

# *Introduction*

# I. INTRODUCTION

## 1.1. LOCATION AND PHYSIOGNOMY

The tea plantations of Darjeeling hills of India are situated in the extreme north of the state of West Bengal between  $26^{\circ}$  and  $27^{\circ} 13'$  north latitude and between  $87^{\circ} 59'$  and  $88^{\circ} 53'$  east longitude. These are in the lower Himalayas and surrounded by the lower hills and valleys. The climate is temperate with average maximum and minimum temperatures  $25.70^{\circ}\text{C}$  and  $19.63^{\circ}\text{C}$  in summer months (June to September) and  $18.38^{\circ}\text{C}$  and nearly zero or even sub zero in winter months (November to February). Monsoon normally reaches by mid June and continues up to October with heavy downpour with average rainfall of 2000 – 3000 mm per annum. However, around 80 % of the total rainfall is received during 4 months from June to September. Winter is severe and prolong from November to February. The main industrial crop in different valleys is tea, though fruit like orange and vegetables like squash, cabbage, cauliflower, carrot, radish etc. are also grown commercially by individual farmers. Apart from tourism, Tea is the biggest industrial activity, offering the largest employment and earning in the hills.

## 1.2. EARLY HISTORY OF TEA CULTIVATION

The venture of tea cultivation in Darjeeling dates back to January 1834 when Lord William Bentinck proposed to the Council of the East India

Company the setting up of a Tea Committee to investigate and make recommendations on suitable areas for tea cultivation in India. The Tea Committee decided to send their secretary G. J. Gordon to China in order to acquire tea seeds and some tea workmen familiar to tea cultivation and manufacture. Gordon left Calcutta in June, 1834 on the sailing ship "Water Witch". Meanwhile, Tea Committee got the information about the availability of indigenous tea plant near Sadiya, Assam. But, it was too late to call back Gordon and the first consignment of some 80000 tea seeds was on the way to India which reached Calcutta in January 1835. The seeds were sent to Botanical Garden Calcutta for germination under the direction of Dr. Nathaniel Wallich. From this original consignment of china seed around 42000 young plants could be raised which were allocated to three main areas, 20000 to the hill districts in the Kumaon in North India, 2000 to the hills of South India and the remaining 20000 to Upper Assam of the then North East Frontier (Weatherstone, 1992). Out of this initial trial, seeds tried in Darjeeling grew well. As per the available records one Dr. Campbell, a civil surgeon, planted tea seeds in his garden at Beechwood, Darjeeling, 2100 m above mean sea level (amsl) as an experiment with reasonable success. Subsequently the government, in 1847, selected the area to raise tea nurseries. With the plants raised in the government nurseries, the first commercial tea gardens planted out by the British in Darjeeling hill area were Tukvar, Steinthal and Aloobari tea estates in 1852.

Darjeeling was then thinly populated and used as a hill resort by the army and some affluent people. Tea, being a labour intensive crop, required large number of workers for different operations starting from planting to

manufacture. To meet this requirement employment was offered to people from across the border, especially of Nepal.

It appears that in 1866, Darjeeling had 39 gardens producing a total crop of 21,000 kilograms of tea. In 1870, the number of gardens increased to 56 to produce about 71,000 kg of tea harvested from 4,400 hectares. During 1860-64, the Darjeeling Company was established with 4 gardens followed by Darjeeling Consolidated Tea Co. in 1896. By 1874, tea in Darjeeling became a profitable venture with 113 gardens covering approximately 6,000 hectares under tea (Anonymous, 2003a).

### **1.3. PRESENT SCENARIO OF TEA CULTIVATION**

At present there are 86 running gardens producing 'Darjeeling Tea' on a total land of 19,000 hectares. The total production ranges from 10 to 11 million kilograms annually.

Darjeeling estates still restrict to original orthodox type (whole leaf) of manufacture while the tea estates in plains subsequently switched over to CTC (Crushing, tearing and curling) manufacture. The Darjeeling tea, commonly known as "Champagne of tea", is unique in the world and highly valued due to its typical flavour. It has very high demand in different countries and 90 % of total produce is exported.

The planting material of tea is mostly china type with multi-stemmed collar, large number of small branches, small leaves and shoots. However,

Assam type tea was also grown earlier in considerable area, which is being replaced now by replanting with flavoury clones selected from the old china type population, because characteristics of the Assam type tea are not fulfilling Darjeeling requirement (Anonymous, 1957).

