Chapter 1

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Overview

1.1 Introduction

The oldest known beverage, tea is native of China in South East Asia. It was known to the Chinese as early as 2737BC, but attained the status of a popular drink in England in 1664 AD. Now it is still the popular drink in the world. In India, it is grown in an area of 5.10 lakh hectare. Since the first auction of Assam Tea made from indigenous plants held in London in 1839, tea plantation in India has been contributing immensely towards the socio economic development of the people of the tea growing regions of the country. It is an area where the country can take a lot of pride. This is mainly because of its pre-eminence as a foreign exchange earner and its contribution to the country's GNP. The establishment of the first commercial tea plantation, Tukvar Tea Estate, by the British owned East India Company in 1856 was believed to have heralded the beginning of a new era in the Darjeeling Hills by bringing about much needed economic growth. It is an indisputable fact that the economic development of the region coincided with the development of the tea plantations. The tea plantations opened up employment opportunities for local hill people but also for thousands of people from rural Nepal. According to the plantation labour Act (1951), promulgated by the Govt. of India, "a 'Plantation worker' is defined as the person who has been employed by the management to do any work, which is skilled, unskilled, manual or electrical: the person must not have drawn above Rs. 750/month". Indeed, there are thousands of individuals who work on various tea plantations in Darjeeling District as plantation worker for their livelihood. Even these days, the tea industry is providing employment to thousands of people as unskilled/ skilled workers, clerks and Managers [34,38].

Tea belongs to the genus Camellia and family Camelliaceae. The original species, which produces tea, were C. assamica (Assam jats), C.sinensis (China jats) and their natural hybrid, C.assamica subspecies lasiocalyx (Indo China or cambod type). Being a

highly cross-pollinated crop, the present day seedling populations are mixture of both the above two type can be distinguished [38].

1.2 Indian tea: It's position in Global Market

In all aspects of tea production, consumption and export, India has emerged to be the world leader, mainly because it accounts for 28% of global production. It is perhaps, the only industry where India has retained its leadership over the last 150 years. The other leading producers are China, Kenya and Sri Lanka. Indian Tea production in respect to global status is shown in figure 1.1 and production status of Indian tea during last three years may be observed from the figure 1.2 [33,34, 36, 37,38].

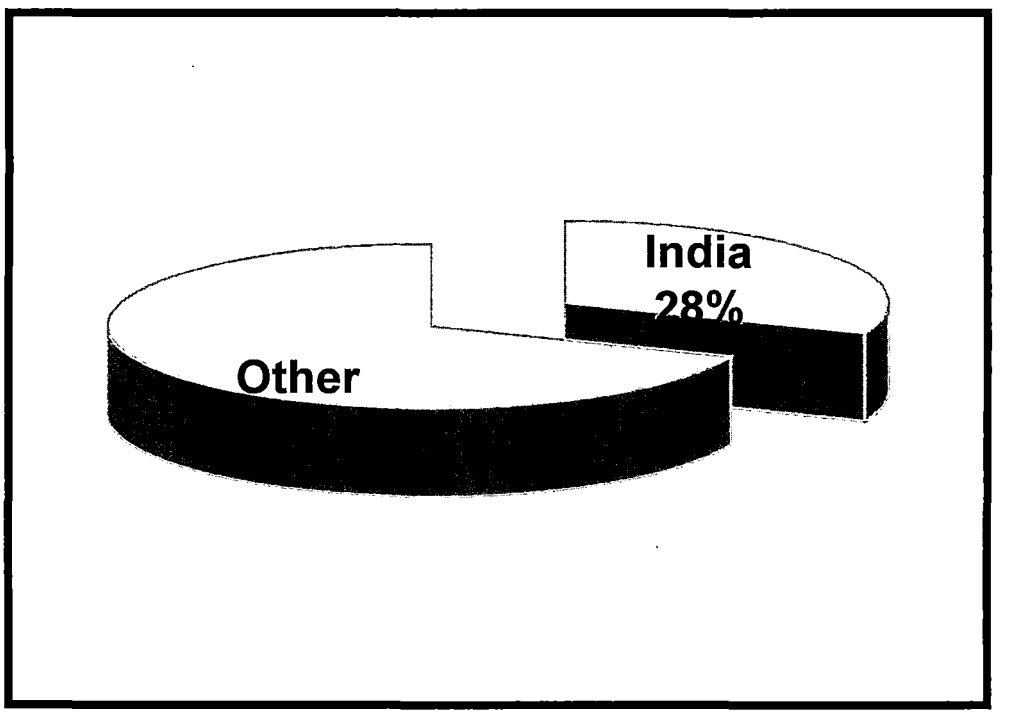
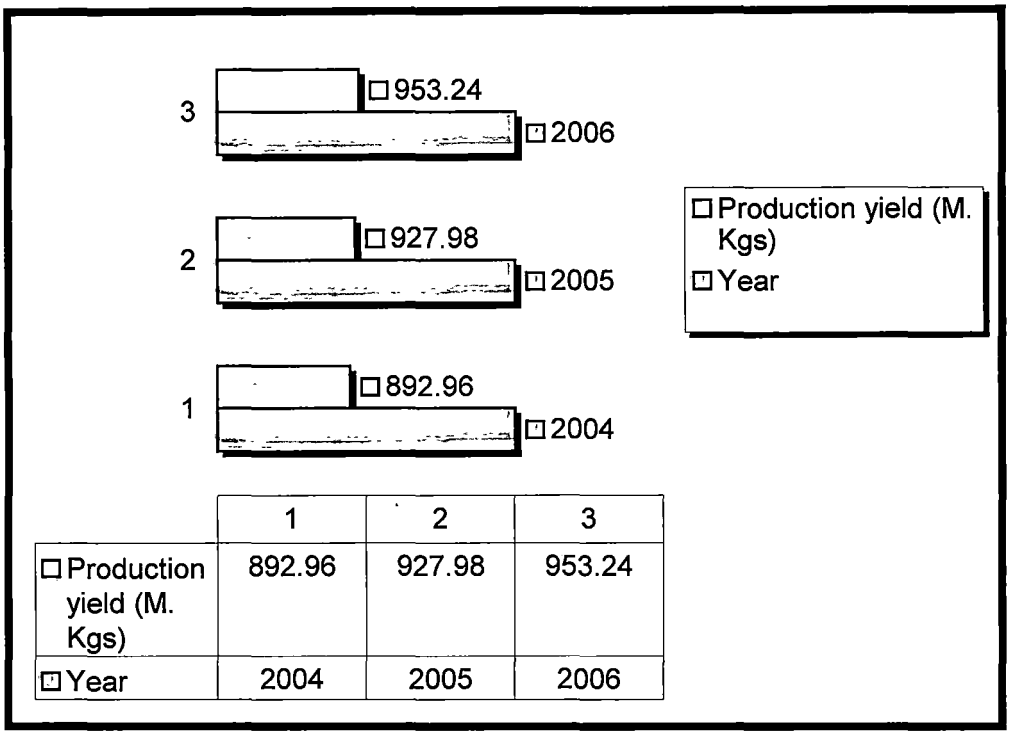


