moist cotton pad in the petridishes. Red spider mite, *Oligonychus coffeae* was provided as food during rearing. The rate of development of predatory mite, *A. coccosocius* was studied at various constant temperature viz, 20, 25, 30 and 35 ± 1°C at relative humidity of 75%. The relative humidity was maintained after Buxton and Mellanby (1934). The desicators were kept in the BOD incubators set at various temperatures. At the start of the experiment, eggs of predatory mite were placed one each on excised leaf dises of tear (3 cm^2) kept upside down on wet cotton placed in petridishes. The colony of *O. coffeae* was provided as food. Observations were made every 6 hrs and 6 replications were maintained in each case. The duration of different development stages, longevity of adults, preoviposition, oviposition and postoviposition periods, fecundity, sex ratio and survival of individuals were recorded by observing them under stereoscopic bionocular microscope (Table 39, 39A & 39B).

3.6.1 Feeding rate of predatory mites under laboratory condition :

Five spp. of predatory mites as mentioned in Table 40 were included in this study . Three stages i.e. protonymph, deutonymph & adult stages of red spider mite were considered. Small leaf disc of tea leaves (2 sq . cm.) were made and kept on web cotton pad. A six hrs old adult predator was released on the leaf disc along with 40 individual of each stages of red spider mite. There were 10 such sets for each of the predatory species. Number of mites consume by a single predator was counted after four hrs. of release and the observation thus recorded and presented in Table 40. The experiment was conducted at 25 ± 1°C temp & 75% R.H.

3.7 TOXICITY OF SOME MODERN CHEMICALS AGAINST *O. Coffeae* AND ITS PREDATORS UNDER LABORATORY CONDITION

The materials used in the experiments were obtained from the stock cultures of *O. coffeae* and predatory mites maintained in the laboratory under mass multiplication programme. There were atleast five to seven concentrations of each pesticide (technical grade) replicated thrice for each concentration to conduct the test as contact poison to 6 hrs. old adult females of phytophagous mite (*O. coffeae*) and predatory mites (*Amblyseus ovalis, A. largoensis, A. multidentatus*) to obtain a concentration-probit mortality curve following the method described by Streibert (1981). One ml of the toxicant was sprayed on the test mites under a pollen's tower at ISI. the exposure hr. was 6 kept as six hrs oftern which they were transferred to a fresh tea leaves. In case of predatory mites, red spider was used as food. A control set was maintained for each test. Twenty-four hrs exposure period (with food) was allowed before mortality counts were taken. The experiments were conducted at laboratory conditions (30±1°C and 75±5 percent R.H. incase of phytophagous mite, 25±1°C and 70±5 percent R.H. for predatory mite (Table 32, 34, 41A, 41B & 41C). The mites which failed to respond either to light or mechanical stimuli were considered as dead. The control mortalities were corrected by Abbott's formula (1925). The data collected on mortality were subjected to probit analysis (Finney, 1952).

3.7.1 Ovicidal and adulticidal action of *B.t.* against red spider mite :

The ovicidal and adulticidal action of *B.t.* formulation var *kurstaki* were tested under a constant-temperature of 28±1°C and 80% R.H. under laboratory condition. The biocides (*B.t.*

and abamectin) were applied at various doses/concentration under a potters tower at 15 lb pressure for contact toxicity . For ovicidal study, six hrs old eggs red spider mite were exposed to toxicant collected on tea leaves. In case of adult, the exposure hrs were 6 hrs with the toxicant and subsequently they were transfer to untreated tea leaves. The mortality counts were taken at various interval and the data have been presented in Table 36 & 36A.

3.8 BIOEFFICACY OF SOME MODERN ACARICIDE AND ACARO-INSECTICIDES AGAINST *O. coffeae* AND ITS PREDATORS UNDER FIELD CONDITION

The experiments were laid out at different locations of Karballa T.E, Debpara T.E. and Nayasylle T.E. at the Dooars coinciding with the peak period of incidence of the mite (May-June). Three to fifteen years old TV_1 clone (60 x 90cm) were selected for this purpose under normal shade condition. The number of treatments varied between 7-15 depending upon the type of chemicals used in the experiment which was designed in randomized block design with three replications along with a control set (water spray). Each replication was consisted of fifty bushes. The doses of the chemicals used in the experiment were within the safe limit recommended for their use in pest control. Altogether one to three sprayings were given at 9-12 days interval depending upto the nature of chemicals used with knapsac sprayer @ 600 l/ha as high volume. The percent reduction/increase in mite population (plant feeding and preator was worked out based on number of motile stages on ten leaves selected randomly from ten bushes choosen at random at various intervals. The data on pest and preator incidence were subjected to analysis of variance after making necessary transformations wherever needed.

3.9 DISSIPATION PATTERN OF ACARICIDE

The residue of dicofol and acrinathrin occurring in made tea has been studied as follows:

3.9.1 Field experiment :

Location : Debpara T.E. & Hilla T.E., Dooars, W. Bengal

Crop : Tea

Variety : TV_9

Season : April, 1995 (1st season)

August, 1995(2nd season)

April, 1996 (3rd season)

Design : Randomised Block Design

Pesticide : Dicofol 18.5 EC (Kelthane),

Acrinathrin 15 EC (Rufast)

Treatment : Dicofol (Kethane) T_1 = 1:400

T_2 = 1: 200

T_3 = Untreated control

Acrinathrin (Rufast) T_4 = 1 : 4000

T_5 = 1 : 2000

T_6 = Untreated control

Replication : Three

No. of bushes per treatment : 100

Spacing : Single

Age of the bush : 10-15 years.

3.9.2 Method and Time of Application:

Dicofol: Dicofol (Kelthane) 18.5 EC was applied to tea bushes as aqueous solutions with Knapsac sprayer at the recommended doses @ 0.0425% (1:400 dilution) and also at double the recommended doses @ 0.085% (1: 200 dilution). The volume of water used was 400 lt/ha.

Acrinathrin : Acrinathrin (Rufast) 15 EC . The method of application was same as dicofol but the doses were 1 : 4000 & 1 : 2000.

3.9.3 Sampling:

Tea leaves were plucked randomly from each treatment replication wise at different time interval (0(4hrs), 1,3,5,7 and 10 days) after application of the chemical. The green leave samples were then processed with standard manufacturing method to made tea (CTC, 100g). The made tea was then stored in aluminium box at 0°C and analysed for residual content of insecticides within 3 days.

3.9.4 Extraction and clean-up:

a) Dicofol :

Tea samples (10g) were homogenized with 150 ml acetone in a Remi automix blender (3 mins.). The homogenate was filtered through buchner funnel and the residue was re-extracted twice (2 x 25ml) with acetone and filtered. The combined filtrate was concentrated (50ml) by a rotary vaccum evaporator at 40°C. The concentrated extract was then transferred into a 500 ml separatory funnel with the addition of 50ml of aqueous saturated sodium chloride solution and shaken vigorously (2-3 min). The upper layer (n-hexane layer) was allowed to stand over sodium sulfate for 30 min. with occassional swirling and filtered through cotton wool plug with anhydrous sodium sulfate. The aqueous layer was again extracted twice with 50ml n-hexane and the upper layer was collected similarly and combined with previous filtrate. The combined filtrate was concentrated (5ml) by a rotary vacuum evaporator at 40°C. The concentrated extract was then subjected to adsorption chromatography over activated florisil (60-100 mesh Spectrochem-15gm) with a 10 cm layer of anhydrous Na_2SO_4 on the top. The column was eluted with a mixture of n-hexane-diethyl ether (9:1, 150ml). The eluate was then concentrated and volume was made upto 20ml with n-hexane for analysis by GLC.

b) Acrinathrin :

Made tea sample (25g) was taken in a conical flask and then added 150 ml of acetonitrile and kept for overnight in a dark place. The material was then blended with 20g of sodium chloride for 20 x 20 min. in a Remi automix blender. The extract was filtered through a Buchner funnel using whatman filter paper No. 1. The blender was rinsed twice with 25 ml acetonitrile and filtered. The combined filtrate was concentrated to about 5-10 ml in a rotary vacuum evaporator. The extract was taken in a 500 ml separatory funnel and diluted with 50 ml of saturated aq. sodium chloride solution and then partitioned with 2 x 50 ml of ethyl acetate and the organic phase was then dried over anhydrous sodium sulphate and subsequently evaporated to dryness in a rotary vacuum evaporator at 40°C and the residue was then dissolved in 5-10 ml of herxane. The residual hexane solution was then subjected to silica gel (60-120 mesh, Qualizen, 25g) column chromatography with sodium sulphate at the top and the bottom. The column was pre-washed with hexane (50 gm) and then residue was poured on to the column and then eluted with 150 ml hexane : diethyl ethar (90 : 10 v/v). This fraction was concentrated in a rotary vacuum evaporator at 40° C and volume was made with hexane to 5 ml for G.C. analysis.

3.9.5 Gas Chromatographic Analysis:

Final analysis of dicofol residue in made tea was done by H.P. Model 5890A Gas Chromatograph with Electron capture (Ni^{63}) detector coupled with 3392A Integrator. Following are the parameters for the gas chromatography analysis of insecticides:

	Dicofol	Acrinathrin
Column	Glass column 1.8m x 2 mm i.d. packed with 3% DC-200 on chromosorb WHP (80-100 mesh).	Same
Oven Temp.	200°C	240°C
Inj. Temp.	220°C	295°C
Det. Temp.	300°C	275°C
N_2	40 ml/min	60 ml/min
Detector	ECD	ECD
Retention time (RT)	1.82min.	5.04min.

The retention time of the insecticide (Dicofol) in all the samples was compared with that of the external standard and the data was recorded. 1-3 µl portion of each cleaned up sample was injected on to the GC with a 10 µl Hamilton syringe. The amount of residues for dicofol was recorded in the integrator chart which was finaly calculated in 1-3 µg/g i.e. ppm using the following equation:

$$\text{Residue in ppm } (\mu g/g) = \frac{X}{V_1} \cdot \frac{V}{M} \cdot \frac{1}{10^3}$$

where,

X= Integrator reading in picogram

V_1 = µl of the sample injected

V= Total volume of cleaned up sample in ml.

M = Weight of the sample.

The minimum detectable limit is 0.005 ppm.

3.9.6 Recovery study:

Made tea samples were spiked with dicofol of different concentration. Then the samples were processed with the same procedures as mentioned earlier. The amount of dicofol recovered was analysed by GLC.

3.9.7 Interpretation of Data:

The data of the residue and persistence of dicofol was represented by regression equation, half life ($T_{½}$) and pre-harvest interval (PHI) or safe waiting period T_{MRL} (Hoskins, 1961).

Table 1a : Monthly average of meterological data pertaining to the period of experimentation at Dooars, W.B.

1994

Month	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph.)
	Max	Min	Mean	Morning	Afternoon	Mean			
January	24.2	10.90	17.55	97	53	75.0	4.22	6.9	1.2
February	23.9	12.30	18.10	96	57	76.5	2.76	5.9	1.6
March	28.1	17.30	22.70	91	55	73.0	6.10	5.2	1.6
April	30.3	19.10	24.70	87	57	72.0	9.36	7.2	1.8
May	32.1	22.50	27.30	89	65	77.0	32.16	6.9	1.7
June	31.0	24.60	27.80	96	81	88.5	56.62	3.7	1.3
July	32.0	24.90	28.45	96	78	87.0	46.86	4.4	1.3
August	32.3	25.10	28.70	97	77	87.0	170.46	4.3	1.3
September	32.0	24.20	28.10	98	74	86.0	206.32	5.2	1.2
October	29.7	19.90	24.80	95	68	81.5	8.48	6.8	1.0
November	28.2	14.60	21.40	94	56	75.0	0.00	7.8	1.3
December	24.9	11.60	18.25	97	50	73.5	2.78	7.9	1.1

Table 1b : **Monthly average of meterological data pertaining to the period of experimentation at Dooars, W.B.**

1995

Month	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph.)
	Max	Min	Mean	Morning	Afternoon	Mean			
January	22.5	9.6	16.05	96	52	74.0	0.10	6.1	1.1
February	24.4	12.6	18.50	94	52	73.0	5.74	6.1	2.3
March	28.3	16.3	22.30	88	47	67.5	0.72	5.7	1.5
April	32.4	19.1	25.75	77	42	59.5	7.12	7.5	2.1
May	31.9	22.9	27.4	91	70	80.5	55.84	5.5	1.8
June	30.2	24.6	27.40	97	83	90.0	78.56	2.1	1.3
July	30.3	24.6	27.45	98	84	91.0	89.28	2.3	1.1
August	31.7	24.5	28.1	97	76	86.5	63.64	4.2	1.3
September	30.8	23.7	27.25	98	78	88.0	49.36	4.2	1.0
October	31.2	20.4	25.80	94	63	78.5	7.76	8.0	1.0
November	28.5	16.3	22.40	96	59	77.5	7.22	7.6	1.0
December	24.4	13.0	18.7	98	60	79.0	0.2	5.5	0.8

3.10 METEOROLOGICAL DATA

The meteorological data viz., temperature, relative humidity, rainfall, sunshine, wind velocity of Nagrakata in the Dooars, West Bengal were collected from the meteorological section of Tea Research Association for the two consecutive years, i.e. January, 1994 to December, 1995 (Table 1a and Ib).

3.11 STATISTICAL METHODS

To measure the extent of variation in respect to different pesticidal treatments against the pests and natural enemies under field and laboratory condition; randomised block design was used. The mortality count on the pest was corrected in respect to control mortality by Abbott's formula (1925) :

$$P = \frac{P' - C}{100 - C} \times 100$$

where, P = % corrected mortality

P' = % observed mortality

C = Control mortality

Chapter - IV

Results And Discussions

Results And Discussions

4.1 RELATIVE DOMINANCE OF PHYTOPHAGOUS MITE IN TEA PLANTATION IN THE NORTH - EAST INDIA

It is revealed from the survey that five spp. of plant feeding mites were frequently encountered on tea bushes out of which the red spider mite *Oligonychus coffeae* (Nietner) was most dominant. The dominance factor was calculated for each of the five species of plant feeding mites and the calculated value was highest in *O.coffeae* (88.05%) followed by *B. phoenicis* (4.51%), *B.obovatus* (4.29%) , *A. theae*(2.11%) and *C.carinatus* (1.04%) (Table.2).

The rate of infestation of red spider mite varied between 5% to 15% depending on the area surveyed in spite of usual sprayings at 15 - 20 days interval. The reddish discolouration caused due to the infestation of red spider mite was noticable even from a distance of 100 metre or more. The inhibitory effect of toxin released during the course of feeding was not lethal to older tea bushes but often resulted in severe loss in production of remunerative 1st & 2nd flushes of tea. On the other hand, bushes less than three years were killed in some areas. Based on the visual rating, it may be considered as the major pest of tea.

On the other hand, the rate of infestation in case of scarlet, pink and purple mites were around 3%, 1% & 0.7% respectively. The infestation of yellow mite was almost negligible.

In India, 12 spp. of plant feeding mites have so far been reported on tea. Of them four species namely red spider mite, *Oligonychus coffeae* (Nietner), scarlet mite, *Brevipalpus phoenicis* (Geij.), pink mite, *Acaphylla theae* (watt) and purple mite, *Calacarus carinatus* (Green) are considered as major while rests are minor or maintain a non pest status (Gupta, 1989). The importance of red spider mite as a major mite pest of tea in North-East India has been indicated by several workers (Das,1959,1963; Banerjee,1966,1971; Gupta,1989). The rate of damage in this case have been reported as high as 14% (Banerjee, 1976). A boost in total yield of

27 million kg/year can be achieved alone through the control of this pest in India (Awasthi & Venkata Krishnan, 1977). In South Indian conditions, the pink mite comes first in the ranking major acarine pest. The crop lossess were reported to vary within 3 to 5% due to the infestation of this mite (Muraleedharan & Radhakrishnan, 1989a). The scarlet mite has a periodic occurrence assuming a important pest status in a cycle of four years (Baptist & Ranawerra, 1955). The purple mite is also no less significance as it is known to cause losses of 22.7 to 68.0 kg of processed tea/acre in Nilgiri Hills (Rau, 1960). The rest of the spp. are known to maintain a non pest status at this point of time. Among the three tenuipalpids reported during the present investigation, *Brevipalpus phoenicis* was recorded as the most dominant and widely distributed species. Our observations are in conformity with those recorded by Gupta (1989).

Table 2 : List of phytophagous mites found in association with tea plantation in the North-East India during 1993-94 and 1994-95 & their relative dominance

Sl. No.	Family	Species	Common name	Relative dominance(D)(%)
1.	Tetranychidae	*Oligonychus coffeae*	Red spider mite	88.05
2.	Tenuipalpidae	*Brevipalpus phoenicis*	Scarlet mite	4.51
3.	Tenuipalpidae	*B. obovatus*	Scarlet mite	4.29
4.	Eriophyidae	*Acaphylla theae*	Pink mite	2.11
5.	Eriophyidae	*Calacarus carinatus*	Purple mite	1.04

4.2 NATURAL ENEMIES OF RED SPIDER MITE OF TEA :

Rapid roving survey were undertaken in the tea growing areas of North East states of India during January 1994 to December 1995 to explore natural enemies found in association with red spider mite of tea. They were divided into two groups i.e. predatory insects and predacious mites. The later group out known insect predators. Therefore, maximum emphasised was given to study the role of predatory mites in the population regulation of red spider mite.

4.2.1 Insect predators of red spider mite:

Among various insect predators recorded during these studies, *Stethorus*, *Scymnus*, *Chrysoperla* and *Scolothrips* were most dominant. It is revealed from Table. 3 that the frequency of occurrence of *Stethorus* was low during the initial population build up of red spider mite but their population was considerably high when the infestation of red spider mite reached epidemic level. A comparative assessment of four important groups of insect predator showed that *Stethorus* was predominent only during high population density of red spider mite indicating its usefulness only under these situations. Economic damage on tea bushes are often encountered under these conditions. The frequency of occurrence of *Scymnus* and *Scolothrips* followed almost similar pattern as observed in case of *Stethorus*. They were almost absent when the population of red spider was low. *Chrysoperla*, on the otherhand, revealed it present at low density level of red spider mite indicating its high searching capacity. It is evident (Table.3) that *Chrysoperla* is an important predator of red spider and helps to check initial build-up of spider mite population. Conversely, *Stethorus* and *Scolothrips* are very important under high density of red spider mite. *Scymnus* plays an useful role under both the situations.

Table 3 : Major groups of insect predator of *O. coffeae* and their relative importance based on frequency of occurrence and relative dominance in tea growing areas of N.E. State (based on two years of observations)

Sl. No.	Insect predators	Frequency of occurrence		Relative dominance	
		Below ETL of red spider mite	Above ETL of red spider mite	Below ETL of red spider mite	Above ETL of red spider mite
1.	*Stethorus* sp.	+	+++	+	+++
2.	*Scymnus* sp.	+	++	+	++
3.	*Chrysoperla* sp.	++	++	++++	++
4.	*Scolothrips* sp.	+	+++	++	++

+ = Low, ++ = Medium, +++ = High, ++++ = Very high.

A perusal of available literature in this direction reveals that *Stethorus*, *Scymnus* and *Chrysoperla* are often encountered in red spider colony infesting tea (Das, 1959; 1960; 1965). They have been identified as important regulating agent of red spider mite on tea. Subsequent studies conducted at Tea Experimental Station (TRA, Jorhat) identified *Stethorus gilvifrons* as the most important insect predator of red spider mite. Similar studies carried out in other parts of the world also posted this four groups of natural enemies as major insect predator of red spider mite on tea (Ananthakrishnan, 1960, Rao, *et al.*1970, Das, 1974, 1979; Sarma, 1976; Tanigoshi & Mcmurtty, 1977; Lo *et al.*, 1990).

4.2.2 Predatory mites found in association with plant feeding mites

Thirty-nine spp. of predatory mites were collected during January, 1994 to December, 1995 from three distinct agroclimatic zones of India (Dooars & Terai in West Bengal and Tripura) where tea is cultivated. These included eighteen sp. of phytoseiidae, six species of Ascidae, four spp. each of stigmaeidae, Tydeidae and Bdellidae and one sp. each of Anystidae, Erythridae and Cunaxidae. Thirty-five spp. have been recorded for first time on tea plant (Table.4).

4.2.3 Regional distribution of plant feeding and predatory mites of tea based on survey undertaken during 1993-96

Among predatory mites, Phytoseiidae, Stigmaeidae, Bdellidae, Ascidae, Tydeidae and Cunaxidae were the predominant groups (Table.5). Among phytoseiids, *Amblyseius* was most important and they formed bulk of the phytoseiids. Only two species of *Typhlodromus* were identified. Only one sp. of phytoseiid was recorded in every location i.e. *A.herbicolus* and the other widely distributed spp. were *A. largoensis*, *A. mcmurtryi*, *A. kulini* and *A.longinspinosus*. Six spp. of asciad mites were recorded out of which *Lasioseius phytoseioides* had wide distribution. Altogether six spp. of stigmaeid mite were collected and *Agistemus terminalis* was the most common. Out of four spp, of bdellid mite, only two were found in various locations. Only one species of anystid and cunaxid mite were recorded and the later one was distributed in six of the eight areas surveyed for this pourpose. Among four spp . of tydied mites, *Pronematus fleschneri* was found in almost all the place other than Darjeeling area.

Table 4 : List of predatory mites collected on tea in the Dooars (W.B.), Terai (W.B.) and Tripura during January 1994 to December, 1995

Sl No.	Species	Family	Remarks
01.	*Amblyseius herbicolus*	Phytoseiidae	-
02.	*A. largoensis*	"	New record
03.	*A. ovalis*	"	-
04.	*A. longispinosus*	"	New record
05.	*A. syzygii*	"	New record
06.	*A. kulini*	"	New record
07.	*A. coccineae*	"	New record
08.	*A. coccosocius*	"	New record
09.	*A. pruni*	"	New record
10.	*A. crotalariae*	"	New record
11.	*A. polyantheae*	"	New record
12.	*A. mcmurtryi*	"	New record
13.	*A. shoreae*	"	New record
14.	*A. neocrotalariae*	"	New record
15.	*A. neorykei*	"	New record
16.	*A. paraaerialis*	"	New record
17.	*A. muraleedharani*	"	New record
18.	*Typhlodromus homalii*	"	New record
19.	*Lasioseius* sp.	Ascidae	-
20.	*Lasioseius* sp. nr. *metthyssei*	"	New record
21.	*L. ometes*	"	New record
22.	*L. matthyssei*	"	New record
23.	*L. phytoseioides*	"	New record
24.	*Asca* sp.nr. *biswasi & caphidioides*	"	New record
25.	*Agistemus terminalis*	Stigmaeidae	New record
26.	*A. hystrix*	"	New record
27.	*A. exsertus*	"	New record
28.	*A. macromatus*	"	New record
29.	*Paraprонematus murshidabadensis*	Tydeidae	New record
30.	*Paraprоnematus* sp.	"	New record
31.	*Pronematus fleschneri*	"	New record
32.	*pronematus* sp.	"	New record
33.	*Bdella maldahaensis*	Bdellidae	New record
34.	*Bdella* sp.nr. *captiosa*	"	New record
35.	*Bdella* sp.	"	New record
36.	*Bdellodes* sp.	"	New record
37.	*Walzia* sp.	Anystidae	New record
38.	*Cunaxa setirostris*	Cunaxidae	New record
39.	*Erythraeus* sp.	Erythraeidae	-

Table 5 : Regional distribution of plant feeding and predatory mites of tea based on survey undertaken during 1993-96

Mite spp.	State							
	Tripura	Assam			West Bengal			
	Agartala	Cachar	Tinsukia	Tejpur	Dooars	Terai	Kurseong	Darjeeling
I. TETRANYCHIDAE								
1.*Oligonychus coffeae*	+	+	+	+	+	+	+	+
2. *Tetranychus* sp.	-	+	+	-	-	-	-	-
3. *Eutetranychus* sp.	-	-	-	+	-	-	-	+
II. TENUIPALPIDAE								
4. *Brevipalpus obovatus*	+	-	+	+	+	+	+	-
5. *B. phoenicis*	+	+	+	+	+	+	+	+
6. *B. deleoni*	-	+	-	-	-	-	+	+
III. ERIOPHYIDAE								
7. *Acaphylla theae*	+	-	+	+	+	+	+	+
8. *Calacarus carinatus*	-	-	+	-	-	+	+	+
IV. TARSONEMIDAE								
9. *Polyphagotarsonemus latus*	+	-	-	+	+	+	-	-
V. PHYTOSEIIDAE								
10. *Amblyseius herbicolus*	+	+	+	+	+	+	+	+
11. *A. largoensis*	+	+	-	+	+	+	+	+
12. *A. Neorykei*	+	-	-	-	-	+	-	-
13. *A. mcmurtryi*	+	+	+	-	+	+	+	-
14. *A. shoreae*	-	-	-	-	+	-	+	-
15. *A. paraaerialis*	+	-	-	-	-	-	+	+
16. *A. kulini*	+	+	-	+	+	+	-	+
17. *A. muraleedharani*	+	-	-	-	-	-	+	-
18. *Amblyseius* sp.	-	-	+	+	-	-	-	+
19. *A. ovalis*	+	+	+	-	+	+	-	+
20. *A. pruni*	+	-	-	+	+	+	+	-

Mite spp.	State							
	Tripura	Assam			West Bengal			
	Agartala	Cachar	Tinsukia	Tejpur	Dooars	Terai	Kurseong	Darjeeling
21. *A. alstoniae*	-	-	+	-	-	-	-	-
22. *A. coccineae*	+	-	-	-	+	+	+	+
23. *A. coccosocius*	+	-	-	-	+	-	+	+
24. *A. multidentatus*	-	+	-	-	-	-	+	+
25. *A.* sp. nr. *areca*	-	-	-	+	-	-	-	-
26. *A. syzygii*	+	-	+	-	+	-	-	+
27. *A. polyantheae*	-	-	-	-	+	-	-	-
28. *A. crotalariae*	-	-	-	-	+	-	-	-
29. *A. neocrotalariae*	-	-	-	-	+	+	+	-
30. *A. longispinosus*	+	-	+	-	+	-	+	+
31. *Typhlodromus homalii*	+	+	-	+	+	-	+	-
32. *T. darjeelingensis*	-	-	-	-	-	-	+	+
VI. ASCIDAE								
33. *Lasioseius* sp.	+	+	-	-	+	-	+	+
34. *L. phytoseioides*	+	+	-	+	-	+	+	-
35. *L. ometes*	+	-	-	-	-	+	-	+
36. *L. matthyssei*	+	-	+	+	-	-	+	+
37. L. sp. nr. *matthyssei*	+	-	-	-	-	-	-	-
38. *Asca* sp. nr. *biswasi* and *caphidioides*	+	-	-	-	-	-	-	-
VII. STIGMAEIDAE								
39. *Agistemus fleschneri*	-	-	-	+	-	-	+	+
40. *A. terminalis*	+	+	-	-	+	-	+	+
41. *A. hystrix*	-	-	+	+	+	-	-	+
42. *A. exsertus*	-	+	+	-	-	+	-	-
43. *A. macromatus*	-	-	-	-	-	+	+	-
44. *A. aramatai*	-	-	+	+	-	-	-	-

Mite spp.	State							
	Tripura	Assam			West Bengal			
	Agartala	Cachar	Tinsukia	Tejpur	Dooars	Terai	Kurseong	Darjeeling
VIII. BDELLIDAE								
45. *Bdella maldahaensis*	+	-	-	-	-	-	-	+
46. *Bdella* sp. nr. *captiosa*	-	-	-	-	-	+	+	-
47. *Bdella* sp.	+	-	+	+	-	-	+	+
48. *Bdellodes* sp.	-	+	+	-	+	+	-	+
IX. ANYSTIDAE								
49. *Walzia* sp.	+	-	-	-	+	-	+	-
X. CUNAXIDAE								
50. *Cunaxa setirostris*	+	+	+	-	+	+	+	+
XI. TYDEIDAE								
51. *Parapronematus* sp.	+	+	+	-	-	+	+	+
52. *P. murshidabadensis*	+	-	-	-	+	+	-	-
53. *Pronematus* sp.	+	-	+	-	-	-	-	+
54. *Pronematus fleschneri*	+	+	+	+	+	+	+	-
XII. ERYTHRAEIDAE								
55. *Erythraeus* sp.	-	-	+	-	-	+	-	-
XIII. ACARIDAE								
56. *Tyrophagus putrescentia*	+	+	-	+	+	+	-	+
XIV. CHEYLETIDAE								
57. *Cheyletus* sp.	-	+	-	-	-	-	-	-
XV. ORIBATULIDAE								
58. Unidentified species	+	+	-	-	+	-	+	-

N.B. + = Present, - = Absent

Though there were no marked preference of the predatory mites to various agroclimatic zones, but Tripura, Kurseong (W.B.) and Dooars (W.B.) harvoured most of the predatory mites.

Gupta (1989) reported thirty-six species of mites in association with tea plants in India during survey made in different tea gardens in north-east India and North Bengal during 1983-1985. These included 12 species of phytophagous mites, 21 species of predatory mites and 3 species of mites associated with fungus. The predatory mites were consisted of four species of Phytoseiidae, three species of Stigmaeidae and one species of each of Bdellidae, Anystidae, Eupodidae, Cunaxidae, Tydeidae, and Oppiidae and these were recorded for the first time on tea plants. Muraleedharan and Chandrasekharan (1981) initiated a detailed survey on tea mites in South India and reported to them *Amblyseius herbicolus* (Chant) as the most important predaceous mites of red spider in South India. *Agistemus* species was also very common and most active in praying on eggs and nymphal stages of *Oligonychus coffeae*. The number of predatory species of other families like Bdellidae, Tydeidae, and Ascidae was so poor that they hardly exerted any influence on their prey population Rao *et al.* (1970) reported some undetermined species of Erythraeidae, Stigmaeidae, Anystidae and Cheyletidae predating upon *O. coffeae* in addition to *A. ovalis* feeding on the some pests. Gupta (1989) opinioned after two years of his survey work that predatory mites belonging to Phytoseiidae and Stigmaeidae are the potential natural enemies which can be exploited for checking the population of mite pests of tea. In the present study the duminance of Phytoseiids among different groups of predaceous mites was evident. The other important groups after Phytoseiidae according to the number of species recorded was Stigmaeidae, Ascidae, Bdellidae and Tydeidae and all of them are represented by three to six species. The least represented family was with one species in each were Cunaxidae, Anystidae and Erythraeidae. Pande and Nandi (1983) also identified Phytoseiidae as the most important predatory species of *O. coffeae*. The composition of various groups of predaceous mites found in association with red spider recorded during the present investigation was almost similar to those reported by Gupta (1989).

4.3 EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE DEVELOPMENT, LONGEVITY AND FECUNDITY OF TEA RED SPIDER MITE, *O. coffeae*

Copulation: The males being sexually mature immediately after emergence looked for female deutonymph and mated with her as soon as she emerged from the deutonymphal skin. Often males helped the females to come out of the nymphal skin. At times, there were competetions among males to have access of the same female and sometimes the same female allowed more than one male to mate with her. According to Das (1959), a female never allowed more than one male to copulate with her while Andrews (1928) observed that a single female had allowed as many as 14 males in succession. During copulation, the male slipped beneath the female and upwardly curved its posterior genital organ. The copulation in an average took 45-60 seconds. A single male could copulate with as many as 14-16 females.

Eggs: The eggs were laid on the upper surface of the leaves along the midrib and veins. Usually 4-8 eggs were laid per day. Eggs were spherical and in average of 110 microns in diameter (Table.6). A filamentous process arises from the upper pole and then bends in the form of a hook. The colour was light red to purplish and changed to light orange before hatching. The egg was tightly glued to the leaf surface and during hatching the silvery white chorion splits along the side of the attachment to the leaf surface. The larvae emerged through the split.

Incubation: This period at different combination of temperature and R.H. was : 6.33±0.52 days at 26.0°C+71.60% R.H., 4.83±0.75 days at 30.5°C + 76.50% R.H. and 4.67±0.82 days at 33.2°C + 79.85% R.H. (Table .6A) According to Muraleedharan (1991), the incubation period was 4-6 days while according to Ahmed & Sana (1990) it was 3.6 days in average. Hence, the present observations are in line with those of others including that of Das (1959).

Larva : The newly hatched 6-legged larva was yellowish orange but subsequently changed to reddish orange. It measured 170 microns in length and 130 microns in width (Table.6). The larval period ranged from 2.4-2.7 days with average being 2.52 ± 0.12 days at 26.0°C + 71.60% R.H. and the corresponding figures at 30.5°C + 76.50% R.H. and 33.2°C + 79.85% R.H. were 1.5-2.5 days i.e. 2.1 ± 0.35 days and 1.2-2.0 days i.e. 1.62 ± 0.28 days respectively (Table.6A). From this it became apparent that the duration of larval stages decreased with increase of temperature. Das (1959) mentioned that duration of larval period during different months ranged from 1.00 day during June and 3.00 days during December while Das & Das (1967) reported that the minimum and the maximum larval periods were 1.00 days at 30.0°C and 1.3 days at 20°C, respectively. All these reports lend support to the observations made during the present study. The larvae passed through a brief quiescent stage before moulting into protonymph.

Table 6 : Measurement (microns) of different stages of *Oligonychus coffeae*

	Egg	Larva	Protonymph	Deutonymph	Male	Female
Length	110	170	220	260	290	390
Width	-	130	150	190	160	210
Length of legs						
1st leg		140	200	220	250	320
2nd leg		120	160	180	200	270
3rd leg		110	150	160	170	250
4th leg			160	180	240	260

Protonymph: The protonymph could be easily distinguished from larva because of the presence of 4 pairs of legs, body being somewhat oval with pale crimson colour on the body and reddish brown on abdomen. The protonymph measured 220 microns in length and 150 microns in width (Table.6). The duration of protonymphal period at different combinations of temperature and R.H. were : 2.18 ± 0.15 days (range: 2.0-2.4 days), 1.65±0.29 days (range : 1.3-2.0 days) and 1.10 ± 0.13 days (range : 1.0-1.3 days) at 26.0°C + 71.60% R.H., 30.5°C + 76.50% R.H. and 33.2°C + 79.85% R.H., respectively (Table.6A). Das & Das (1967) found the minimum protonymphal period being 0.8 days at 30°C and maximum being 1.3 days at 20°C. The protonymphal period passed through a quiescent stage before moulting into adult, the duration of which ranged from 10-15 hrs. The male protonymph after passing through a quiescent stage entered into adult directly without passing through the deutonymphal stage.

