Chapter 1

GENERAL INTRODUCTION

The tea (*Camellia sinensis* (L.) O. Kuntze) is an evergreen plant of the family Theaceae that is native to China, Tibet and North East India. It is an intensively managed perennial monoculture crop cultivated on large and small scale plantations. It is a dicotyledonous perennial crop. The plant produces dark green, shiny leaves and small, white blossoms. Tea is the most popular and inexpensive beverage produced from young leaves of the commercially cultivated perennial plantation crop - *Camellia sinensis* (L.) O. Kuntze (tea plant). It is grown in over 60 countries and consumed round the World in 117 countries, is known to the mankind from the Shengnong period in China, over 4000 years ago. The earliest reference to tea as a health drink dates back to 475 to 221 BC (Chen Zong Mao, 2009). Tea is claimed to have originated somewhere in the Mongolian plateau of central China (Barua, 1989; Weatherstone, 1992). Tea (*Camellia sinensis* (L.) O. Kuntze) the word has derived from t’ee of the Chinese Fukien dialect. The Dutch introduced tea in Europe. In Cantonese, tea is known as Cha. In this form, the name reached Japan, India, Russia, Iran and the Middle East countries (Barma, 1963). Detailed account of the origin of tea drinking in China has been provided by Fu Hung (1974). Tea was used as medicine in China by boiling fresh tea leaves in water. The people of Lishuangbanna area, Yunnan province of China started planting and cultivated tea trees during 220 to 265 AD. From the primary centre, tea dispersed towards the South, reaching the secondary centre near the source of the Irrawady (Barua, 1989). Further dispersal took place from the secondary centre in three different directions along the source of the three great rivers: Yang Tse, Mekong and Brahmaputra (Bezbaruah, 1999). The genus *Camellia* L. is indigenous to the forests of South-East Asia, where the plant grows as under-trees/ trees of 9-12 m tall (Weatherstone, 1992). Spread of tea, has been traced initially as medicinal and subsequently as a beverage plant from its home in China to Japan in 815 AD, Korea in 828 AD, Europe about 800 years later in 1607 and Russia
in 1618; tea was introduced into India in the early 19th century (Chen Zong Mao, 2009).

Most of the genera of Theaceae and species of *Camellia* are found in Yunnan province in Southwest China and North east India bordering Burma having maximum genetic diversity (Weatherstone, 1992; Singh, 1999). It is grown on over 2.71 million ha of land in more than 34 countries across Asia, Africa, Latin, America and Oceania to produce 3.22 million tons of tea annually (Barua, 1994; Deka et al., 2006; Wilson et al., 1992).

Tea cultivation was initiated in India around 1886 with the opening of few gardens under two tea companies of Assam. Now, India is the largest producer of tea (944.68 million kg). Assam is the leading producer (479925 thousand kg) with a total area of 3.128 lakh under tea cultivation. Worlds total tea production in 2007 was 3.527 million tones and the total area under cultivation is around 5 million hectares (Saravankumar et al., 2007). The seven top tea producing countries are China, India, Kenya, Sri Lanka, Indonesia, Turkey and Vietnam, where total production occupies 80.56% of the world production (Alkan et al., 2009).

Tea plays a major role in the economy of several underdeveloped and developing nations in Asia and Africa. In India this crop is grown in more than 500,000 ha, of which about 97,600 ha is cultivated by 123,000 small growers. The Indian tea industry directly employs more than a million people of which 50% are women. The industry generates income and livelihood for more than 10 million people in this country. The tea gardens situated in the rural areas contribute significantly to the social, educational and economic development of the people of these regions. The tea ecosystem, situated close to the forest ecosystem has a predominant role in the maintenance of terrestrial ecology by providing extensive land cover and preventing soil erosion.