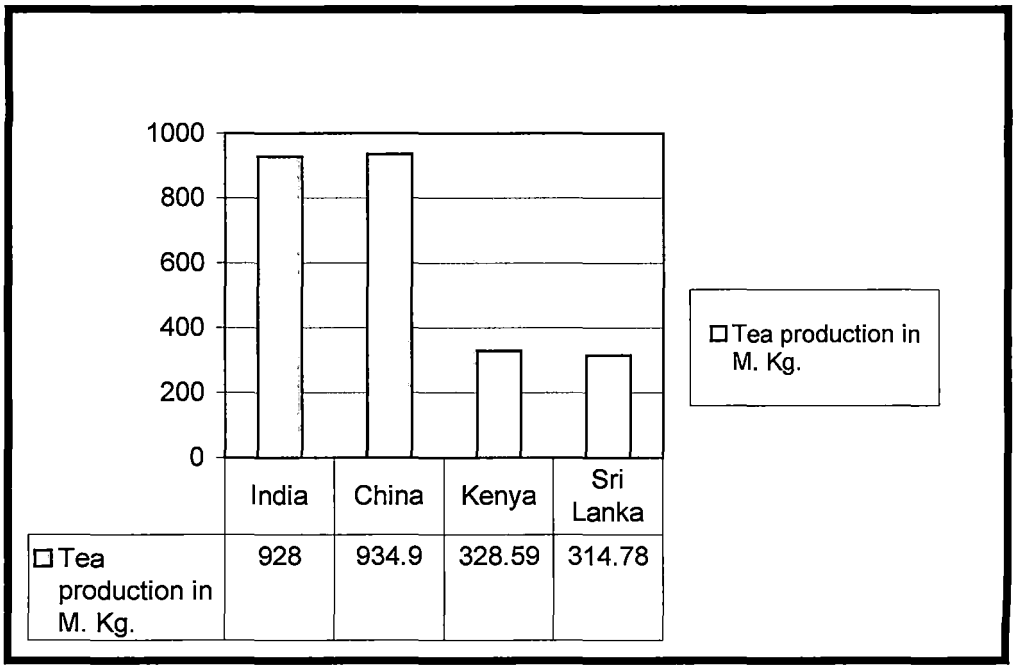
Figure 1.1: Indian tea production in respect of global scenario

But it has been seen that in 2005 China became the world leader in tea production by overtaking India. In 2005, world tea production was 3361.6 M. kgs where India produced 928 M. kgs and China produced 934.9 M. kgs. The figure 1.3 shows production of four major countries during the year 2005[40].



	1	2	3
Production yield (M. Kgs)	892.96	927.98	953.24
Year	2004	2005	2006

Figure 1.2: Indian tea production (M. Kgs)



	India	China	Kenya	Sri Lanka
Tea production in M. Kg.	928	934.9	328.59	314.78

Figure 1.3: Tea production of four major Countries during 2005

India continued to be the largest tea consuming country in the world, accounting for 22% of the global total, followed by China at 20%. The Russian Federation was at 5% and Japan 4.5%. Global tea consumption is shown in figure 1.4. Domestic tea consumption of Indian tea is increasing about 21 to 22 M. Kgs per year, which is shown in figure 1.5 [39].

Today the major tea growing states of India are Assam, West Bengal, Tripura, Tamil Nadu, Kerala and Karnataka. Himachal Pradesh and Uttaranchal are also traditional tea growing states, albeit to a less significant extent. Besides, tea plantation has come up recently in states like Arunachal Pradesh, Manipur, Sikkim, Nagaland, Meghalaya, Bihar, Orissa, etc. Mizoram has also the potential for development of commercial tea plantation. Among these states Assam is the major producer contributing about 52% of the total Indian production followed by West Bengal (about 22 %). Statewise production is shown in figure 1.6 [35,40].

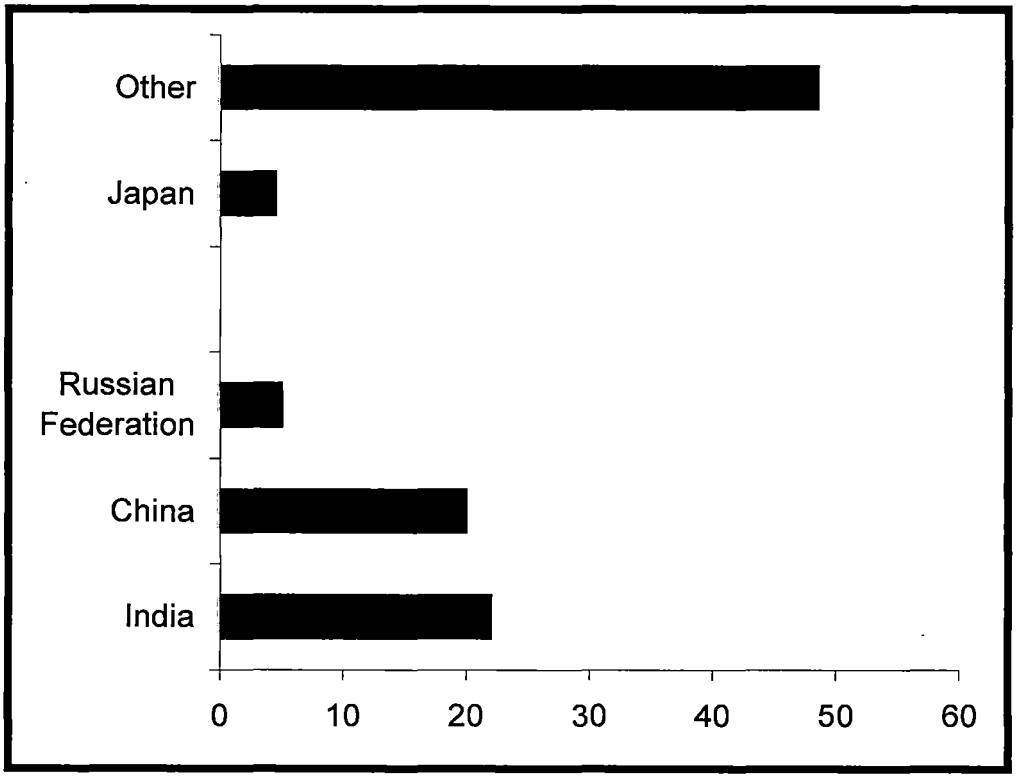
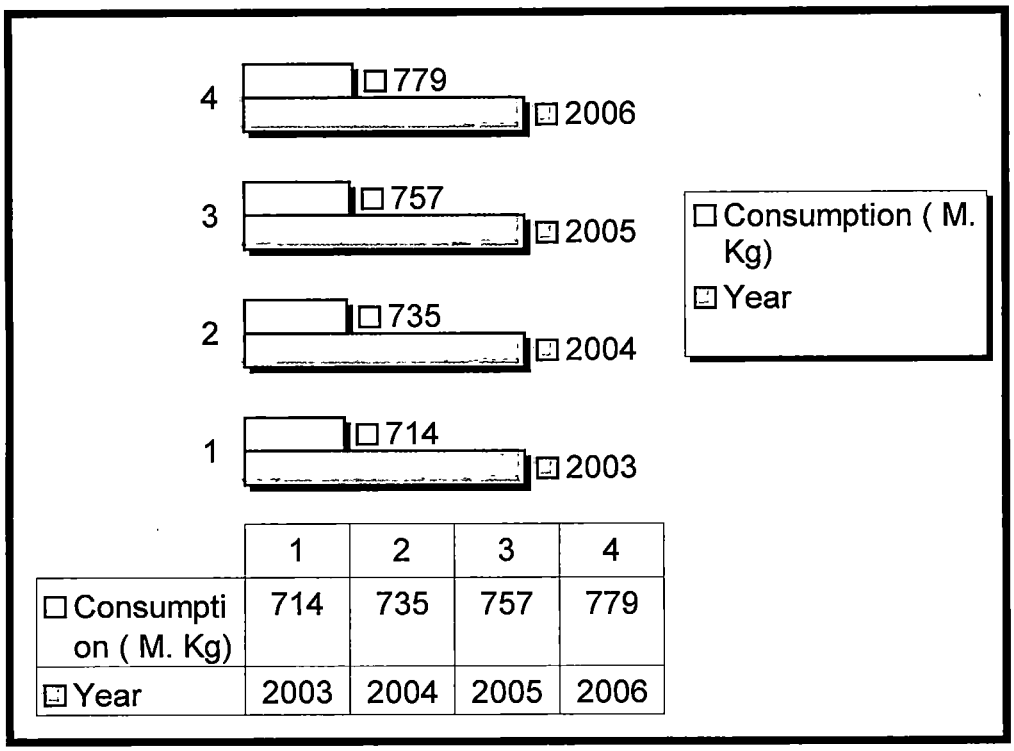