Table 6.A : Duration (days)of different stages of *Oligonychus coffeae* (Red Spider Mite of Tea)

Sl. No.	Incubation period	Larva	Proto nymph	Deuto nymph	Total period Egg to Adult	Longevity		AverageFecundity	
						♂	♀	Fertilised ♀	Unfertilised ♀
At an average temperature 26°C, R.H. 71.60 per cent									
1.	6	2.5	2.1	2.3	12.9	12.8	26.6	69	58
2.	7	2.7	2.4	2.0	14.1	12.4	26.2	66	55
3.	6	2.4	2.1	2.5	13.0	12.1	25.1	68	60
4.	6	2.5	2.3	2.1	12.9	12.3	25.0	69	58
5.	7	2.6	2.0	2.3	13.9	12.6	25.4	69	61
6.	6	2.4	2.2	2.0	12.6	12.4	25.5	70	59
Total	38	15.1	13.1	13.2	79.4	74.6	153.8	411	351
Average	6.33	2.52	2.18	2.20	13.23	12.43	25.63	68.50	58.50
SD ±	0.52	0.12	0.15	0.20	0.61	0.24	0.63	1.38	2.07
At an average temperature 30.5°C, R.H. 76.50 per cent									
1.	4	2.5	1.3	2.1	9.9	11.6	24.0	72	54
2.	5	2.4	1.6	1.8	10.8	12.2	23.6	70	59
3.	4	2.0	2.0	1.5	9.5	12.0	24.1	72	61
4.	6	2.1	1.6	2.1	11.8	12.3	23.4	71	55
5.	5	1.5	1.4	1.8	9.7	12.1	23.8	73	59
6.	5	2.1	2.0	1.4	10.5	11.4	24.0	72	57
Total	29	12.6	9.9	10.7	62.2	71.6	142.9	430	345
Average	4.83	2.1	1.65	1.78	10.37	11.93	23.82	71.67	57.5
SD±	0.75	0.35	0.29	0.29	0.86	0.36	0.27	1.03	2.66
At an average temperature 33.2°C R.H. 79.85 per cent									
1.	5	1.5	1.0	1.6	9.1	10.2	21.3	74	61
2.	4	2.0	1.2	1.8	9.0	11.1	22.5	75	59
3.	5	1.7	1.3	1.4	9.4	10.6	20.9	74	70
4.	6	1.2	1.0	1.3	9.5	10.0	21.1	70	68
5.	4	1.5	1.1	1.6	8.2	10.3	20.8	78	62
6.	4	1.8	1.0	1.3	8.1	11.0	21.5	76	65
Total	28	9.7	6.6	9.0	53.3	63.2	128.1	447	385
Average	4.67	1.62	1.10	1.50	8.88	10.53	21.35	74.5	64.17
SD±	0.82	0.28	0.13	0.20	0.60	0.45	0.62	2.66	4.26

Deutonymph: The deutonymph was longer and more plumpy than the protonymph, measuring 260 microns in length and 190 microns in width with body eliptical and reddish brown (Table.6). The durations of deutonymphal stage at different combinations of temperature and R.H. were 2.20±0.20 days (range: 2-2.5 days), 1.78±0.29 days (range: 1.4-2.1 days) and 1.50±0.20 days (range: 1.3-1.8 days) at 26.0°C+71.60% R.H., 30.5°C ± 76.50% R.H. and 33.2°C + 79.85% R.H., respectively (Table.6A). Das & Das (1967) reported the duration of this stage as 0.9 days at 30°C and 1.8 days at 20°C while Ahmed & Sana (1990) reported that larval and nymphal stages lasted for 1-2 days each. The deutonymph passed through a quiescent stage before it moulted into adult female.

Egg-adult period: The duration of egg to adult period during different combinations of temperature and R.H. were 13.23±0.61 days (range: 12.6-14.10 days), 10.37 ± 0.86 days (range: 9.50-11.80 days) and 8.88 ± 0.60 days) (range: 8.10-9.50 days) at 26.0°C + 71.60% R.H., 30.5°C + 76.50% R.H. and 33.2°C + 79.85% R.H. respectively (Table.6A). Das (1959) reported that the minimum duration of egg-adult period was during June and the maximum was 11.00 days during December-February. This report more or less conforms the present observations indicating that duration of egg-adult stage varied inversely with temperature. According to Sudoi (1992) the life cycle took 8.6-11.5 days. On the contrary, Tsai *et al.* (1989) while studying the biology of another mite, *Tetranychus kanzawai* on tea at different temperatures, *viz.* 15,20,25,30°C reported that development was slowest at the lowest temperature and fastest at higher temperatures. According to Muraleedharan (1991) the life cycle of *O. coffeae* took 10-14 days.

Adult Male: The male was different in shape and size from female being more slender with posterior tip tapering. It measured 290 microns in length and 160 microns in width (Table.6) with body colour being bright crimson. It was fairly active.

Adult Female: The female was larger in size, body being elliptical with broadly rounded abdomen. The colour of abdomen was dark purplish bronze and legs were bright crimson. It measured 390 microns in length and 210 microns in width (Table.6).

Preoviposition period: In general, this period ranged from 12-16 hrs after copulation.

Fecundity: The average fecundity of fertilized and unfertilized female at different combinations of temperature and R.H. were respectively 68.50±1.38 eggs (range: 66-70 eggs) and 58.50 ± 2.07 eggs (range: 55-61 eggs) at 26.0 + 71.60% R.H.; 71.67 ± 1.03 eggs (range: 70-73 eggs) and 57.50 ± 2.66 eggs(range 54-61 eggs) at 30.5°C + 76.50% R.H. and 74.50 ± 2.66 eggs (range : 74-78 eggs) and 64.17 ± 4.26 eggs (range: 59-70 eggs) at 33.2°C + 79.85% R.H. (Table.6A) Das & Das (1967) reported the mean fecundity being minimum i.e. 12.0 eggs at 32°C and maximum being 107.3 eggs at 20°C. The fecundity at other temperatures was 99.7 eggs at 25°C, 77.8 eggs at 27°C and 59.3 eggs at 30°C. The results obtained in the present study do not conform with the observations of Das & Das (1967) as they recorded higher fecundity at lower temperature and the same gradually decreased as the temperature increased. In the present study the trend was just the reverse as fecundity increased with the increase of temperature. According to Sudoi (1992) the egg laying ranged from 1.2-4.2 per day.

Longevity: The longevity of adult male and female at different combinations of temperature and R.H. was respectively, 12.43±0.24 days (range: 12.1-12.8 days) for male and 25.63±0.63 days (range: 25.1-26.6 days) at 26.0°C + 71.60% R.H.; 11.93 ± 0.36 days (range : 11.4-12.3 days) and 23.82 ± 0.27 days (range: 23.6-24.1 days) at 30.5°C + 76.5% R.H. and 10.53 ± 0.45 days (range: 10.2-11.1 days) and 21.35 ± 0.62 days (range: 20.80 - 22.5 days) at 33.2°C + 79.85% R.H.(Table.6A) Das (1959) reported longevity of female being 24.4 days and that of male being 12 days. The present observation does not conform with that of Das (1959) as the duration of adults of both sexes was found to be much shorter in this case but certainly indicates that duration was longer at lower temperature and shorter at higher temperature. In fact, this is the normal trend as reported by the earlier workers in case of other Tetranychid species. Tsai *et al.* (1989) reported in case of another tea mite, *Tetranycus kanzawai* that the adult life span averaged 32.8 days in female and 34.8 days in males at 15°C while the respective figures were 19.9 and 19.2 days at 30°C.

4.4 INFLUENCE OF METEOROLOGICAL FACTORS ON POPULATION DYNAMICS OF RED SPIDER MITE AND ITS PREDATORY MITE COMPLEX

4.4.1 On red spider mite, *O. coffeae*

The population build up of any pest is very closely associated with weather conditions prevailing during the preceding and corresponding period. The season wise relationship between meteorological parameters are therefore, important on the incidence of pest spp. Spider mites like other arthropods are greatly affected by meteorological conditions. Temperature, humidity, rain, light and wind are important in the life of spider mites. These are very much relevant in case of red spider mite of tea as evidenced from Table.7 and Fig.7.1. The build up of spider mite population on tea started from January reaching its peak in May-June. Thereafter, the population started declining and it was lowest in December. In order to study the effect of different abiotic factors on the population build-up of spider mite, correlation analysis was done. The data revealed that temperature, humidity, rainfall and wind velocity were found to be significantly correlated with spider mite population build-up. A high incidence of spider mite was observed with an ambient temperature of 27°C, high humidity - 88.5%, moderate rainfall (56.62 cm) and 1.3 miles wind speed during the first year of studies i.e. January, 1994 to December, 1994.

In the next year i.e. January, 1995 to December, 1995, the high incidence of spider mite was recorded with an temperature of 27.4°C, high humidity -90%, moderate rainfall (78.5 cm) and moderate wind velocity (1.3 miles) (Table.8 and Fig. 8.1). These values were very close to those observed during the first year of observation. It was further observed that the influence of meteorological factors of the preceding months was more pronounced in the build up of red spider population. It was evident from the two years of studies that temperature, humidity and rainfall played the most important role in population dynamics of red spider mite.

4.4.2 On predatory mites

The population build-up of predatory mites as observed during January, 1994 to December, 1994 started from January reaching maximum level during October - Novembet (Table.9 and Fig.9.1). At the initial stage, the predator's number was 1.5/leaf and it increased almost four folds i.e. 4.93/leaf during October-November. Among five major abiotic factors, temperature and rainfall played significant positive role in build-up its population. A mild temperature condition i.e. 21-24°C prevailed during this period and the rainfall was also very low (0.00-8.48 cm).

In the second year of observation, i.e. January, 1995 - December, 1995, almost similar trend in population build-up of predatory mites was observed (Table.10 and Fig. 10.1). The peak population i.e. 4.69/leaf was recorded during November. Three major abiotic factors temperature, humidity and rainfall played significant positive role. The mean temperature was

Table 7 : **Influence of major abiotic factors on seasonal incidence of red spider mite, *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, W.B.) during January 1994 to December 1994**

Month	Mean no. of motile stage/ leaf	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph.)
		Max	Min	Mean	Morning	Afternoon	Mean			
January	07.46	24.2	10.9	17.55	97	53	75.0	4.22	6.9	1.2
February	12.65	23.9	12.3	18.10	96	57	76.5	2.76	5.9	1.6
March	15.76	28.1	17.3	22.7	91	55	73.0	6.10	5.2	1.6
April	29.86	30.3	19.1	24.7	87	57	72.0	9.36	7.2	1.8
May	41.27	32.1	22.5	27.3	89	65	77.0	32.16	6.9	1.7
June	46.58	31.0	24.6	27.8	96	81	88.5	56.62	3.7	1.3
July	39.87	32.0	24.9	28.45	96	78	87.0	46.86	4.4	1.3
August	34.48	32.3	25.1	28.70	97	77	87.0	170.46	4.3	1.3
September	09.36	32.0	24.2	28.1	98	74	86.0	206.32	5.2	1.2
October	07.61	29.7	19.9	24.8	95	68	81.5	8.48	6.8	1.0
November	03.11	28.2	14.6	21.4	94	56	75.0	0.00	7.8	1.3
December	02.06	24.9	11.6	18.45	97	50	73.5	2.78	7.9	1.1

Factors	Values of 'r' (correlation coefficient)	Regression coefficient	Values of 't'	Remarks
1. Mite population and temperature (°C)	0.720	1.582	1.253	Sig*
2. Mite population and relative humidity (%)	0.503	1.899	1.299	Sig*
3. Mite population and total rainfall (cm)	0.221	-0.107	-1.924	Sig**
4. Mite population and sunshine (Hrs)	-0.619	-0.516	-0.129	NS
5. Mite pupulation and wind velocity (miles)	0.420	39.321	2.085	Sig*

Multiple correlation coefficient (R) = 0.918
Multiple regression 'F test' value = 6.42

* Significant at 5% level , ** Significant at 1% level.

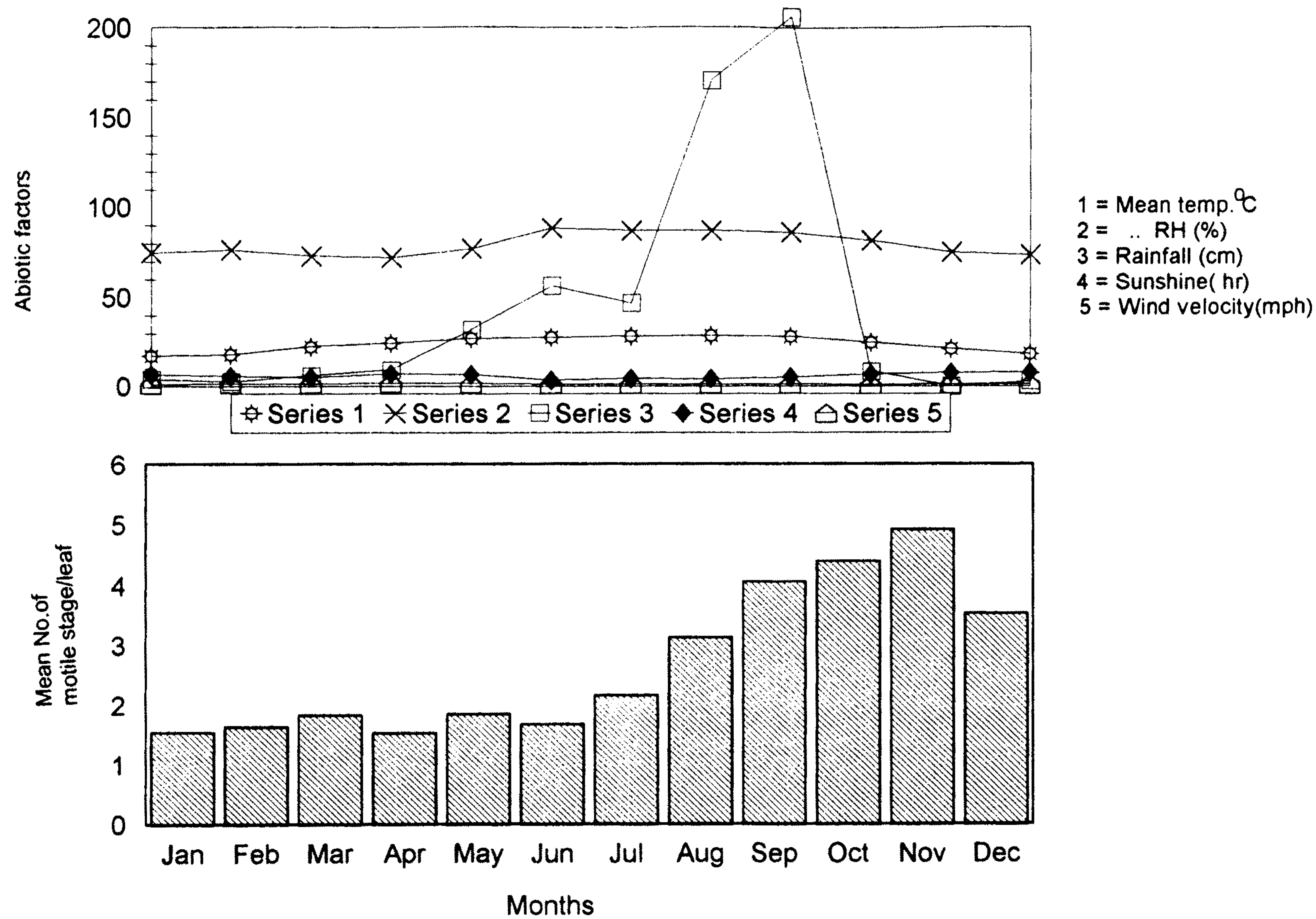


Fig.7.1 Influence of major abiotic factors on seasonal incidence of predatory spider mite, *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, West Bengal) during January 1994 to December 1994

Table 8 : **Influence of major abiotic factors on the seasonal incidence of red spider mite, *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, W.B.) during January 1995 to December 1995**

Month	Mean no. of motile stage/ leaf	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph)
		Max	Min	Mean	Morning	Afternoon	Mean			
January	06.32	22.5	9.6	16.05	96	52	74.0	0.10	6.1	1.1
February	10.46	24.4	12.6	18.50	94	52	73.0	5.74	6.1	2.3
March	13.67	28.3	16.3	22.30	88	47	67.5	0.72	5.7	1.5
April	24.56	32.4	19.1	25.75	77	42	59.5	7.12	7.5	2.1
May	38.31	31.9	22.9	27.40	91	70	80.5	55.84	5.5	1.8
June	41.58	30.2	24.6	27.40	97	83	90.0	78.56	2.1	1.3
July	36.77	30.3	24.6	27.45	98	84	91.0	89.28	2.3	1.1
August	34.46	31.7	24.5	28.10	97	76	86.5	63.64	4.2	1.3
September	08.61	30.8	23.7	27.25	98	78	88.0	49.36	4.2	1.0
October	06.18	31.2	20.4	25.80	94	63	78.5	7.76	8.0	1.0
November	02.33	28.5	16.3	22.40	96	59	77.5	7.22	7.6	1.0
December	01.81	24.4	13.0	18.70	98	60	79.0	0.20	5.5	0.8

Factors	Values of 'r' (correlation coefficient)	Regression coefficient	Values of 't'	Remarks
1. Mite population and temperature (°C)	0.697	-0.429	-0.424	Sig*
2. Mite population and relative humidity (%)	0.385	-1.166	-2.066	Sig*
3. Mite population and total rainfall (cm)	0.829	0.701	2.635	Sig*
4. Mite population and sunshine (Hrs)	-0.651	0.576	0.225	NS
5. Mite pupulation and wind velocity (miles)	0.302	2.244	0.350	NS

Multiple correlation coefficient (R) = 0.954
Multiple regression 'F test' value = 12.18

* Significant at 5% level.

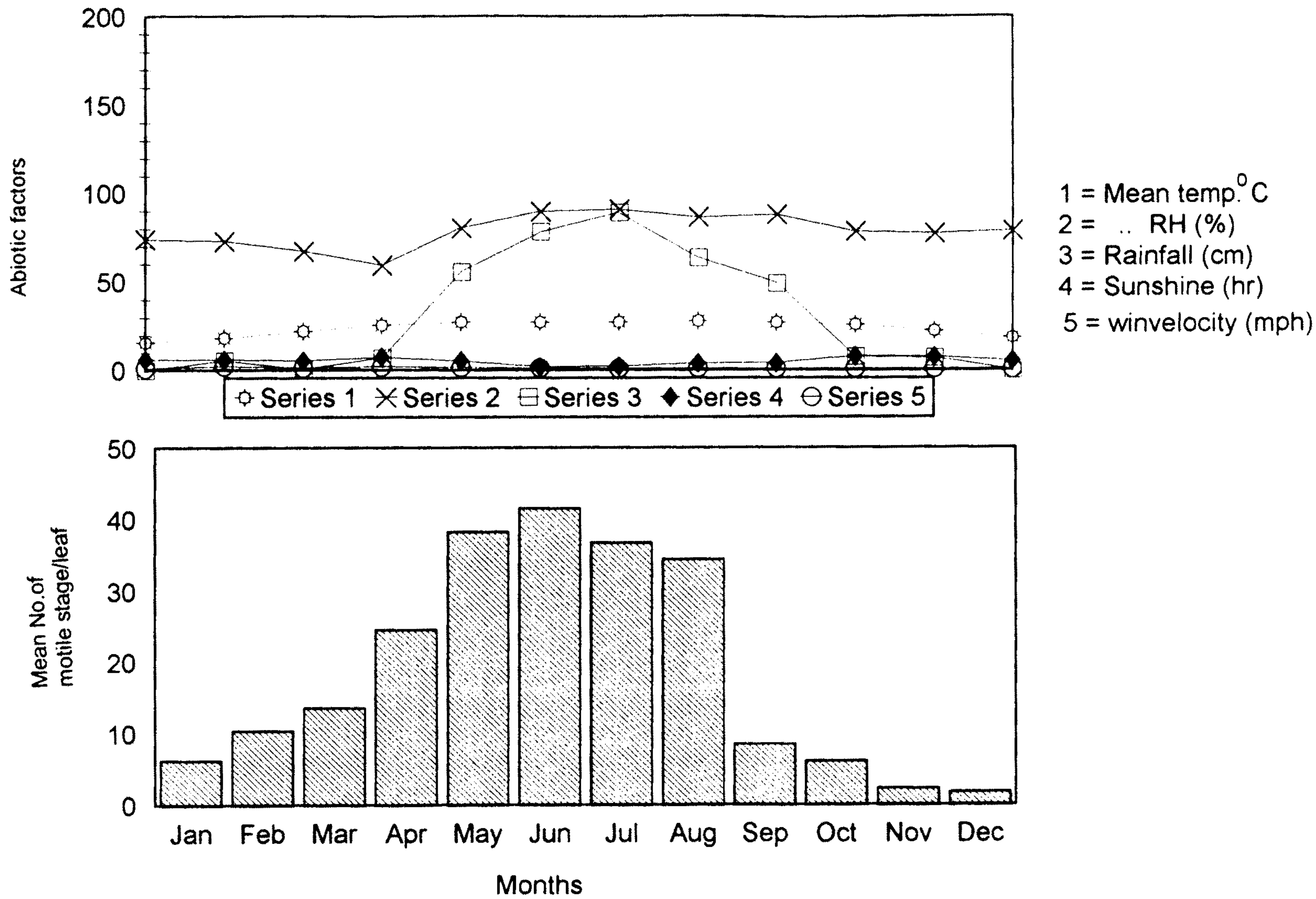


Fig.8.1 Influence of major abiotic factors on seasonal incidence of red spider mite, *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, West Bengal) during January 1995 to December 1995.

Table 9 : **Influence of major abiotic factors on the seasonal incidence of predatory mite complex of *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, W.B.) during January 1994 to December 1994**

Month	Mean no. of motile stage/ leaf	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph.)
		Max	Min	Mean	Morning	Afternoon	Mean			
January	1.55	24.2	10.90	17.55	97	53	75.0	4.22	6.9	1.2
February	1.64	23.9	12.30	18.10	96	57	76.5	2.76	5.9	1.6
March	1.84	28.1	17.30	22.70	91	55	73.0	6.10	5.2	1.6
April	1.54	30.3	19.10	24.70	87	57	72.0	9.36	7.2	1.8
May	1.86	32.1	22.50	27.30	89	65	77.0	32.16	6.9	1.7
June	1.69	31.0	24.60	27.80	96	81	88.5	56.62	3.7	1.3
July	2.17	32.0	24.90	28.45	96	78	87.0	46.86	4.4	1.3
August	3.14	32.3	25.10	28.70	97	77	87.0	170.46	4.3	1.3
September	4.07	32.0	24.20	28.10	98	74	86.0	206.32	5.2	1.2
October	4.41	29.7	19.90	24.80	95	68	81.5	8.48	6.8	1.0
November	4.93	28.2	14.60	21.40	94	56	75.0	0.00	7.8	1.3
December	3.54	24.9	11.60	18.25	97	50	73.5	2.78	7.9	1.1

Factors	Values of 'r' (correlation coefficient)	Regression coefficient	Values of 't'	Remarks
1. Mite population and temperature (°C)	0.058	0.116	0.849	Sig*
2. Mite population and relative humidity (%)	0.142	-0.036	0.226	NS
3. Mite population and total rainfall (cm)	0.253	0.006	0.931	Sig*
4. Mite population and sunshine (Hrs)	0.300	0.516	1.192	NS
5. Mite pupulation and wind velocity (miles)	-0.638	-3.381	-1.660	NS

Multiple correlation coefficient (R) = 0.827
Multiple regression 'F test' value = 2.60

* Significant at 5% level.

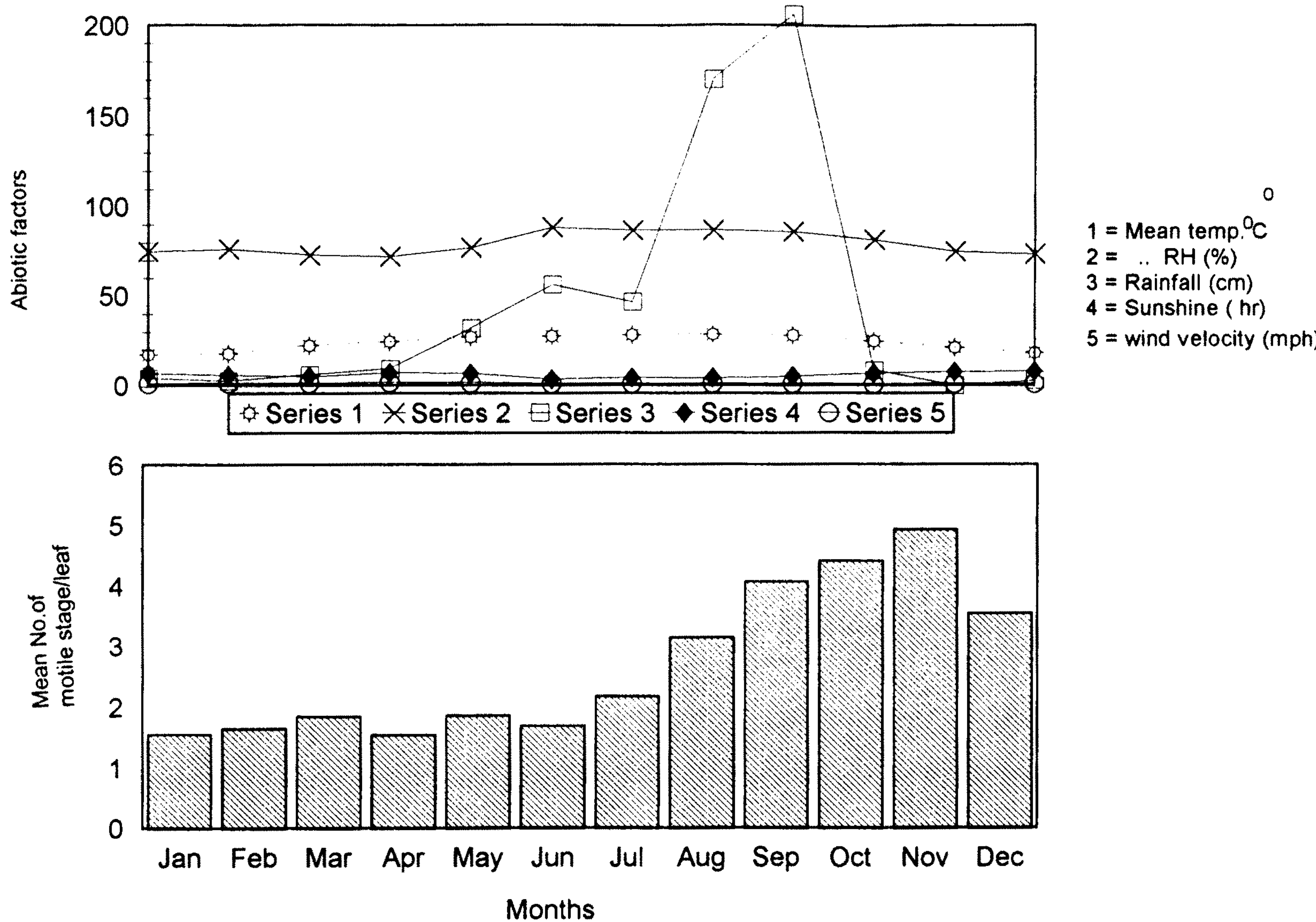


Fig.9.1 Influence of major abiotic factors on seasonal incidence of predatory mite complex of, *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, West Bengal) during January 1994 to December 1994

Table 10 : Influence of major abiotic factors on seasonal incidence of predatory mite complex of *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, W.B.) during January 1995 to December 1995

Month	Mean no. of motile stage/ leaf	Temperature (°C)			RH (%)			Total rainfall (cm)	Sunshine (Hrs)	Wind (mph.)
		Max	Min	Mean	Morning	Afternoon	Mean			
January	1.62	22.5	9.6	16.05	96	52	74.0	0.10	6.1	1.1
February	1.68	24.4	12.6	18.50	94	52	73.0	5.74	6.1	2.3
March	1.82	28.3	16.3	22.30	88	47	67.5	0.72	5.7	1.5
April	1.61	32.4	19.1	25.75	77	42	59.5	7.12	7.5	2.1
May	1.84	31.9	22.9	27.4	91	70	80.5	55.84	5.5	1.8
June	1.74	30.2	24.6	27.40	97	83	90.0	78.56	2.1	1.3
July	2.14	30.3	24.6	27.45	98	84	91.0	89.28	2.3	1.1
August	3.07	31.7	24.5	28.1	97	76	86.5	63.64	4.2	1.3
September	4.14	30.8	23.7	27.25	98	78	88.0	49.36	4.2	1.0
October	4.44	31.2	20.4	25.80	94	63	78.5	7.76	8.0	1.0
November	4.69	28.5	16.3	22.40	96	59	77.5	7.22	7.6	1.0
December	3.46	24.4	13.0	18.7	98	60	79.0	0.2	5.5	0.8

Factors	Values of 'r' (correlation coefficient)	Regression coefficient	Values of 't'	Remarks
1. Mite population and temperature (°C)	0.139	0.217	2.624	Sig*
2. Mite population and relative humidity (%)	0.290	0.155	3.364	Sig**
3. Mite population and total rainfall (cm)	0.134	-0.048	-2.199	Sig*
4. Mite population and sunshine (Hrs)	0.299	0.259	1.232	NS
5. Mite pupulation and windj velocity (miles)	-0.650	-0.533	-1.015	NS

Multiple correlation coefficient (R) = 0.950
Multiple regression 'F test' value = 11.12

* Significant at 5% level, ** Significant at 1% level.

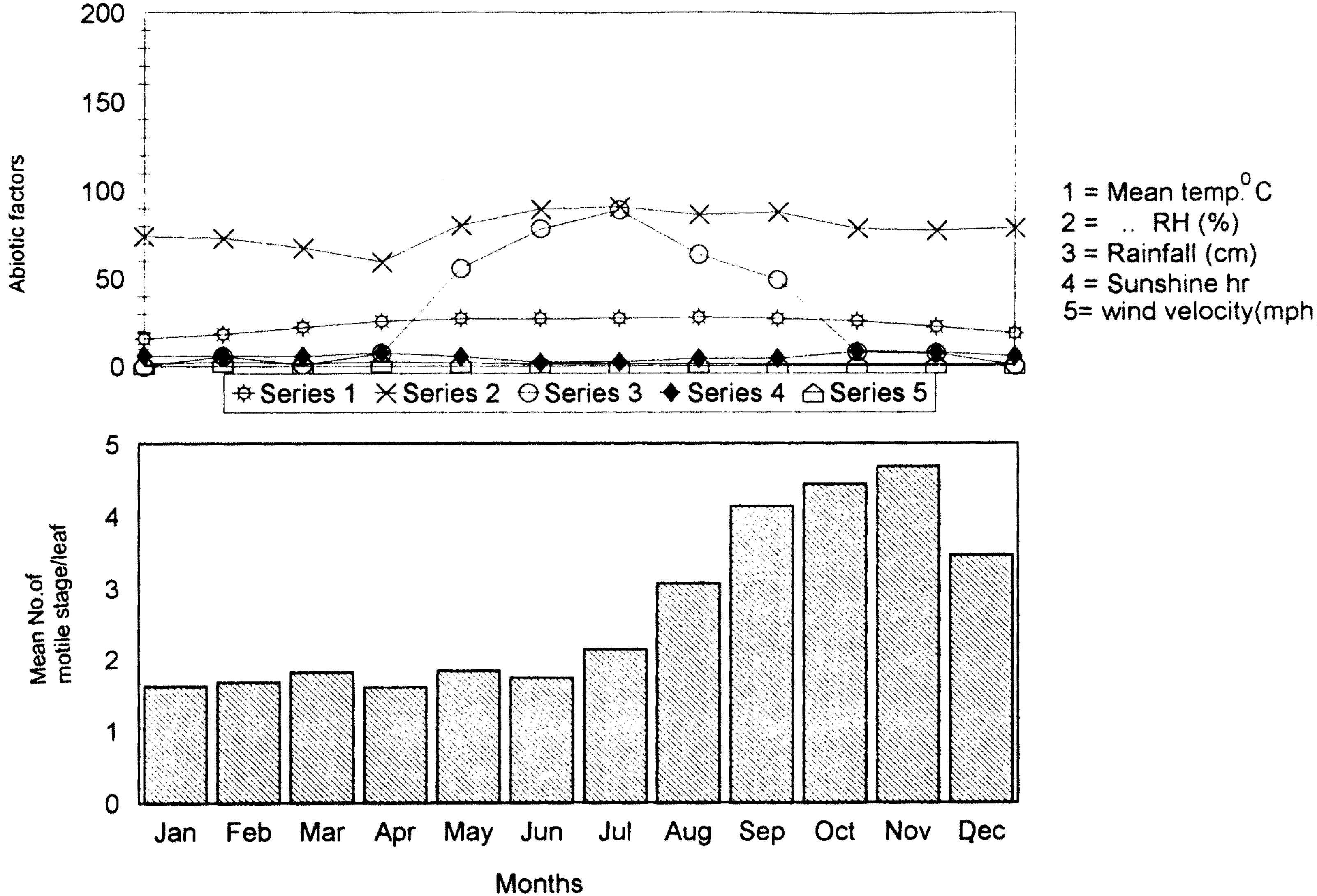


Fig.10.1 Influence of major abiotic factors on seasonal incidence of predatory mite complex of *Oligonychus coffeae* on tea bush at Debpara Tea Estate (Dooars, West Bengal) during January 1995 to December 1995.

22.4 - 25.8°C while r.h. and rainfall were 77-78% and 7.2-7.76 cm, respectively during the peak period of the predatory mites.

The combined effect of all the abiotic factors on the population dynamics of spider mite and its predatory complex was also considered. The significant multiple regression 'F' test in each of the two years indicated that temperature, r.h. and rainfall had the maximum influence on the population build-up of red spider and predatory mites. It is also evident from the present investigation that the optimum condition for build up of red spider mite was warm temperature (27°C), high r.h. (85% and above) and moderate to low rainfall (56 cm). On the other hand, predatory mites of red spider preferred mild temperature (22°C), moderate high humidity (78%) and scanty rainfall (7 cm). Therefore, the requirement of meteorological parameters for rapid build up of red spider and its predators varied widely. Under these circumstances, predatory mites would not be able to check the build-up of red spider population during the peak period of infestation. Incidentally, two population peaks of red spider mite are often encountered being one during pre-monsoon (May-June) with very high population density and the other during post-monsson (September-October) with moderately high population particularly in young tea bush. As the ecological conditions prevailing during September-October are favourable to predatory mites, there is likelyhood that the population build-up of red spider during the formation of second peak would be checked by predators. The main problem arising out of red spider infestation is in May-June and predatory mites are not effective to hold on the population of red spider during this period. However, augmentation of predatory mites through mass rearing would be considerable help under this situation. In other words, periodic colonisation or release of important spp. of predatory mites in large number during February-April would certainly help to check the infestation of red spider mite.