## 1.4. GROWTH HABIT OF TEA, THE FLUSHES AND THE HARVEST

Tea bush has a periodical growth habit with alternating states of growth and dormancy. The growing condition in between two states of dormancy is known as a flush. In North East India, though up to five flushes of growth is noticed in tea under pruning and plucking conditions, but the fifth flush is rare and found in only few genotypes (Anonymous, 1935). In commercial tea plantation of Darjeeling, there are four distinct flushes namely first, second, rain and autumn. The crop in each flush is having its own characteristics. In first flush, the new shoots starts to grow towards end February with increasing temperature and day length after a prolong dormancy during winter months from December to February. The shoots are small but dark green and having a tendency to go dormant at a small stage of 2 or 3 leaves and a bud. Along with the plucking, which removes the *banjhi* shoots, gradually the density of growing shoots and growth rate increases reaching its peak in April. Tea produced in this period is very valuable with typical first-flush flavour and characteristic thin liquor. There is great demand in the market. Around 16-18 % of season's crop is harvested during March-April. Then the first distinct dormancy (*banjhi*) spell starts from early May. After a heavy crop in April the

bushes pass through a long dormancy of three to four weeks depending on weather conditions. Towards end of May the shoots again start to grow entering into the second flush reaching the peak of second flush in June. The shoots are more uniform than first flush, yellowish and not as green as in the first flush. The crop harvested during this period is also very valuable with the typical muscatel flavour and fetches very high price in the export market. The crop during May and June is around 21-22 % of the whole season. The second dormancy comes towards early July. However, it is for a very short spell of say for 12-15 days. Then the rain flush starts from mid July or end July and continued to mid September. During this period the growth is fastest with all the favourable weather conditions. The shoot size is also largest with dark green luxuriant look in this period. The crop during this flush is really heavy and bulk of the crop *i.e.* around 45 % of the total crop of the season is harvested during the rain flush (July to September). But, the quality is diluted during this period. The flavour level goes down due to weather factors, mainly heavy rain, and faster growth rate. Sometimes unmanageable leaves also come to the factory affecting the typical Darjeeling manufacture, which requires great care. Plucking at required intervals to harvest standard size shoots also is affected due to shortage of pluckers. The price is the lowest for rain teas. This is followed by the third distinct dormancy period of 15-20 days. The autumn flush starts from mid October and continues to the end of November. The crop during this period is also valuable due to good flavour and typical autumn characters and fetches good price in the market. Around 15-18 % crop is produced from October to end of the season by first week of December. The time period of flush and dormancy mentioned above may vary slightly depending on weather conditions. Though tea under plucking condition

in Darjeeling undergoes into a total dormancy during winter, but during other dormancy periods some growths are always there on the plucking table though they are mixed with dormant (*banjhi*) shoots. The dormancy period varies in section to section depending on elevation and planting materials. Hence, plucking continues also during these dormancy periods (Barua, 1989; Darjeeling Planters' Associations' monthly crop data and personal observation).

In tea, the main harvestable produce is the top bud with two leaves below of a growing shoot, which is commonly known as "Two and a Bud". While plucking, ready "Two and a Buds" and soft dormant shoots (*Banjhi*) with one or two leaves are plucked leaving the immature ones. Under growing conditions these left over shoots generally achieve the harvestable stage in between 5-7 days in Darjeeling conditions. Hence, a plucking interval of 5-7 day is maintained in Darjeeling depending on the growth rate and to pluck the standard size of shoots to produce the world's finest tea.

## **1.5. MAJOR SUCKING PESTS OF TEA IN HILL SLOPES**

In the world more than thousand species of arthropods are known to be associated with different parts of tea plants. Out of them Lepidoptera form the major component (31.53%) followed by Hemiptera (26.29%) and Coleoptera (18.76%) (Chen and Chen, 1989). But, only around 300 species of insects and mites are recorded in India as tea pests under orders Acarina, Thysanoptera, Coleoptera, Lepidoptera, Isoptera and Hemiptera. A few minor pests have also been reported under Diptera, Hymenoptera and Orthoptera (Muraleedharan et

al. 2001).