Figure 1.4: Global picture of tea consumption



	1	2	3	4
Consumption (M. Kg)	714	735	757	779
Year	2003	2004	2005	2006

Figure 1.5: Domestic Consumption of tea in India

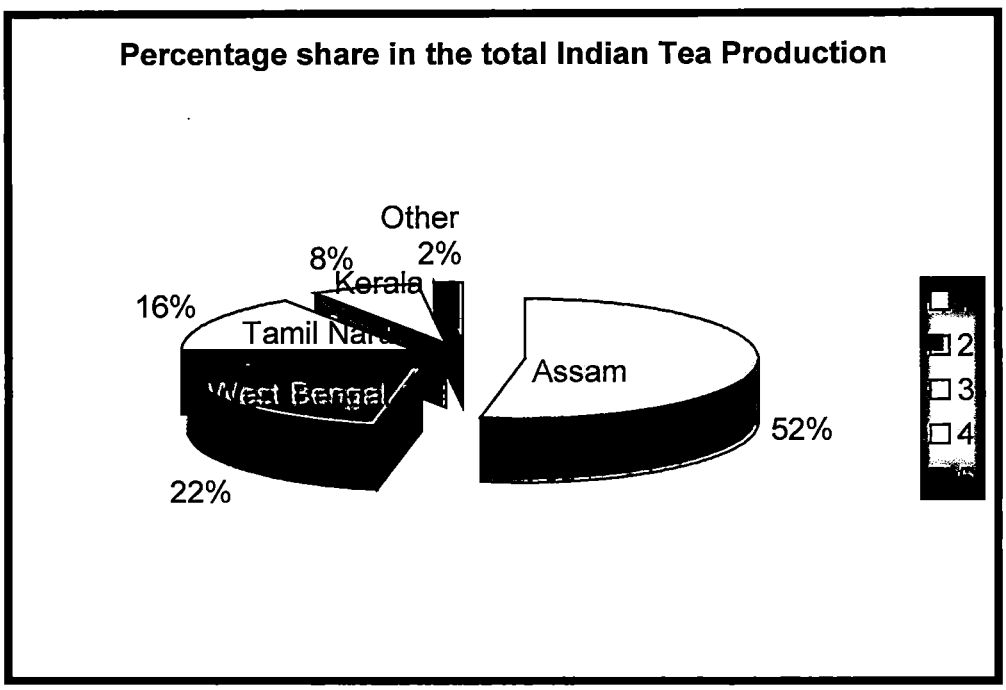


Figure 1.6: State wise Tea Production in India

The range of tea offered by India – from the original Orthodox to CTC and Green Tea, from the aroma and flavour of Darjeeling Tea to the strong Assam and Nilgiri Tea remains unparalleled in the world.

Here are some statistical facts about the Indian Tea Industry:

- The total turnover of the tea industry is around Rs. 10,000 crores.
- Since independence tea production has grown over 250%, while land area has just grown by 40%.
- Total net foreign exchange earned per annum is around Rs. 1850 crores.
- The labour intensive tea industry directly employs over 1.1 million workers and generates income for another 10 million people approximately. Women constitute 50% of the workforce.

To improve the growth of tea production the following things are to be monitored properly.

- Plucking scheduling
- Pruning scheduling
- Fertilizer scheduling
- Scheduling of pesticides
- Scheduling of herbicides
- Drainage system
- Shade tree

To achieve these objectives one needs to know some aspects of tea plantation. Glimpse of some is given in section 1.3.

1.3 Some aspects of Tea Plantation

1.3.1 Climate and Soil

Tea is exacting in its climatic requirements. The temperature may vary from 16 to 32^0C and annual rainfall should be 125 to 150 cm, which is well distributed over 8 to 9 months in a year. The atmospheric humidity should be always around 80% during most of the time. Very dry atmosphere is not suitable for tea.

There are five basic principles of soil management, which are essential for sustained crop production. They are (1) replenishment of nutrients removed by crop, (2) maintenance of the physical condition of soil, (3) preventing build up of weed, pest, and diseases, (4) maintaining optimum soil acidity and checking build up of toxic elements and (5) adoption of proper soil conversion measures to minimize soil erosion. To ensure optimum growth of plants the soil has to be maintained in proper physical, chemical and biological condition [7,12,13,14,16].

There are some important physical conditions of soil to improve the plant growth. These are soil temperature, soil moisture, bulk density and porosity. These are described in section 1.3.1.1 to 1.3.1.4.

1.3.1.1 Soil Temperature

It regulates all physiological functions, microbial activity, root and shoot growth and nutrient availability. Microbial activity in the soil is optimum at 25 – 35^{0}C but decreases with lowering of soil temperature and is minimum below 10^{0}C.The rate of chemical reaction almost doubles with raise of every 10^{0}C in temperature. Soil temperature is increase by tillage, primarily by increasing evaporation of soil water.

1.3.1.2 Soil Moisture

Tillage increases infiltration rate and water storage capacity of soil. Water is retained in the pore spaces of soil and affects many physico-chemical reactions that have a direct bearing on plant growth.

1.3.1.3 Bulk Density

The bulk density of soil is defined as the ratio of its mass to its volume and can be expressed as d = M / V, where d is the bulk density, M is mass (g) and V is volume (cm^3) of the soil sample taken. The bulk density is a measure of soil compactness and is influenced by structure and texture of soil. When the bulk density exceeds 1.7g/ cm^3, the

hydraulic conductivity of the soil will be so low that drainage may become difficult and associated with very low productivity. So production and bulk density is inversely proportional. Tillage, organic matter incorporating and cultural practices can reduce the soil bulk density.

1.3.1.4 Porosity

Soil porosity is defined as the ratio of the volume of pores to the total soil volume. Pore spaces are as important as the solid particles. Porosity is of great importance, since the chemical and biological processes occur in the pores. Large pores induce aeration and infiltration. Medium sized pores facilitate capillary conductivity and small pores induce greater water holding capacity. Under condition of high rainfall, water storage pores (small pores) are not so important, but aeration pores are essential for optimum plant growth.

Soil testing is a valuable tool for assessing the suitability of the soil, fertility status and for requirement of amendments. To make soil testing a valuable diagnostic tool, reliable and representative soil sampling is important. For sustained productivity not only the soil fertility has to be maintained in optimum level through balanced manuring but also the physical conditions of the soil has to be improved by an effective organic matter management and elimination of other constraints of soil productivity like impeded drainage, soil erosion, etc.