Further studies were also taken up to reveal the extent of relationship existing between red spider mite and different groups of predatory mites (Table .11). It was observed that significant negetive relation was found between red spider mite with each of the two groups belonging to *Amblyseius* and *Pronematus*. On the other hand, no relationship wheather it was positive or negative was recorded in between red spider with *Agistemus* and *Cunaxa*. These observations were based on two years of studies. It may be explained in the light of difference in preference in ecological parameters of the prey and the predators. It was surprising to note that no relationship was recorded in between *Agistemus* and *Cunaxa* though they are well-known

Table 11: Extent of relationship between predatory and red spider mite (*O.coffeae*) based on their seasonal incidence on tea bush in a Debpara Tea Estate (Dooars) during January 1994 to December 1995

Month	Mean No. of motile stage/leaf in 1994					Mean No. of motile stage/leaf in 1995				
	O.coffeae	*Amblyseius* spp.	*Agistemus* spp.	*Pronematus* spp.	*Cunaxa* spp.	*O. coffeae*	*Amblyseius* spp.	*Agistemus* spp.	*Pronematus* spp.	*Cunaxa* spp.
January	7.46	2.18	1.64	1.41	0.96	6.32	2.46	1.79	1.38	0.85
February	12.65	2.67	0.82	2.26	0.82	10.46	2.78	1.01	2.21	0.72
March	15.76	2.35	1.15	2.52	1.34	13.67	2.26	1.26	2.39	1.38
April	29.86	1.94	0.93	2.14	1.16	24.56	2.11	0.82	2.26	1.27
May	41.27	1.81	1.38	2.30	1.97	38.31	1.69	1.41	2.42	1.86
June	46.58	1.19	1.62	1.92	2.04	41.58	1.16	1.59	2.06	2.16
July	39.87	1.42	1.95	3.15	2.18	36.77	1.58	1.82	3.06	2.11
August	34.48	2.63	2.21	5.38	2.34	34.46	2.46	2.38	4.98	2.48
September	9.36	4.18	3.66	5.91	2.55	8.61	4.29	3.87	5.96	2.46
October	7.61	4.55	3.82	6.14	3.13	6.18	4.66	3.99	6.11	3.01
November	3.11	5.69	4.94	5.83	3.26	2.33	5.08	4.56	5.74	3.38
December	2.06	3.81	3.19	3.76	3.41	1.81	3.37	3.28	3.69	3.52

Relationship	Values of 'r' (correlation coefficient)	Regression coefficient	Values of 't'	Remarks
1. Between *O. Coffeae* and *Amblyseius* spp. in 1994	-0.783	-17.167	-3.506	Sig**
2. Between *O. coffeae* and *Agistemus* spp. in 1994.	-0.542	1.494	0.199	NS
3. Between *O. coffeae* and *Pronematus* spp. in 1994	-0.389	4.825	1.573	Sig*
4. Between *O. coffeae* and *Cunaxa* spp. in 1994	-0.262	3.807	0.545	NS
5. Between *O. coffeae* and *Amblyseius* spp. in 1995	-0.793	-18.598	-4.593	Sig**
6. Between *O. Coffeae* and *Agistemus* spp. in 1995	-0.547	0.153	0.026	NS
7. Between *O. Coffeae* and *Pronematus* spp. in 1995	-0.349	8.220	3.360	Sig**
8. Between *O. coffeae* and *Cunaxa* spp. in 1995	-0.202	-0.597	-0.125	NS

* Significant at 5% level, ** Significant at 1% level.

predator of red spider mite. It is probably due to the fact that the population build-up of these two predators progressively increased from January and reached their peak during October-November, irrespective of increase or decrease of red spider mite. As such it is evident that the effect of ecological factors was more pronounced on their population build-up and they might be feeding on other pests besides red spider mite. Their importance should not be undermined as they are already known as efficient predator of red spider mite. The development of mass rearing technique of these two predators would pave the way for their fruitful utilization in applied bio-control of red spider mite. The techniques of mass rearing of phytoseiid are knwon at present and this group holds the key position in applied bio-control of red spider mite through periodic colononisation / augmentation. The conservation of other groups of predatory mites which are not amenable to mass rearing would be of immense importance in management of red spider mite on tea.

It is evident from present study that the red spider active and breed throughout the years in the Dooars of West Bengal. Similar observation were recorded by Das (1959). According to him red spider does not pass the winter in hibernation. It continuous to breed during the cold weather and can be found on a few old leaves, but only in small numbers in pruned bushes, and inslightly greater numbers on unpruned and skiffed bushes and young tea. The earlier findings (Carpenter and Antram, 1911; and Hope, 1915) were contrary on this observation. They stated that the mites enter into a kind of hibernating stages in the cracks and crevices of the bark of the stem or in the soil.

The samples of tea leaves drawn from different profile of bushes revealed the presence of mites in every segment of a month (weekly and fortnightly) during the course of present studies. Different stages of red spider were encounter on the sample leaves. It is therefore evident that the mites multiplies even during the cold months prevailing during November-February in the Dooars of West Bengal. However, no attempts was made to locate their presence either in the soil or in the barks of the tea bushes. Therefore, the alternative mode of overwintening of red spider in hibernating stage could not be acertain with certinity. However, evidences gathered during these studies proved beyond doubt that red spider remains active and reproduces even during winter moths as reported by Das (1959). The other deviation recorded during the study is that red spider had only one peak during dry nonrainy season and even during rainy months the population build-up was considerably high. Banerjee (1977;1978) reported that red spider start increasing in number from March and reaches it peaks in between April and July. Thereafter with the onset of the monsoon, their numbers decline with the washing effect. A second but small peak may develop during October-November. In our case no such phenomenon was recorded probably due to the equitable distribution of good monsoon rain during October-November.

4.5 SPATIAL PATTERN OF PLANT FEEDING (RED SPIDER) AND PREDATORY MITE ON VARIOUS CLONES OF TEA

This study will enable us to understand the distribution pattern of red spider mite and its predators in three segments (upper, middle and lower) of tea bushes. It will also help us to understand the movement pattern of red spider and its predators in different directions of bushes as well as to identify the safe ecological zone (ecological niche) for both the groups of mites.

It is evident from (Table.12-17) that at the very initial stage of population build up of red spider mite during January-February, the pest (red spider) and defender (predatory mite) ratio was most favourable being 1.05:1 and 2.29:1 at Nagrakata and Debpara, respectively. If the ratio between pest : defender remains at 1:1, the effective biocontrol of red spider mite is likely to be achieved. Incidentally, the ratio gradually changed during summer months in favour of red spider mite varying between 6:1 to 23.61:1 at Debpara and 4.07:1 to 20.41:1 at Nagrakata resulting in population explotion of red spider mite in tea plantation in the Dooars.

It was further observed that tea clones varied greatly in respect of pest and defender ratio. At Debpara, the most favourable ratio i.e. 1.16:1 was recorded in TV_{25} while the ratio was as high as 4.72:1 in TV_{16}. At Nagrakata, several clones like TV_1, TV_2, TV_{16} and so on harvoured higher number of predatory mites (defender) and the ratio of pest : defender varied between 1:1.1 to 1:3.5. Conversely, a few clones such as TV_{18},TV_{20},TV_{23} had lower number of defender and the ratio between pest : defender was on the reverse direction i.e. between 1.4:1 to 4:1.

It is also indicated from this study that the ratio beween red spider : predator varied significantly during different periods of observation. Most favourable ratio (pest : defender) was observed during January-February i.e. 1.05:1 and 2.29:1 at Nagrakata and Debpara respectively and it reached as high as 20.41:1 and 23.61:1 during May-June in the respective places. Thus, the seasonal variations played a major role in population dynamics of the pest as well as its predators.

Table 12 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during Jan. - Feb. '94 at Debpara Tea Estate, Dooars, West Bengal (Un-shaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_1	1:1.57	2.59:1	1.87:1	1.46:1
TV_9	1.14:1	2.14:1	2.5:1	1.95:1
TV_{11}	1:2	2.6:1	3.17:1	1.89:1
TV_{12}	1:1.14	5.6:1	3.62:1	3.05:1
TV_{16}	2:1	4.14:1	9.67:1	4.72:1
TV_{17}	1:2	2.7:1	6:1	2.7:1
TV_{18}	1:1.5	4.75:1	4.8:1	3.13:1
TV_{19}	1:3.5	3.4:1	3.62:1	2.67:1
TV_{20}	1:1.25	2.5:1	4.6:1	2.61:1
TV_{23}	1:1.67	4.4:1	3.83:1	2.99:1
TV_{25}	1:1.75	1.33:1	1.8:1	1.16:1
TV_{26}	1:7	3.33:1	1.6:1	1.27:1
TV_{27}	1:1.99	1.8:1	2.25:1	1.54:1
TV_{28}	1:1.99	1.79:1	3.33:1	1.71:1
Mean	1:1.47	3:1	3.47:1	2.29:1

Table 13 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during March - April,'94 at Debpara Tea Estate, Dooars, West Bengal (Un shaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_1	2.75:1	14.99:1	4.25:1	4.7:1
TV_9	1:1.67	18.01:1	3.33:1	3.4:1
TV_{11}	8:1	21.02:1	5.99:1	10.26:1
TV_{12}	5.5:1	10.99:1	4:1	6.12:1
TV_{16}	-	8.33:1	8:1	9.49:1
TV_{17}	1.67:1	22.02:1	10.49:1	7.99:1
TV_{18}	2.99:1	8.33:1	6.33:1	6.25:1
TV_{19}	3.5:1	10.99:1	4.75:1	5.99:1
TV_{20}	5:1	9.49:1	5:1	6.5:1
TV_{23}	9:1	7:1	6.99:1	7.33:1
TV_{25}	7.99:1	6.33:1	5.33:1	6.37:1
TV_{26}	8:1	19.01:1	5.33:1	5.37:1
TV_{27}	-	8.5:1	5.5:1	3.99:1
TV_{28}	4:1	5.33:1	3.67:1	4.43:1
Mean	3.6:1	9.82:1	5.39:1	6:1

Table 14 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during May - June,'94 at Debpara Tea Estate, Dooars, West Bengal (Un shaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_{1}	-	52.05:1	15.67:1	31.28:1
TV_{9}	7.49:1	17.49:1	8.33:1	10.71:1
TV_{11}	9.99:1	8.33:1	8.99:1	8.99:1
TV_{12}	41.04:1	30.98:1	19.67:1	26.99:1
TV_{16}	10.67:1	65.07:1	25:1	24.56:1
TV_{17}	19.49:1	-	28.48:1	39.95:1
TV_{18}	-	37.48:1	70.06:1	61.73:1
TV_{19}	15.99:1	18.67:1	26.98:1	20.28:1
TV_{20}	21.99:1	21:1	28.98:1	23.56:1
TV_{23}	26.03:1	43.04:1	13.67:1	22.02:1
TV_{25}	7:1	69.07:1	27.99:1	21.85:1
TV_{26}	44.04:1	21:1	14.75:1	20.75:1
TV_{27}	14.49:1	84.08:1	14.75:1	24.56:1
TV_{28}	25.02:1	14.67:1	65.06:1	26.83:1
Mean	19.19:1	30.77:1	21.24:1	23.61:1

Table 15 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during Jan. - Feb. '94 at Nagrakata Tea Estate, Dooars, West Bengal (Un shaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_{1}	1:3.16	1.09:1	1.1:1	1:1.3
TV_{9}	1:2.7	1:1.8	1.3:1	1:1.8
TV_{11}	1:11	1:2.3	2:1	1:1.8
TV_{12}	1:10	1:1	3.3:1	1:1.3
TV_{16}	-	1:2	1:1	1:3.5
TV_{17}	1:2.06	1:1.6	1:1	1:1.6
TV_{18}	1:1	5:1	-	4:1
TV_{19}	1.5:1	1.9:1	2:1	1.7:1
TV_{20}	1.8:1	1.7:1	3.6:1	2.2:1
TV_{23}	1.8:1	4.3:1	1.5:1	2.2:1
TV_{25}	1:1.8	1.6:1	5.3:1	1.4:1
TV_{26}	1:1.85	2.3:1	3.3:1	1.9:1
TV_{27}	1:6.1	1:1.3	1:1.15	1:1.7
TV_{28}	1:4.3	1:1.1	2.6:1	1:1.1
Mean	1:2	1.3:1	1.7:1	1.05:1

Table 16 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during March - April '94 at Nagrakata Tea Estate, Dooars, West Bengal (Unshaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_1	3.5:1	6.3:1	5.7:1	4.82:1
TV_9	1.9:1	5.08:1	22:1	4.9:1
TV_{11}	2.06:1	5.3:1	6:1	4:1
TV_{12}	1.9:1	5.3:1	9:1	4.4:1
TV_{16}	3.8:1	3.6:1	12.3:1	4.83:1
TV_{17}	1:1.8	4.6:1	7.6:1	2.83:1
TV_{18}	3:1	4.8:1	12.3:1	5.9:1
TV_{19}	1:1.2	3:1	4.67:1	2.38:1
TV_{20}	1.28:1	4.3:1	8.5:1	3.25:1
TV_{23}	1:1.4	6.3:1	7:1	3.36:1
TV_{25}	3.67:1	5.3:1	3.75:1	4.2:1
TV_{26}	3:1	3.25:1	10.99:1	4.89:1
TV_{27}	1:1	18:1	6.67:1	4.4:1
TV_{28}	1.3:1	7.99:1	19:1	4.78:1
Mean	1.69:1	5.16:1	8.03:1	4.07:1

Table 17 : Spatial pattern of plant feeding (red spider) and predatory mites on different clones of tea during May - June, '94 at Nagrakata Tea Estate, Dooars, West Bengal (Un shaded condition)

Clone	Ratio of red spider/predatory mite on three segments of tea bush			Mean
	Upper	Middle	Lower	
TV_1	2.36:1	15.33:1	15:1	6.4:1
TV_9	7.75:1	15:1	40.04:1	14.5:1
TV_{11}	14.99:1	24.49:1	14.67:1	17.57:1
TV_{12}	6.25:1	27.99:1	47.05:1	18.28:1
TV_{16}	15.99:1	24.99:1	58.06:1	27.98:1
TV_{17}	8.3:1	27.48:1	70.07:1	24.99:1
TV_{18}	11.49:1	63.06:1	51.05:1	34.28:1
TV_{19}	10.49:1	28.48:1	63.06:1	28.18:1
TV_{20}	32.03:1	60.06:1	34.48:1	40.29:1
TV_{23}	14.49:1	26.99:1	71.07:1	30.77:1
TV_{25}	9.99:1	18:1	26.99:1	18.28:1
TV_{26}	23.02:1	26.49:1	24.49:1	24.98:1
TV_{27}	10.67:1	25.67:1	22.49:1	19.25:1
TV_{28}	15.99:1	67.06:1	41.04:1	35.03:1
Mean	8.96:1	27.08:1	33.94:1	20.41:1

The distribution of pest and its predatory complex varied significantly in three segments of tea bushes. The pest and defender ratio was most favourable in the upper segment of tea bushes being 1:2, 1.69:1 and 8.96:1 during January-February, March-April and May-June respectively, at Nagrakata. The corresponding values in the middle segment were 1.3:1, 5.16:1 and 27.08:1 while these were 1.7:1, 8.03:1 and 33.94:1 in lower segment.

The relative distribution of predators and prey is an important factor in predation. If the prey (red spider mite) have areas of escape in space or periods of escape in time, the efficiency of the predator may be reduced. Chant (1958) stated that reliable biological control cannot be attained if there are areas where prey are free from attack. It is revealed from this study that the distribution of *Amblyseius herbicolus* was well synchronized with that of red spider mite (Table.18). It was found in all segments of tea bushes inhabited by red spider mite. The next important predatory mites were *A. largoensis*, *A. mcmurtryi*, *A. ovalis*, *Typhlodromus homalii*, *Agistemus terminalis*, *Cunaxa setirostris* and *Lasioseius* sp. recorded in two zones of tea bushes. The remaining predatory species were found to occupy only one segment of tea bushes.

Banerjee (1979) observed a marked variation in the distribution of *Oligonychus coffeae* in the upper, middle and lower zones of shaded and unshaded tea bushes. In unshaded tea, middle zone has the highest mite population and the upper zone was least. According to him, leaf temperature and light penetration within the bushes appear to regulate the distribution of mites. In the present investigation, a definate gradient in the distribution of mites were observed within the tea bushes. Out of six situation (Table.12-17) lower sigment of tea bush exhibited higher order of red spider mite in the ratio under every situation like middle zone while upper segment showed higher order of predatory mite in the ratio at list in two situation (Table.12 & 15) . The discripancy in the findings might be resulted from the age of the tea bushes selected in two cases. In Debpara, the age of the tea bushes was around 10 years while it was only 3 years at Nagrakata. Keeping in view, the effect of leaf temperature and light penetration in the regulation of distribution of mites tea bushes as suggested by Banerjee (1979) the observation recorded at Nagrakata on spatial distribution of red spider mite and its predator appears to be more consistance. Out of 3 observations taken during 6 different months in two situations more number of plant feeding mite was observed in the middle zone which is inclose confirmity with those of Banerjee (1979). Variation in leaf temperature and light penetration are totally different in very young teas compared to bushy nature of old tea plant. Therefore, a change in distribution pattern was noticed at Nagrakata where population of mites were always highest in the lower zone of young tea plants. The difference in the pattern of distribution of red spider and predator was also recorded during 6 different months of the year in different segments of tea bushes. Similar observation was also recorded by Banerjee (1979) on the variation of distribution pattern of red spider in different segments of tea bushes.

Table 18 : Spatial pattern of different species of predatory mites of *Oligonychus coffeae* in tea bushes in the Dooars during Jan. - June, 1994

Predatory species	Occurrence in three segments of tea bushes			Mean % occurrence
	Upper	Middle	Lower	
Amblyseius herbicolus	P	P	P	100.00
A. coccineae	P	A	A	33.33
A. largoensis	P	A	P	66.67
A. mcmurtryi	P	P	A	66.67
A. pruni	A	P	A	33.33
A. ovalis	P	P	A	66.67
A. kulini	A	P	A	33.33
A. coccosocius	A	P	A	33.33
A. longispinosus	A	A	P	33.33
Typhlodromus homalii	P	P	A	66.67
Agistemus terminalis	P	A	P	66.67
Pronematus fleschneri	A	P	A	33.33
Cunaxa setirostris	P	P	A	66.67
Lasioseius sp.	P	A	P	66.67
Walzia sp.	P	A	P	33.33

P = Present, A = Absent.

4.6 DIVERSITY OF PREDATORY MITES IN THREE COMMUNITIES

The number of species in an unit area speaks about species diversity. In other words, the number of species with numerical superiority indicates species diversity. In stable ecosystem, the number of species as well as the number of individuals will be on the higher side with a momentum to increase. Disturbed conditions reduce diversity in an ecosystem. Conversely the availability of a large number of ecological niches will invite more no. of species to servive and sustain. An ecosystem with more ecological niches provides more opportunities towards successful biological control of pests.

Table 19 : Diversity index (D) of predatory mite found in association with major plant feeding mite on different clones of tea in Dooars, West Bengal, during January, 1994 to December, 1995

Sl. No.	Clones	Diversity Index (D)
1.	TV_1	0.64
2.	TV_9	0.75
3.	TV_{11}	0.77
4.	TV_{12}	0.71
5.	TV_{16}	0.84
6.	TV_{17}	0.79
7.	TV_{18}	0.81
8.	TV_{19}	0.62
9.	TV_{20}	0.86
10.	TV_{23}	0.80
11.	TV_{25}	0.86
12.	TV_{26}	0.71
13.	TV_{27}	0.80
14.	TV_{28}	0.88

Table 20 : Diversity index (D) of predatory mite found in association with major plant feeding mite on different clones of tea in the Terai region, West Bengal, during January 1994 to December 1995

Sl. No.	Clones	Diversity Index (D)
01.	TV_1	1.08
02.	TV_9	1.08
03.	TV_{11}	0.82
04.	TV_{12}	0.83
05.	TV_{16}	1.23
06.	TV_{17}	0.86
07.	TV_{18}	1.10
08.	TV_{19}	1.04
09.	TV_{20}	0.98
10.	TV_{25}	1.03
11.	TV_{28}	0.99

Table 21 : Diversity index (D) of predatory mite found in association with major plant feeding mite on differnt clones of tea in Tripura during February 1994 to December 1995

Sl. No.	Clones	Diversity Index (D)
1.	TV_1	1.13
2.	TV_9	1.17
3.	TV_{11}	1.23
4.	TV_{12}	1.26
5.	TV_{17}	1.28
6.	TV_{18}	1.18
7.	TV_{19}	1.20
8.	TV_{20}	1.19

In light of this, species diversity of predatory mites in three tea ecosystems viz., Dooars Terai and Tripura was studied following the Shannon-Wiener diversity index (D). Table.19 show that the index values ranged between 0.62 - 0.88 in tea bushes in the Dooars during January, 1994 to December, 1995. These varied between 0.82 - 1.23 and 1.13 - 1.28 in Terai and Tripura condition in tea bushes during January, 1994 to December, 1995 respectively (Table 20 & 21). It is, therefore, evident that species diversity was highest in Tripura followed by Terai and Dooars (W.B). In general, the diversity was low indicating lower number of predatory species in tea yielding bushes resulted from the excessive use of pesticides. Considerable variations with respect to diversity index of predatory mites were also observed among tea clones in the three regions under study. But the pattern of occurrence of predatory mite in the three regions on different colnes of tea was not uniform.

4.6.1 Nature of association between plant feeding and predatory mites

Inter-specific relationship between predators and hosts, prey specificity, competition between predatory species, and the extent of mutualism are important parameters in biotic factor influency species association. Without these basic information, successful biological control programme can not be attempted for. Therefore, the coefficient of association (V_{AB}) and frequency of joint occurrence (J_{AB}) was calculated for three regions (Dooars, Terai & Tripura).

4.6.1.1 Red spider mite (*Oligonychus coffeae*)

The coefficient of association was measured in three scales-high, medium and low. In Dooars, the highest coefficient was recorded in case of *Parapronematus, Lasioseius* and *Bdellodes* while it was medium in *Amblyseius* spp. like *A. herbicolus, A. largoensis, A. ovalis, A. syzygii* and *Agistemus fleschneri* and was lowest in *A. kulini, A. pruni, A. coccineae, Typhlodromus homalii, Cunaxa setirostris, Agistemus terminalis* etc. (Table.22) . In Terai, the highest coefficient of association was observed in *Amblyseius herbicolus, A. largoensis, Parapronematus* and *Bdellodes* sp. followed by *Amblyseius kulini, A. pruni, Agistemus exsertus* and minimum bondage in *A. ovalis, Lasioseius* etc. (Table.23). More or less similar picture emerged in Tripura ecosystem as observed in Terai (Table.24).

Table 22 : Coefficient of association (V_{AB}=A) between predatory and plant feeding mites in tea plantation in the Dooars, West Bengal during January 1994 to December, 1995

Sl. No.	Plant feeding mite / Predatory mite	Coefficient of association (V_{AB}=A)			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.30	0.10	0.14	0.02
02.	*A. largoensis*	0.35	0.31	0.09	0.13
03.	*A. ovalis*	0.37	0.50	0.00	0.00
04.	*A. longispinosus*	0.21	0.11	0.00	0.07
05.	*A. syzygii*	0.41	0.09	0.05	0.07
06.	*A. kulini*	0.14	0.16	0.06	0.42
07.	*A. coccineae*	0.13	0.19	0.44	0.11
08.	*A. coccosocius*	0.35	0.00	0.00	0.00
09.	*A. pruni*	0.19	0.11	0.19	0.03
10.	*A. crotalariae*	0.35	0.06	0.00	0.00
11.	*A. polyantheae*	0.23	0.00	0.00	0.00
12.	*A. mcmurtryi*	0.22	0.26	0.44	0.58
13.	*A. shoreae*	0.06	0.06	0.65	0.28
14.	*A. neocrotalariae*	0.09	0.29	0.65	0.44
15.	*Typhlodromus homalii*	0.11	0.37	0.19	0.37
16.	*Agistemus terminalis*	0.14	0.20	0.00	0.04
17.	*A. hystrix*	0.09	0.04	0.00	0.00
18.	*Cunaxa setirostris*	0.14	0.22	0.05	0.03
19.	*Parapronematus murshidabadensis*	0.75	0.16	0.29	0.00
20.	*Pronematus fleschneri*	0.22	0.32	0.00	0.16
21.	*Lasioseius* sp. *nr. matthyssei*	0.58	0.00	0.00	0.00
22.	*Lasioseius* sp.	0.65	0.18	0.00	0.00
23.	*Bdellodes* sp.	0.55	0.34	0.00	0.00

Table 23 : Coefficient of association (V_{AB}=A) between predatory and plant feeding mites in tea plantation in the Terai region, West Bengal during January 1994 to December, 1995

Sl. No.	Plant feeding mite / Predatory mite	Coefficient of association (V_{AB}=A)			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.44	0.12	0.13	0.00
02.	*A. largoensis*	0.31	0.37	0.21	0.04
03.	*A. ovalis*	0.04	0.44	0.13	0.00
04.	*A. kulini*	0.26	0.15	0.04	0.38
05.	*A. coccineae*	0.00	0.52	0.13	0.26
06.	*A. pruni*	0.26	0.15	0.31	0.00
07.	*A. mcmurtryi*	0.26	0.00	0.38	0.00
08.	*A. neocrotalariae*	0.04	0.04	0.00	0.44
09.	*A. neorykei*	0.15	0.15	0.04	0.54
10.	*Agistemus exsertus*	0.15	0.26	0.04	0.08
11.	*A. macromatus*	0.04	0.04	0.00	0.00
12.	*Cunaxa setirostris*	0.00	0.52	0.00	0.24
13.	*Parapronematus murshidabadensis*	0.15	0.26	0.04	0.00
14.	*Parapronematus* sp.	0.52	0.04	0.13	0.00
15.	*Pronematus fleschneri*	0.04	0.04	0.13	0.24
16.	*Lasioseius phytoseioides*	0.14	0.15	0.00	0.54
17.	*L. ometes*	0.14	0.26	0.00	0.08
18.	*Bdella* sp. nr. *captiosa*	0.14	0.26	0.04	0.08
19.	*Bdellodes* sp.	0.44	0.00	0.18	0.04
20.	*Erythraeus* sp.	0.04	0.00	0.13	0.24

Table 24 : Coefficient of association (V_{AB} = A) between predatory and plant feeding mites in tea plantation in Tripura during February 1994 to December 1995

Sl. No.	Plant feeding mite / Predatory mite	Coefficient of association (V_{AB}=A)			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.26	0.07	0.29	0.04
02.	*A. largoensis*	0.34	0.63	0.05	0.10
03.	*A. ovalis*	0.09	0.43	0.20	0.46
04.	*A. longispinosus*	0.00	0.16	0.45	0.08
05.	*A. syzygii*	0.47	0.15	0.00	0.00
06.	*A. paraaerialis*	0.26	0.74	0.00	0.06
07.	*A. kulini*	0.19	0.16	0.38	0.50
08.	*A. coccineae*	0.19	0.36	0.30	0.16
09.	*A. coccosocius*	0.00	0.30	0.45	0.23
10.	*A. neorykei*	0.48	0.00	0.00	0.00
11.	*A. muraleedharani*	0.00	0.45	0.37	0.07
12.	*A. mcmurtryi*	0.00	0.15	0.00	0.33
13.	*A. pruni*	0.00	0.00	0.49	0.49
14.	*Typhlodromus homalii*	0.00	0.16	0.36	0.61
15.	*Agistemus terminalis*	0.13	0.11	0.24	0.05
16.	*Cunaxa setirostris*	0.35	0.02	0.09	0.16
17.	*Parapronematus murshidabadensis*	0.26	0.17	0.31	0.23
18.	*Parapronematus* sp.	0.32	0.22	0.07	0.03
19.	*Pronematus fleschneri*	0.00	0.00	0.36	0.24
20.	*Pronematus* sp.	0.00	0.16	0.35	0.70
21.	*Lasioseius* sp. nr. *matthyssei*	0.13	0.36	0.00	0.05
22.	*Lasioseius ometes*	0.51	0.31	0.00	0.03
23.	*L. matthyssei*	0.13	0.11	0.03	0.40
24.	*L. phytoseioides*	0.00	0.50	0.32	0.24
25.	*Lasioseius* sp.	0.09	0.16	0.13	0.15
26.	*Asca* sp. nr. *biswasi & caphidioides*	0.19	0.41	0.00	0.00
27.	*Walzia* sp.	0.00	0.33	0.00	0.00
28.	*Bdella maldahaensis*	0.50	0.30	0.07	0.03
29.	*Bdella* sp.	0.00	0.20	0.13	0.29

Table 25 : Frequency of joint occurrence between predatory (A) and plant feeding (B) mites in tea plantation in the Dooars, West Bengal during January 1994 to December 1995

Sl. No.	Plant feeding mite (B) / Predatory mite (A)	Jt. occurrence (J_{AB})			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.59	0.56	0.22	0.26
02.	*A. largoensis*	0.50	0.48	0.40	0.22
03.	*A. ovalis*	0.35	0.61	0.00	0.00
04.	*A. longispinosus*	0.32	0.08	0.00	0.00
05.	*A. syzygii*	0.17	0.40	0.25	0.29
06.	*A. kulini*	0.42	0.17	0.29	0.50
07.	*A. coccineae*	0.45	0.26	0.57	0.17
08.	*A. coccosocius*	0.40	0.00	0.00	0.00
09.	*A. pruni*	0.65	0.49	0.44	0.13
10.	*A. crotalariae*	0.40	0.25	0.00	0.00
11.	*A. polyantheae*	0.50	0.00	0.00	0.00
12.	*A. mcmurtryi*	0.49	0.28	0.86	0.67
13.	*A. shoreae*	0.20	0.25	0.67	0.40
14.	*A. neocrotalariae*	0.33	0.20	0.75	0.57
15.	*Typhlodromus homalii*	0.36	0.37	0.33	0.53
16.	*Agistemus terminalis*	0.48	0.42	0.00	0.00
17.	*A. hystrix*	0.33	0.40	0.00	0.00
18.	*Cunaxa setirostris*	0.42	0.54	0.25	0.15
19.	*Parapronematus murshidabadensis*	0.86	0.33	0.20	0.00
20.	*Pronematus fleschneri*	0.65	0.47	0.00	0.00
21.	*Lasioseius* sp. nr. *matthyssei*	0.80	0.31	0.00	0.00
22.	*Lasioseius* sp.	0.33	0.45	0.00	0.00
23.	*Bdellodes* sp.	0.77	0.18	0.00	0.00

Table 26 : Frequency of joint occurrence between predatory (A) and plant feeding (B) mites in tea plantation in the Terai region, West Bengal during January 1994 to December 1995

Sl. No.	Plant feeding mite (B) / Predatory mite (A)	Jt. occurrence (J_{AB})			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.59	0.56	0.22	0.26
1.	*Amblyseius herbicolus*	0.39	0.57	0.33	0.00
2.	*A. largoensis*	0.28	0.44	0.50	0.29
3.	*A. ovalis*	0.29	0.29	0.33	0.00
4.	*A. kulini*	0.50	0.25	0.29	0.53
5.	*A. coccineae*	0.00	0.57	0.33	0.40
6.	*A. pruni*	0.50	0.25	0.86	0.00
7.	*A. mcmurtryi*	0.50	0.00	0.00	0.00
8.	*A. neocrotalariae*	0.29	0.29	0.00	0.50
9.	*A. neorykei*	0.25	0.25	0.29	0.67
10.	*Agistemus exsertus*	0.25	0.50	0.29	0.33
11.	*A. macromatus*	0.29	0.29	0.00	0.00
12.	*Cunaxa setirostris*	0.00	0.57	0.00	0.40
13.	*Parapronematus murshidabadensis*	0.26	0.50	0.29	0.00
14.	*Parapronematus* sp.	0.57	0.29	0.33	0.00
15.	*pronematus fleschneri*	0.29	0.29	0.33	0.40
16.	*Lasioseius phytoseioides*	0.25	0.25	0.00	0.67
17.	*Lasioseius ometes*	0.25	0.50	0.57	0.33
18.	*Bdella* sp. nr. *captiosa*	0.29	0.50	0.29	0.33
19.	*Bdellodes* sp.	0.67	0.00	0.25	0.29
20.	*Erythraeus* sp.	0.27	0.00	0.33	0.40

Table 27 : Frequency of joint occurrence between predatory (A) and plant feeding (B) mites in tea plantation in Tripura during February 1994 to December 1995

Sl. No.	Plant feeding mite (B) / Predatory mite (A)	Jt. occurrence (J_{AB})			
		O. coffeae	*B. phoenicis*	*B. obovatus.*	*A. theae*
01.	*Amblyseius herbicolus*	0.43	0.35	0.31	0.28
02.	*A. largoensis*	0.49	0.54	0.13	0.27
03.	*A. ovalis*	0.10	0.28	0.26	0.57
04.	*A. longispinosus*	0.33	0.13	0.58	0.20
05.	*A. syzygii*	0.44	0.42	0.00	0.00
06.	*A. paraaerialis*	0.57	0.22	0.00	0.33
07.	*A. kulini*	0.47	0.30	0.58	0.53
08.	*A. coccineae*	0.44	0.65	0.39	0.30
09.	*A. coccosocius*	0.16	0.53	0.60	0.33
10.	*A. neorykei*	0.53	0.00	0.00	0.00
11.	*A. muraleedharani*	0.16	0.60	0.40	0.20
12.	*A. mcmurtryi*	0.33	0.40	0.00	0.50
13.	*A. pruni*	0.00	0.00	0.50	0.50
14.	*Typhlodromus homalii*	0.11	0.30	0.54	0.70
15.	*Agistemus terminalis*	0.13	0.17	0.30	0.13
16.	*Cunaxa setirostris*	0.42	0.11	0.19	0.17
17.	*Parapronematus murshidabadensis*	0.38	0.33	0.42	0.47
18.	*Parapronematus* sp.	0.13	0.33	0.20	0.16
19.	*pronematus fleschneri*	0.33	0.00	0.36	0.45
20.	*pronematus* sp.	0.00	0.25	0.45	0.74
21.	*Lasioseius* sp. nr. *matthyssei*	0.35	0.35	0.00	0.13
22.	*Lasioseius ometes*	0.71	0.55	0.00	0.16
23.	*L. matthyssei*	0.31	0.36	0.33	0.58
24.	*L. phytoseioides*	0.25	0.29	0.58	0.25
25.	*Lasioseius* sp.	0.45	0.13	0.28	0.40
26.	*Asca* sp. nr. *biswasi & caphidioides*	0.36	0.37	0.00	0.00
27.	*Walzia* sp.	0.33	0.25	0.00	0.00
28.	*Bdella maldahaensis*	0.62	0.53	0.36	0.16
29.	*Bdella* sp.	0.41	0.34	0.28	0.39

While the frequency of joint occurrence of the host and predator was considered, it was observed that in Dooars, *Amblyseius herbicolus, A. kulini, A. pruni, Agistemus, Bdellodes* had the highest order of association followed by *Amblyseius ovalis, A. coccosocius, A. longispinosus, Lasioseius* etc. and it was lowest in *Amblyseius syzygii* and *A. shoreae* (Table.25). In Terai situation, *Amblyseius herbicolus, A. kulini, Parapronematus, Bdellodes* again maintained their superiority over other spp. followed by *A. largoensis, Agistemus macromatus* and minimum relation was recorded in *Cunaxa* and *A. coccineae* (Table.26). In Tripura tea ecosystem, again *A. herbicolus, A. kulini, Bdella, A. coccineae, A. largoensis* maintained their lead followed closely by *A. longispinosus, A. syzygii, A. mcmurtryi* and *Cunaxa* etc. and it was lowest in *A. ovalis, T. homalii, A. terminalis* and so on (Table.27). Based on the three important ecological parameters, it may be concluded that a few *Amblyseius* spp. such as *A. herbicolus, A. largoensis, A. coccineae, A. kulini*, as well as *Agistemus terminalis, Lasioseius* sp. *Parapronematus* sp. *Bdellodes* sp. are important predatory mite complex of red spider mite.