Cramer (1967) estimated that tea in Asia suffers 8 % crop loss due to pests. Glover *et al.* (1961) reported 13 % crop loss, where as Banerjee (1993) reported a steady loss of 10 % due to overall pest attack as a generally accepted figure, which may at times go up to 40 % in devastating attack by defoliators. Sivepalan (1999) also reported that various assessments on crop loss by respective tea pest had been done from time to time in the different tea growing countries (most often empirically). This loss ranges from 5 to 10 to as high as over 50 percent. But, these differences are also dependent on the prevailing climate, genetic variation / uniformity (seed/clone), age of tea, soil type and the prevailing fertility status etc. As such, it is difficult to estimate the crop loss accurately caused by a particular species.

Like in plains, tea in the Darjeeling hills and its lower elevations is also attacked by a number of arthropod pests. Out of them, sap sucking pests like – thrips, green fly, aphid, tea mosquito bug, red spider mite are common. Foliage feeders like – flush worm, different lymantriid caterpillars, bunch caterpillar, red slug etc are occasionally active. Root borers and cockchafer are also found active. The sap sucking group causes considerable damage to tea every year and is a major factor of crop reduction. Out of them thrips and greenfly are most common in all the tea estates situated at higher elevations (1200 to 1800 m) of Darjeeling hills. Aphid is occasionally active mainly in pruned teas. Tea mosquito bug and red spider mite are generally found at lower elevation.



## 1.5.1. COMMON THRIPS – *Mycterothrips setiventris* Bagnall

(Thripidae: Thysanoptera)

Genus *Scirtothrips* include 40 species of thrips spread through the tropics of which 10 are known to be pests of different crops (Jacot-Guillarmond, 1971). Four species of the genus namely *S. bispinosus*, *S. dorsalis*, *S. auranti* and *S. kenyensis* attack tea in South India, Japan and North-East India, Malawi and Kenya respectively (Mound and Palmer, 1981). However, none of them are active in the high elevations of Darjeeling hills; instead a unique species of thrips, *Mycterothrips setiventris* has become a major pest of tea in Darjeeling heights.

**Early history** : Thrips are amongst the oldest insect pests known in tea plantation of Darjeeling. The pest attracted attention of the planters as early as 1907. Considering its severity during 1908, two Entomologists namely– H. Maxwell Lefroy, the then Imperial Entomologist to the Government of India and C. B. Antram, Entomologist to the Indian Tea Association were entrusted to conduct independent studies on thrips in Darjeeling. The publications of their studies were the first formal records of thrips pests in Darjeeling tea (Lefroy 1909 and Antram 1909). They reported three species of thrips active in tea and Antram named them as “Common thrips”, “Black thrips” and “Flower thrips”. Out of them Common thrips were reported to be the common in Darjeeling tea plantation, which attacked tea shoots, other two being mainly flower dwelling thrips.

Subsequently, Bagnall (1918) first described the common thrips as

*Physothrips setiventris* Bagnall after receiving some specimen of the insect in 1916 from E. A. Andrews (Andrews,1925). Thereafter the species was mentioned as *Taeniothrips setiventris* (Bagnall) by Dev (1964) and in subsequent publications of Tea Research Association.

The genus *Physothrips* is no longer in use since it has been synonymised. Ananthakrishnan and Sen (1980) while reviewing Indian Thysanoptera classified this species as *Mycterothrips setiventris* (Bagnall, 1918). The taxonomic classification of Common thrips by Ananthakrishnan (after Priesner, 1964) is as follows:

Order – Thysanoptera, Suborder – Terebrantia, Superfamily – Thripodea, Family – Thripidae, Subfamily – Thripinae, Tribe – Thripini, Subtribe – Thripina, Genus – *Mycterothrips*, Species – *M. setiventris*.

Common thrips is still a dominant species of thrips in Darjeeling, attacking tea shoots though other two species of thrips are also found to be active mainly on flowers.

**Damage symptoms:** This insect lives and feeds on the unopened and partially opened buds and tender leaves. The adult and the nymph make slits in the upper surface by inserting the stylets and suck the sap oozing out through the wounds causing lacerations of the tissues. The initial symptoms of attack are light brownish discolouration of the tip and the basal



Fig 1: a. Tea shoot severely infested by thrips  
b. Sand papery line →

part of infested buds and leaves. The leaf surface becomes uneven and curled. The puncture marks appear as minute brown spots in scattered patches and / or in continuous lines. The slit made in continuous lines in unopened buds appear as corky lines when the leaves unfold, commonly known as "sand papery line" (Fig.1b). There may be two or four such lines on a leaf with one or two on each side of the mid rib. Pruned tea under recovering stage is worst affected. The severely infested leaf shows roughened appearance, curls up and deforms. In pruned tea, severely infested shoot exhibits scorched-brownish appearance and remains stunted with short internode and small leaves (Fig.1a). The shoot will not grow further until the pest is controlled. Mkwaila (1982) reported up 20 % crop loss in late pruned teas due to attack of tea thrips *Scirtothrips aurantii*. It is also agreed by all concerned that there is a heavy loss of crop from thrips damage in Darjeeling (Anonymous 1994).