One of the most important problems associated with soil testing is the matter of obtaining a soil sample that represents the area to be tested. Some steps of collecting soil sample are given below:

- If areas within a section are different in appearance, slope, drainage, texture and soil color, sample each area separately.
- The sample site shall be away from a path/road, away from a drain, away from the shade tree and not from a vacant patch. Collect sample from four corners of a section from the space between two plants in a row.
- Do not sample a section within 3 months after an application of dolomite or fertilizers.
- Sample should be collected during dry winter months.

- Place about 400-500 gm of soil sample in a clean polythene bag. Label each sample with garden name, section number, and depth of sampling and pack the samples in a carton and send it to a laboratory.

Tea grows best within a pH range 4.5 to 5.5. Soil samples should be analyzed regularly for assessment of acidity status so that necessary corrections can be carried out. Lime requirement of the soil should be determined every 3 to 5 years by a soil test. Dolomite is generally broadcast uniformly on the ground. It should be applied in winter at least 6 to 8 weeks prior to manuring. As a rule of thumb application of 1 mt. of dolomite per hectare increases pH by 0.3 to 0.5 units and 0.2 to 0.3 units in medium and fine textured soils respectively. Liming makes fine textured soils less sticky and crumbier. It improves soil tilth and porosity. As a result, it provides favorable conditions for root growth and water movement in the soil. It decreases bulk density, increases infiltration rate and percolation of water in the soil. Liming prevents potassium being leached out and makes phosphorus more available. It supplies calcium and magnesium for plant nutrition. It increases the availability of nitrogen by hastening the decomposition of organic matter. Testing value of PH level and corresponding corrective measures are given in table 1.1 [7,12,18]

Table 1.1: PH level and corrective measure of soil

PH range	Corrective measures
< 4.5	Dolomite (80 – 100 mesh) @ 2 t/ha, forked into soil.
4.51 – 4.80	Dolomite (80 – 100 mesh) @ 1 t/ha, forked into soil.
4.81 – 5.60	No correction needed.
5.61 – 5.80	• Improve drainage • Apply either finely ground Iron or sulfur pyrate @ 1 t/ha which need to be forked into soil after a minimum of 15 days of Oxidation or use Aluminium sulphate.
5.81 – 6.50	• Improve drainage • Application rate of pyrate or Aluminium sulphate varies between 2 – 4 mt/ ha.
> 6.50	Unsuitable for tea

1.3.2 Plantation

The land is cleared of the roots of the fallen trees and drains are taken at suitable intervals depending upon the slope to conserve the soil. In the olden days, up and down system of planting at 1.2 x 1.2m are followed. Presently, contour planting either in a single hedge or double hedge system is followed.

The last method has many advantages over the first two viz., early and high yield, better soil conservation, less weed growth in the hedge and efficient cultural practices. Pits of 30x30x45cm size are dug and plants of 12 – 15 months old are planted by removing the polythene sleeves. Immediate after planting, plants are staked to prevent wind damage.

Immediately after planting, the soil surface around the plants should be mulched; usually cutgrasses of gautemala are employed for this purpose. About 25 tonnes of grass is required to mulch one hectare. Care must be taken to keep the mulch materials away from the collar region last they may cause collar diseases. If there is a dry weather, mud tubes or etah tubes may be buried 15 cm deep near the plant in a slanting position and one litre of water per plant may be poured or injected at weekly intervals [13,18,35].

1.3.3 Shade Management

In Terai and Dooars of India where ambient temperature rises to 32 – 35^{0}C during the main tea growing season of June- October, provision of moderate shade to tea areas by planting a number of leguminous trees has been found beneficial for health and productivity of tea bushes. The light, broad leaf bushes of the Assam race of tea benefit more from shading than bushes of the dark leaf China race. Reduction of excessive heat and light radiation is the main causes of benefit from shading. Addition of organic matter by leaf fall, prevention of soil moisture during the dry winter months, reduction of red spider incidence etc. are the other benefits of shade.

The popular shade tree species in N. E. India are

Albizzia odoratissima

Albizzia chinensis

Accacia lenticularis

Albizzia lebek

Derris robusta

The beneficial effects of shade trees in tea plantations were realized long ago and organized plantation of shade trees in North East India began towards the close of the last century. The "Sau" (*Albizzia chinensis)* was the first shade tree used extensively for planting in tea plantation. Gradually other leguminous species were introduced as shade trees in tea [7].

Tea requires filtered shade and if it is exposed to direct sun, its growth is affected. Shade is hence essential and beneficial to tea as

- It regulates the temperature.
- It minimizes the effects of drought and radiation injury.
- It increases the soil fertility
- It helps in recycling of nutrients.
- It reduces the incidences of pests.
- It helps in getting even distribution of crop.

It generates additional income by way of timber and fuel.

1.3.4 Weed Control

Any plant unwanted in a field is regarded as weed. They are highly competitive in nature, depriving the crop plants their due share of water, space, nutrient, sunlight etc. It is estimated that weeds account for about 10 – 15 percent crop loss in tea and removes approximately 250 kg soil nitrogen annually from tea field. Based on the longevity of weed species they are broadly classified in three groups as follows:

Annuals, which are quick growers and complete their life cycle within one year. They produces large quantity of seeds and in most cases, their growing period coincides with flushing season of tea plants. Biennials, which complete their lives in two years and their flowering and seed setting usually take place in the second year, for which low temperature is necessary. Perennials are the persistent type, which live more than two years.

Weed control measures are either manual or chemical. Manual weed control in tea is expensive and limited to uprooting of rank/stubborn weeds. Chemical weed control is more efficient and economical in the long run. It improves the tilth and encourages feeder roots to grow in the surface layer of soil. For chemical weed control however, they are categorized in two groups, monocots (grasses) and dicots(broad leaf weeds). While the monocots are the major problem in young tea areas, dicots particularly the creeper types create problem both for young as well as mature tea areas. Weed removes half as much Nitrogen as that removed by tea, equal amount of phosphate and twice the amount of Potash. Weed control is now second most expensive input, next to fertilizer. Weed usually grows during April to September. So emphasis should be given to start controlling weeds from the beginning itself. Herbicides application is most effective when the weeds are in their vegetative growth phase. So it is necessary to apply herbicides before flowering. Glimpse of some herbicides are given in section 1.4.4.1 and the time and method of application of the same is given in section 1.4.4.2 and 1.4.4.3 respectively. Once the weeds reach their flowering stage it becomes difficult to control them. The table 1.2 shows the most common weed control method [7,11,12,13].

Table 1.2: Weed control method

Type of weeds	Herbicides	Dosage
Dicots	Paraquat (gramoxone)	1.12 lt. / ha.
Dicots	Sodium salt of 2, 4-D (Fernoxone)	1.4 kg. /ha.
Grasses	2, 2 Dichloro propionic acid (Dalapon)	5.6 kg. / ha.
	Glyphosate	2.3 lit. / ha.

On the basis of their nature of actions, herbicides are broadly classified into two categories; these are pre-emergent herbicide and post emergent herbicides.

1.3.4.1 Herbicides

Some common herbicides are described in section 1.3.4.1.1 to 1.3.4.1.8

1.3.4.1.1 Paraquat

Paraquat is a broad spectrum contact herbicide applied post-emergence on the weed foliage. Very little of it is translocated inside the plant, and hence it can only kill the foliage with which it comes into contact. The root systems remain intact. And new growth starts appearing 1 to 4 weeks after spraying, depending upon the rate applied and the type of weed. This necessitates repeat applications. Paraquat is most effective when sprayed on young weeds. Mature broadleaf weeds like *Borreria* are, however, tolerant to paraquat.