4.6.1.2 Scarlet mite (*B. phoenicis*)

In case of this plant feeding mite, maximum association was noticed with *A. ovalis, A. largoensis, T. homalii* etc. with second order of association with *A. coccineae, A. kulini, A. mcmurtryi, A. terminalis* etc. and the minimum with *A. herbicolus, A. largoensis, A. pruni* and so on under Dooars condition (Table 22 & 25). The pattern of association in other two ecosystems i.e. Terai & Tripura remained more or less unchanged. In the order of frequency of association, *A. largoensis* and *A. ovalis* was far ahead in importance compared to other predatory mites (Table 23 & 25).

4.6.1.3 Scarlet mite (*B. obovatus*)

In case of this species, the first order of association occupied by *A. coccineae, A. mcmurtryi* etc. followed by *A. herbicolus, A. pruni, T. homalii* and so on in the Dooars situation and uneven change in pattern of assoiation of other predatory mites with scarlet mite was noticed. In the order of frequency of association, *A. coccineae, A. mcmurtryi* maintained their lead over others (Table 22 - 27).

4.6.1.4 Pink mite (*A. theae*):

In Dooars condition, major associating predatory mites were *A. kulini, A. mcmurtryi, T. homalii* followed by *A. largoensis, A. shoreae, Pronematus* sp., *A. coccineae* occupying second order and the bottom line association was observed with *A. herbicolus, A. longispinosus, A. syzygii, Cunaxa* sp. and *A. terminalis* (Table 22 & 25). In other two situations, *A. kulini* retained its first position indicating its wide host preference while lot of change in position in order of association of predatory mites was noticed. It is further revealed from the order of frequency of association that *A. kulini* and *A. macmurtryi* were most important predatory mites found in association with plant feeding mites (Table .27) .

4.7 ECOLOGICAL NICHE OF RED SPIDER MITE AND ITS PREDATORY MITES

Identification of ecological niche of pests and predators are of immense importance in successful pest management once the prefered ecological niche of pests is located. Augmentation or release of natural enemies at the suitable sites helps to establish natural enemies more easily. It is known since long that border rows of tea bush harbour more red spider mite and are considered as best ecological niche for the pest. However, the position of predatory mites under this situation is not well documented. It was found during the present investigation that the ratio of red spider and phytoseiid mite was much more greater in the border rows (2756.6:1) and gradually narrowed down (9.43:1) in inside rows (Table.28). The dust content in foliages of road side bushes probably limited the choice of predatory mites to favour the place as suitable ecological niche for them though their hosts were found in abundance in these places. Similar picture was emerged in case of two groups of predatory mites though stigmaeid were more abundant than phytoseiid under this situation.

Das (1960) conducted similar type studies with special referrence to the incidence of coccinellid predators on dust covered road side bushes. He indicated that the presence of a greater number of lateral branches of road side bushes helped red spider mite to overwinter in large numbers and the lower prevalence of predators on dust covered bushes were partly responsible for the increased of red spider on those road side bushes. Fleschner (1958) recorded higher incidence of mites on terminal shoots of *Citrus* plants treated with talc, road dust etc. and

Table 28 : **Horizontal distribution pattern of *Oligonychus coffeae* and two major groups of mite predators in a section of tea plantation during peak (May-June '95) and off (Jan-Feb '95) period of infestation in the Dooars, West Bengal**

Sl. No.	**Position of rows from border**	**RATIO**			
		Red spider mite/ phytoseiid mite		**Red spider mite/ stigmaeid mite**	
		Peak period	**Off period**	**Peak period**	**Off period**
01.	1st	-	866.9:1	-	346.76:1
02.	2nd	2756.6:1	292.44:1	-	182.77:1
03.	3rd	1415.87:1	180.18:1	707.93:1	120.12:1
04.	4th	1217.8:1	112.11:1	405.93:1	95.8:1
05.	5th	313.3:1	51.32:1	215.02:1	71.85:1
06.	6th	148.42:1	36.81:1	119.69:1	49.08:1
07.	7th	61.89:1	24.05:1	71.09:1	28.42:1
08.	8th	32.82:1	7.45:1	38.61:1	8.94:1
09.	9th	20.19:1	3.22:1	20.99:1	3.71:1
10.	10th	9.43:1	1.57:1	11.14:1	2.03:1

concluded that this increase was due to a direct stimulating effect of inert residues of mites. The similar observation recorded during the course of present investigation might be attributed to the reason like more number of lateral branches of road side bushes. Adverse effect of dust on predatory mite and stimulating effect of inert material on red spider mite as reported by various authors may be the other reasons in this case (Muraleedharan, 1991, Anonymous 1994) .

4.8 EFFECT OF PRUNING CYCLE IN CONSERVATION OF PREDATORY MITES

Cultural practices have great influence in conservation of predatory mites in a given ecosystem. Therefore, different pruning cycles practiced in tea plantation would effect the population dynamics of predatory mites and their host. It was observed that different pruning methods had significant effect in altering the host : predator ratio in tea bushes. The maximum ratio between the red spider mite : phytoseiid predator was observed in unpruned or light skiffed bushes while it was minimum in pruned bushes. The maximum ratio was recorded during the peak period of mite infestation at two different locations i.e. Dooars and Darjeeling were as high as 33.71 : 1 or 10.23 : 1 respectively while these were 6.07:1 or 8.9:1, 12.87:1 or 10.13:1 and 8.75:1 or 8.21:1 in pruned, light skiffed or deep skiffed bushes, respectively (Table.29 & 30). However, the ratio of red spider mite : predatory mite was much low during the off-season in different types of pruned bushes. The probable reason for the lower ratio in pruned or in deep skiffed bushes might be attributed to lesser number of foliage in pruned bushes helping predators to search their host in smaller area as well as mechanical removal of more number of host than predators during the course of pruning or skiffing.

In Darjeeling district, the influence of pruning on red spider and predatory mites was studied on Assam and China types of tea bushes. The ratio was greater in China type than Assam type in the same location. It holds good for both the predatory groups i.e. phytoseiid and stigmaeid mites (Table.30 & 31). The probable reason might be the more number of foliages of small type with large size of bush in China type compared to Assam one rendering predators to take more time to search their host. It may be presumed from this investigation that cultural practices like pruning in tea bushes did not have any adverse effect on population build up of predatory mites. Rather deep pruning or deep skiffing helped to maintain favourable prey : predator ratio.

Table 29 : **Effect of pruning on relative abundance of predatory mites in tea plantation in the Dooars, West Bengal during peak (May ' 94) and off (Jan '94) seasons of occurrence of red spider mite (RSM) on Assam type**

Sl. No.	Type of pruning practiced in previous year	RATIO			
		RSM/Phytoseiid mite		RSM/Stigmaeid mite	
		Peak season	Off season	Peak season	Off season
1.	Pruned	6.07:1	1:1	7.73:1	2.67:1
2.	Unpruned	33.71:1	6.67:1	33.71:1	8:1
3.	Light skiffed	12.87:1	5.67:1	15.85:1	9.71:1
4.	Deep skiffed	8.75:1	4.31:1	15.00:1	4.79:1

Table 30 : **Effect of pruning on relative abundance of predatory mites in tea plantation in Kurseong, West Bengal during peak (May '94) and off (Jan '94) seasons of occurrence of red spider mite (RSM) on Assam type**

Sl. No.	Type of pruning practiced in previous year	RATIO			
		RSM/Phytoseiid mite		RSM/Stigmaeid mite	
		Peak season	Off season	Peak season	Off season
1.	Pruned	8.9:1	1.26:1	6.36:1	2.67:1
2.	Unpruncd	10.23:1	1.59:1	7.39:1	2.83:1
3.	Light skiffed	10.13:1	3.19:1	33.14:1	10.2:1
4.	Dccp skiffed	8.21:1	3.09:1	26.00:1	7.71:1

Table 31 : **Effect of pruning on relative abundance of predatory mites in tea plantation in Kurseong, West Bengal during peak (May '94) and Off (Jan '94) seasons of occurrence of red spider mite (RSM) on China type**

Sl. No.	Type of pruning practiced in previous year	RATIO			
		RSM/Phytoseiid mite		RSM/Stigmaeid mite	
		Peak season	Off season	Peak season	Off season
1.	Pruned	12.55:1	4.08:1	12.55:1	4.82:1
2.	Unpruned	21.42:1	5.35:1	21.42:1	6.5:1
3.	Light Skiffed	20.5:1	8.00:1	46.86:1	17.33:1
4.	Deep Skiffed	15.08:1	6.8:1	39.2:1	13.60:1

Das (1960) while working on the incidence of red spider mite on different types of pruned tea bushes reported that pruned tea had less attack of red spider than unpruned or skiffed tea in which comparatively more leaves were left on bushes. According to him, pruning helped mechanical removal of red spider from tea bushes. The degree of removal of red spider (cleaning out) had a direct influence on the incidence of red spider. The type of pruning and cleaning out which remove most of the old leaves will help to reduce the intensity of attack of red spider of tea bushes. His observations lend further support to the observation recorded during the present studies.

4.9 RELATIVE EFFICACY OF SOME CONVENTIONAL, BOTANICAL AND MICROBIAL PESTICIDES AGAINST RED SPIDER MITE UNDER LABORATORY AND FIELD CONDITION:

Attempts were made to test the relative efficacy of different formulations of a given pesticides which are available in the market. In the laboratory test, LC-50 values of some modern pesticides were also worked out against adult female of red spider mite and the findings are given below:

4.9.1 Relative toxicity of some modern pesticides as coantact poison to adult female of red spider mite under laboratory condition:

Out of nine pesticides, fenazaquin was most toxic to red spider mite as evident from the lowest LC-50 values (0.000012). In other words it was more than 400 times toxic as compared to cypermethrin which exhibited least toxicity to red spider mite. The highest LC-50 values i.e. 0.0183 was recorded in this case. Among others, dicofol occupied the 2nd rank in the order of toxicity and its LC-50 value (0.000013) was very close to fenazaquin. The DDVP and monocrotophos placed themselves in the 3rd and 4th rank with LC-50 values 0.000017, and 0.00002 respectively. The order of their relative toxicity as compared to cypermethrin were 295.29 and 251.00 respectively. The LC-50 values of endosulfan and phosphamidon were 0.00003 and 0.000038, respectively and these were found to be 167.33 and 132.10 time more toxic as compared to cypermethrin. Sulphur and α-cypermethrin occupied the bottom rank indicating their very low toxicity to adult female of red spider mite and as such no appreciable difference in LC-50 values of these three pesticides (cypermethin, sulphur and α-cypermethrin) was recorded (Table .32).

LC-50 means a lethal concentration or dose of a pesticide to kill 50% of a pest population, an important parameter to identify a chemical to be choosen for pest control programme. It is evident from the study that fenazaquin possessed high killing action against adult female of red spider mite and provided 50% kill even at a very low concentration of 0.000012. Almost similar toxic effect was provided by dicofol where 50% kill were recorded at the concentration of 0.000013. Interestingly, high adulticidal action was also noted incase of DDVP where 50% kill were obtained with a concentration of 0.000017. Surprisingly, the adulticidal action of sulphur was extremely low and a concentration of 0.00502 which by any means on the higher side gave only 50% kill. Incidentaly, sulphur is widely used in the control of plant feeding mites of tea and its efficacy in the control of red spider mite is well recognised. The relative low efficacy of sulphur in the laboratory test may be attributed to short exposure period of 6 hrs given to test materials. It is well known that inorganic sulphur does not possess any acaricidal properties but provides excellent killing action as being oxidised to SO_2 or SO_3. Probably, the 6 hrs time was too short for oxidation of elimental sulphur to SO_2 or SO_3. This study lends further support to the contention that cypermethrin, α-cypermethrin etc. are least toxic and monocrotophos, endosulfan, phosphamidon are moderately toxic to plant feeding mite belonging to red spider group.

Table 32 : Relative toxicity of different pesticides as contact poisons to red spider mite, *Oligonychus coffeae* (Nietner) of tea

Sl. No.	Pesticides	Heterogenity (χ^2)	Regression equation	LC-50	Fiducial limit	Relative toxicity
1.	Dicofol	0.842306	Y=3.9029+0.519x	0.000013	(1.725649,2.502097)	386.15
2.	Sulphur	0.11153	Y=3.786+0.328x	0.00502	(2.66739,4.7346)	1
3.	Fenazaquin	0.52224	Y=3.759+0.403x	0.000012	(2.222306,3.943494)	418.33
4.	DDVP	0.127467	Y=4.170+0.371x	0.000017	(1.115422,3.357137)	295.29
5.	Cypermethrin	0.071733	Y=3.4973+0.4605x	0.0183	(2.44045,4.08638)	0.274
6.	Monocrotophos	0.924773	Y=3.906+0.772x	0.00002	(0.679287,2.153217)	251.00
7.	Endosulfan	0.588306	Y=4.281+0.474x	0.00003	(0.405797,2.624249)	167.33
8.	Phosphamidon	0.874848	Y=4.036+0.372x	0.000038	(1.547725,3.630858)	132.10
9.	α- Cypermethrin	0.07730	Y=3.8124+0.450x	0.00433	(1.791865,3.481004)	1.16

4.9.2 Field evaluation of some modern chemicals against red spider mite

Taking a cue from the laboratory evaluation of various chemicals as mentioned in the foregoing para, a field trial was laid out to evaluate the effectiveness of fenazaquin *vis* a *vis* other standard chemicals used as acaricide against red spider mite of tea during peak period of incidence in the Dooars, West Bengal. Three other chemicals namely amitraz, acarinathrin, bromopropylate which are widely used as acaricide in other part of the world were also included in this study. The data on the polled efficacy of the chemicals have been presented in the Table.33 & Fig.33.1 . Significant difference was observed in respect of efficacy among chemicals against red spider mite. Maximum reduction of red spider was recorded in fenazaquin treated plots followed by amitraz, acrinathrin and bromopropylate treated plots and minimum reduction was recorded in case of endosulfan. Fenazaquin showed its superiorty over to all other treatments and the differences recorded were statistically significant. No significant difference in efficacy was recorded in between amitraz and acrinathrin. However, these two treatments differed significantly in efficacy compared to that of bromopropylate. On the other hand no significant difference in efficacy was observed in between bromopropylate and dicofol treated plots but these treatments proved their superiority over ethion. It is also evident that fenazaquin, amitraz, acrinathrin and brmopropylate exhibited excellent knockdown effect resulting more than 90% reduction of motile stages of mites within 24 hrs of application. On the other hand, dicofol and ethion reduced only around 80% of motile stages during same period and it was least (approx.60%) incase of endosulfan. When the persistance action of these chemicals in mite control was consider, it was observed that all of the them retained their efficacy up to 7 days, after which a fall in efficacy was recorded. Incase of fenazaquin, amitraz and acrinathrin, the persistence was significantly better as these chemicals continued to provide more than 90% reduction even on 12th day after spraying and this was around 80% incase of bromopropylate, dicofol and ethion. The efficacy of the chemicals was dose dependent and significant better kill was obtained with the increase in doses. The effect of interaction of the two factors i.e. days and chemicals was significant indicating that the rate of increase or decrease in efficacy of chemicals recorded during differnt days of observation did not follow similar pattern.

As of now, chemical control of red spider mite in tea is mostly achieved with the use of three conventional pesticides i.e. dicofol, ethion and sulphur (Cranham 1962; 1963; Mukarjea, 1962; 1963; 1964; 1967 Ananthakrishnan, 1963; Banerjee, 1971; 1976; 1978; 1979 and Das, 1983). The increasing evidence available on the use pattern of these chemicals in tea gardens in the Dooars that 5-10 rounds of application are required to check the infestation of red spider during peak period of infestation. It often brings about pesticide contamination in made tea. Wide spread use of sulphur in mite control in tea has its own limitation owing to the phytotoxic nature of the compound and tainting effect in made tea. However, it does not possess any contamination problem like dicofol and ethion in made tea. Under these circumstances, the incorporation of newer pesticides in the control of red spider mite appears to be rewarding. In view of these, four acarcides, new to India, were tested to evaluate their performance against the most injurious mite species of tea. It was observed that fenazaquin possessed excellent acaricidal properties and even at a very low doses of 1000 ml/ha gave effective check of the red spider buildup on tea. Similarly, superiority of other three chemicals like amitraz, bromopropylate and acrinathrin over dicofol and ethion was proved undoubtly during present investigation. Therefore, all these four chemicals desume due attention for their introduction in the control of red spider mite in tea. Similar studies under taken in the other parts of the world indicated that fenazaquin was highly effective in the control of *Tetranychus urticae* and *Panonychus ulmi* on straw berries and apple, respectively (Pollak *et al.*, 1992; Fitzgerald *et al.*, 1992; Solomon *et al.*, 1993). Effectiveness of bromopropylate in the control of *Polyphagotarsonemus latus* infesting citrus & tea, *Acalitus essigi* on blackberry leaves, eriophyid on cocoa and *Aculus schlechtendali* on apple orchard have been reported by Fourie *et al.*, (1989), Labanowska & Suski, (1990), Jesus Soria *et al.*, (1991) and Vogl (1992). In poland, single spray of acrinathrin was effective to control *Tetranychus urticae* and *Tetranychus cinnabarinus* on cucumber and tomato (Szwejda, 1993; 1994). Several workers reported the excellent efficacy of amitraz in mite control. It was widely used in the control of *Polyphagotarsonemus latus, Tetranychus ludeni, T. urticae*, and *T. cinnabarinus* on cotton, chilli, pea, bean and apple, respectively in different parts of the world (Carvalho *et al.*, 1983; Sannaveerappanavar & Channa Basavanna, 1986; Rajasri *et al.*, 1991; Cheng & Pan 1994). The observations recorded during the course of present studies regarding the efficacy of new and conventional pesticides are almost at par with those of other workers. However ,no comparative discussion could be undertaken on the efficacy of the four new acaricides due to the non availability of information on red spider mite of tea. Most of these information are so far

Table 33 : Relative efficacy of some modern chemicals against red spider mite, *O.coffeae* of tea in the Dooars, W.B. during April-May, 1996 (mean of three applications)

Chemical	Dose (ml/ha)	Mean percent reduction at various days after spraying				
		1	3	7	12	Mean
Fenazaquin (10% EC)	2000	96.66 *(79.65)	99.97 (89.43)	100.00 (90.00)	93.42 (75.24)	97.51 (83.58)
	1000	90.67 (72.23)	96.17 (78.86)	97.12 (80.28)	87.10 (68.96)	92.76 (75.08)
Amitraz (20% EC)	2000	95.66 (78.18)	98.84 (84.49)	99.66 (88.08)	92.68 (74.36)	96.71 (81.28)
	1000	90.81 (72.38)	93.66 (75.52)	95.56 (77.91)	87.40 (69.23)	91.86 (73.76)
Acrinathrin (15% EC)	400	96.03 (78.69)	99.55 (87.60)	99.60 (87.89)	91.90 (73.52)	96.77 (81.93)
	200	90.59 (72.14)	94.77 (76.83)	95.37 (77.60)	88.65 (70.34)	92.34 (74.23)
Bromopropylate (50% EC)	2000	90.41 (72.08)	94.94 (77.07)	95.51 (77.80)	81.42 (64.49)	90.57 (72.84)
	1000	81.73 (64.70)	87.76 (69.54)	84.33 (66.69)	74.39 (59.61)	82.05 (65.13)
Dicofol (18.5% E.C.)	2000	87.40 (69.23)	93.07 (74.78)	95.24 (77.44)	82.42 (65.23)	89.53 (71.67)
	1000	81.57 (64.59)	86.51 (68.47)	88.42 (70.14)	79.24 (62.89)	83.93 (66.52)
Ethion (50% E.C.)	2000	81.33 (64.40)	86.67 (68.66)	91.78 (73.37)	80.92 (63.86)	85.17 (67.57)
	1000	75.91 (60.63)	81.47 (64.51)	83.87 (66.33)	68.74 (56.01)	77.50 (61.87)
Endosulfan (35% E.C.)	2000	62.98 (52.53)	67.84 (55.47)	71.46 (57.73)	62.54 (52.27)	66.20 (54.50)
	1000	53.58 (47.05)	60.65 (51.15)	59.94 (50.74)	51.20 (45.69)	56.34 (48.66)
Control (water spray)	-	05.05 (12.98)	05.52 (13.58)	05.15 (13.11)	05.13 (13.07)	05.21 (13.18)
Mean		78.69 (64.09)	83.16 (69.06)	84.20 (70.34)	75.14 (60.98)	80.30 (66.12)

Difference between C.D. at	P=0.05	P= 0.01
Days	0.67	0.89
Chemicals	1.29	1.71
Day x Chemicals	2.59	3.43

* Figures in parentheses are angular transformed values

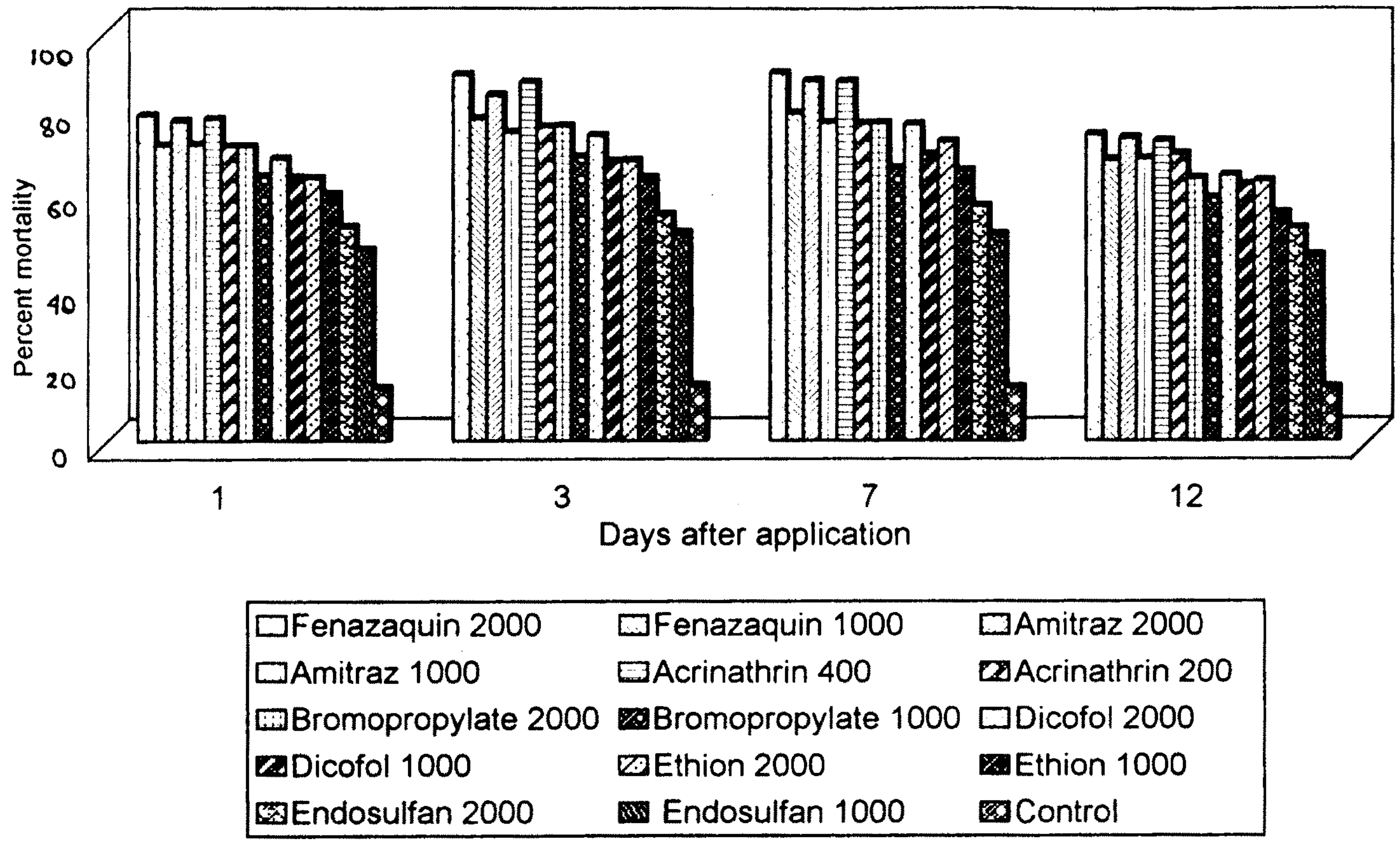


Fig 33.1 : Relative efficacy of some modern chemicals against red spider mite *O. coffeae* of tea in the Dooars, W.B. during April-May, 1996 (mean of three applications)

available on these four new chemicals are parteing to mite species infesting field crops. The extensive field trails undertaken in various Tea Research Institutions spread over the world indicated that dicofol and ethion at the rate of 1:200 and 1:400 are effective in the control of red spider mite, of tea. However, several rounds of spraying are required to control the mite during peak period of infestation i.e. April to May (Banerjee, 1977, 1978) Our observation in this regard are in full conformity with those of others.

4.9.3 Relative toxicity of three formulation of sulphur as contact poison to adult female of red spider mite under laboratory condition:

There is a renewed interest in the use of sulphur in the control of plant feeding mites around the world due to its safety to mammals and its ecofriendly nature. But the major limiting factor for its large scale use attributed to limited toxicity to different stages of mite along with short residual toxicity. However, these deficiencies have been largely overcome with the advancement of formulation technology giving in colloidal and liquid form of sulphur with the incorporation of more micronised particles. It is established that the toxicity of sulphur increases with the decrease in particle size. In other words, more micronised sulphur formulation would provide more toxicity to phytophagous mites than less micronised form.

Table 34 : Relative toxicity of different sulphur formulation as contact poisons to adult female of red spider mite of tea *Oligonychus coffeae*

Sl. No.	Sulphur formulations	Heterogenity (χ^2)	Regression equation	LC-50	Fiducial limit	Relative toxicity
1.	Wettable Sulphur (80%)	0.11153	Y=3.786+0.328x	0.00502	(2.66739, 4.7346)	9.96
2.	Liquid Sulphur (20%)	0.0461	Y=3.671+0.385x	0.0284	(2.46076, 4.4472)	1.76
3.	Colloidal Sulphur ('52'%)	0.148106	Y=4.213+0.296x	0.05	(1.42436, 3.89319)	1

The information on the toxicity of micronised form of sulphur to red spider mite of tea is lacking. It may be seen from Table.34 that the LC-50 value of wettable sulphur was lowest (0.00502) followed by liquid (0.0284) and colloidal (0.05) form of sulphur. It indicates that the wettable sulphur provided 50% mortality of adult female of red spider mite at a concentration of 0.005% a.i. while colloidal and liquid sulphur needed 0.05% a.i. required 0.0284% a.i. to give similar mortality. In other words, wettable sulphur was around ten times more toxic to adult female of red spider mite than colloidal sulphur. The colloidal sulphur was least toxic while the liquid formulation was one and half times more toxic than colloidal sulphur to red spider mite.

4.9.4 Field evaluation of three formulations of sulphur and a neem formulation against red spider mite of tea.

In this RBD experiment, relative performance of three formulations of sulphur and a kernel based neem formulation (1500 ppm) was evaluated against red spider mite during its peak period of incidence in the Dooars, West Bengal. It is revealed from the experiment that there was significant difference in efficacy in between the treatments. Similarly, significant difference in efficacy was noticed during different days of observation (Table.35 & Fig.35.1). Among the three formulations of sulphur, colloidal form gave the best control of red spider mite followed by wettable and liquid sulphur. The rate of population reduction of red spider in colloidal form was 88.26% at a dilution of 1 : 100 and these were 86.47% & 76.52% in wettable and liquid sulphur, respectively. The differences in efficacy in between colloidal and wettable sulphur as well as between wettable and liquid sulphur were statistically significant. The efficacy of colloidal sulphur was very close to that of dicofol which provided the best control of the mite in this experiment. The efficacy of neem formulation against red spider mite was not satisfactory. Even a dilution of 1:100 gave only around 66% reduction of mite population though its efficacy was superior to that of endosulfan when applied at a dilution of 1:100. The residual toxicity of sulphur remained till 9th day after application though the maximum population reduction was noticed on seven day after application. The knockdown effect of wettable and colloidal sulphur was more pronounced than liquid formulation. In the former two cases, more than 80% population reduction was recorded after 1st day application while it was 68% in liquid form. Neem formulation did not show any appreciable knockdown effect on mite population. But its residual toxicity was evident even on 9th day after application. The effect of interaction of the two factors (day x chemical) on mite population was significant. It shows that the pattern of population reduction recorded during the different days of observation was not similar in different treatments.