**Life cycle:** (Fig.: 2) Eggs are laid singly in the tissues of the buds and young leaves generally towards the veins and ribs. The incubation period is around 10 -16 days. The newly hatched pale yellow nymphs emerge through the upper surface. In case of eggs laid inside an unopened bud, the newly hatched nymphs emerge into the cavity inside the bud,

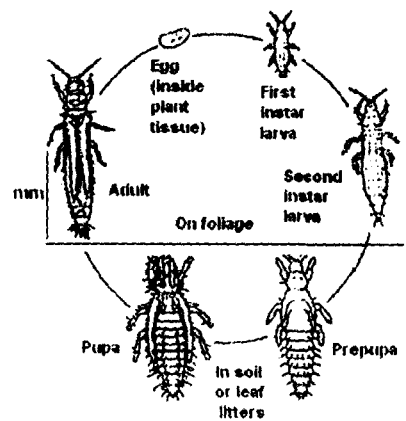


Fig 2: Diagrammatic representation of life cycle of thrips (adapted from Dev 1964)

where they live feeding happily until the bud unfolds. It moults to a similar second instar, but with a bigger size. It soon assumes a pale yellow colour and increases in size until it reaches around 1 mm in length. In general, the full

grown nymph goes to the ground and forms a prepupal stage distinguished by the shortening and swelling of the abdomen and development of two pairs of wing buds on two hinder thoracic segments. The prepupal is followed by pupal stage with more elongated abdomen, and developed wing-buds so as to reach almost half – way down the abdomen. This pupal stage gives rise to adult insect. There is considerable variation in the duration of the life cycle from the date of deposition of the egg to the maturity, which is 18 to 32 days suggesting over-lapping of generations. This in fact occurs and all stages of the insect are found throughout the season.

The adult female is minute and yellowish brown insect of 1.25 – 1.50 mm long (Fig. 3). Head and thorax are golden yellow while the abdomen is brownish black. Head bears a pair of large black compound eyes on each side and three simple eyes, red, looking like tiny rubies, arranged in a triangle with one in front and two behind.



**Fig.3: Common thrips (Female)**

The antennae, actually consisting of eight joints, appear to consist of six due to fusion and telescoping. The ovipositor is distinct as a narrow yellow band along the centre line. The two pairs of brownish narrow wings are fringed on both margins with long hairs. The male is slightly smaller than the female, around 1 mm long and golden yellow except the hind end of abdomen which is brown (Andrews, 1925).

The species is mainly confined to high elevation and not generally found

active in the plains. Dev (1964) reported that this species was not found active in the plains of the tea district of Cachiar, the Assam Valley, the Dooars and Terai suggesting its specific adaptation to hilly areas.

### **1.5.2. GREENFLY – *Empoasca flavescens* Fabricius (Cicadellidae: Homoptera)**

Though there is a change in the generic name of tea greenfly in recent years, in this publication, the pest is referred to as *Empoasca flavescens*, which was most commonly used in earlier literatures. The greenfly or jassid or tea leaf hopper is another common sucking insect pest in Darjeeling particularly during the period of first and second flush i.e. March to June. However, the pest remains active at various level of intensity through out the season. It was reported that green fly alone could cause around 10 % yield loss in Darjeeling during the period from mid March to end June (Grice, 1967).

**Damage symptoms:** (Fig. 4) Both adults and nymphs (Fig. 5) suck the sap from young leaves and tender stems. Nymphs are more damaging than adults. The affected leaves curl downwards; the margins become recurved, subsequently turn brown and gradually dry up. This typical symptom is known as “Rim Blight”. The mid rib and veins of affected leaves also show somewhat brownish discolouration. The infested shoots remain stunted and turn yellowish brown in colour. Reduced photosynthetic activities due to loss of chlorophyll coupled with likely imbalance in growth hormones as a result of jassid feeding might account for the stunted growth. The pest remains mainly on the under

surface of the leaves.