This herbicide can be tank mixed with other pre-emergence herbicides like diuron, oxyfluorfen etc.

1.3.4.1.2 Diuron

Diuron is a soil-applied pre-emergence herbicide absorbed by roots. It kills weed seedlings soon after their emergence by inhibiting photosynthesis. It is very effective on most of the broadleaf weeds and some annual grasses. It should not be applied in tea of less than 3 years age. Depending upon the intensity and duration of rainfall and texture of soil, the effective period of weed control by diuron varies from 3 months to I year after application.

Diuron may also be applied post-emergence in tea in combination with *paraquat.*

1.3.4.1.3 Simazine

Simazine is also a soil-applied pre-emergence herbicide, which acts like diuron. Its effect lasts for 2 to 6 months. It is most effective on broadleaf weeds and a few annual grasses. It can be applied in young tea immediately after planting.

Simazine may also be applied in a mixture with paraquat at post-emergence.

1.3.4.1.4 Glyphosate

It is a broad spectrum, post-emergence, systemic herbicide applied to the weed foliage. It is actively translocated to the underground rhizomes, bulbs, tubers and stolons of perennial weeds, inhibiting their regenerative capacity. Hence, it js very effective on many perennial weeds like *Imperata, Cynodon, Cyperus, Paspalum, Setaria, Arundinella, Saccharum, Polygonum, Axonopus* etc.

It should be applied when weeds are actively growing. It can be used in young as well as in mature tea and also can be tank mixed with pre-emergence herbicide.

1.3.4.1.5 Oxyfluorfen

Oxyfluorfen is a pre-emergence herbicide, which shows only contact action on emerging seedlings. It is non-systemic and a non-selective herbicide, which shows better results on light textured soil. The herbicide is relatively stable to leaching.

This herbicide may be tank mixed with paraquat or glyphosate.

1.3.4.1.6 Glufosinate ammonium

Glufosinate ammonium is post-emergence herbicide showing contact action on a broad spectrum of weeds. It shows delayed symptoms of action but persists for a longer period. It is very effective against ferns growing inside tea areas.

1.3.4.1.7 2,4-D

It is a translocated systemic post-emergence herbicide very effective when sprayed on the foliage of the annual broadleaf weeds. The affected weeds show curling and twisting symptoms. Since broadleaf weeds continue to germinate from April to September/October, 2 to 3 rounds of spraying would be necessary to control them.

2,4-D, available in sodium salt and dimethyl amine salt formulations, may be used at different recommended doses.

1.3.4.1.8 Dalapon

It is a translocated systemic post-emergence herbicide effective on *Imperata cylindrica* (thatch grass) and other grasses. It should be applied when *Imperata* is actively growing. Its effect ranges from moderate to complete control depending upon the time of application and environmental factors such as temperature, humidity and rainfall affecting weed growth.

It should not be applied in tea below 3 years.

1.3.4.2 Application of Herbicides

Herbicides are applied at two stages in the life cycle of a weed, viz., at pre-emergence and post-emergence. These are given in section 1.3.4.2.1 and 1.3.4.2.2

1.3.4.2.1 Pre-emergence Application

The herbicides are applied to soil before the weeds germinate to prevent their emergence and establishment. They should preferably be applied on clean moist soil. At present, diuron and simazine are the only pre-emergence herbicides used in tea.

1.3.4.2.2 Post-emergence Application

The herbicides are applied on weed foliage from germination to maturity of weeds. Contact herbicide like paraquat and its combinations with other herbicides may be applied at any stage of weed growth. But translocated herbicides, 2,4-D, dalapon and glyphosate should be applied when weeds are actively growing.

1.3.4.3 Method of Application

The herbicides should be applied at the appropriate dose after mixing with water with hand operated Bakpak, Knapsack sprayers. Herbicide spray should be directed on

the ground or on the weeds. Utmost care should be taken to avoid spraying herbicide on any part of the tea plant, although mature tea is relatively tolerant to many of these herbicides.

1.3.5 Plucking of Tea

Plucking in tea is synonymous with harvesting in other crops. The prime objective of plucking is to increase the production of young tender shoots from the crown of the tea bush, which in turn is directly proportional to the cash inflow. On an average, about 30 – 36 weeks rounds of plucking is done during a year. In each round of plucking a single tea bush gives 20 – 30 gm green leaf. Production is much less during initial few round of plucking, termed as 'tipping'. Tipping is done at a predetermined height to maintain the table. It depends on the type of pruning. The tender apical portions of shoots consisting of 2-3 leaves and the terminal buds are nipped off in plucking. It is the most labour intensive operation in a tea industry and also decides the yield and quality of made tea. Normally, a pluckable shoot takes 60 to 90 days for harvesting since its sprouting from the auxiliary buds. When the shoot is harvesting up to mother leaf, it is known as light plucking and if it is plucked below mother leaf, it is called hard plucking. Description about plucking round and systems are given in section 1.3.5.1 and 1.3.5.2 respectively [7,13].

1.3.5.1 Plucking Round

The time interval between two successive plucking in the same area is called plucking round. Plucking round may be extended from 4 to 14 days, but to keep a balance between crop and quality, normally 6-8 days plucking round is practiced depending on the growth rate as well as quality of tea one desires to produce. The time required for unfolding of successive leaves from a growing bud vary from 3 to 6 days depending on climatic variation. This is called leaf period. The mean leaf period of seed jat plants of N.E. India is 4 days during the main flushing season and the leaf should not be plucked a day earlier than twice of the leaf period (2 x leaf period – 1 = 7 days).

1.3.5.2 Plucking System

Plucking system varies according to the agro-climatic situation, which influences the rate of growth. Depending on the point at which the shoot is detached, the system of plucking is categorized into two: fish leaf plucking and janam plucking. Fish leaf plucking is practiced in the area where growth is slow or plucking is done through out the year. In N.E. India janam plucking is practiced.

1.3.6 Pruning

Pruning is one of the most important operations, next to plucking, which directly determines the productivity of tea bushes. If pruning is delayed, in other words as the age of wood from pruning increases, the size and weight of growing shoots on plucking surface decreases. Therefore to maintain the vegetative growth, pruning is necessary [7,13]. The objectives are:

- To renew the wood.
- To provide stimulus for vegetative growth.
- To divert stored energy to production of growing shoots.
- To correct past defects in bush architecture.
- To maintain ideal frame or table height for economic plucking.
- To improve bush hygiene.
- To reduce the incidence of pests and diseases.
- To regulate the crop.
- To facilitate consolidation by infilling of vacancies.

There are generally four types of pruning and skiffing, which are described briefly in section 1.3.6.1 to 1.3.6.4.

1.3.6.1 Light prune (LP)

Tea bushes are usually pruned every 3 or 4 years at 4- 5 cm above the last pruning cut. The time period from one light prune year to another is called one pruning cycle. In

the plains it is given across a flat level, but in the hills cutting parallel to the slopes(i.e. slope pruning) is more popular. The height of cut above the last prune level is determined by the thickness of the wood intended to be pruned. The objective of LP is:

- To renew the wood
- To regulate the distribution of crop
- To get rid of pests and diseases
- To maintain ideal frame height of the bushes

1.3.6.2 Height reduction prune (HRP) and Medium prune (MP)

When the tea bushes grow tall and plucking becomes difficult, they are brought down to an optimum height by height reduction prune (HRP) at 60 – 70 cm, or medium prune (MP) at 45 – 60 cm above ground. This is a drastic type of prune with the following objectives:

- To remove knots and renew wood.
- To reduce excess biomass of bush frame.
- To reduce frame height of bushes
- To reduce incidence of pest and diseases
- To facilitate consolidation by infilling of vacancies

In between two successive prune (LP) years, tea bushes are given lighter forms of cuts which are termed as deep skiff (DS), medium skiff (MS), light skiff (LS), level of skiff (LOS) or untouched which is called unpruned.