Plant disease is caused by a diverse collection of microbes including fungi, bacteria, viruses, viroids, nematodes and parasitic plants. Tea (*Camellia sinensis* (L.) O. Kuntze) like any other agricultural crop is exposed to many pests and disease causing organisms i.e. pathogens. Tea fields are also invaded by several species of weeds.
Being a perennial monoculture crop it provides stable microclimate and continuous supply of food for pests. Each tea growing country has its own distinctive pests, diseases and weeds though several of them might have been recorded from more than one region. The number of pests associated with tea plants in an area depends on the length of time for which it is cultivated in that area. About 300 species of insects and mites are recorded from India but only a few of these are economically important. Nearly, 400 plant pathogens are associated with tea globally but only 58 pathogenic fungi are known to cause diseases in tea in this country. More than 130 species of weeds cause problems in young tea clearings, pruned fields and vacant patches of tea gardens in India. Crop loss due to pests, diseases and weeds varies between 15 and 20 percent. The value of crop loss is bound to be higher in the recent time in view of the higher productivity of the recent introduced clonal plants and adoption of improved cultivation practices (Morang et al., 2012).

In Barak valley, tea is usually grown on low hillocks (tillahs) peculiar to the region and to some extent on the flat land surrounding the tillahs. Barak valley with its peculiar climatic condition and topography is an ideal breeding ground for large number of pest and disease causing organisms. Red rust and black rot are the two major diseases responsible for yield erosion in young and mature tea bushes respectively. Majority of the tea diseases are of fungal origin and more than 300 species of fungi are reported to affect different parts of tea plant (Agnihothrudu, 1964; Chen and Chen, 1990). Being a foliage crop, leaf diseases are of most concern as it leads to direct crop loss and quality deterioration of the final produce (Baby et al., 1998). Various assessments have been made from time to time in the different tea growing countries of the World with regard to crop losses caused by the respective organisms infesting the tea plantations. Such assessments of losses range from 5%-10% to as high as over 50% in terms of made tea production per unit area (hectare). The difference in the prevailing climatic condition, the variety of tea and its age, genetic variation or uniformity (seedling or vegetatively propagated clonal tea), the soil type and its prevailing fertility status, variation in the nutrient inputs, the presence or absence of shade trees and green crops etc. are the deciding factors in the establishment of the diseases.
The peculiarity of black rot disease (*Corticium theae*) is that the diseased leaves are attached to the branches and other leaves by the mycelium. The diseased patches are larger, usually covering about half, and sometimes the entire area of the leaf. The colour on the upper surface is a yellowish brown and grayish white smears and the margin of the diseased patch is little less irregular and is more prominent. The under surface is more evenly coloured with grayish white and there is no sunken appearance of the diseased patch. Conditions which most favour the damage from black rot are heat combined with high humidity (Tunstall and Sarmah, 1917).