Table 35 : Relative efficacy of three formulations of sulphur, *vis-a-vis* neem biocide and conventional pesticides against red spider mite, *O. coffeae* of tea in the Dooars, W.B. during March-April, 1996 (mean of three applications)

Chemical	Dilution	Mean % reduction in population of predatory mite at various days after spray				
		1	3	7	9	Mean
Wettable sulphur (80% WP)	1:100	81.74 *(64.73)	86.92 (68.81)	89.65 (71.24)	87.57 (69.39)	86.47 (68.84)
	1:200	67.54 (55.30)	77.58 (61.76)	81.58 (64.60)	79.36 (62.98)	76.51 (61.16)
Liquid sulphur (20% E.C.)	1:100	68.51 (55.88)	75.74 (60.50)	81.74 (64.71)	80.08 (63.50)	76.52 (61.15)
	1:200	54.59 (47.64)	66.81 (54.83)	71.84 (57.95)	68.73 (56.00)	65.49 (54.11)
Colloidal sulphur ('52' S)	1:100	82.25 (65.11)	91.32 (72.89)	92.94 (74.67)	86.54 (68.61)	88.26 (70.32)
	1:200	66.80 (54.83)	75.24 (60.17)	79.42 (63.04)	76.83 (61.25)	74.57 (59.82)
Neem (1500 ppm)	1:100	59.04 (50.21)	68.72 (56.00)	70.66 (57.20)	65.92 (54.30)	66.08 (54.43)
	1:200	45.87 (42.63)	54.52 (47.60)	58.57 (49.94)	55.42 (48.11)	53.59 (47.07)
Endosulfan (35% E.C.)	1:200	57.32 (49.21)	65.80 (54.22)	71.09 (57.48)	61.61 (51.71)	63.95 (53.16)
	1:400	49.01 (44.43)	58.89 (50.12)	61.61 (51.72)	52.72 (46.56)	55.56 (48.21)
Dicofol (18.5% E.C.)	1:200	84.50 (66.85)	92.92 (74.71)	95.94 (78.47)	84.44 (66.79)	89.45 (71.71)
	1:400	77.61 (61.78)	85.76 (67.86)	86.74 (68.66)	78.11 (62.12)	82.05 (65.11)
Control (water spray)	-	05.09 (13.04)	05.48 (13.54)	05.47 (13.53)	05.25 (13.25)	05.32 (13.34)
Mean		61.48 (51.64)	69.47 (56.96)	72.72 (59.27)	67.83 (55.67)	67.87 (55.89)

	Days	Chemical	Day x Chemical
C.D. at 5%	0.57	1.11	2.22
C.D. at 1%	0.76	1.46	2.93

* Figures in parentheses are angular transformed values

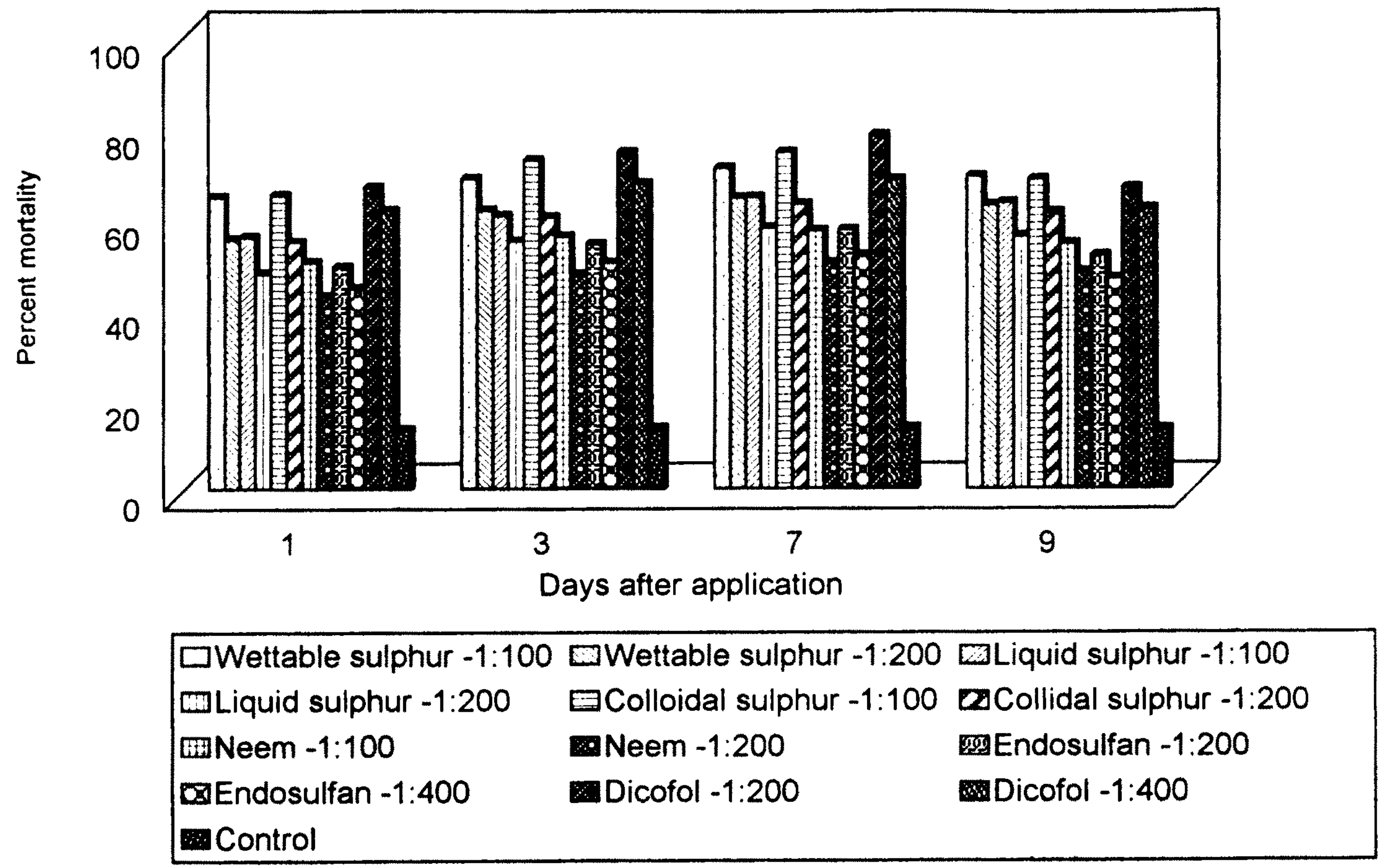


Fig. 35.1 : Relative efficacy of three formulations of sulphur *vis-a-vis* neem biocide and conventional pesticides against red spider mite, *O.coffeae* of tea in the Doorars, W.B. during March-April, 1996 (mean of three applications)

In the laboratory test, the performance of wettable sulphur against red spider mite was observed to be much superior compared to those of other two formulations i.e. liquid and colloidal sulphur. The LC-50 values of wettable sulphur was 0.005% a.i. while those of other two was 0.0284% a.i. and 0.05% a.i. respectively (Table.34). It is evident that the efficacy of colloidal sulphur was ten times lower than wettable sulphur and while liquid sulphur was one and half times more toxic to colloidal sulphur. The efficacy of sulphur formulation against plant feeding mites largely depends on its particle size. Colloidal sulphur is said to be more micronised than other two forms. Inspite of that it showed lowest toxicity to red spider mite in the laboratory experiment. It may be explained in the light of oxidation theory proposed by Brady, 1988 . Accordingly inorganic form of sulphur is nontoxic to plant feeding mites and it is to be oxidised to SO_2 or SO_3 to reveal its toxicity to plant feeding mites. The time of exposure of test material in the laboratory experiment was of 6 hrs. duration and probably due to the short exposure period, colloidal sulphur failed to expressed its full toxicity to mite species. The picture was totally opposite under field condition. Here, the colloidal sulphur was much superior in performance in red spider control compared to other two forms. The total duration of observation was much longer i.e. upto 9th day (under field conditions). Probably, this longer duration provided sufficient time to oxidise smaller particle of colloidal form more efficiently to SO_2 or SO_3 compared to other two forms. The other parameter to be considered in this situation is the total a.i. content of sulphur in different formulations. The a.i. is the highest (80%) in the wettable form followed by colloid (52%) and liquid (20%) forms. The colloidal formulation having 52% of sulphur content gave much better performance in the control of red spider mite. The efficacy of liquid sulphur may be viewed from the same angle as it contents only 20% sulphur a.i. meaning around 40% and 60% less a.i. content of sulphur compared to colloidal and wettable forms. Inspite of this, it brought about mite reduction to the tune of 70-80% at a dilution of 1:100. This findings lends further support to the oxidation theory of sulphur. The sulphur content in the formulation is certainly an important parameter to impact toxicity to might species but more important is the percentage of micronised particle of sulphur present in the formulation. As a matter of fact, the liquid and colloid sulphur having more micronised sulphur, probably gave significant superior performance in mite control though the in sulphur contents are much lower. The poor performance of neem against red spider mite as observed during the present experiment indicates that its use will not be rewarding in red spider control in tea. The neem kernel extract which primarily works as antifeedent failed to provide effective check of red spider mite which is having a sucking type of mouthparts.

However AZA enriched formulations of neem which are known to possess ovicidal and adulticidal action against mite may be useful under this situation.

4.9.5 Efficacy of microbial pesticides

4.9.5.1 Ovicidal and adulticidal action of *Bacillus thuringiensis* var. *kurstaki* against red spider mite under laboratory condition.

Experiments were laid to test the ovicidal and adulticidal action of *B.t.k.* under laboratory condition. Table.36A reveals that it possessed moderate adulticidal action as a little over 50% mortality was obtained at the concentration of 0.2%. On the otherhand, its ovicidal action was accountable as it inflicted little over 70% mortality of egg stage of red spider mite of tea Table.36.

4.9.5.2 Relative toxicity of abamectin against female of red spider mite under laboratory condition:

Studies were conducted with abamectin to reveal its toxicity as contact poison to adult female of red spider mite. The data presented in Table.37, showed that abamectin provided total mortality of red spider mite within the dose limit ranged between 1000 mg to 125mg/ml. Further lowering of the dose to 62.5 mg/ml gave around 95% mortality of the spider mite. It provided 50% mortality at a dose of 7.8 mg/ml. The chemical displayed excellent knockdown as well as killing action against red spider mite.

4.9.5.3 Field evaluation of abamectin against red spider mite of tea in the Dooars, West Bengal.

An experiment was laid out in RBD to test the relative efficacy of abamectin against red spider mite under field condition with an objective to find out the lethal concentration which may be recommended for its control (Table.38). It was observed that abamectin was highly effective against red spider mite providing 100% killing effect at a dose of 1000 to 500 mg/ml. This killing action was achieved with 24 hrs. after spray. When the dose was further reduced either to ½ or ¼ th, the initial mortality was little over 90% but the mortality was total within 5 days. Further reduction of doses to 62.5 mg/ml helped to control 93% population within 5th day after spraying. The reduction of mite population was 87.49% with subsequent covering of dose to 31.2 mg/ml within the same period of observation. The dose of 15.6 mg/ml was not adequate and the mortality reduced to 74.84% which may not help to check the buildup of red spider population during the peak period of incidence.

Table 36 : **Ovicidal effect of *Bacillis thuringiensis* var. *Kurstaki* on *Oligonychus coffeae* under laboratory condition at constant temp. 28 ± 1°C & 80% R.H. (mean of three experiment)**

Sl. No.	Concentration (%)	% mortality Exp-1	Exp-2	Exp-3	Mean of experiments
1.	0.2	70.25 *(56.95)	76.69 (61.13)	76.86 (61.25)	74.60 (59.78)
2.	0.1	66.29 (54.51)	68.88 (56.09)	61.56 (51.68)	65.58 (54.09)
3.	0.05	40.26 (39.38)	38.66 (38.45)	35.82 (36.76)	38.25 (38.20)
4.	0.025	26.24 (30.81)	20.75 (27.12)	22.73 (28.47)	23.25 (28.80)
5.	Control	04.68 (12.49)	08.43 (16.88)	05.62 (13.71)	06.24 (44.36)
	S.Em ±	2.675	1.397	1.717	
	C.D. (0.05)	8.724	4.555	5.599	

*Figures in parentheses are angular transformed values

Table 36.A : **Effect of *Bacillus thuringiensis* var, *Kurstaki* on adult female of *Oligonychus coffeae* under laboratory condition at constant temp. 28 ± 1°C & 80% R.H. (Mean of three replication)**

Sl No.	Concentration (%)	% mortality at various hrs. after treatment 12	24	36	Mean
1.	0.2	46.67 *(43.08)	56.67 (48.85)	66.67 (54.78)	56.67 (48.90)
2.	0.1	36.67 (37.22)	53.33 (46.92)	56.67 (48.85)	48.89 (44.33)
3.	0.05	16.67 (23.86)	30.00 (33.21)	33.33 (35.22)	26.67 (30.76)
4.	0.025	13.33 (21.14)	13.33 (21.14)	20.00 (26.57)	15.55 (22.95)
5.	Control	0.0025 (0.29)	3.335 (6.34)	6.67 (12.38)	3.34 (6.34)
S.E.±		2.73	4.109	3.484	
C.D. (0.05)		8.914	13.400	11.363	

*Figures in parentheses are angular transformed values

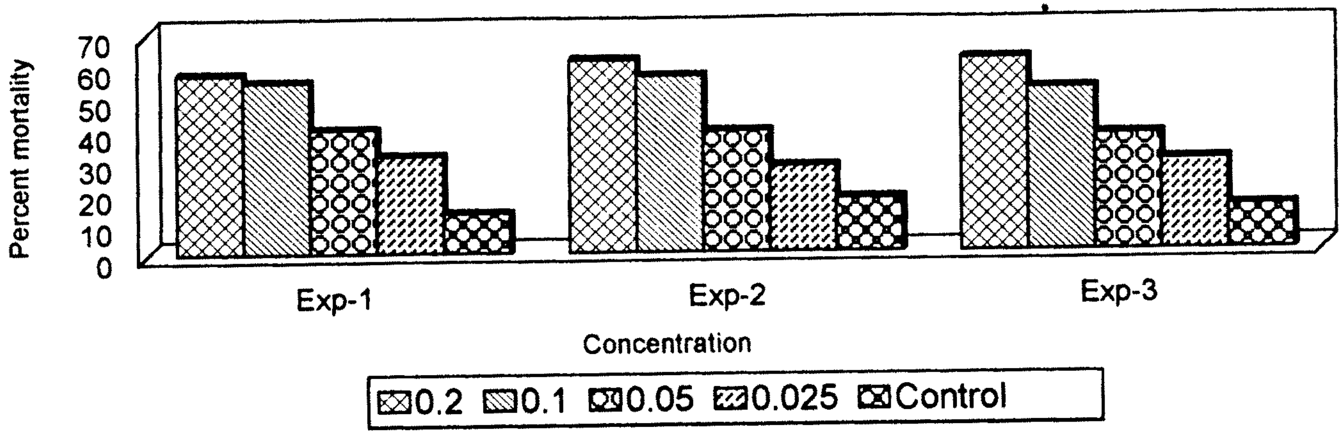


Fig. 36.1 Ovicidal effect of *Bacillus thuringiensis* var. *Kurstaki* on *Oligonychus coffeae* under laboratory condition at constant temperature 28 ± 1^{0}C & 80% R.H.

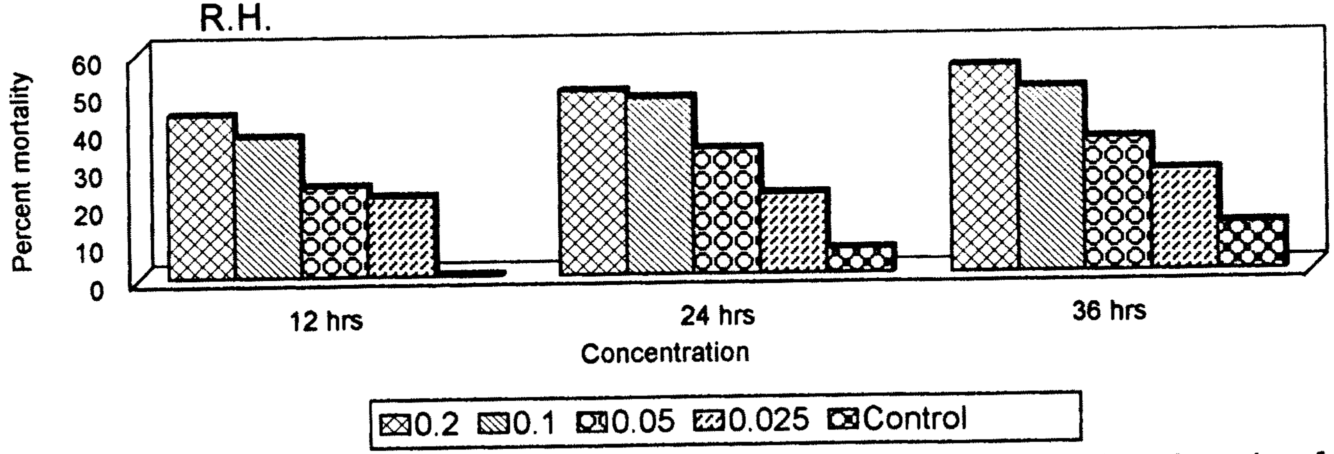


Fig.36.A.1 Effect of *Bacillus thuringiensis* var. *Kurstaki* on adult female of *Oligonychus coffeae* under laboratory condition at constant temperature 28 ± 1^{0}C & 80% R.H.

Table 37 . **Bioefficacy of abamectin against adult stage of red spider mite of tea under laboratory condition of 28± 1°C & 80% R.H. (mean of three replications)**

Sl . No.	Dose (mg/ml)	% mortality on different days after applications			
		1st	2nd	5th	Mean
1.	1000	100.00	-	-	100.00
		*(90.00)			(90.00)
2.	500	100.00	-	-	100.00
		(90.00)			(90.00)
3.	250	100.00	-	-	100.00
		(90.00)			(90.00)
4.	125	100.00	-	-	100.00
		(90.00)			(90.00)
5.	62.5	93.33	96.67	96.67	95.56
		(77.71)	(83.86)	(83.86)	(81.81)
6.	31.2	80.00	83.33	86.67	83.33
		(63.93)	(66.14)	(68.86)	(66.31)
7.	15.6	63.33	70.00	73.33	68.89
		(52.78)	(56.79)	(59.00)	(56.19)
8.	7.8	53.33	56.67	56.67	55.57
		(46.92)	(48.85)	(48.85)	(48.21)
9.	3.9	40.00	43.33	46.67	43.33
		(39.15)	(41.15)	(43.08)	(41.13)
10.	2	26.67	33.33	36.67	32.22
		(31.00)	(25.22)	(37.22)	(34.48)
11.	Control	3.80	6.90	6.90	5.87
		(9.36)	(13.89)	13.89)	(12.38)
	Mean	69.13	71.84	73.05	71.34
		(61.89)	(64.17)	(64.98)	(67.32)

	Treatments	Days
S.Em±	1.59	0.83
C.D. at 5%	4.50	2.35

*Figures in parentheses are angular transformed values

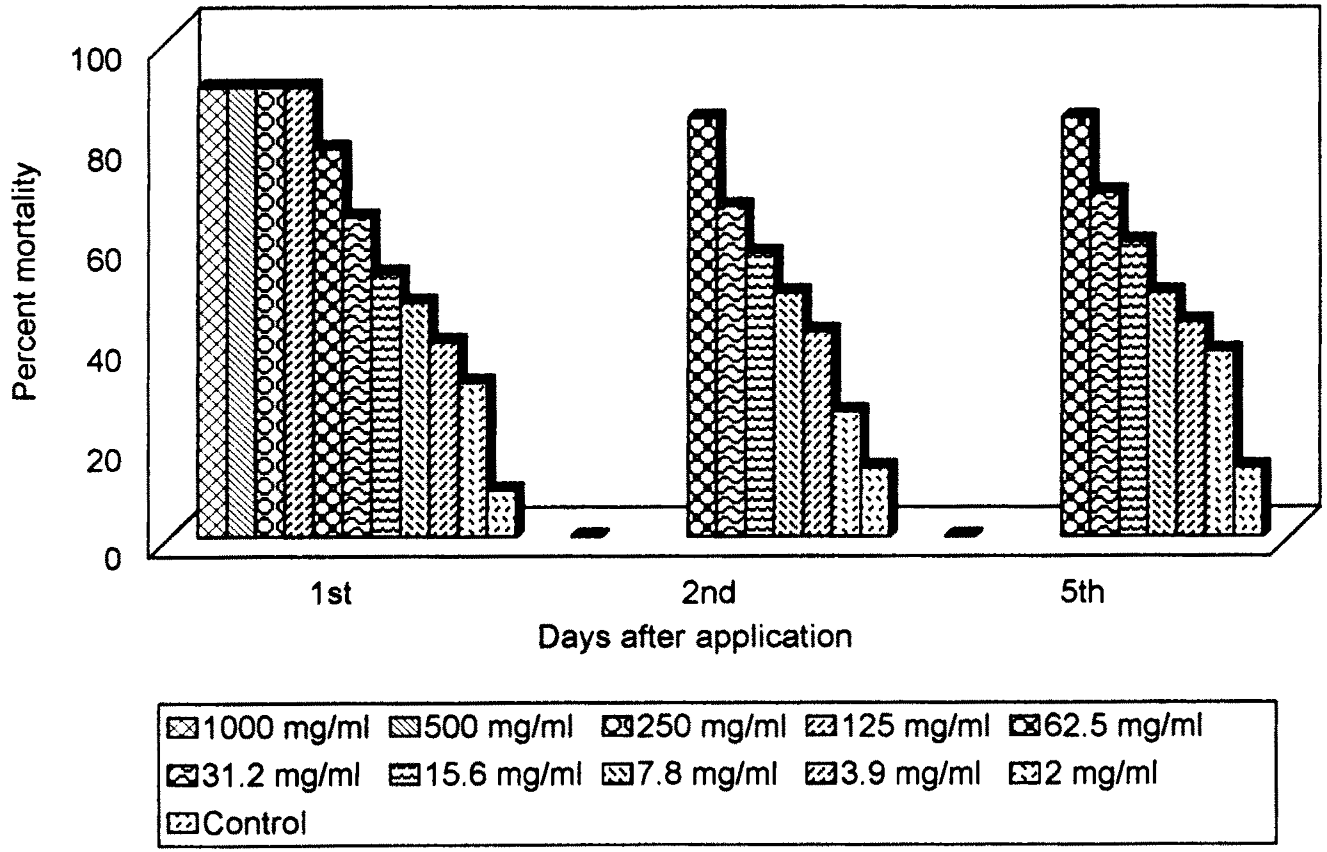


Fig.37.1: Bioefficacy of abamectin against adult stage of red spider mite of tea under laboratory condition at constant temperature $28 \pm 1^{0}C$ & 80% R.H.

Table 38 . Effect of different treatment schedules of abamectin against red spider mite of tea in the Dooars, West Bengal during March, 1994 (mean of three replications)

Sl . No.	Dose (mg/ml)	% reduction on different days after applications			
		1st	2nd	5th	Mean
1.	1000	100.00	-	-	100.00
		*(90.00)			(90.00)
2.	500	100.00	-	-	100.00
		(90.00)			(90.00)
3.	250	93.89	97.78	100.00	97.22
		(78.55)	(85.01)	(90.00)	(84.52)
4.	125	94.11	97.62	100.00	97.24
		(78.52)	(84.83)	(90.00)	(84.45)
5.	62.5	88.16	92.11	93.62	91.30
		(69.94)	(73.73)	(75.47)	(73.05)
6.	31.2	80.09	84.71	87.49	84.10
		(63.58)	(67.07)	(69.5)	(66.72)
7.	15.6	64.84	68.81	74.84	69.50
		(53.66)	(56.15)	(59.90)	(56.57)
8.	7.8	33.39	46.66	48.62	42.89
		(35.28)	(43.07)	(44.20)	(40.85)
9.	3.9	22.53	33.91	35.76	30.73
		(28.26)	(35.59)	(36.66)	(33.50)
10.	2	19.72	23.56	25.22	22.83
		(26.12)	(29.00)	(30.14)	(28.42)
11.	Control	0.707	2.85	2.85	2.14
		(4.82)	(8.38)	(8.38)	(7.19)
	Mean	63.40	68.00	69.85	67.09
		(56.25)	(60.26)	(62.21)	(59.57)
	Treatments	Days			
S.Em±	1.49	0.78			
C.D. at 5%	4.21	2.21			

* Figures in parentheses are angular transformed values

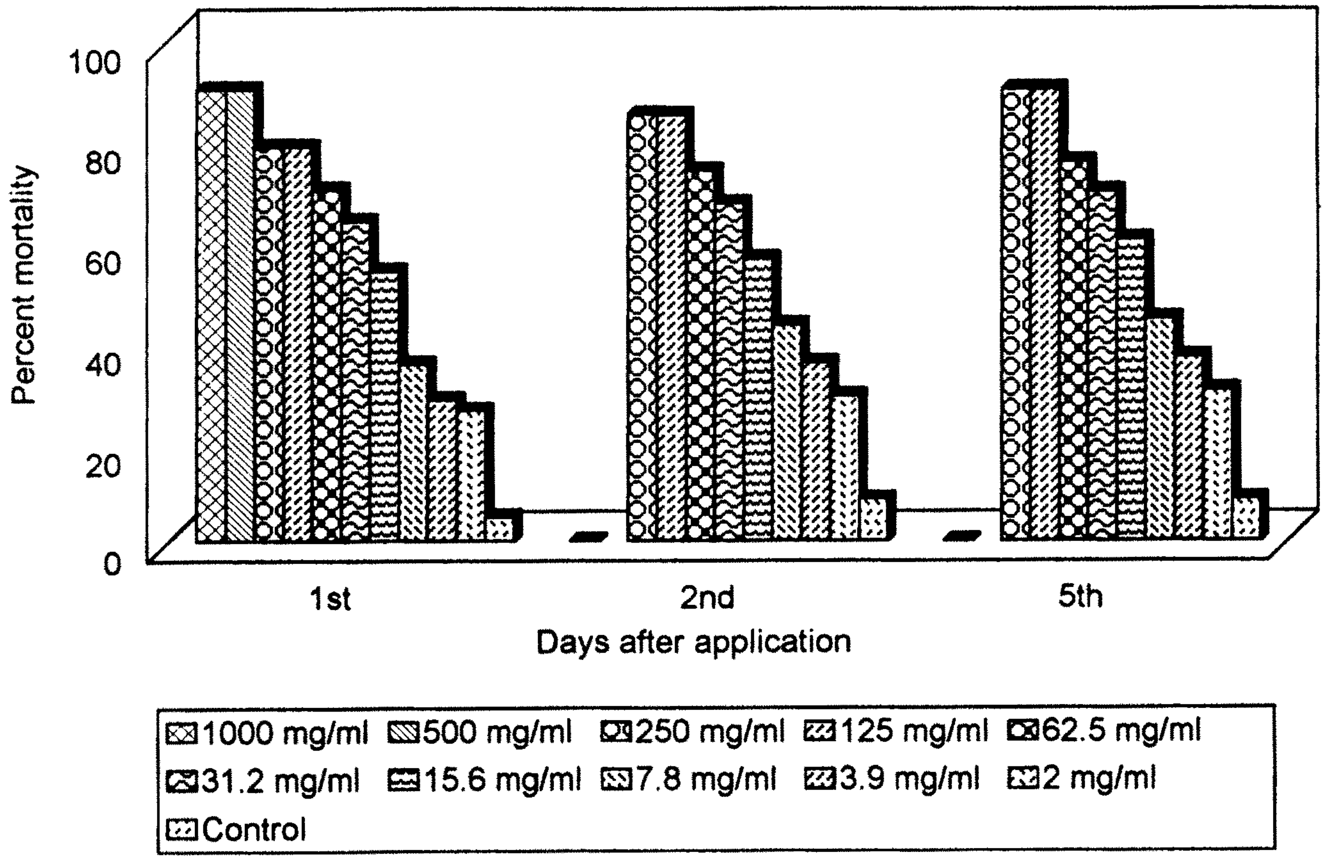


Fig.38.1:Effect of different treatment schedules of abamectin against red spider mite of tea in the Dooars, West Bengal during March, 1994 (mean of three replications)

Table 38.A : Effect of two microbial pesticides against red spider mite, *O. coffeae* of tea at the Dooars, W.B. during April, 1996 (mean of one application)

Sl. No.	Biocide	Dose (ml/lt)	% reduction at various days after applications				
			1	3	7	15	Mean
1.	Abamectin (*Streptomyces* toxin)	0.5	73.26 *(58.89)	90.12 (71.76)	95.57 (78.00)	92.11 (73.84)	87.76 (70.20)
2.	Abamectin	1.0	82.88 (65.61)	95.56 (78.00)	99.82 (88.40)	95.86 (78.48)	93.53 (77.62)
3.	Abamectin	1.5	96.45 (79.43)	99.65 (88.43)	100.00 (90.00)	98.60 (83.28)	98.67 (85.28)
4.	*B.t.* (OF)	2.0	46.07 (42.74)	56.34 (48.65)	66.71 (54.76)	52.47 (46.42)	55.40 (48.14)
5.	*B.t.* (OF)	3.00	55.66 (48.26)	63.80 (53.02)	74.99 (60.00)	58.85 (50.10)	63.32 (52.84)
6.	*B.t.* (OF)	4.00	64.12 (53.21)	72.00 (58.07)	80.48 (63.80)	68.51 (55.87)	71.28 (57.74)
7.	*B.t.* (OF)	5.00	73.05 (58.74)	83.53 (66.09)	89.50 (71.14)	75.66 (60.48)	80.43 (64.11)
8.	Control	-	4.53 (12.25)	6.98 (15.28)	8.12 (16.52)	12.39 (20.56)	8.01 (16.15)
	Mean		62.00 (52.39)	71.00 (59.91)	76.90 (65.33)	69.31 (58.63)	69.80 (59.06)
SEm ±			1.247	1.175	0.939	1.180	
C.D. (P=0.5)			3.793	3.573	2.855	3.588	

* Figures in parentheses are angular transformed values

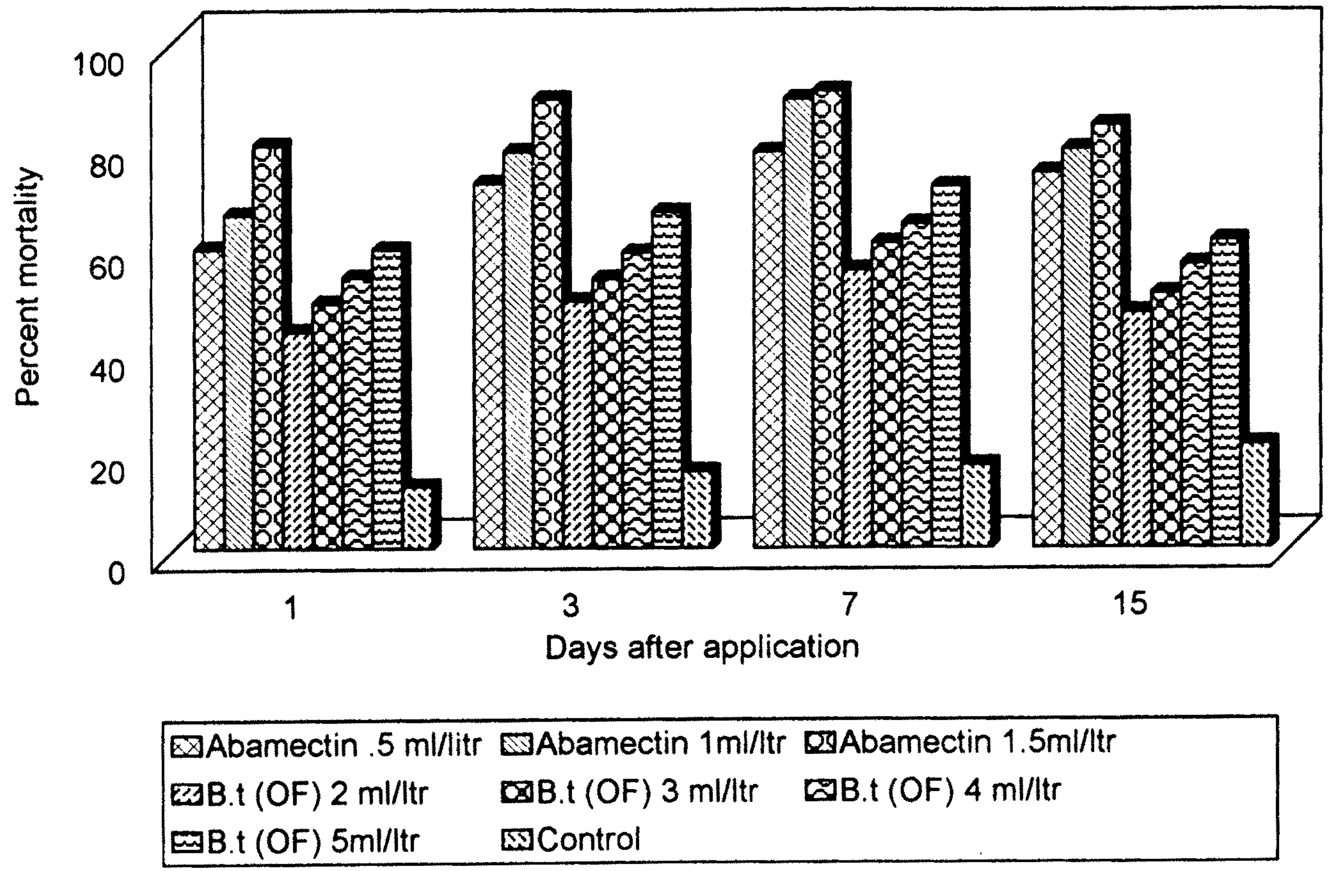


Fig.38.A.1:Effect of two microbial pesticides against red spider mite, *Oligonychus Coffeae* of tea in the Dooars, West Bengal during April, 1996

Another experiment was set up with abamectin and *B.t.* (Oil formulation) to test their efficacy against red spider mite in the Dooars, West Bengal during April 1996. The data on polled efficacy of the biocide have been presented in the Table 38.A & Fig. 38.A.1. It is evident that the two biocides differed significantly in respect of their efficacy against red spider mite. The efficacy of abamectin was significantly superior to that of *B.t.* even when abamectin was used ¼th of the dose used in case of *B.t.*. The best control of red spider was achieved when abamectin was sprayed at the dose of 1.5 ml/lt. and total mortality of motile stages was achieved within seven days of application. Even a lower dose of 1 ml or 1.5 ml/lt provided excellent mortality (over 95%) within 7 days of application. On the otherhand, *B.t.* formulation was moderately effective when applied at the rate of 5 ml/lt. In this case around 89% mortality was recorded on 7th day after application. Evidently, abamectin showed excellent knockdown and residual effect along with excellent killing action. But *B.t.* failed to show such initial knockdown or residual affect against red spider mite.

With the momentum gathering on IPM of plant feeding mites, the use of natural or bioproducts is likely to get more favour in near future in the control of plant feeding mites specially in a crop like tea. Abamectins are natural compounds produced by the soil actinomycetes, *Streptomyces avermitilis*. The most important commercial use of abamectin being a acaricides. This are highly effective against wide range mite pest such as Tetranychidae, Tenuipalpidae and Eriophyidae (Huengens and Degheele, 1986; Donatoni *et al.*, 1988; Rangel *et al.*, 1990; Zie *et al.*, 1992; Szwejda, 1993; 1994). In extensive worldwide studies and commercial use, abamectin has been documented to be more effective than other products tested as standard application rates for the control of spider mite (*Tetranychus urticae*). Incidentally, no detailed studies have been undertaken to reveal its efficacy against red spider mite of tea. It is evident from the present investigation that abamectin was highly effective against red spider mite of tea and it will provide an effective check of red spider population at 1 ml/l of water. Its excellent knockdown, residual and killing action as demonstrated during present investigation and supported by other workers puts it as the best biocide available in the world market. Its superiority over other synthetic chemicals also evaluated from its ecofriendly nature being safe to natural enemies. However, no such studies were carried out during the present investigation. *Bacillus thuringiensis*, the other best known widely used pathogen, produced a toxin that affects different species of Lepidoptera. A few studies have been made of the effect of Bt. on spider mites. The result of these studies demonstrated that the spore crystal complex of B.t. has no effect on spider mite. The ß-exotoxin, on the otherhand, possesses a clearly toxic action towards several species of Tetranychidae (Kreig, 1968; Hall *et al.*, 1971). The killing action of *B.t.* formulation recorded on spider mite population by some earlier workers is attributed to the presence of by-products in the formulations, and not necessarily to the action of the bacterium or its metabolic products. The moderate killing action of oil formulation of B.t. recorded during the present investigation may be due to the presence of by-products in the formulation. Being an oil formulation, it provided much better killing action against red spider mite compared to observations made by other workers. It is interesting to note that the application of oil formulation of *B.t.* @ 5.0ml/l of water provided around 80% reduction of mite population in single application. Its gives clear indication that this microbial pesticides may provide satisfactory control of red spider mite in tea with 3-4 applications. This two microbial pesticides require special attention in management of red spider mite considering their ecofriendly nature.

4.10 INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF THE PREDATORY MITE *Amblyseius coccosocius*

Incubation period: The duration of incubation period of *Amblyseius coccosocius* varied considerably in different constant temperatures. It was maximum (1.55 ± 0.10 days) at 20°C and minimum (0.83±0.12 days) at 30°C (Table.39)

Duration of different active life stages : The duration of different active life stages varied in relation to different constant temperatures. The minimum larval period was observed to be 0.87 ± 0.08 days at 35°C whereas maximum duration (1.88 ± 0.08 days) was observed at 20°C. The protonymphal duration was minimum (0.90 ± 0.09 days) at 35°C and maximum (1.50 ± 0.09 days) at 20°C. The deutonymphal period declined with increase in temperature from 20°C to 35°C. The deutonymphal duration was minimum (2.15±0.10 days) at 35°C whereas maximum (3.6 ± 0.11 days) at 20°C (Table.39).

Total development period : The total developmental period decreased with increase in temperature. It was minimum (4.83 ± 0.22 days) at 35°C and maximum (8.53±0.17) at 20°C. However, no difference was observed in between the total developmental period of male and female at different temperatures. (Table.39).