1.3.6.3 Deep skiffing (DS)

Deep skiffing of tea bushes is done normally between 12 – 15 cm above the last light prune cut. The objectives of DS are as follows:

- To regulate the distribution of crop
- To reduce the ill effect of drought
- To get rid of excessive creep
- To reduce the height of plucking table

1.3.6.4 Medium skiffing (MS)

Medium skiffing is normally given 5 cm above the last deep skiff (DS) mark. The objectives of MS are as follows:

- To regulate the distribution of crop
- To reduce the ill effect of drought
- To reduce the incidence of excessive banji formation.
- To reduce the height of plucking table

With tea of normal vigour, generally higher yields are obtained with lighter cuts over light pruning. The average percentage increases in crop with different forms of skiff and unprune over light prune as is follows

Deep skiff	: 10 – 15 %
Medium skiff	: 15 – 20 %
Light skiff	: 20 – 25 %
LOS/ Unprune	: 30 – 35 %

Pruning is done in November to December. Skiffing can be performed at any time between mid December to mid January. It is difficult to arrive at the exact time of pruning as it depends upon various factors like climate, locality, requirement of crop and quality, seasonal distribution of crop, incidence of pests and diseases etc. In Darjeeling, pruning can be started as early as November.

Some factors which influences the choice of pruning cycles are:

- Higher percentage of unprune or light skiffed tea means larger quantity of both early season and total crop but lower quality of made tea, vice-versa.
- In comparison to annual prune which causes a heavy rush only during the main season, well balanced extended pruning cycle will provide even distribution of crop resulting in even flow to the factory throughout the season.

- Unpruned sections are more susceptible to a host of pests and diseases such as mites, caterpillars, scale insects, black rot etc. than deep skiffed or pruned sections.
- In droughty areas or years, unproned sections suffer more from drought than pruned sections. Usually, drought prone areas are always the first ones to catch mites and caterpillar infestations.

There are some pre and post pruning operations to be performed. These are outlined in section 1.3.6.5 and 1.3.6.6.

1.3.6.5 Pre Pruning Operations

In case of Light Pruning (LP)

- Raise temporary shade trees where the shade status is inadequate at least a year before pruning.
- Rest the weak section(s) for a period of three weeks before pruning.
- Retain one "lung/ breather" in the centre of each bush to improve the standard of pruning and for better recovery.

In case of Medium pruning (MP)

- Raise temporary shade trees where the shade status is inadequate at 3 – 4 m apart at least a year before pruning.
- Rest the bushes for a period of 6 – 8 weeks before pruning.
- Apply dose of potash and phosphate @ 60 kg K2O and 40 kg P2O5 each as broadcast in the year of prune preferably at the end of last rain.
- Retain one healthy "lung/ breather" on each bush at the time of pruning.

1.3.6.6 Post Pruning Operations

- Spray a round of any approved Copper Oxychloride(COC) formulation at 1:400 dilution on the cut surfaces within 48 hours of pruning.
- In case of MP seal the surfaces of large cuts with a recommended bituminous paint immediately following the application of COC.

- Remove all the banji shoots dead/ disease wood by a round of good knife cleaning.
- Control measures against termite should be completed between December-January.
- Protect all the newly opened buds/ shoots from the sucking pests by spraying approved pesticides.
- Complete cultural operations like ground-leveling, filling up of depressions around the collar of the bushes, improvement of drainage system, uprooting of dead shade tree and tea stumps etc. during February- March.

1.3.7 Manures and Fertilizers

Among the nutrients, N is considered as the most important particularly for a leaf crop like tea. N is a constituent of proteins and important pigments like chlorophyll. P occurs in the plant as inorganic anions or bound largely by sugars forming esters. Phosphate esters are involved in energy transfer reactions. Phosphate helps in root growth. S occurs in proteins and is required for synthesis of vitamins. Though K does not enter into composition of any of the cell constituents, it is essential for formation of carbohydrates and proteins as well as regulation of water content within the plant cell. It also helps in building up of a strong bush frame with adequate maintenance foliage [7,11,12,13,17,18].

Tea responds to manuring and it has been estimated that to produce 100 kg. of made tea, tea plants utilizes on an average 10.2, 3.2 and 5.4 kg. of Nitrogen, Phosphorus and Potash per ha. Manuring in tea starts from nursery stage itself. Once they strike roots (after 4 months) 30 g of soluble mixtures (Ammonium phosphate (20: 20) 35 parts, potassium sulphate and Magnesium sulphate each 15 parts and zinc sulphate and Magnesium sulphate each 15 parts and zinc sulphate – 3 parts) is dissolved is 10 litres of water and is applied with rosecan for about 900 plants. This must be repeated at 15 days intervals [15,16,17].

The young seed bearers' upto fourth year after planting should be manured with young tea dose (YTD) mixture at 2:1:2 ratio of NPK. Table 1.3 shows the manuring of young tea bushes and table 1.4 shows the manuring of mature bushes.

It is important to ensure adequate replenishment of nutrients in the soil removed by harvest. A series of field experiments conducted under different agro climatic conditions have recorded that annual application of balanced dose of NPK is required to harvest maximum crop. Results have shown that for sustaining a crop of 2300 kg made tea per hectare (KMTH) in different regions, in general, a dose of nitrogen not exceeding 140 kg, phosphate 20 – 50 kg and potash not exceeding 140 kg would suffice.

Table 1.3: NPK manuring in young tea

Age of the Tea bush (in year)	**Average spread of the trees (cm)**	**Application NPK (2:1:2) mixture (gm/tree in 4 split doses)**
0	30.0	20.0
+1	60.0	90.0
+2	90.0	190.0
+3	120.0	340.0
+4	150.0	530.0

Table 1.4: NPK manuring in mature tea

Yield range in KMTH	**N kg / ha**	**P2O5 kg / ha**	**K2O kg / ha**		
			Soil available potash status		
			Low (< 60 ppm)	**Medium (60-100 ppm)**	**High (> 100 ppm)**
Up to 1500	Up to 90	20	Up to 90	Up to 70	Up to 50
1500-2000	90 – 110	20 – 30	90 – 110	70 – 80	50 – 70
2000-2500	110– 140	30 –50	110 – 140	80 – 120	70 – 100
2500-3000	140 - 165	50	140 - 165	120 -140	100 –120

In the Darjeeling hills the agro climatic conditions are different from those of plains. The cool temperature slows down the organic matter decomposition and the productivity levels are lower as compared to the plain districts. Therefore the N levels should not exceed 110 – 120 kg / ha. Table 1.5 gives the NPK manuring of mature tea in hills.