Red rust is yet another disease of young tea stems and where it occurs it is found to be troublesome. It is brought about by a small parasitic alga, *Cephaleuros parasiticus*, thus being distinct from most other tea diseases which are the result of attacks by fungi. Infection takes place during the fruiting period, in April each year, by means of spores which are dispersed by wind or rain. When a spore comes to fall on a green shoot or leaf, it germinates and grows into the tissue of the host. There it multiplies at the expense of the host cells and penetrates deeper into the bark tissue. Whilst this is happening the tea plant responds by developing new bark underneath each affected parts, in an attempt to throw off the infection. Due to the pressure of the developing alga the bark of the infected patches split in minute cracks. In the meantime the alga has been stimulated to fructify and hair like fruiting bodies emerge through the minute cracks. These hairs are red in colour and bear several knobs or sporangia in their tips. They resemble small red pins stuck upright into a flat pin cushion. The parasitized stems are easy to locate because their leaves are variegated, green and white or green and pale yellow, and they are usually situated around the perimeter of the bush. The first visual symptoms of most *Cephaleuros* infections are small, yellowgreen colonies on the upper surface of infected leaves. Colonies consist of a primary disc-like thallus which slowly enlarges in diameter by cell division. Filaments (rhizoids) differentiate beneath the colony and penetrate the host cuticle and epidermis. The epidermal cells die and a secondary thallus develops in the mesophyll tissues. With age, the algal colony assumes a 'velvety' texture due to the formation of sterile hairs (setae) and sporangiophores. These structures usually contain haematochrome pigment which gives the colony a rust-red colour and its common name, red rust disease. Both sexual and asexual reproduction continues for many months. Asexual reproduction in *Cephaleuros* spp. involves the formation of zoosporangia around the bulbous head
cell of sporangiophores. After detachment the zoosporangia release quadriflagellate zoospores. Zoosporangia are dispersed by wind, rain, spiders, mites and insects, but do not live long after their release from the sporangiophore. Sexual reproduction is accomplished by the production of relatively large, flask-shaped gametangia in the thallus. In the presence of free water, 8-64 biflagellate gametes are released from each gametangium. Pairs of compatible gametes subsequently fuse and form a dwarf diploid sporophyte which, after meiosis, gives rise to microsporangia bearing quadriflagellate haploid zoospores. Both asexual and sexual zoospores or young thalli must actively penetrate the cuticle or fortuitously settle in a scratch, wound or other break in the cuticle if they are to infect successfully. Propagation can also be achieved by the formation of akinetes (non-motile resistant reproductive cells) from the sporangiophore initials. Under favourable conditions, akinetes produce either a sporangiophore or 32 quadriflagellate zoospores. Infections of *Cephaleuros* spp. on plants can be broadly classified into three groups according to the organ infected and the host's reaction to infection. Leaf infections tend to be of little economic importance unless the leaves are the harvested product (e.g. tea). However, leaf infections may provide an important inoculum source for secondary infections. Host leaves typically react to infections by the formation of cork tissue (or thick-walled mesophyll cells) which acts as a barrier to further algal colonisation. *Cephaleuros* infections on host stems tend to be more serious as they can cause branch die-back or stunted growth accompanied by leaf chlorosis. Quite often the bark of infected plants becomes scaly and develops prominent cracks and swellings. Fruit infections usually amount to nothing more than the presence of unattractive, superficial spots (the algal thalli). However, they can affect the marketability of coffee berries and fruits such as citrus, avocado and guava. Most field reports indicate that infections of *Cephaleuros* spp. are most severe when host vigour is reduced (Tunstall, 1917).

Affected patches are usually circular and are noticeable when the alga produces its fructifications during the months of April to July. The fruiting patches are brick red or orange in colour and the numerous small red hairs bearing the sporangia can be clearly seen. New shoots developing below the affected part may also get infected and if the disease is not checked, the process will be repeated. The net result of repeated attacks is gradual weakening of the bush and the consequent reduction in crop. Such
bushes recover poorly after pruning, the new shoots being weak, are spindly and with few leaves (Sivapalan et al., 1986).

In brown blight of tea (Colletotrichum camelliae Massee), the diseased patches usually start at the margin of the leaves and spread inwards. The edges of the patches are sharply defined and more often marked with delicate zonation. The colour of the upper surface is yellowish to chocolate brown at first, gradually changing to grey from the centre outwards. Minute black, scattered dots of the fructifications appear on both sides of the diseased patch (Sivapalan et al., 1986).

Grey blight has received considerable attention in recent years especially after the introduction of shear harvesting. The pathogen Pestalotiopsis sp. is a weak parasite that gains entry mainly through the wounds. Besides, affecting old leaves it causes die-back of the stubs left on the bush after plucking. The diseased patches are light to dark brown with a greyish centre on the upper surface, roughly circular to oval marked with concentric zonations almost from the centre to the edge. The diseased patch may occur at the margin or in the middle of the leaf. On the older leaves, it starts from any damage - a cut, a break or a bruise- on the leaf blade. On young leaves, the patch is usually dark brown or almost black, rather irregular in shape, usually starting at the margin of the leaves and spreading inwards (Sivapalan et al., 1986).

These two diseases are common to the old or damaged tea leaves. They are weak parasites and are harmless unless they can gain entrance through a wound or into tissues that in some way has been weakened. Frequently an affected leaf has both brown blight and grey blight at the same time. Typically, grey blight differs from brown blight in that the dead tissues of leaves affected by the former gradually turn grey, whereas in the latter they remain brown and become so brittle that pieces fall out leaving the veins with fragments of dead leaf tissue attached. Very often both the fungi are found in the same dead zone, and as the dead tissues are usually brown the disease is called brown blight whether the fungus Pestalotiopsis is present or not.