Table 39 : Development (in days ± S.D.) of *Amblyseius coccosocius* at different temperatures

Temperature (°C)	Incubation period	DURATION			Total developmental period	LONGEVITY	
		Larva	Protonymph	Deutonymph		Female	male
20	1.55±0.10	1.88±0.08	1.50±0.09	3.6±0.11	8.53±0.17	18.42±1.01	10.25±0.53
25	1.13±0.16	1.08±0.15	1.08±0.12	2.55±0.10	5.85±0.23	23.52±0.84	12.13±0.47
30	0.83±0.12	0.95±0.22	0.93±0.10	2.42±0.23	5.13±0.36	15.20±0.58	07.77±0.33
35	0.91±0.12	0.87±0.08	0.90±0.09	2.15±0.10	4.83±0.22	12.08±0.82	06.98±0.34

Table 39.A : Viability of eggs, percentage of larvae attaining adult stage and percentage mortality of *A. coccosocius* from larva to adult at different temperatures

Temperature (°C)	% hatch	% of larvae attaining adult stage	% mortality from larva to adult
20	100	95.83	04.17
25	100	100.00	0.00
30	100	56.67	43.33
35	100	30.00	70.00

Table 39.B : Duration of preoviposition, postoviposition and oviposition periods (in days ± S.D.), fecundity, daily rate of egg production and sex ratio of *A. coccosocius* at different temperatures

Temperature (°C)	Preoviposition period	Oviposition period	Postoviposition period	Fecundity	Daily rate of egg production	Sex ratio □ : □
20	1.3±0.14	16.05±0.10	1.05±0.15	20.58±1.02	1.28	4.25:1
25	1.15±0.10	21.28±0.15	1.07±0.05	46.28±1.27	2.17	3.27:1
30	1.37±0.14	12.9±0.18	0.93±0.08	13.18±0.65	1.02	2.50:1
35	0.92±0.07	09.92±0.15	1.26±0.12	08.28±0.29	0.83	1.67:1

Survival at different life stages : All the eggs of *A. coccosocius* were viable at all levels of constant temperatures. No mortality was observed at 25°C. However, the percentage of larvae attaining adult stages was 95.83%, 100%, 56.67% and 30% at 20, 25, 30 and 35°C, respectively (Table.39.A).

Preoviposition, oviposition and postoviposition periods : The preoviposition, oviposition and postoviposition period varied with temperature. The minimum preoviposition period was observed (0.92±0.07 days) at 35°C and maximum (1.37±0.14 days) at 30°C. The oviposition period was comparatively of longer duration; it was maximum (21.28±0.15 days) at 25°C and minimum (9.92±0.15 days) at 35°C. The postoviposition period was short being maximum (1.26±0.12 days) at 35°C and minimum (0.93±0.08 days) at 30°C (Table .39.B).

Fecundity, daily rate of egg production and sex ratio : The maximum fecundity (46.28±1.27 eggs) was observed at 25°C and minimum (8.28±0.29 eggs) at 35°C. The maximum daily rate of egg production 2.17 eggs per day was observed at 25°C whereas minimum 0.83 eggs per day was observed at 35°C (Table.39.B). It was evident from the data that the number of males increased with increase in temperature from 20 to 35°C as the sex ratio (female : male) decreased with increase in temperature. It was observed to be 4.25:1 at 20°C and 1.67:1 at 35°C (Table.39.B).

Longevity of adults : The maximum longevity of females was observed to be 23.52±0.84 days and of males 12.13±0.47 days at 25°C and minimum 12.08±0.82 days for females and 06.98±0.34 days for males was observed at 35°C. It was observed that the longevity of females as well as males increased with increase in temperature from 20 to 25°C and then decreased with further increase in temperature (Table. 39).

It was observed in *A. coccosocius* that the developmental period decreased with increase in temperature being maximum at 20°C and minimum at 35°C. Similar trend was observed in *A. fallacis* (Garman) by Smith and Newsom (1970), in *A. citrifolius* (Denmark and Muma) by Moraes (1979), in *A. swirski* Athias-Henriot by Yousef *et al.*(1982), and in *Euseius mesembrinus* by Abou-Setta and Childers (1987).

All the eggs of *A. coccosocius* hatched in larvae at all the temperatures. Lee and Devis (1968) reported 98% hatching in *Typhlodromus occidentalis* (Nesbitt). In *Phytoseiulus* *macropilis* (Banks), it was 97%, while 99.7% hatching was observed in *P. persimilis* Athias-Henriot (Stenseth, 1979). Smith and Newsom (1970), however, suspected that shifting procedure might have reduced egg viability. The cent percent hatchability at all temperatures is a useful feature of this predatory mite. Higher mortality rate (70%) was observed at higher temperatue (35°C). The results of Hamamura *et al.*(1976) support these observations who found higher mortality at above 32.5°C in *P. persimilis*.

In *A. coccosocius*, the oviposition period increased with the increase in temperature from 30 to 35°C and decreased with further increase in temperature which is a common phenomena in phytoseiids (Smith and Newsom, 1970; Ma and Laing, 1973; Tanigoshi *et al.*, 1975). Thus we conclude that 25°C is the most suitable temperature for the predatory mite *A. coccosocius*, as at this temperature, the total developmental period was quite short with no mortality, longer oviposition period and higher fecundity.

Table 40. Rate of feeding of five species of predatory mite on red spider mite of tea (mean of ten replications)

Predatory mite.	No. of individuals of different stages of red spider mite consumed/adult predator in four hrs.			
	Protonymph	Deutonymph	Adult	Mean
Amblyseius herbicolus	5.93	5.31	2.86	4.70
	*(13.99)	(13.30)	(9.68)	(12.32)
Amblyseius coccineae	4.58	3.79	1.17	3.18
	(12.30)	(11.17)	(6.19)	(9.89)
A. coccosocius	4.96	4.48	1.29	3.58
	(12.81)	(12.19)	(6.49)	(10.50)
A. largoensis	4.88	4.13	1.21	3.41
	(12.71)	(11.68)	(6.28)	(10.22)
Typhlodromus homalii	4.58	3.76	1.10	3.15
	(12.31)	(11.08)	(5.99)	(9.79)
	Stage	Predatory mite		
S.Em±	0.04	0.05		
C.D. at 5%	0.13	0.15		

* Figures in parentheses are angular tranformed values

4.11 FEEDING RATE OF FIVE SPECIES OF PHYTOSEIID PREDATORY MITE ON RED SPIDER MITE OF TEA

It is evident from Table .40 that the rate of consumption of prey varied significantly among five predatory mites. The highest feeding rate was observed in *Amblyseius herbicolus* followed by *A. coccosocius, A. largoensis* and it was minimum in *Typhlodromus homalii* and *A. coccineae*. No significant difference was recorded in between the later two species ragarding their rate of feeding on spider mite of tea. All the five species were found to feed on all the stages except egg stage of the prey. Based on their distribution and feeding habits, they are likely to be efficient predator of red spider mite at low density level and may not be reliable predator under very high population levels of red spider mite.

4.12 SELECTIVITY OF SOME MODERN PESTICIDES TO THREE IMPORTANT PREDATORY MITES OF *O. coffeae*

Adverse effects of commercial pesticides on the natural enemies of pests has been recorded in numerous instances, especially since the advent of modern; broad spectrum organic pesticides. Assessment of potential effects of pesticides on beneficial arthropods has been recognized as one of the main prerequisites to the establishment of effective integrated pest control programme. Selectivity is the measure of the capacity of a treatment to spare natural enemies while destroying pests.

Therefore, the relative toxicity of nine pesticides as contact poisons to the adults of three predatory mites was determined following the standard bioassay technique to obtain the concentration probit mortality curve and the data were subjected to probit analysis (Finney, 1952).

4.12.1 Toxicity to *A. ovalis*

Out of nine pesticides, fenazaquin was the least toxic to the predatory mites and therefore the relative toxicity of different pesticides has been calculated by taking the LC_{50} value of this pesticide as unity. Other pesticides such as cypermethrin endosulfan and α -cypermethrin, DDVP and phosphamidon, dicofol, monocrotophos and sulfur proved to be more toxic than fenazaquin being about 100.00, 66.67 & 66.67, 40.00 & 40.00, 16.67; 11.11 & 2.63 times respectively as toxic as fenazaquin (Table.41.A).

Table 41.A : Relative toxicity of different pesticides as contact poisons to adult of *Amblyseius ovalis*

Sl. No.	Pesticide	Heterogenity (χ^2)	Regression equation	LC_{50}	Fiducial limit	Relative toxicity
1.	Dicofol	0.116737	Y = 3.997 + 0.482x	0.000012	(1.172552, 2.986691)	16.67
2.	Sulphur	1.588197	Y = 4.245 + 0.262x	0.000076	(1.519527, 4.248071)	2.63
3.	Fenazaquin	0.133690	Y = 3.880 + 0.339x	0.000200	(2.310940,4.293060)	1.00
4.	DDVP	0.277170	Y = 4.060 + 0.567x	0.000005	(0.815380, 2.519080)	40.00
5.	Cypermethrin	0.716087	Y = 4.153 + 0.581x	0.000002	(0.549908, 2.368534)	100.00
6.	Monocrotophos	0.112798	Y = 4.152 + 0.375x	0.000018	(1.178736, 3.339394)	11.11
7.	Endosulfan	0.301515	Y = 4.272 + 0.488x	0.000003	(0.437744, 2.549854)	66.67
8.	Phosphamidon	0.832818	Y = 4.304 + 0.452x	0.000005	(0.453927, 3.090753)	40.00
9.	α-cypermethrin	0.790430	Y = 4.401 + 0.395x	0.000003	(0.422641, 2.892767)	66.67

Table 41.B : Relative toxicity of different pesticides as contact poisons to adult of *Amblyseius largoensis*

Sl. No.	Pesticide	Heterogenity (χ^2)	Regression equation	LC_{50}	Fiducial limit	Relative toxicity
1.	Dicofol	1.229567	Y = 4.095 + 0.356x	0.000033	(1.444378, 3.616124)	10.55
2.	Sulphur	0.106425	Y = 4.014 + 0.278x	0.000348	(2.343603, 4.739737)	1.00
3.	Fenazaquin	0.173451	Y = 4.096 + 0.328x	0.000058	(1.659740, 3.856150)	6.00
4.	DDVP	1.266651	Y = 4.018 + 0.491x	0.000010	(1.014917, 2.986682)	34.80
5.	Cypermethrin	0.684431	Y = 4.280 + 0.413x	0.000005	(0.402688, 3.081579)	69.50
6.	Monocrotophos	0.556949	Y = 4.082 + 0.354x	0.000039	(1.534198, 3.658627)	8.92
7.	Endosulfan	0.527374	Y = 3.889 + 0.604x	0.000006	(0.992418, 2.687517)	58.00
8.	Phosphamidon	0.286676	Y = 4.079 + 0.492x	0.000007	(0.924560, 2.824244)	49.70
9.	α-cypermethrin	0.271436	Y = 3.987 + 0.611x	0.000005	(0.855100, 2.456502)	69.50

4.12.2 Toxicity to *A. largoensis*

Out of nine pesticides, sulfur was the least toxic to this predator and therefore, the relative toxicity of different pesticides has been calculated by taking the LC_{50} values of sulfur as unity. The remaining eight pesticides such as α-cypermethrin & cypermethrin, endosulfan, phosphamidon, DDVP, dicofol, monocrotophos and fenazaquin proved to be more toxic than sulfur being about 69.50 & 69.50, 58.00, 49.70, 34.80, 10.55, 8.92 and 6.00 times respectively as toxic as sulfur (Table.41.B).

Table 41.C : Relative toxicity of different pesticides as contact poisons to adult of *Amblyseius multidentatus*

Sl. No.	Pesticide	Heterogenity (χ^2)	Regression equation	LC_{50}	Fiducial limit	Relative toxicity
1.	Dicofol	0.727554	Y = 4.007 + 0.379x	0.0000410	(1.636666, 3.605981)	6.59
2.	Sulphur	0.806860	Y = 4.081 + 0.323x	0.0000690	(1.729008, 3.957385)	3.91
3.	Fenazaquin	0.325210	Y = 3.889 + 0.323x	0.0002700	(2.400100, 4.472500)	1.00
4.	DDVP	0.282285	Y = 4.193 + 0.394x	0.0000110	(0.969421, 3.132144)	24.55
5.	Cypermethrin	0.454505	Y = 4.038 + 0.563x	0.0000051	(0.84926, 2.56675)	52.94
6.	Monocrotophos	0.211542	Y = 4.301 + 0.339x	0.0000110	(0.800720, 3.320497)	24.55
7.	Endosulfan	0.675580	Y = 4.307 + 0.384x	0.0000030	(0.377243, 2.806658)	90.00
8.	Phosphamidon	0.706876	Y = 4.522 + 0.550x	0.0000020	(0.55897, 2.39684)	135.00
9.	α-cypermethrin	0.231983	Y = 4.199 + 0.492x	0.0000040	(0.549188, 2.699075)	67.50

4.12.3 Toxicity to *A. multidentatus*

Out of nine pesticides, fenazaquin was the least toxic to this predatory and therefore, the relative toxicity of different pesticides has been calculated by taking the LC_{50} vlaues of fenazaquin as unity. The remaining eight pesticides such as phosphamidon, endosulfan, α - cypermethrin, cypermethrin, DDVP and monocrotophos, dicofol and sulfur proved to be more toxic than fenazaquin being about 135.00, 90.00, 67.50, 52.94, 24.55 & 24.55, 6.59 and 3.91 times respectively as toxic as fenazaqin (Table. 41.C).

It was evident from present investigation that most the conventional pesticides being used in tea pests control are highly toxic to major predatory mites of *O. coffeae*. The use of these chemicals in recommended dosages i.e. 0.01-0.07% a.i. would annihilate them as evidenced from this study. A dosage as low as 0.000004% a.i. would kill 50% of their population.

However, out of the nine pesticides tested here, sulfur and fenazaquin were relatively safe to the predatory mites. On the other hand, phosphamidon, cypermethrin, and endosulfan were extremely toxic to these predators and their use should be restricted to preserve these important natural enemies of red spider mite. Incidentally, three species of predatory mites showed wide variation in their response (selectivity) to these pesticides. *A. ovalis* showed its ability to tolerate higher dosages of phosphamidon while *A. multidentatus* proved other way. *A. largoenisis* showed the ability to tolerate higher of toxicant doses followed by *A. ovalis*. In general, none of the pesticides included in this study were safe to the important phytoseiid mites of red spider.

4.13 EFFECT OF ECOFRIENDLY BIOCIDES ON RED SPIDER AND PREDATORY MITES:

Two goups of biocide i.e. neem based and microbial type were included in the present investigation as pesticide contamination in made-tea has assumed an alarming proportion in recent years with the increase in pest problem in tea. Therefore, ecofriendly safe pesticides merit special attention in this case. Keeping these in view, two biocides were tested against red spider mite including the adverse effect of than, if any on predatory mite complex.

Neem biocides are now available in different formulations. However, oil and AZA enriched formulations are widely used rather than crude kernel based formulation in pest control. It was observed that AZA enriched formulation like Neemazol (10,000ppm) provided moderate control of red spider mite within 24 hrs while the mortality was much lower in oil based formulation (Table.42). It may therefore be said that neem biocide possess killing action against red spider mite besides killing the pest spp through other modes of action.

It is also evident from this investigation that both the formulation were very safe to three predatory mites included in this study. The rate of mortality was less than 50% as compared to those were observed in red spider mite (Table .42). It might be attributed to selectivity of the predatory mites to the biocide resulting in low mortality of these beneficial natural enemies.

The response of three predatory spp. varied greatly to two types of formulations of neem. The AZA enriched formulation was found to be considerably toxic to *A. multidentatus* while it was least toxic to *A. largoensis*. However, the case was reversed in case of oil based formulations. (Table.42).

Table 42 : **Effect of two formulations of neem biocide on red spider and predatory mites under laboratory condition at constant temp. of 28 ± 1°C & 80% R.H.**

Sl. No.	Neem biocide	Dilution	% mortality at 24 hrs. after treatment			
			Plant feeding mite	predatory mite		
			O. coffeae	*A. largoensis*	*A. ovalis*	*A. multidentatus*
1.	Neemazol - F 1% (AZA enriched formulation	1:100	71.83 *(57.97)	31.40 (34.06)	37.70 (37.89)	53.07 (46.77)
2.	Neemazol - F 1% (AZA enriched formulation	1:500	57.24 (49.17)	19.44 (26.11)	20.06 (26.59)	30.44 (33.47)
3.	Neemazol - F 1% (AZA enriched formulation	1:1000	42.22 (40.52)	13.09 (21.17)	14.67 (22.49)	21.57 (27.65)
4.	Bioneem 0.03% (oil formu-lation)	1:100	56.55 (48.77)	41.15 (39.90)	42.20 (40.15)	35.79 (36.72)
5.	Bioneem 0.03% (oil formu-lation)	1:500	46.82 (43.18)	33.80 (35.54)	32.09 (34.50)	25.99 (30.61)
6.	Bioneem 0.03% (oil formu-lation)	1:1000	37.28 (37.62)	23.30 (28.84)	21.35 (27.50)	19.42 (26.12)
7.	Control	-	01.13 (6.11)	00.025 (0.906)	01.13 (6.11)	01.13 (6.11)
	Mean		44.72 (40.48)	23.17 (26.65)	24.17 (27.94)	26.77 (29.64)

	Species	Treatments	Dilutions
S.Em ±	0.236	0.167	0.204
C.D. at 5%	0.463	0.327	0.400
	Species x Treatment	Species x Dilution	Treatment x Dilution
S.Em ±	0.333	0.408	0.288
C.D. at 5%	0.653	0.800	0.564
	Species x Treatment x Dilution		
S.Em ±	0.577		
C.D. at 5%	1.131		

* Figures in parentheses are angular transformed values

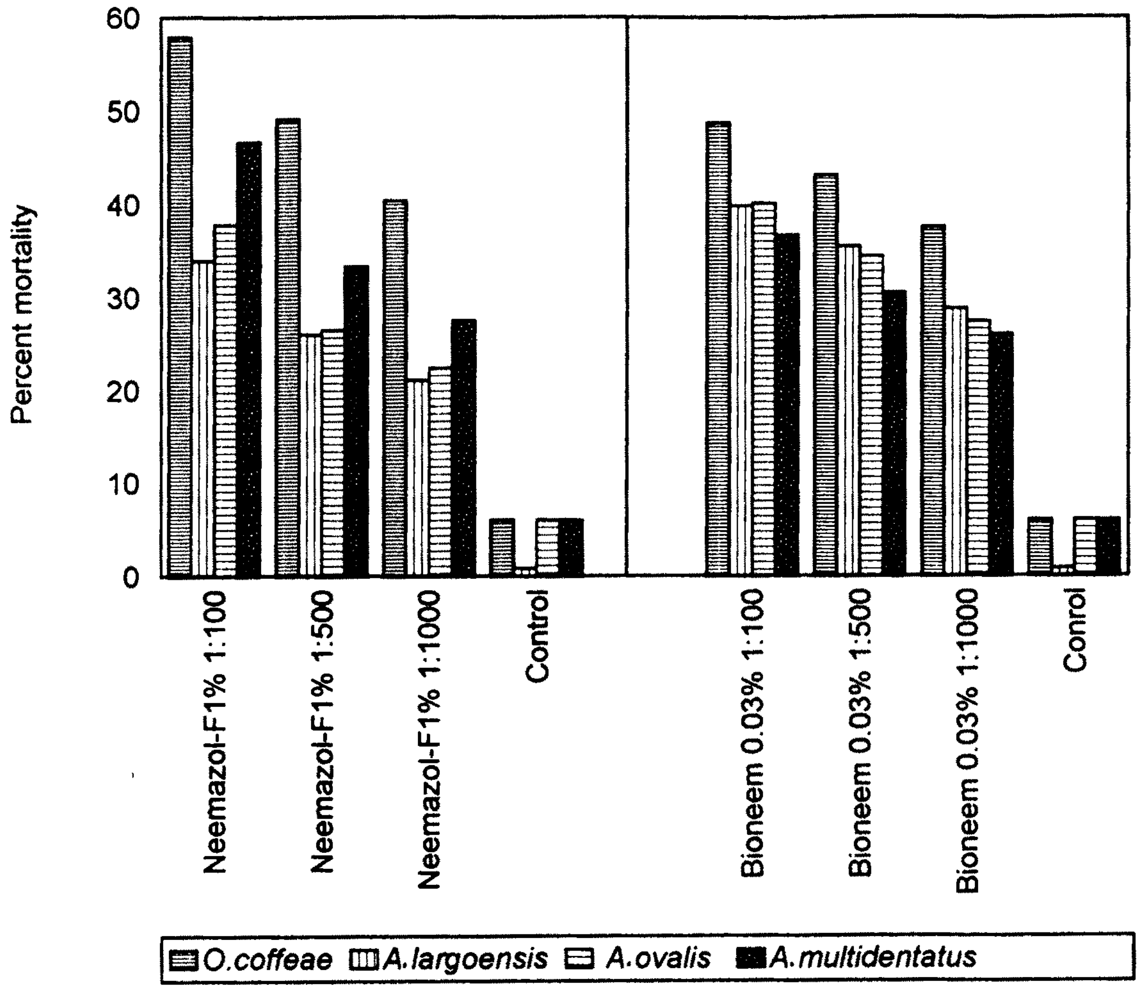


Fig. 42.1 Effect of forumualtions of neem biocide on red spider and predatory mites under laboratory condition at constant temp. of 28 ± 1 C & 80% R.H

Very scanty information are available on the relative toxicity of different formulation of neem to plant feeding and predaceous mite species. Mansour *et al.*, (1987) demonstrated that the different neem seed kernel extract were more toxic to *Tetranychus cinnabarinus* than to a predatory mite *Phytoseiulus persimilis*. Pande *et al.* (1987) showed that the efficacy of neem leaf extract depend on the solvent used in the extraction. Wide variation in toxicity of some commercial formulation of neem to phytophagous and predatory mites was reported by Mansour *et al.* (1993). The influence of host plant in changing the efficacy of neem biocides against plant feeding mites was noted by Patel *et al.*(1993). It may be seen from some of scanty information available in this direction that the efficacy of neem biocide on the type of formulation used was has also be reflected. In this studies AZA enriched formulation like neemazol superior than to neem oil. However predatory mites showed differential response to neem formulations included in this study.

4.14 ADVERSE EFFECT OF SOME MODERN CHEMICALS ON PREDATORY MITES OF RED SPIDER MITE

4.14.1 Adverse effect of some modern chemicals on *Amblyseius* spp., predatory mite of red spider of tea under field condition in the Dooars, West Bengal during April-May 1996.

The polled data on the adverse effect of eight modern chemicals on *Amblyseius* species have been presented in Table 43.A and Fig.43.A.1. Significant variation was recorded between chemicals in respect of adverse effect of eight chemicals on *Amblyseius* species. Fenazaquin had the minimum adverse effect on the predatory mite belonging to Phytoseiidae. As such, it may be considered as the safest chemical included in this study. In this case, only 24.54% reduction was recorded at the lowest doses (1000 ml/ha) compared to 34.49% at the highest doses (2000 ml/ha). The respective mortalities in case of amitraz, acrinathrin and bromopropylate were 42.55%, 51.75% & 42.46% at the lowest dose and the corresponding reduction at the highest dose were 57.28%, 67.29% & 55.33%. Amitraz and bromopropylate were relatively safe compared to acrinathrin, dicofol, ethion and endosulfan and no significant difference was recorded in between acrinathrin, dicofol, ethion and endosulfan regarding their adverse effect on *Amblyseius* species. In most of the cases the adverse effect of chemicals increased progressively upto 7 days after application except in fenazaquin where a sharp fall in killing action was noted. The effect of interaction of two factors on the adverse effect of eight chemicals was significant indicating that the pattern of reduction in phytoseiid population was not similar under different chemicals.

Table 43.A : Adverse effect of some modern chemicals on *Amblyseius* spp. (predatory mites of red spider) of tea under field condition in the Dooars, W.B. during April-May, 1996 (mean of three applications)

Chemical	Dose (ml/ha)	Mean percent reduction at various days after spraying				
		1	3	7	12	Mean
Fenazaquin (10% EC)	2000	41.61 *(40.17)	44.24 (41.69)	31.60 (34.18)	20.50 (26.90)	34.49 (35.74)
	1000	28.81 (32.45)	33.08 (35.10)	22.54 (28.33)	13.73 (21.73)	24.54 (29.40)
Amitraz (20% EC)	2000	53.84 (47.20)	66.09 (54.39)	67.70 (55.38)	41.49 (40.09)	57.28 (49.27)
	1000	41.33 (40.00)	47.20 (43.39)	49.39 (44.65)	32.26 (34.61)	42.55 (40.66)
Acrinathrin (15% EC)	400	75.28 (60.21)	77.35 (61.63)	71.52 (57.77)	45.00 (42.12)	67.29 (55.43)
	200	55.52 (48.17)	60.50 (51.06)	55.93 (48.41)	33.05 (35.08)	51.75 (45.68)
Bromopropylatc (50% EC)	2000	51.43 (45.82)	61.17 (51.46)	66.12 (54.42)	42.61 (40.75)	55.33 (48.11)
	1000	42.45 (40.66)	45.44 (42.38)	48.87 (44.24)	33.08 (35.10)	42.46 (40.60)
Dicofol (18.5% E.C.)	2000	60.56 (51.10)	67.62 (55.33)	70.00 (56.81)	50.91 (45.52)	62.27 (52.19)
	1000	42.33 (40.59)	47.91 (43.73)	49.74 (44.85)	38.34 (38.26)	44.58 (41.86)
Ethion (50% E.C.)	2000	62.79 (52.42)	69.31 (56.37)	71.60 (57.81)	53.73 (47.14)	64.36 (53.43)
	1000	51.64 (45.94)	57.48 (49.30)	59.99 (50.76)	46.09 (42.76)	53.80 (47.19)
Endosulfan (35% E.C.)	2000	61.03 (51.37)	68.84 (56.09)	71.19 (57.56)	65.79 (54.21)	66.71 (54.86)
	1000	48.37 (44.07)	53.19 (46.83)	55.74 (48.30)	52.82 (46.62)	52.53 (46.45)
Control (water spray)	-	03.93 (11.42)	03.93 (11.42)	03.83 (11.06)	04.14 (11.72)	03.96 (11.41)
Mean		48.06 (43.24)	53.56 (46.68)	53.05 (46.30)	38.24 (37.51)	48.26 (43.48)

Difference between C.D. at	P = 0.05	P= 0.01
Days	0.61	0.80
Chemicals	1.17	1.55
Day x Chemicals	2.35	3.10

* Figures in parentheses are angular transformed values

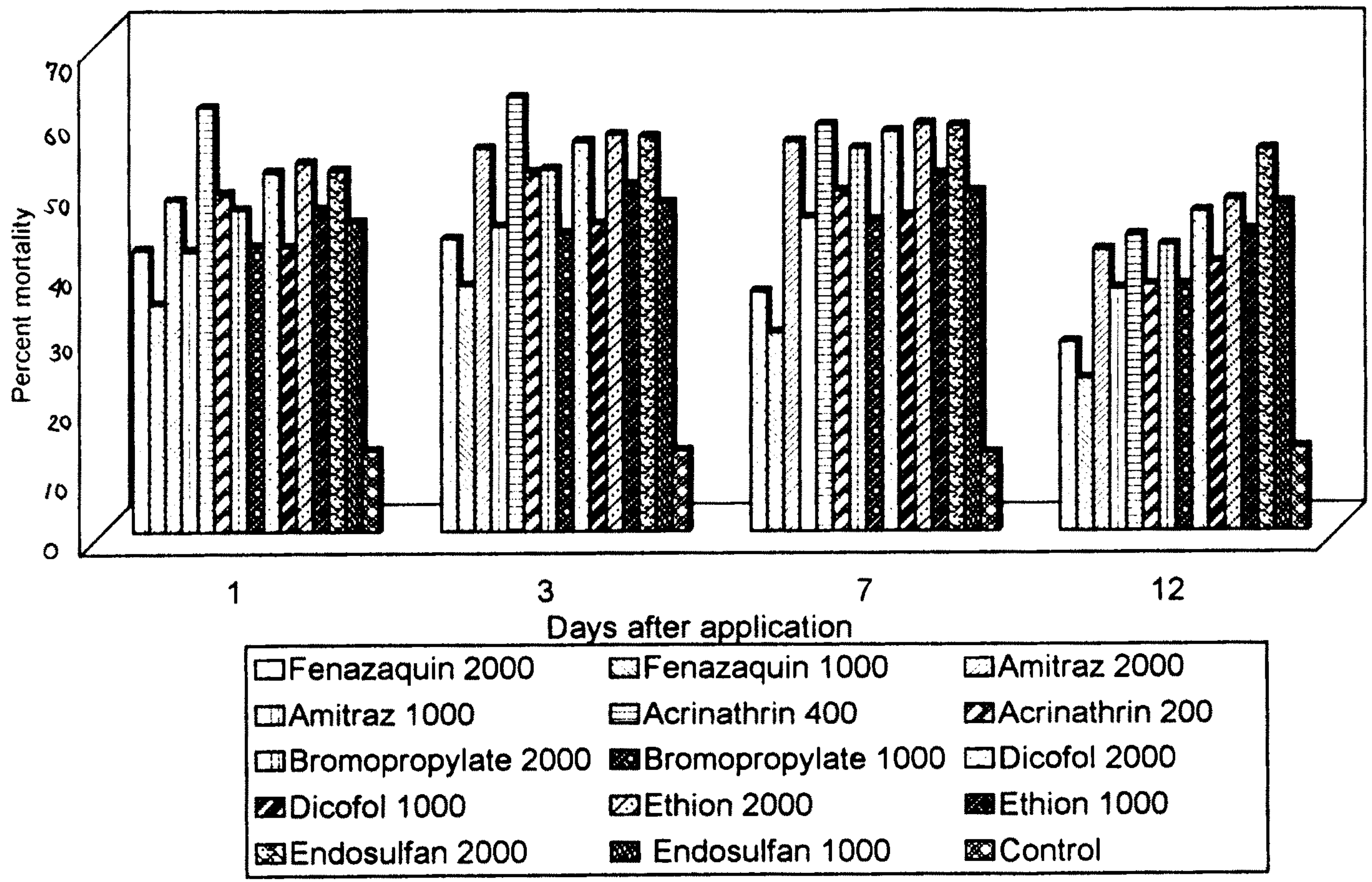


Fig. 43.A.1 Adverse effect of some modern chemicals on *Amblyseius* spp. (predatory mites of red spider) of tea under field condition in the Dooars, W.B. during April-May, 1996 (mean of three applications)

Table 43.B : Adverse effect of some modern chemicals on *Agistemus* spp. (predatory mite of red spider) of tea under field condition in the Dooars during April-May, 1996 (mean of three applications)

Chemical	Dose (ml/ha)	Mean percent reduction at various days after spraying: 1	3	7	12	Mean
Fenazaquin (10% EC)	2000	38.86 *(38.56)	44.11 (41.62)	28.23 (32.08)	18.92 (25.77)	32.53 (34.51)
	1000	27.99 (31.93)	32.29 (34.63)	20.09 (26.61)	15.93 (23.51)	24.08 (29.17)
Amitraz (20% EC)	2000	56.79 (48.91)	70.90 (57.35)	71.97 (58.04)	57.31 (49.21)	64.24 (53.38)
	1000	40.18 (39.33)	52.73 (46.57)	55.01 (47.88)	47.10 (43.34)	48.76 (44.28)
Acrinathrin (15% EC)	400	56.21 (48.57)	68.63 (55.95)	70.28 (56.97)	50.24 (45.14)	61.34 (51.66)
	200	42.32 (40.58)	54.11 (46.36)	55.09 (47.92)	40.75 (39.67)	48.07 (43.63)
Bromopropylate (50% EC)	2000	61.88 (51.87)	64.61 (53.50)	58.77 (50.05)	48.10 (43.91)	58.34 (49.83)
	1000	50.37 (45.21)	55.23 (48.00)	48.89 (44.36)	37.90 (37.99)	48.10 (43.89)
Dicofol (18.5% E.C.)	2000	45.51 (42.42)	52.65 (46.52)	40.31 (39.41)	37.39 (37.69)	43.97 (41.51)
	1000	36.15 (36.96)	42.22 (40.52)	32.33 (34.65)	30.44 (33.49)	35.29 (36.40)
Ethion (50% E.C.)	2000	68.27 (55.73)	73.57 (59.08)	62.51 (52.28)	58.49 (49.89)	65.71 (54.32)
	1000	52.69 (46.54)	62.30 (52.12)	54.89 (47.81)	50.38 (45.22)	55.07 (47.92)
Endosulfan (35% E.C.)	2000	52.64 (46.51)	65.55 (54.07)	67.29 (55.12)	62.31 (52.13)	61.95 (51.96)
	1000	40.95 (39.79)	53.97 (47.28)	55.50 (48.16)	52.35 (46.35)	50.69 (45.39)
Control (water spray)	-	03.66 (11.01)	03.82 (11.25)	04.19 (11.80)	03.60 (10.92)	03.82 (11.25)
Mean		44.96 (41.60)	53.11 (46.32)	48.36 (43.56)	40.75 (38.95)	46.79 (42.61)

Difference between C.D. at	P=0.05	P=0.01
Days	0.51	0.67
Chemicals	0.98	1.29
Day x Chemicals	1.96	2.59

* Figures in parentheses are angular transformed values

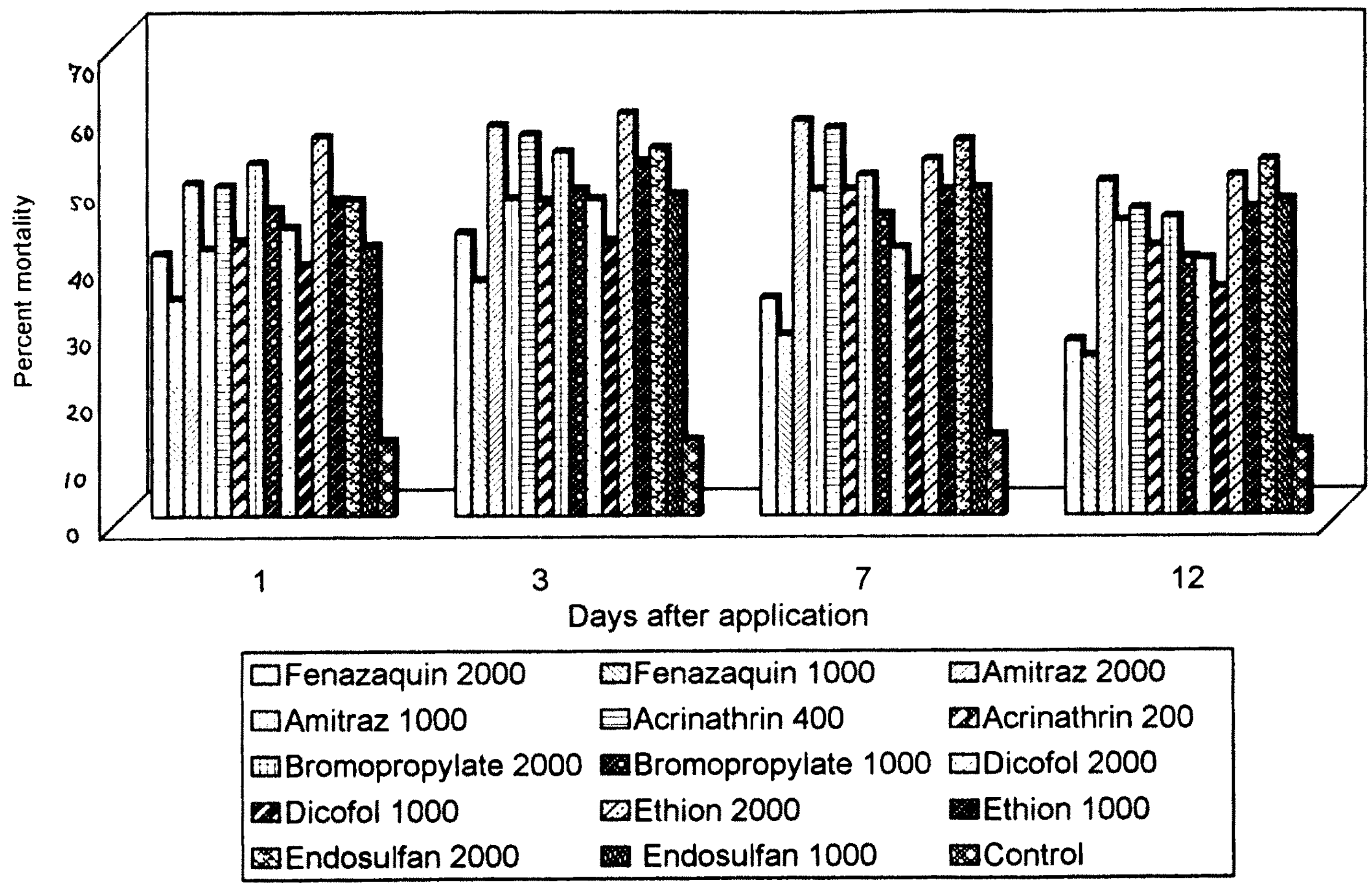


Fig. 43.B.1 : Adverse effect of some modern chemicals on *Agistemus* spp. (predatory mites of red spider) of tea under field condition in the Dooars, W.B. during April-May, 1996 (mean of three applications)

4.14.2 Adverse effect of some modern chemicals on *Agistemus* spp., a predatory mite of red spider of tea under field condition in the Dooars, West Bengal, during April-May 1996.