Table 1.5: NPK manuring in mature tea in Darjeeling hills

Yield range in KMTH	**N kg / ha**	**P2O5 kg / ha**	**K2O kg / ha**		
			Soil available potash status		
			Low (< 60 ppm)	**Medium (60-100 ppm)**	**High (> 100 ppm)**
Up to 600	Up to 60	20	Up to 60	Up to 50	Up to 35
600-1000	60 - 90	20	60 – 90	50 – 70	35 – 50
1000-1400	90 - 120	20	90 – 120	70 – 100	50 - 70

Till the garden can be enriched with organic build up process of inorganic fertilizer application will continue. In many gardens, exact requirement of fertilizer is not ascertained which in turn result in either excess of deficient fertilizer application. Somewhere right kind of fertilizers is not used. In a soil having high PH (above 5.5), rock phosphate should not be used because it is an acid soluble phosphate. Single super Phosphate, which is water soluble Phosphate should be the best proposition in those kind of soil.

Fertilizers should be applied only when the tea bushes are ready to utilize them. As a general rule, the best time for fertilizer application is after the first rain in spring has moistened the soil to a depth of 45 cm. In case of pruned and skiffed teas, the fertilizer should be applied after the bushes have produced two new leaves. A weed free clean ground is desirable at the time of manuring.

It is recommended to apply N and K in two splits if the dose exceeds 100 kg / ha. 60 % should be applied on March – April and 40% of N and K should be applied on August – September.

It is sometimes recommended to add Sulphur @ 20 – 45 kg /ha to improves yield and quality of tea. Sometimes Zinc is beneficial for increase the yield but recommendation is not to exceed 12.5 kg zinc sulphate / ha / yr.

Foliar nutrition is beneficial under stress condition or coinciding with physiological changes in the bush. NPK mixture 2-1-2 or 2-1-3 where potash status is low, @0.5-1 percent can be sprayed during this period.

Up to three years the fertilizers should be applied in rings keeping a distance around the collar to bring them within the reach of the developing roots. Broadcasting fertilizers in young tea sections in the initial year will be wastage since the roots of young tea plants do not completely occupy the ground. In the +4 and +5 years, fertilizers are applied in strips between the rows of tea. In the mature tea, after complete coverage of ground, NPK fertilizers are applied uniformly on the ground as broadcast. In the hills of Darjeeling and other areas, fertilizers should be applied in a half circular band on the up slope keeping a distance from the collar.

Use of bio-fertilizer viz. Azotobacter, Phosphobactrin, Azospirrilium, Bacillus megatherium, can be quite productive.

1.3.8 Drainage System

Drainage system in tea gardens of plane region is very essential because water logging is very harmful for tea bushes. However in hilly region there is no need of drainage system. Generally in hills water does not logged. But sometimes there are some situations in hills where water can be logged during heavy rainfall. In such cases water pumps can be used for suction of water.

The objective of drainage planning is to remove the excess moisture in the root zone within a specified time so that the soil returns to field capacity without any harm to tea plants. Quick and safe disposal of water from the catchments is the basis of drainage design. Without a proper outlet, drainage planning can not be successful and thus for efficient drainage outlet, development of outlet should be taken up first with the ultimate objective of lowering the water level below the root zone depth. It has been found that improved drainage can increase the yield to the extent of 30 – 35 % over a period of time. To design an effective drainage system the information of soil properties like texture and hydraulic conductivity as well as records of highest flood level are important.

There are two types of drainage, 1) Open Drainage System and 2) Pipe Drainage System. Open drainage system consist of a network of field drains, collector drains and the main drain which discharges into natural drainage channels such as streams or river. They are advantageous for removing large volumes of water from tea fields with minimum cost. A pipe drainage system is a drainage network in which slotted PVC, corrugated plastic and cement- asbestos pipes, etc. are laid at 1.2 to 1.5 m depth to remove excess water from the root zone. Around the pipes, a layer of graded gravels is used as filter material to prevent clogging of the slots or joints. The advantages of the pipe drains are (1) there is no loss of planting area, (2) maintenance cost is almost nil if properly laid, (3) effective in unstable sandy soils where open drains can not be maintained and (4) does not interfere with farming operations. However the initial cost of pipe drainage is very high [7,12,13].

The depth and shape of drains suitable for tea plantations of Tarai and Dooars are given in table 1.6.

Table 1.6: Depth and shape of drains in Tarai and Dooars

Drain	**Depth (cm)**	**Bottom width (cm)**
Field drain	105	20 – 25
Collector drain	120	30 – 50
Main drain	150	50 - 100

The drains should have sufficient batter (side slope) to ensure that their sides do not collapse. The suggested tentative spacing of drains for soils with different texture are given in table 1.7.

Table 1.7: Spacing of drains for soil with different texture

Region	**Loamy sand (k=3.4m/d)**	**Sandy loam (k=1m/d)**	**Loam (k=0.35m/d)**	**Slit loam (k=0.35m/d)**
Assam	25 m	15 m	12 m	9 m
Dooars & Terai	18 m	12 m	9 m	6 m

* k is hydraulic conductivity (m/day)

When outfall is inadequate, disposal rate of excess water by gravity is slow and sometimes may have even backflow during peak monsoon months. Pump drainage becomes necessary when the difference between the elevation of tea fields and the highest / average water level in the outfall is negligible.

1.3.9 Irrigation

Distribution of rainfall in North East India is highly uneven. During the period from October – February, rainfall is scanty and the quantity varies from 5 to 10 % of the annual rainfall. In this period average evaporation exceeds average precipitation by 8 to 357 mm. Therefore, conservation and supplementation of soil moisture by irrigation becomes necessary during this period of moisture stress[7,13].

a) Water requirement in Dooars and Terai during October – March are as follow:

October – 105 mm

November – 65 mm

January – 30 mm

February – 45 mm

March – 90 mm

b) Excess over this quantity will be lost through drainage while lower rate will increase the moisture deficit.

c) The depth of irrigation should ideally be the difference of incident rainfall and the water requirement of the month

d) Soil infiltration rate for different soil type:

Soil type	Infiltration rate mm / hr
Light	18 – 24 mm hr
Medium	12 – 15 mm hr.
Heavy	10 – 12 mm hr.

The duration of irrigation need to be adjusted as par infiltration rate.

- Apply irrigation at a rate matching the intake capacity of the soil. High intensity irrigation leads to runoff losses of water.

- Follow a monthly schedule of irrigation (4 – 5 cm per setting) up to February. Thereafter reduce frequency to 3 weeks.
- If dry spell continues beyond mid March, irrigate the pruned teas too. Water requirement of pruned teas following bud break increases rapidly.
- A conductive micro – climate can only ensure optimum response from irrigation. A good stand of shade and wind barriers along the boundaries help to create the desired micro – climate.

  Avoid excessive irrigation in young teas.

1.3.10 Pest Control

Some common pests and diseases and their control measure are discussed in section 1.3.10.1 to 1.3.10.9.

1.3.10.1 Red spider mites (Oligonychus coffeae)

The Red spider normally attacks the upper surface of mature leaves but in severe cases young leaves are also equally attacked and the mites then spread to undersurface. It cause damage by sucking the sap. Reddish spots develop on the sucking sites, which subsequently unite to form large brown patches and ultimately turn bronze[11].

With the increase of temperature the life cycle of red spider becomes shorter. The incubation period is 11 days when temperature is 20° C and 4.5 days when temperature is 32° C. So in normal temperature follow up spraying should be done at 12 to 14 days but in high temperature spraying should be done at 5 – 6 days interval.