**Life cycle:** Whitish eggs are inserted singly inside the soft tissues of growing tea shoots and site of oviposition is indicated by swelling tissues. Eggs are elongated narrower at one end, slightly curved with smooth surface, measuring about 0.5 mm in



Fig. 4: Tea shoot infested by greenfly

length and 0.25 mm in width. Eggs turn to pale yellow in later stage with an incubation period of 10-13 days in March, 9-11 days in April and 6-8 days in May, June and July under laboratory condition at Tocklai , Assam.

The newly hatched nymph is a small colourless insect (Fig. 5b) with pink eyes and soon after feeding turns yellowish green. When disturbed it moves sideways. There are five instars with a total nymphal duration of 12-15



a



b

Fig. 5 : a. Greenfly adult  
b. Greenfly nymph

8-10 days in May and June. The exuviae remains attached to the leaf surface. The adult is a small yellowish green insect with pale yellow forewing (Fig. 5a). The male and female are 2.50 and 2.75 mm in length respectively (Anon., 1994).

### 1.5.3. APHID – *Toxoptera aurantii* Boyer de Fons (Aphididae: Homoptera)

This species of aphid is common and widely distributed throughout tea growing district of North – East India. In North East India, it was first noticed in 1873 on tea in Jorhat, Assam, then in Kumaon in 1885 and shortly afterwards in Darjeeling (Anonymous, 1994). In Tocklai (Assam, India), more tea aphids were observed in spring on young shoots of mature tea bushes as well as on seedlings in nurseries (Anonymous, 1994). Tulashvili (1930), King (1939) and Kalandadze (1956) reported *T. aurantii* as the most injurious pest of tea in Russia, Sri Lanka and in the Georgian republic respectively. Smee (1943) reported that *T. aurantii* was prevalent on tea in Nyesaland early in the season.

**Damage symptoms:** It is a ubiquitous pest colonizing the tender shoots, particularly of the young tea and the new growth after pruning. Both nymphs and adults suck the sap from tender stems, buds, petioles and lower surface of tender leaves along the mid rib. As a result of feeding, leaves crinkle and curl inwards



Fig.6: Tea shoot infested by aphids (inset - close up of aphids)

(Fig. 6) resulting in marginal necrosis at later stage of infestation. In the plains of Assam, pruned tea suffers from worst attack at the recovering stage when the fresh shoots are growing from mid January (Anonymous, 1994).

Aphids produce honeydew which serves as a medium on which a sooty

fungus, called sooty mold, grows. Sooty mold blackens the leaf, decreases photosynthetic activity and thus vigor of the host.

**Life cycle:** Males are not found and reproduction takes place parthenogenitically. Females are oval, shiny black, brownish-black or reddish brown in color, either with wings (alate form) or without wings (apterous form), measuring 1 – 2 mm in length. The antennae are short having black-and-white bands. Winged individuals normally have darker abdomens and are slightly thinner. The development of alate form is dependent on the population density and leaf age. Female (both alate and apterous forms) produce young nymphs throughout the year. Newly born nymphs remain in group. The nymphs undergo four moults to develop into an adult female. Total life cycle is completed in 9-10 days, 7-8 days, 6 days, 5 days, 5-6 days and 7 days during January-February, March, April-May, June, July-October and November respectively. Apterous female produces more nymphs than alate form. (Anonymous, 1994).

The above 3 sucking insect-pests (common thrips, green fly and aphid) attack the growing shoot, which is the only harvest in tea, thus causing a considerable loss in crop every year. But, there is a common belief amongst the planters that thrips and green fly infested shoots produce more flavoury tea and they are reluctant to use control measures during quality period like March – June and October. However, the matter has not been studied scientifically and it is doubtful if the crop loss is compensated by price realization due to improvement in quality. Moreover, no detailed study was conducted so far on the population dynamics of these sucking pests from hill slopes of Darjeeling



and natural enemies active under hill conditions.

Tea of Darjeeling slopes is having superior flavour and is highly priced. Any change in its quality or loss in quantity resulting from the attack of the sucking pests, specially thrips and green fly in Darjeeling valleys is worth investigating. So, a study was undertaken to know their varietal preference population dynamics, natural enemies, alternate hosts and the feeding impact on Darjeeling tea with the objectives detailed in following chapter.