The adverse effect of 8 chemicals on *Agistemus* spp. has been presented in Table 43B & Fig.43.B.1. The activity of the chemicals varied significantly among themselves. Again, fenazaquin prove to be the safest chemical spraing around 67.47% population at the highest dose (2000 ml/ha) and 75.92% at the lowest dose. Dicofol occupied the second position sparaing 56.03% and 64.71% at the highest (2000 ml/ha) and lowest doses (1000 ml/ha) respectively. In all other cases, the percentage of survival of *Agistemus* was litre higher than 40% except in bromopropylate where 41.66% survival was recorded at the highest dose. Most of the chemicals retained their toxicity on *Agistemus* upto 7 day after application except incase of fenazaquin, dicofol and ethion. The significant interaction of the two parameter (day x chemicals) indicated that the influence of chemicals in reduction of predatory mite population did not follow similar pattern among 8 treatments.

4.14.3 Adverse effect of some modern chemicals on *Cunaxa* spp., a predatory mite of red spider of tea under field condition in the Dooars, West Bengal during April-May 1996.

The polled data on the adverse effect of eight modern chemicals on *Cunaxa* speices have been presented in Table.43.C and Fig.43.C.1. Fenazaquin showed the minimum adverse effect on this predatory group belonging to cunaxidae. Therefore, it may be considered was the safe chemical to *Cunaxa* sp. In this case, only 23.25% reduction was recorded at the lowest doses (1000 ml/ha) compared to 32.34% at the highest doses (2000 ml/ha). The respective mortalities in case of amitraz, acrinathrin, bromopropylate were 44.69%, 53.40% & 36.24% at the lowest dose and the corresponding reductions at the highest dose were 54.31%, 65.14% & 43.28%. The maximum reduction was recorded in acrinathrin treated plots and therefore, it was most toxic to *Cunaxa* sp. while amitraz, dicofol, ethion and endosulfan was moderately toxic. Bromopropylate occupied the second position and may be considered as relatively safe acaricide to *Cunaxa* species. The differences recorded in between different treatments were significant except in the case of dicofol, ethion and endosulfan. The percentage reduction of cunaxid mite recorded during different days vary significantly among different treatments. The maximum reduction of predatory

Table 43.C: Adverse effect of some modern chemicals on *Cunaxa* spp. (predatory mite of red spider) of tea under field condition in the Dooars, W.B. during April-may, 1996 (mean of three applications)

Chemical	Dose (ml/ha)	Mean percent reduction at various days after spraying				
		1	3	7	12	Mean
Fenazaquin (10% EC)	2000	30.94 *(33.78)	42.71 (40.81)	32.02 (34.46)	23.68 (29.11)	32.34 (34.51)
	1000	22.81 (28.51)	32.90 (34.99)	22.83 (28.52)	14.48 (22.35)	23.25 (28.58)
Amitraz (20% EC)	2000	45.63 (42.49)	55.89 (48.39)	63.13 (52.62)	52.58 (46.48)	54.31 (47.50)
	1000	36.44 (37.12)	45.72 (42.54)	52.34 (46.34)	44.27 (41.71)	44.69 (41.93)
Acrinathrin (15% EC)	400	56.59 (48.79)	67.30 (55.14)	73.20 (58.84)	63.48 (52.82)	65.14 (53.90)
	200	44.23 (41.68)	56.37 (48.66)	61.71 (51.78)	51.29 (45.74)	53.40 (46.96)
Bromopropylate (50% EC)	2000	38.75 (38.49)	49.22 (44.55)	47.02 (43.29)	38.15 (38.13)	43.28 (41.12)
	1000	32.12 (34.52)	41.29 (39.98)	41.63 (40.18)	29.92 (33.15)	36.24 (36.96)
Dicofol (18.5% E.C.)	2000	53.12 (46.79)	63.02 (52.55)	62.04 (51.97)	51.31 (42.42)	57.37 (48.43)
	1000	42.12 (40.47)	50.67 (45.38)	50.12 (45.06)	41.41 (40.06)	46.08 (42.74)
Ethion (50% E.C.)	2000	46.71 (43.11)	55.51 (48.17)	58.59 (49.96)	66.66 (54.74)	56.87 (48.99)
	1000	33.07 (35.09)	41.45 (40.07)	44.07 (41.59)	52.66 (46.53)	42.81 (40.82)
Endosulfan (35% E.C.)	2000	45.57 (42.45)	59.45 (50.46)	65.91 (54.29)	62.44 (52.21)	58.34 (49.85)
	1000	38.50 (38.35)	50.31 (45.18)	52.91 (46.67)	54.93 (47.83)	49.16 (44.51)
Control (water spray)	-	03.84 (11.28)	04.00 (11.52)	04.20 (11.81)	03.73 (11.12)	03.94 (11.43)
Mean		38.03 (37.53)	47.72 (43.23)	48.78 (43.83)	43.40 (40.29)	44.48 (41.22)

Difference between C.D. at	P = 0.05	P = 0.01
Days	0.69	0.91
Chemicals	1.33	1.76
Day x Chemical	2.66	3.51

* Figures in parentheses are angular transformed values

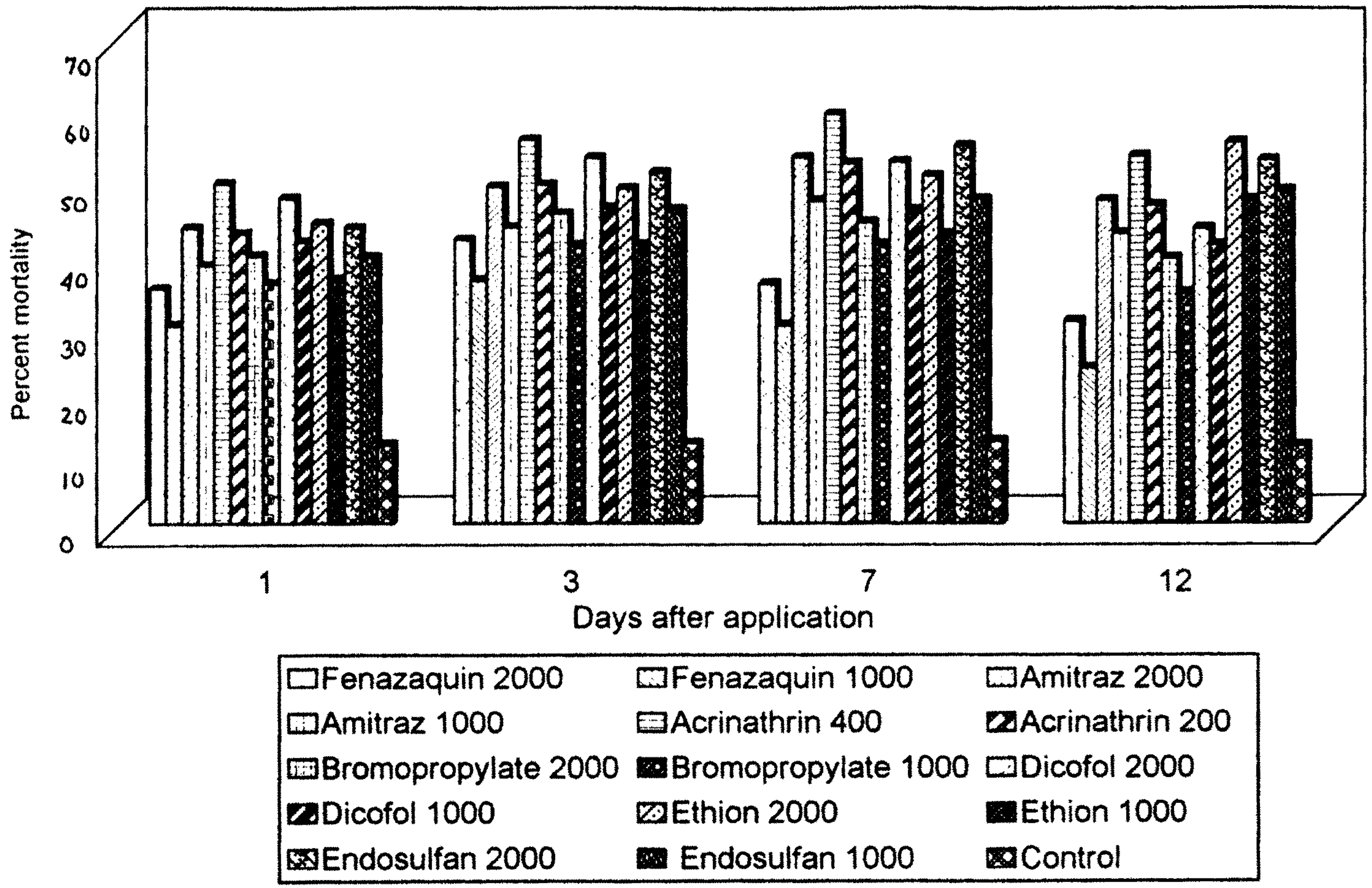


Fig. 43.C.1 : Adverse effect of some modern chemicals on *Cunaxa* spp. (predatory mites of red spider) of tea under field condition in the Dooars, W.B. during April-May 1996 (mean of three applications)

mite was recorded on 7th day in most of the cases except in fenazaquin and bromopropylate. The significant interaction between two factors indicated that the adverse effect of chemicals was no similar following different patterns among the treatments.

It has been reported in several instances that most of the chlorinated hydrocarbons and their relatives are toxic to predatory mites. Endosulfan is relatively non-toxic and specific acaricides like dicofol and tetradifon have low toxicity in most of the predatory mites (Jeppson *et al.*, 1975). The range of mortality on *Phytoseiulus persimilis* varied between 30-69% when exposed to endosulfan and the corresponding values in bromopropylate, cypermethrin, fenvalerate etc. ranged between 70-100% (Stamenkovic and Peric, 1984). Studies undertaken in different parts of the world with fenazaquin revealed that it is relatively safe to natural enemies belonging to Phytoseiid. It is widely recomended for use in IPM programme in apple against *Panonychus ulmi* (Fitzgerald *et al.*, 1992; Pollak *et al.*, 1992; Solomon *et al.*, 1993). Almost similar observation was recorded during the present investigation. Fenazaquin has proved itself as a most promising candidate in respect of its safeness to predatory mites. The reduction in population of the three groups of predatory mite i.e. *Amblyseius*, *Agistemus* and *Cunaxa* species was less than 50% in the fenazaquin treated plots. In case of *Amblyseius* and *Agistemus* it was little over 30%.On the otherhand, conventional acaricides like ethion, dicofol etc. inflicted around 60% reduction in population of these predatory mites. A wide range in selectivity of the pesticides on different groups of predator was evident from this present investigation. Bromopropylate was relatively safe to *Cunaxa* sp. while dicofol was relatively safe to *Agistemus* sp. when the relative toxicity of eight chemicals taken into acount. Fenazaquin by virtue of its selectivity to predatory mites may be univocally recomended in IPM of red spider mite for its low toxicity to all, the three groups of predatory mites.

4.15 ADVERSE EFFECT OF THREE FORMULATIONS OF SULPHUR, NEEM BIOCIDE AND CONVENTIONAL PESTICIDES ON PREDATORY MITES OF RED SPIDER OF TEA

4.15.1 Adverse effect of three formulations of sulphur neem biocide and conventional pesticides on *Amblyseius* spp., a predatory mite of red spider of tea under field condition at Dooas, W.B. during March-April 1996

The polled data on the adverse effect of three sulphur formulations, neembiocide and conventional pesticides on *Amblyseius* sp. have been presented in Table.44.A and Fig.44.A.1. Significant variation was recorded in respect of population reduction of *Amblyseius* spp. among seven treatments. Minimum adverse effect on *Amblyseius* sp. was recorded in sulphur treated plots and no significant difference was recorded among three formulations of sulphur. The respective mortality in case of wettable sulphur, liquid sulphur & colloidal sulphur were 38.07%, 40.87%, 34.26% at the lowest dose (1:100) and the corresponding reductions at the highest dose (1:200) were 49.69%, 49.49% & 48.85%. Neem (1500 ppm) has significant less adverse effect on *Amblyseius* sp. compared to conventional pesticides like endosulfan & dicofol used in mite control. The percentage of reduction of *Amblyseius* sp. in case of neem was 56.92% at the highest doses (1:100) and 41.53% at the lowest doses (1:200). In case of conventional pesticides like endosulfan and dicofol, the percentage of reduction of *Amblyseius* sp. were 67.21% & 62.37%, respectively at the highest doses (1:200) and 53.33%, 44.96%, respectively at the lowest doses (1:400). A decline in toxicity was recorded in all the cases on the 7th day after application. The pattern of toxicity of chemicals recorded during different days after application was not similar in seven treatments.

4.15.2 Adverse effect of three formulations of sulphur, neem biocide and conventional pesticides on *Agistemus* spp. a predatory mite of red spider of tea under field condition at Dooas, W.B. during March-April 1996.

The adverse effect of three sulphur formulations, neem biocide and conventional pesticides on *Agistemus* sp. have been presented in Table.44.B and Fig.44.B.1. Seven treatments

Table 44.A : Adverse effect of three formulations of sulphur , neem biocide and conventional pesticides on *Amblyseius* spp. (predatory mites of red spider) of tea under field conditions in the Dooars, W.B. during March-April, 1996 (mean of three sprayings)

		Mean % reduction in population of predatory mite at various days after spray				
Chemical	**Dilution**	**1**	**3**	**7**	**9**	**Mean**
Wettable sulphur (80% WP)	1:100	48.85 *(43.34)	54.02 (47.31)	55.45 (48.13)	40.43 (39.48)	49.69 (44.81)
	1:200	36.13 (36.94)	41.80 (40.28)	43.58 (41.31)	30.78 (33.69)	38.07 (38.06)
Liquid sulphur (20% E.C.)	1:100	51.15 (45.66)	52.93 (46.68)	54.16 (47.39)	39.74 (39.08)	49.49 (44.70)
	1:200	42.16 (40.49)	44.49 (41.83)	46.68 (42.52)	30.15 (33.30)	40.87 (39.53)
Colloidal sulphur ('52'S)	1:100	50.71 (45.41)	55.09 (46.92)	55.06 (47.91)	34.56 (36.00)	48.85 (44.06)
	1:200	33.00 (35.05)	37.76 (37.91)	38.77 (38.51)	27.51 (31.62)	34.26 (35.78)
Neem (1500 ppm)	1:100	59.97 (50.75)	62.29 (52.12)	59.62 (50.55)	45.82 (42.60)	56.92 (49.01)
	1:200	42.42 (40.64)	47.03 (43.29)	44.14 (41.63)	32.53 (34.76)	41.53 (40.08)
Endosulfan (35% E.C.)	1:200	61.16 (51.46)	69.97 (56.78)	71.93 (58.01)	65.78 (54.21)	67.21 (55.12)
	1:400	50.06 (45.03)	55.69 (48.27)	56.07 (48.49)	51.52 (45.87)	53.33 (46.91)
Dicofol (18.5% E.C.)	1:200	61.57 (51.69)	69.54 (56.51)	68.29 (55.74)	50.07 (45.04)	62.37 (52.25)
	1:400	42.43 (40.64)	48.60 (44.20)	50.20 (45.08)	38.60 (38.41)	44.96 (42.08)
Control (water spray)	-	03.67 (11.01)	04.03 (11.57)	03.61 (10.94)	03.47 (10.70)	03.69 (11.05)
Mean		45.89 (42.14)	50.30 (44.68)	50.75 (44.94)	37.90 (37.45)	46.21 (42.30)

	Days	Chemicals	Day x Chemical
C.D. at 5%	0.54	1.04	2.09
C.D. at 1%	0.71	1.38	2.76

* Figures in parentheses are angular transformed values

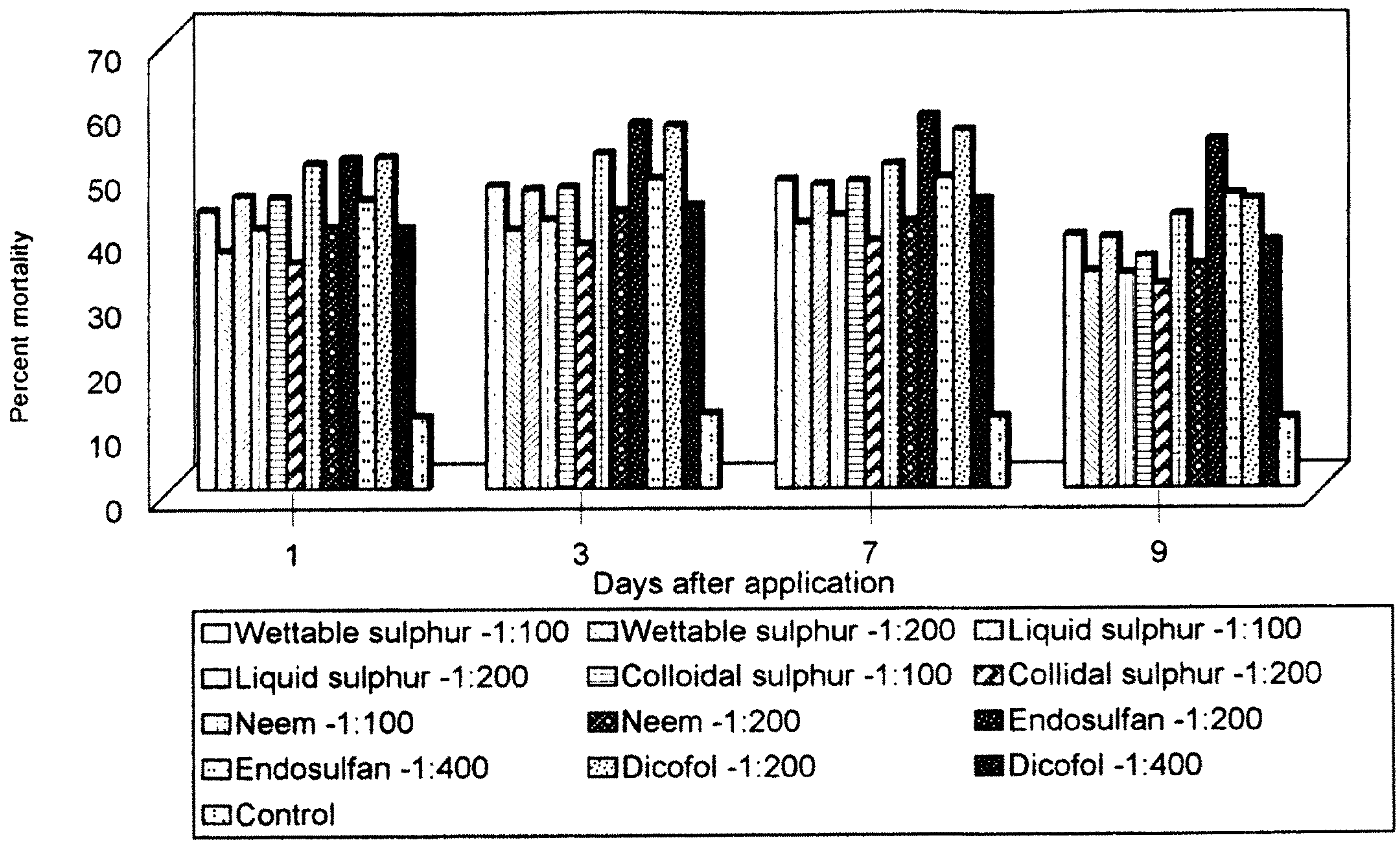


Fig. 44. A.1 : Adverse effect of three formulations of sulphur, neem biocide and conventional pesticides on *Amblyseius* spp. (predatory mites of red spider) of tea under field conditions in the Dooars, W.B. during March-April, 1996 (mean of three sprayings)

Table 44.B: Adverse effect of three formulations of sulphur, neem biocide and conventioned pesticide on *Agistemus* spp., (predatory mites of red spider) of tea under field condition in the Dooars, W.B. during March - April, 1996 (mean of three applications)

Chemical	Dilution	Mean % reduction in predatory mite of population at various days after spray				Mean
		1	3	7	9	
Wettable sulphur (80% WP)	1 : 100	53.80 *(47.18)	56.89 (48.96)	61.22 (51.49)	50.20 (45.11)	55.53 (48.19)
	1 : 200	42.60 (45.14)	46.35 (42.91)	49.34 (44.62)	38.47 (38.33)	44.19 (42.75)
Liquid sulphur (20% E.C)	1 : 100	50.19 (45.11)	54.67 (47.68)	57.96 (49.62)	47.48 (43.55)	52.57 (46.49)
	1 : 200	40.98 (39.80)	46.73 (43.12)	48.84 (44.33)	36.97 (37.44)	43.38 (41.17)
Colloidal sulphur ('52' S)	1 : 100	41.56 (40.14)	47.47 (43.55)	48.59 (44.19)	36.73 (37.30)	43.59 (41.29)
	1 : 200	31.51 (34.15)	36.56 (37.20)	38.20 (38.18)	29.44 (32.86)	33.93 (35.60)
Neem (1500 ppm)	1 : 100	50.89 (45.51)	55.57 (48.20)	57.92 (49.56)	50.60 (45.34)	53.74 (47.15)
	1 : 200	37.53 (37.77)	43.51 (41.27)	46.39 (42.93)	39.29 (38.82)	41.68 (40.20)
Endosulfan (35% E.C.)	1 : 200	55.90 (48.39)	65.30 (53.92)	67.64 (55.35)	64.24 (53.28)	63.27 (52.73)
	1 : 400	45.57 (42.26)	54.99 (47.86)	57.15 (49.10)	54.78 (47.75)	53.12 (46.79)
Dicofol (18.5% E.C.)	1:200	49.18 (44.53)	54.39 (47.52)	42.53 (40.70)	38.54 (38.37)	46.16 (42.78)
	1:400	41.06 (38.94)	44.64 (41.92)	35.28 (36.43)	32.06 (34.48)	38.26 (38.17)
Control (water spray)	-	03.94 (11.41)	04.06 (11.59)	03.55 (10.96)	03.47 (10.72)	03.75 (11.17)
Mean		44.08 (41.40)	49.12 (44.05)	49.82 (44.45)	41.89 (39.74)	46.23 (42.41)

	Days	Chemicals	Day x Chemical
C.D. at 5%	0.65	1.26	2.52
C.D. at 1%	0.86	1.67	3.33

*Figures in parentheses are angular transformed values

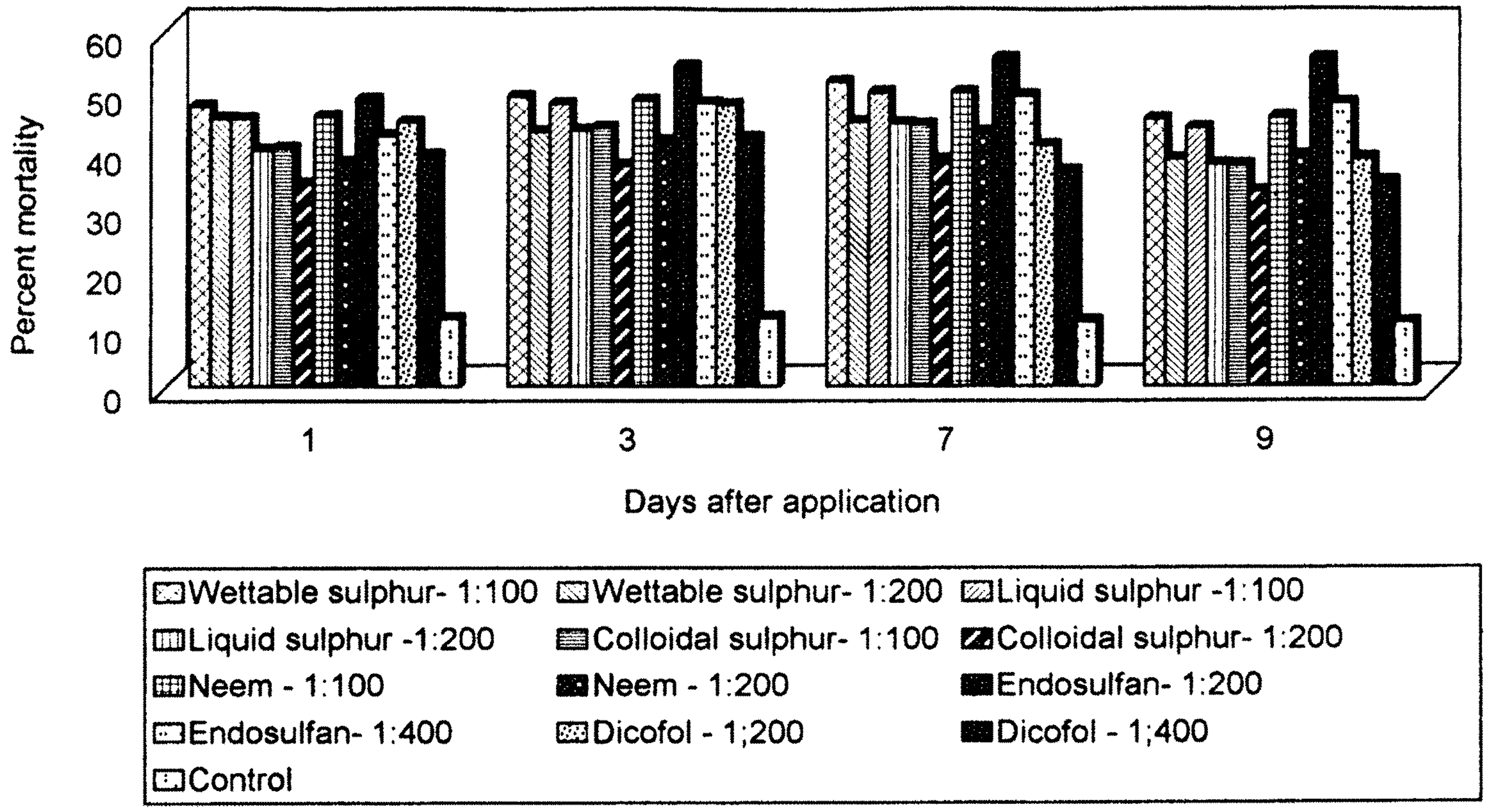


Fig. 44.B.1: Adverse effect of three formulations of sulphur, neem biocide and conventional pesticides on *Agistemus* spp. (predatory mites of red spider) of tea under field conditions in the Dooars, W.B. during March -April, 1996 (mean of three sprayings)

differed significantly in its adverse effect to *Agistemus* sp. Colloidal sulphur showed significant less adverse effect compared to others and the reduction of *Agistemus* sp. to the tune of 43.59% at highest doses (1:100) and 33.93% at lowest doses (1:200) were recorded. The respective mortality in case of wettable sulphur and liquid sulphur were 55.53%, 52.57% at the highest doses (1:100) and the corresponding figures at the lowest doses (1:200) were 44.19%, 43.38%. Dicofol ranked second in position in safety to *Agistemus* sp. providing only 46.16% and 38.26% reduction at the highest and lowest doses, respectively. The maximum reduction was recorded in endosulfan treated plots. The toxic effect of the chemicals persisted upto 7 days with a sharp decline thereafter. The pattern of decline in toxicity was not similar in different treatments. Therefore, the interaction of two factors, chemicals and day was significant. The toxicity of pesticides largely depends on their formulation used . A change in formulation not only brings in an increase or decrease in the toxicity of chemicals, but its selectivity to predaceous species may also change to a great extent. A change in toxicity pattern was recorded to two groups of predatory mites with the change in sulphur formulation. Colloidal sulphur was found to be relatively safe to *Agistemus* sp. compared to other two formulations. But it was as toxic as other two formulation incase of *Amblyseius* sp. All the sulphur formulaltions proved themselves to be much safer compared to dicofol which is a specific acaricide.

4.16 RESIDUE OF INSECTICIDES

4.16.1 Residue of dicofol (Kelthane 18.5 EC)

Residual data of dicofol (Kelthane 18.5 EC) in made tea at different post harvest interval in three different season is presented in Table.47 - 49. The corresponding regression equation, half life & T_{MRL} (waiting period or preharvest interval or PHI) have also been calculated on the basis of residual data. The initial deposits (after 4 hrs. of spraying) of dicofol were found to be in the range of 6.32 to 22.81 ppm irrespective of any seasons at the recommended doses (1:400). On the otherhand the initial deposit of dicofol were found to ranges from 8.77 to 32.81 ppm irrespective of any season at double the recommended doses (1:200). It is evident from the table that the dicofol residue gradually dissipated with increment of time. More than 60% residue dissipated within 7 days after application. The most salient feature of this study that the level of dicofol residual content present on 10th day sample is around 1 ppm at the recommended doses, whereas, at double the recommended doses it ranged from 1.74 to 4.36 ppm. In all the cases more than 80% dicofol residue was dissipated within 10 days after application. The half life values ($T_{1/2}$) were found to be in the range of 2.62 to 5.10 days irrespective of any doses & seasons.

It is evident from the meterological data of three different seasons that rainfall has significant contribution towards poor deposits of dicofol in the monsoon experiment (August, 1995). But in the dry season (pre-monsoon) the initial deposit of dicofol was as high as 32.81 ppm. However, the dissipation pattern is almost similar and the rate of discipation followed a first order direction kinetics irrespect of doses and season (Fig. 47.1, 48.1 & 49.1)

Various pesticide regulatory bodies of tea importing countries such as EPA (USA), Codex Alimentarius (UK), German Regulation (G.L.), FAO & WHO etc have set different tolerance limits (MRL) in tea especially for dicofol (Table.45). It is very much clear from the table that a wide variations in fixing MRL values by different regulatory bodies of different countries. In this study 5 ppm was considered as maximum residue limit recommended by FAO/WHO for determination of T_{MRL} value (PHI) (Anonymous, 1975).

On the basis of above MRL value, the T_{MRL} (PHI) value of dicofol was found to ranges from 1.589 to 5.833 days, Incase of double the recommend doses this values ranged from 4.136 to 10.474 days.

Very recently Barooah et al., (1995) determined the PHI values of dicofol in made tea, from two different field trials namely Tocklai & Dasjeeling. The PHI values were calculated as 4.64 & 4.32 days for Tocklai and Darjeeling, the resuls of which are comparable in our studies. From the waiting period data (PHI) it might be stated that the one round of plucking may be dicarded when dicofol is applied at the recommended doses.

4.16.2 Residual data of Acrinathrin (Rufast 15EC)

The residue data at different time interval, regrassion equation , half life & T_{MRL} for acrinathrin were represented in Table 50 to 52.

Table 45 : Maximum Residue Limit (MRL) in ppm

	FAO/WHO	EPA	Codex	G.L.	Japan	E.C	Russia
Dicofol	5	45	8	2	--	(d)	--

(d) Should levels be not adopted by 1.1.98, the maximum level (0.1) shall apply

Table 46 : Recovery of Insecticides from made Tea

Substrate	Sl.No.	Amount of insecticide added (ppm)	Amount of insecticide recovered(ppm)	% Recovery	Average % Recovery
Made Tea					
Dicofol	1	1.0	0.95	95.0	
	2	0.5	0.467	93.4	93.46
	3	0.1	0.092	92.0	
Rufast	1	1.0	.96	96	
	2	0.5	.472	94.4	95.8
	3	0.1	0.97	97	

Table 47 : Residue of Dicofol (Kelthane) in made Tea (1st season ; Premonsoon).

Sampling in days (PHI)	Residues in ppm (µg/g) [% Dissipation]	
	T_1 (1 : 400)	T_2 (1 : 200)
0	19.74	27.16
1	14.37 (27.2)	21.72(20.02)
3	11.24 (41.03)	17.50 (35.36)
7	5.39 (72.69)	10.35 (61.89)
10	1.08 (96.48)	3.05 (88.77)

For T_1, Regression equation : $Y = 3.337 - 0.115X$, $T_{1/2}$: 2.62 d $T_{MRL} = 5.185$

T_2, Regression equation : $Y = 3.467 - 0.086X$, $T_{1/2}$: 3.50 d $T_{MRL} = 8.546$

Table 48 : Residue of Dicofol (Kelthane) in made Tea (2nd season ; monsoon).