Some common pesticides for this mite are listed below:

Profenphos (1 : 1000 by HV spray)

Dicofol (1 : 400 HV)

Ethion (1 : 400 HV)

Fenpropathrin (1 : 1000 HV)

Fenazaquin (1 : 1000 HV)

1.3.10.2 Tea mosquitoes (Helopeltis)

Small adult bugs and hairy orange nymphs suck the sap from fresh leaves and tender shoots; leaves curl up, dry and die.

Helopeltis injects toxic saliva, which causes to break down of the tissue surrounding the puncture. The badly affected leaves become deformed and affected area may not flush for weeks [11].

With the increase of rainfall the life cycle of this mosquito becomes shorter. So, spraying interval should be maintained depending on the life cycle. Incubation period of Helopeltis in different sessions are given in table 1.8.

Table 1.8: Incubation periods of Helopeltis in different seasons

Season	**Incubation period**	**Life Cycle (Days)**	**No. of rainy days / year**	
			2005	2006
Mar-April	7 –8	23-28	*	*
Jun-July	4 –6	12-15	51	57
Aug-Sept	5 – 6	12-15	48	39
Nov- Jan	16 -20	35-40	*	*

From table 1.8 it is clear that during June to September when rainfall is heavy, Helopeltis multiplies at a faster rate and such cases spraying is virtually ineffective.

Mild attack of helopeltis can be dealt with by spraying any approved neem formulation for two rounds at 7 days interval. In severe cases use two rounds of any approved insecticides

Some common pesticides for this are listed below:

Deltamethrin (1: 4000 HV)

Endosulfan (1: 400 HV)

Thiomethoxam (100 gm/ 400 lts water)

1.3.10.3 Thrips (Scirtothrips)

Leaf surface becomes uneven, curly and metty, exhibiting parallel lines of feeding marks on either side of the midrib.

Apply one of these pesticides to get rid of these

Endosulfan (1: 400 HV)

Propanofos (1: 1000 HV)

Quinalfos (1: 400 HV)

1.3.10.4 Pink mites (Acaphylla theae)

Young leaves turn pale and get twisted by attack of pink mites.

Apply Dicofol /Ethion @ 1 lt. / ha.

1.3.10.5 Termite

It is the silent killer generally active from December and the damage to tea bushes is very severe in some sub districts predominated by red bank soil.

The following chemicals are recommended for termite control:

Endosulfan (1: 300 HV)

Chlorpyriphos(1: 300 HV)

Lindane 20 EC (300 ml /200 lt. of water with HV)

Imidacioprid 17.8 SL (75 ml / 200 lt. Water with HV)

Among the diseases, red rust is a common one in young tea areas. However in mature tea, besides this red rust, black rot, poria (red root disease), blister blight and brown root are very common.

1.3.10.6 Red rust

This disease turns the leaves partly yellow. Red fructification on the stem also found.

Use copper oxychloride (COC) 1: 400 for 2 rounds at 15 days interval. Improve drainage system and shade tree. Mix Urea and MOP @ 2% with Copper fungicide.

1.3.10.7 Black rot

Rotting of leaves is major symptom of this disease.

Use copper oxychloride (COC) 1: 400 for 2 rounds at 15 days interval. Improve drainage system and heavy shade should be thin.

1.3.10.8 Red root (Poria)

Infected roots exhibit blood red mycelium on washing. It spreads fast but slowly kills.

1.3.10.9 Blister blight

Blister blight is one of the primary leaf diseases attacking the tender shoots of tea. It is caused by the fungus *Exobasidium vexans* Massee.

Blister blight appears in Darjeeling during the rainy season (June-August) while in Upper Assam it shows up during Nov - May. Tea bushes on the northern aspect of hills in Darjeeling are more severely attacked.

Copper based fungicides are economic and efficient in controlling blister blight. Among the different formulations of copper tested only copper oxychloride is found to be the most effective. With high volume sprayer COC@1:400 dilution Hexaconazole /Protriconazole @ 1:1000 dilutions COC 4-6 weekly rounds, Hexaconazole /Protriconazole 2-3 rounds at 15 days interval is found to be highly effective for controlling Blister blight.

1.4 Objectives and Proposals

For last couple of years, due to rapid changes in global economic scenario, globalization of Indian economy, breaking of USSR, increasing presence of countries like Kenya, Sri Lanka, Indonesia etc. in global export market and unorganized way of using pesticides, herbicides in the tea gardens, Indian tea industry is under recession. Industry and Government has realized that there is immediate need to modernize the tea production process to make it globally competitive. The major national objective of tea industry is to manage tea estates to maximize profits. So, it is required to generate a GIS anchored tea management system for managing the profit in the tea estates through the strength of IT in the form of GIS [33].

GIS is an acronym for geographic information system. There have been so many attempts to define GIS that it is difficult to select one definitive definition. Some of the shorter definitions give an idea of what a GIS is, albeit in a superficial way. For example, Rhind (1989) proposes that GIS is 'a computer system that can hold and use data describing places on the Earth surface'. According to Burrough (1986) GIS is: 'a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes', and as per the Department of the Environment (1987) GIS is: 'a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the Earth' [8,9,10].

In general, Geographic Information System (GIS) is an organized collection of computer hardware and software designed to create, manipulate, analyze and display all types of geographically or spatially referenced data efficiently. Through this study it is proposed to develop some tools, which may be integrated with open source to enhance the capability of tea management system [8,9].

Most of the tea gardens are maintained manually. *Due to large amount of data in tea gardens it becomes time consuming and tedious task to find the reason behind the less production rate. The response time for a management and monitoring will be reduced drastically because it is very difficult to monitor huge amount of data manually to monitor and maintain system of cycles various from day to day multiple years.*

To mitigate the situation arising in tea garden a better, time efficient and appropriate computer based management system has been developed. With this aim the research has been carried out. Several field works have been performed. Lots of interviews with various experts and workers of tea gardens have also been conducted. Requirement analysis is done as per suggestions of various levels of the users. As a result of this research a computer-based management information system of tea garden has been proposed, designed and implemented during the course of study. Various tools are generated [7,11,12].

The management information system developed for the following functionalities

- *Plucking scheduling*
- *Pruning scheduling*
- *Fertilizer scheduling*
- *Scheduling of pesticides*
- *Scheduling of herbicides*

The outcome of these research is to impart time efficient, people efficient, better future directives of the system to enhance the productivity of tea industries.

The tools are generated in JAVA under ORACLE platform on windows based operating system [19,20,21,22,23,30,31,32]. The organization of the thesis is given in section 1.5.

1.5 Organization of the Thesis

This thesis is divided into twelve major chapters. Current chapter provides the history of Indian Tea and its position in global market, objective of the research and some aspects of tea plantation like plucking, pruning, manuring, spraying, soil management, drainage management, weather, shade tree etc. Chapter 2 discusses a proposed digitization technique of garden map. Chapter 3 presents the database design of the system. Chapter 4 presents the pruning/plucking management system. Chapter 5 shows fertilizer management system. Chapter 6 shows weed control system. Chapter 7 presents pest management system. Chapter 8 shows the demand analysis phase of the system where individual demand, market demand, demand estimate and least squares regression

method, economic forecasting, time series analysis and forecasting of tea production using Neural Network based on fuzzy data are discussed. Chapter 9 shows different menus and forms and Chapter 10 gives all the reports on different management queries. Chapter 11 is the concluding chapter where the study site, method of data collection and some limitations to develop the proposed system and some future scope of the proposed system is discussed and Chapter 12 is the instruction manual of the system. In Appendix A, list of tables and figures are included. References and list of publications of the author are given at the end of the thesis.