Sampling in days (PHI)	Residues in ppm (μg/g) [% Dissipation]	
	T_1 (1 : 400)	T_2 (1 : 200)
0	6.32	8.77
1	3.50 (44.62)	5.96 (32.26)
3	2.95 (53.32)	4.26 (51.42)
7	2.25 (64.39)	3.74 (57.35)
10	1.06 (83.22)	1.74 (80.15)

For T_1, Regression equation : $Y = 2.707 - 0.064X$, $T_{1/2}$: 4.70 d $T_{MRL} = 1.589$

T_2, Regression equation : $Y = 2.88 - 0.059X$, $T_{1/2}$: 5.10 d $T_{MRL} = 4.136$

Table 49 : Residue of Dicofol (Kelthane) in made Tea (3rd season ; Premonsoon).

Sampling in days (PHI)	Residues in ppm (μg/g) [% Dissipation]	
	T_1 (1 : 400)	T_2 (1 : 200)
0	22.81	32.81
1	17.37 (23.84)	21.35(34.92)
3	13.05 (42.78)	16.25 (50.47)
7	6.25 (72.59)	10.28 (68.66)
10	1.34 (94.12)	4.36 (86.71)

For T_1, Regression equation : $Y = 3.404 - 0.113X$, $T_{1/2}$: 2.66 d $T_{MRL} = 5.833$

T_2, Regression equation : $Y = 3.469 - 0.078X$, $T_{1/2}$: 3.86 d $T_{MRL} = 10.474$

Table 50 : Residue of Acrinathrin (Rufast) in made Tea (1st season ; Premonsoon).

Sampling in days (PHI)	Residues in ppm (µg/g) [% Dissipation]	
	T_4 (1 : 4000)	T_5 (1 : 2000)
0	3.21	5.87
1	1.02(68.22)	3.14(49.40)
3	0.45 (85.98)	1.25 (78.70)
7	0.03 (99.06)	0.52 (91.14)
10	< 0.01(N.D)	0.09(98.46)

N.D. = Not-detected (minimum detectable limit 0.01ppm)

For T_4, Regression equation : $Y = 3.412- 0.277X$, $T_{1/2}$: 1.08 d $T_{MRL} = 5.44$

T_5, Regression equation : $Y = 3.696- 0.165X$, $T_{1/2}$: 1.82 d $T_{MRL} = 10.72$

Table 51 : Residue of Acrinathrin (Rufast) in made Tea (2nd season ; monsoon).

Sampling in days (PHI)	Residues in ppm (µg/g) [% Dissipation]	
	T_4 (1 : 4000)	T_5 (1 : 2000)
0	1.998	4.46
1	1.296 (35.13)	2.50 (43.94)
3	0.151 (98.14)	0.369 (91.17)
7	0.02	0.06 (98.65)
10	< 0.01(N.D.)	< 0.01(N.D.)

N.D. = Not-detected (minimum detectable limit 0.01ppm)

For T_4, Regression equation : $Y = 3.33 - 0.29X$, $T_{1/2}$: 1.04 d $T_{MRL} = 4.59$

T_5, Regression equation : $Y = 3.592 - 0.27X$, $T_{1/2}$: 1.11 d $T_{MRL} = 6.10$

Table 52 : Residue of Acrinathrin (Rufast) in made Tea (3rd season ;Premonsoon).

Sampling in days (PHI)	Residues in ppm (µg/g) [% Dissipation]	
	T_4 (1 : 4000)	T_5 (1 : 2000)
0	3.52	6.82
1	1.51 (51.10)	3.07 (54.98)
3	0.61 (82.38)	1.75 (74.34)
7	0.17 (95.17)	0.69 (89.88)
10	0.04 (98.86)	0.12 (98.24)

For T_4, Regression equation : $Y = 3.431 - 0.181X$, $T_{1/2}$: 1.663 d $T_{MRL} = 8.54$

T_5, Regression equation : $Y = 3.757 - 0.157X$, $T_{1/2}$: 1.917 d $T_{MRL} = 11.68$

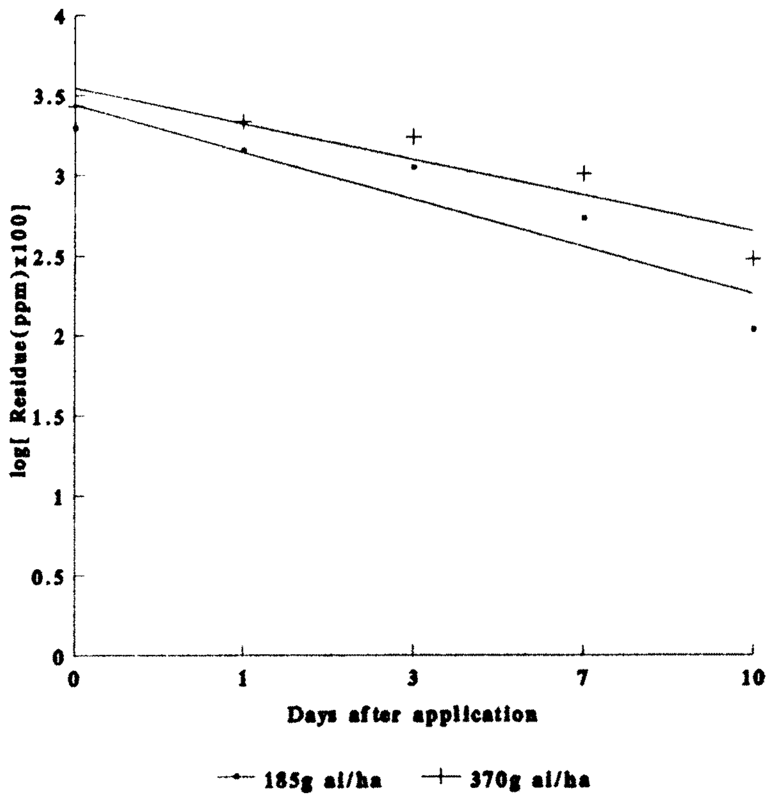


Fig-47.1:Linear plot for first order reaction kinetics of Dicofol on made tea(pre-monsoon,1995).

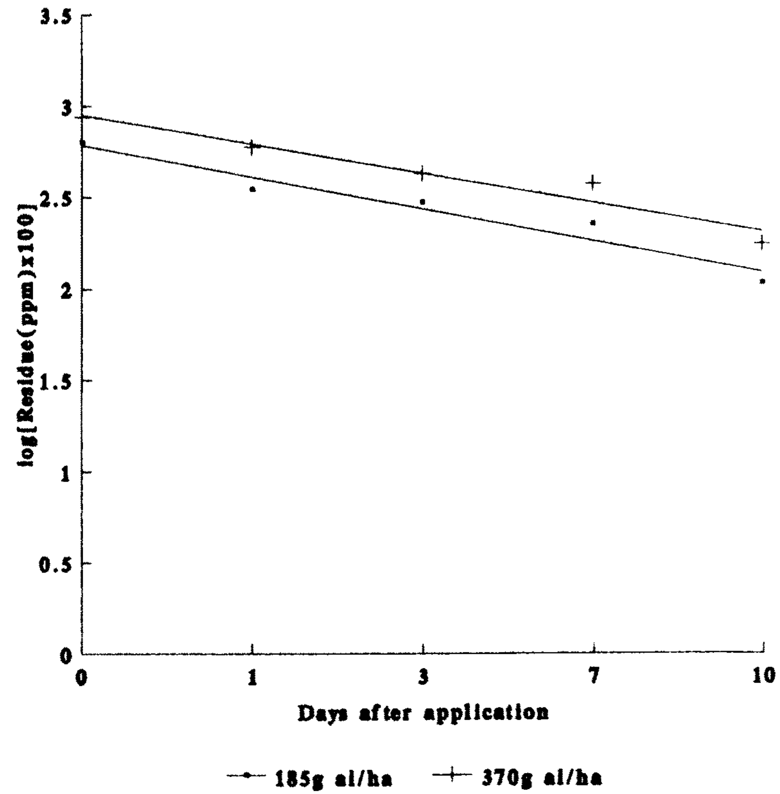


Fig-48.1:Linear plot for first order reaction kinetics of Dicofol on made tea (monsoon, 1995)

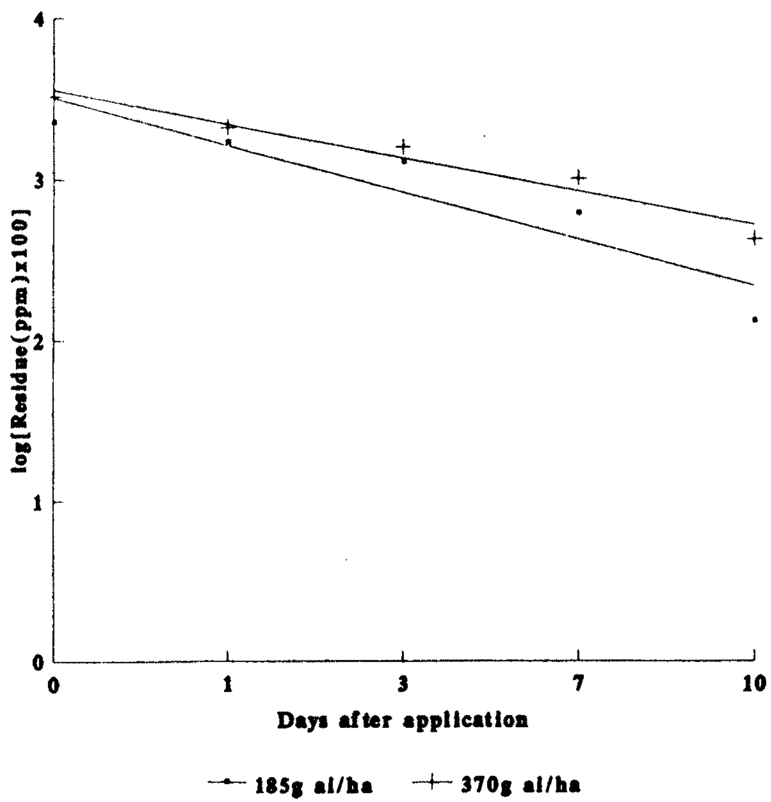


Fig-49.1:Linear plot for first order reaction kinetics of Dicofol on made tea (pre-monsoon, 1996)

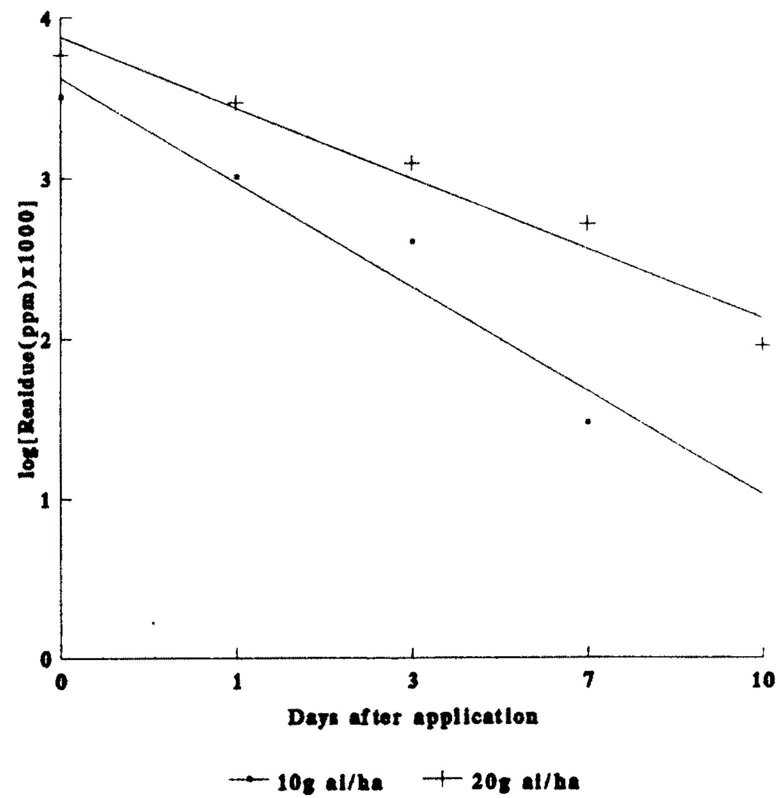


Fig-50.1:Linear plot for first order reaction kinetics of Rufast on made tea (pre-monsoon,1995)

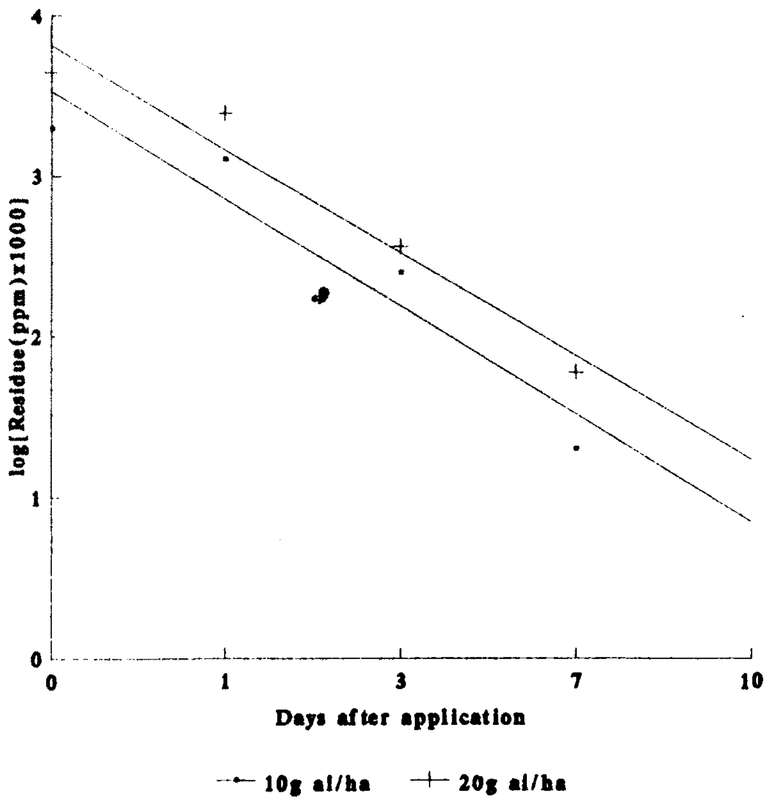


Fig-51.1:Linear plot for first order reaction kinetics of Rufast on made tea (monsoon,1995)

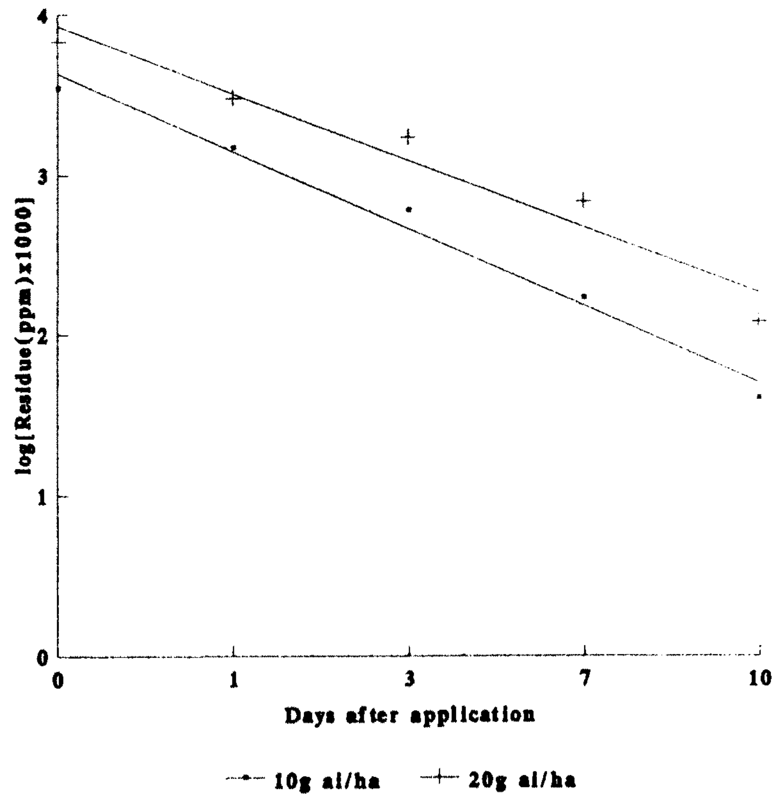


Fig-52.1:Linear plot for first order reaction kinetics of Rufast on made tea (pre-monsoon,1996)

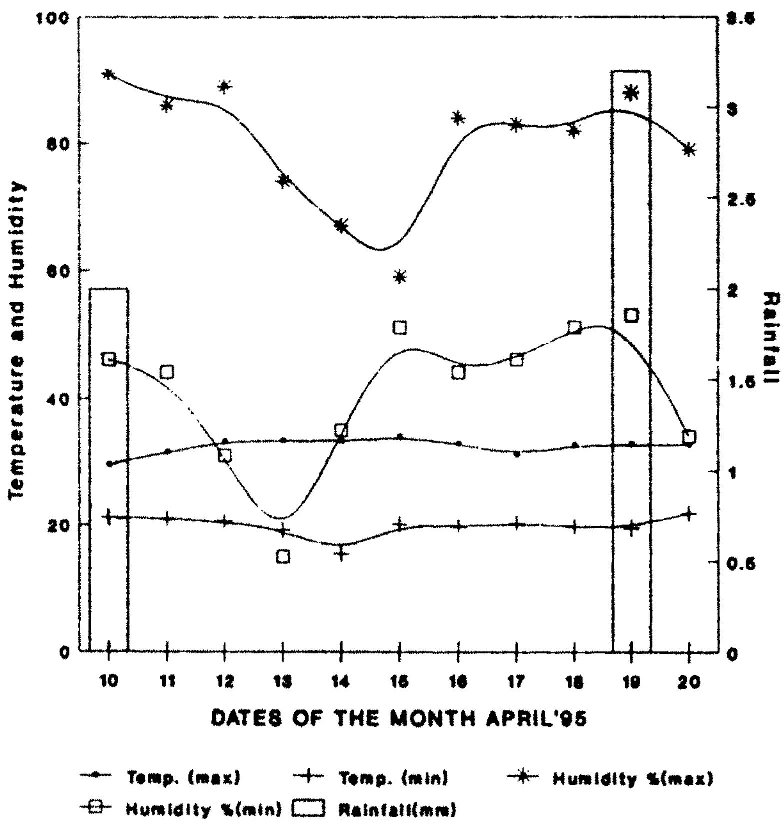


Fig.53.1:GRAPHICAL REPRESENTATION OF WEATHER PARAMETERS (Pre-monsoon,1995) DURING THE EXPERIMENT.

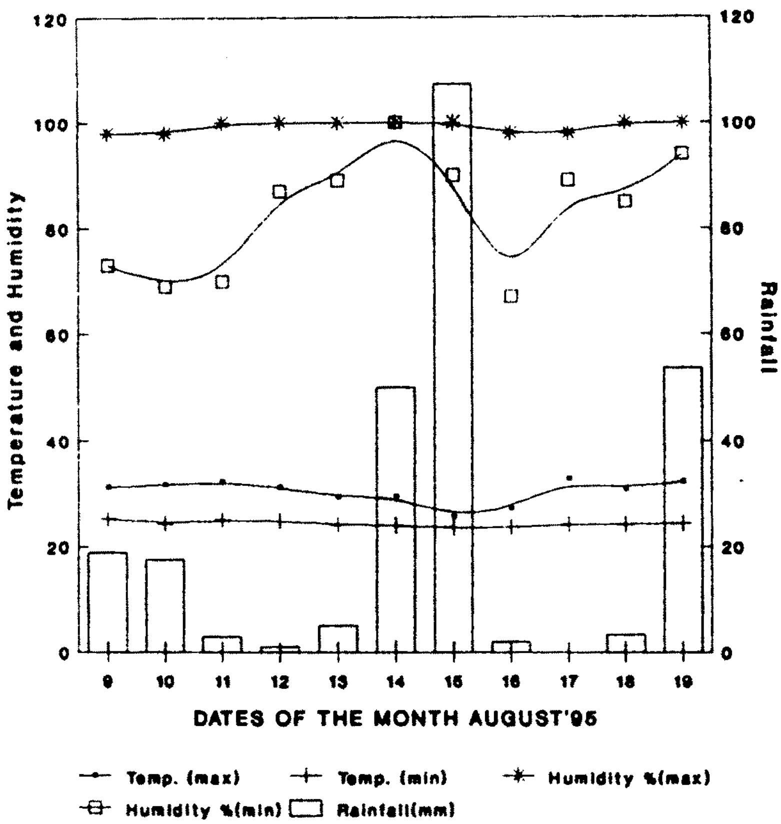


Fig.53.2:GRAPHICAL REPRESENTATION OF WEATHER PARAMETERS (Monsoon,1995) DURING THE EXPERIMENT.

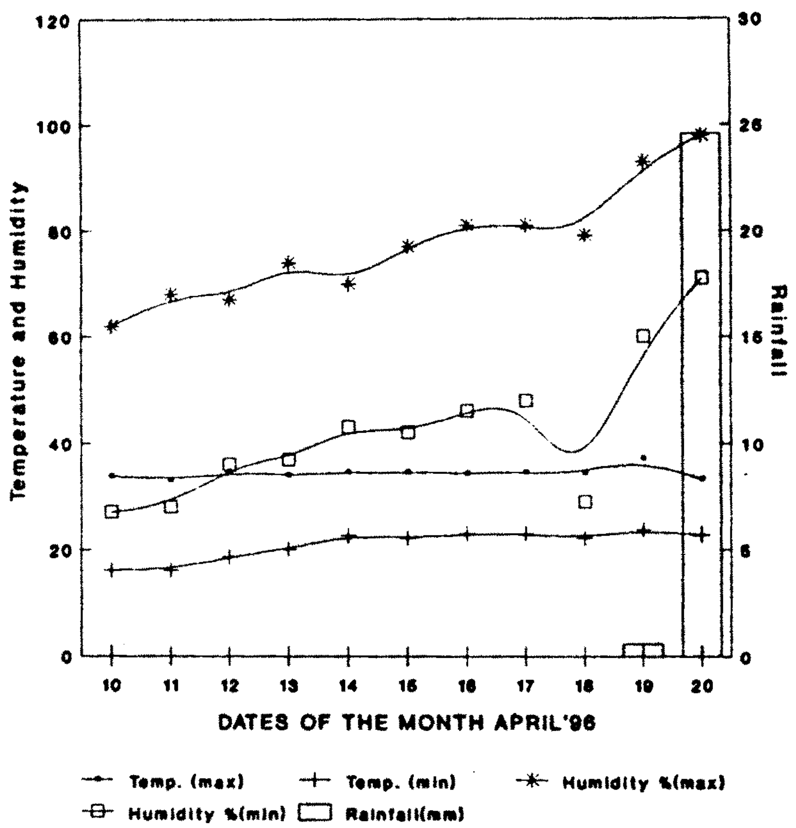


Fig.53.3:GRAPHICAL REPRESENTATION OF WEATHER PARAMETERS (Pre-monsoon,1996) DURING THE EXPERIMENT.

The initial deposits of acrinathrin were found to ranges from 1.998 to 3.52 ppm at recommended dose (1:4000). It is evident from the Table 50 to 52 acrinathrin gradually dissipated with increment of time irrespective of any season. On the other hand the initial deposits of acrinathrin were found to be ranges from 4.46 to 6.82 ppm irrespective of any season at double the recommend dose (1 : 2000). In case of recommended dose more than 95% residues dissipated within 7 days after application. But more than 98% residue of acrinathrin was eliminated within 3 days after application incase of August '95 (monsoon season). This discripency might happened due to heavy down pour during this period. In case of double the recommended dose (1:2000) the rate of dissipation was more or less similar with the recommended dose irrespective of any season. The half life values were varying from 0.497-1.917 days.

It is evident from the meteorological data of three different seasons that rainfall has significant contribution towards poor deposits of acrinathrin in the monsoon experiment (August, 1995). But in the dry-season (pre-monsoon) the initial deposit of acrinathrin was high as 6.82 ppm. However, the dissipation pattern is almost similar.

The MRL value of acrinathrin has not yet been established in tea. From various literatures survey it has been observed that European Community (E.C) has given a guideline level value (0.1ppm) for determination of PHI of new synthetic pyrethroids in tea. On the basis of above value the PHI value of acrinathrin was found to ranges from 4.59 to 11.68 days at recommended doses. Therefore, it is our opinion on the basis of the present study tht there is no necessity to discard first plucking when acrinathrin is being applied at the recommended dose in Tea plantation.

Chapter - V

Summary and Conclusion

Summary And Conclusions

It appears from the survey, that the most prevailing species of phytophagous mite in tea plantation was the red spider mite, *Oligonychus coffeae*. The mite species was found to dominate over the other phytophagous species belonging to family Tenuipalpidae, *Brevipalpus phoenicis*, this was substituted through the calculated value of dominance factor which was highest in case of *O. coffeae* (88.05%) among the other available phytophagous species, i.e. *Brevipalpus phoenicis* (4.51%) *B. obovatus*,(4.29%) *Acaphylla theae*(2.11%) and *Calacarus carinatus* (1.04%).

Among insect predators, four groups were identified as major regulating factors of red spider mites population. *Stethorus*, *Scymnus* and *Scolothrips* were most important under high host density condition while *Chrysoperla* was considered to be important under moderate and low host density levels.

Thirty-five species of predatory mites were reported for the first time on tea plants during Junuary 1994 to December 1995 from three distinct agroclimatic zones of India (Dooars and Terai in West Bengal and Tripura) where tea is cultivated. About forty species of predatory mites have already been reported by us for the first time in the world on tea based on survey under taken during 1993-1996 in the north-east India.

Among predatory mites, Phytoseiidae, Stigmaeidae, Bdellidae, Ascidae, Tydeidae and Cunaxidae were the predominent groups. Among phytoseiids, *Amblyseius* was most important and they formed bulk of the phytoseiids. Only two species of *Typhlodromus* were identified. Only one species of phytoseiid was recorded in every location i.e. *A. herbicolus* and the other widely distributed species were *A. largoensis*, *A. mcmurtryi*, *A. kulini* and *A. longispinosus*. Six species of asciad mites were recorded out of which *Lasioseius phytoseioides* had wide distribution. Altogether six species of stigmaeid mite were collected and *Agistemus terminalis* was the most common. Out of four species of bdellid mite, only two were found in various locations. Only one species of anystid and cunaxid mite were recorded and the later one was distributed in six of the eight areas surveyed for this purpose. Among four species of tydeid mites, *Pronematus fleschneri* was found in almost all the place other than Darjeeling area. Though there were no preference of the predatory mites to various agroclimatic zones but Tripura, Kurseong (W.B.) and Dooars (W.B.) harvoured most of the predatory mites.

Among predatory mites, *Amblyseius herbicolus, A. largoensis, A. kulini, Agistemus fleschneri, A. terminalis, Typhlodromus homalii* etc. were found to be most important in regulating initial population build up of red spider mite based on the studies undertaken on three important ecological parameters like diversity index(D), coefficient of association (V_{AB} = A) and frequency of joint occurrence (J_{AB}) with their host.

The biology of *O. coffeae* studied under laboratory condition at different three combination of temperatures (26.0°C + 71.60% R.H., 30.5°C + 76.5% R.H. and 33.2°C + 79.85% R.H.) exhibited that the, life cycle (8.88±0.60 days) took shorter time and the egg laying capacity in cases both unfertilized (64.17±4.26 eggs) and fertilized (74.50±2.66 eggs) females were highest at 33.2°C and 79.85% relative humidity. Considering the effect of lower temperature, it appeared that, at that temperature, the life cycle was longest(13.23±0.61 days) but the fecundity in two cases fertilized (68.50±1.38 eggs) and unfertilized(58.50±2.07 eggs) were lowest.

Attempts were also made to study the seasonal incidence of the red spider in two different years, revealed that the regression of different abiotic factors on mite population were significant excepting sunshine hours and wind velocity. In case of predatory mite complex, it was found that during 1994, only rainfall and temperature has got positive and significant relationship with the build up of population, but, during next year, i.e., 1995, the three major abiotic factors i.e., temperature, R.H. and rainfall exhibited significant relationship with the fluctuating population. The extent of relationship between phytophagous mite in one hand with the predatory groups on the other showed that the effect of combination of *O. coffeae* and *Amblyseius, O. coffeae* and *Pronematus* were significant indicating their possibilities in suppressing the phytophagous mite population.

It is evident from the present investigation that the pest (red spider mite) and defender ratio (predatory mite) remained favourable (1.05:1 - 2.29:1) during the early part (January - February) of build up of red spider mite population. But it reached as high as 20.41 :1 - 23.61:1 during May-June when the flare up of red spider mite used to take place. The favourable ratio of 1:1 can be maintained to a great extent by judicious use of pesticides and thorough periodic release of predatory mites by restoring prey-predatory balance. The most interesting and contributing observation is that, the distribution of *A. herbicolus* is well synchronized with that of red spider mite. It also inhabits the areas of the tea bush which were occupied by red spider mite. Therefore, the predatory arachnid, *A. herbicolus* can contribute immensely in applied biological control of red spider mite in combination with other predatory species viz., *Agistemus terminalis, Amblyseius kulini* and *A. coccineae* occupying different ecological niches.

Border rows were identified as the most favoured ecological niche of red spider mite. The prey : predator ratio was exceedingly high under this situation indicating special attention to augment predatory insects rather than predatory mites in these special ecologically suitable place of red spider. However, stigmaeids (predatory mite) were able to maintain better favourable prey : predator ratio in comparison to phytoseiids.

Different types of pruning were found to have profound effect on relative abundance of red spider and predatory mites. Deep pruning and deep skiffing as against unpruned and light pruned were much better to maintain a favourable prey : predator ratio.

Out of nine pesticides evaluated, fenazaquin was found to be most against toxic red spider mite as evident from the lowest LC-50 values (0.000012). In other words it was more than 400 times toxic as compared to cypermethrin which exhibited least toxicity to red spider mite. The highest LC-50 values (0.0183) was recorded in this case. Among others, dicofol occupied the 2nd rank in the order of toxicity and its LC-50 values (0.000013) was very close to fenazaquin. The DDVP and monocrotophos placed themselves in the 3rd and 4th rank with LC-50 values 0.000017 & 0.00002, respectively. Sulphur and α- cypermethrin occupied the bottom rank indicating their very low toxicity to adult female of red spider mite and as such no appreciable difference in LC-50 values of these three pesticides (cypermethrin, sulphur and α-cypermethrin) was recorded.

In the conservation programme of natural enemies against four recently developed acaricides such as fenazaquin, amitraz, acrinathrin and bromopropylate were conducted to study their selective action, if any, against the red spider mite as well as predatory mite complex. It was observed, that, fenazaquin which is to be introduced in india shortly has least hazardous effects on predatory mite such as *Amblyseius, Agistemus, Cunaxa,* but, it was highly toxic against red spider mite of tea.

Adverse effect of conventional chemicals generally in mite control was evaluated against predatory mite. Sulphur and neem biocide (1500 ppm) provided least toxic effect on predatory fauna but sulphur alone gave good control of red spider mites, while neem (1500 ppm) failed to do so. AZA enriched neem formulation was found to possess good cidal effect of red spider but considerably safe to predatory mites. However, the killing action of AZA enriched formulation varied significantly among predatory species.

Advance formulations of pesticides are now being introduced in India. Selective use of formulations being safe to natural enemies but toxic to the pest has become a part and parcel in conservation of natural enemies. It was observed that colloidal and liquid sulphur formulations were relatively safe to predatory mite compared to conventional wettable powder formulation.

Use of microbial pesticides has long way to go in biocontrol of red spider mite. Two chemical preparation of biocides namely vertimec (*Streptomyces avermitilis*) and delfin (*Bacillus thuringiensis*) oil formulations were tested against red spider mite. It was observed that, vertimec was highly effective against red spider mite while the new formulation of *B.t.* was effective at higher doses. In addition, the oil formulation of *B.t.* was found to have good ovicidal action against red spider mite. In an other set of experiment, it was observed that the abamectin was effective at very low dose (62.5 mg/ml) with initial and persistant control of mites. It is safe to environment and does not cause any contamination to prepare tea and relatively safe to predatory mites. It deserves due attention for introduction in the control of red spider mite.

The rate of development of *Amblyseius coccosocius* was evaluated at different temperatures of 20,25,30 and 35°C with constant R.H. of 70% on the leaves of tea. The most suitable temperatures was found to be 25°C, as at this temperature the total developmental period was quite short with no mortality, longer oviposition period and higher fecundity. The highest mortality was observed at 35°C.

It was revealed from the feeding behaviour of five species of predatory mite viz., *Amblyseius herbicolus, A. coccineae, A. largoensis, A. coccosocius* and *Typhlodromus homalii*, that they were likely to be efficient at regulating red spider mite population at lower density level and may not be reliable predators of red spider at very high population level necessitating periodic releases of predatory mites during February-March to keep the red spider population below ETL.

The adverse effect of nine chemical such as dicofol, sulphur, fenazaquin, DDVP cypermethrin, monocrotophos, endosulfan, phosphamidon and α-cypermethrin was applied in tea red spider control programme against three major predatory mites. The LC-50 values of these chemicals varied between 0.0002 (in sulphur and fenazaquin being the least toxic to 0.000002 cypermethrin, α–cypermethrin and phosphamidon being most toxic). It was seen that the use of any of these chemicals at recommended doses would distrub the natural balance (prey-predator relationship) in favour of plant feeding mite necessitating mass scale release of predatory mites to restore the balance.

The residue of dicofol and acrinathrin was studied during three consecutive seasons viz., premonsoon (April, 1995), monsoon (August, 1995) and premonsoon (April, 1996) in the Dooars, West Bengal. The initial deposits (after 4 hrs. of spraying) of dicofol were found to be in the range of 6.32 to 22.81 ppm irrespective of any seasons at the recommended doses (1:400). On the other hand, the initial deposit of dicofol were found to vary from 8.77 to 32.81 ppm irrespective of any season at double the recommended doses (1:200). It was revealed that the dicofol residue gradually dissipated with increment of time. More than 60% residue dissipated within 7 days after application. In all the cases more than 80% dicofol residue was dissipated within 10 days after application. From the waiting period data (PHI) it might be stated that the one round of plucking may be discarded when dicofol is applied at the recommended doses. But incase of acrinathrin the initial deposits were found to ranges from 1.998 to 3.52 ppm at recommended dose (1:4000). On the other hand the initial deposits of acrinathrin were found to be ranges from 4.46 to 6.82 ppm at double the recommended dose (1:2000). Therefore, it is our opinion on the basis of the present study that there is no necessity to discard first plucking when acrinathrin is being applied at the recommended dose in tea plantation.

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