Fungicides are one of the major types of pesticides which are designed to suppress the phytopathogenic fungi, at the same time might have lasting effect on the non-target
organisms or on the germination of some vegetable or plant seeds. Effective and efficient management of crop disease is generally achieved by the use of synthetic pesticides (Kiran et al., 2006). Fungicides are essential for maintaining healthy crops, and consistent yields of high quality produce. There are several reports where fungicides have been used for the control of plant diseases (Saoud et al., 1952; Illiesea et al., 1985).

The aims of use of chemicals in plant disease control are (i) to create a toxic barrier between the host surface or tissues and the pathogen and (ii) to eradicate the pathogen present at a particular site on or in the host including seed, foliage and roots. The chemicals oppose the germination, growth and multiplication of the pathogen or directly destroy it through its toxicity.

The antifungal chemicals (fungicides) are expected to perform three major functions: (i) reduction in inoculum density or eradication of inoculum from the source of growth, multiplication and survival, (ii) inactivation or destruction of the pathogen when it lands on the treated surface and (iii) cure of the diseased plant (therapy) (Sharma, 1998).

Chemical control measures are effective in controlling tea diseases (Premkumar and Baby, 2005). But persistent, injudicious use of chemical has toxic effect on the non-target organisms and cause undesirable changes in the environment and continuous use of some fungicides leads to resistance of the pathogen (Sengupta, 2004). Large scale and long term use of resistant cultivar is likely to result in significant shifts in the virulence characteristics of pathogens, culminating in resistance breakdown. Thus adoption of plant (botanicals) or microbial (biopesticides) products as part of biological control measures in the integrated disease management (IDM) has a significant role to play.

Traditionally, plant fungal diseases are controlled by synthetic fungicides, which increases agricultural costs and contaminate the environment with their very toxic properties (Carvalho, 2004). A possible alternative to solve such problems is the use of plants which are able to produce antifungal substances (Miranda, 2003). Allelopathy is a biological phenomenon by which an organism produces one or more
biochemicals that influence the growth, survival, and reproduction of other organisms. The word allelopathy derives from two separate words. They are *allelon* which means "of each other", and *pathos* which means "to suffer". Allelopathy has been accepted widely as an important ecological phenomenon. Controlling of microorganism originated plant disease with plant extracts as components in Integrated Pest Management strategy has been suggested by many scientists since 1990s (Yusuf et al., 2011). In the past two decades, a lot of work has been done on the plant derived compounds as environmentally safe alternatives to pesticides for plant disease control (Rice, 1984; Vyvyan, 2002).

Certain plants exhibit allelopathy and influence other plants and microorganisms by releasing different chemicals such as phenol, glycosides, amino acids, alkaloids, terpenes and sugars. Furthermore, pesticides of plant origin are cheap; readily available and cost effective in developing countries, where synthetic fungicides are scarce and expensive for resource poor farmers. Recent studies have shown the importance of natural chemicals as a possible source on non-phytotoxic, systemic and easily biodegradable alternate pesticides (Mathew, 1996).

*Clerodendrum* is a genus of flowering plants in the family Lamiaceae. Its common names include glorybower, bagflower and bleeding heart (Yao-Wu Yuan, *et al.*, 2010). *Chromolaena (Eupatorium)* is a genus of flowering plants in the aster family, Asteraceae. They are commonly called bonesets, thoroughworts or snakeroots. The genus is named after Mithridates Eupator, King of Pontus (David, 2008). They are mostly herbaceous perennial plants growing to 0.5-3m tall, while a few are shrubs. *Eupatorium* has many more presumed beneficial uses, including treatment of dengue fever, arthritis, certain infectious diseases, migraine, intestinal worms, malaria and diarrhea etc (King, *et al.*, 1987).

*Ipomoea carnea*, the pink morning glory, is a species of morning glory, Convolvulaceae. This flowering plant has heart shaped leaves that are rich green in colour and 6-9 inches long. The plant is also of medicinal value (Navin *et al.*, 2005). It contains a component identical to marasilin, a sedative and anticonvulsant. A glycosidic saponin has also been isolated from *I. carnea* with anti-carcinogenic and toxic properties (Chand, *et al.*, 2005).
*Melastoma* is a genus in the family Melastomaceae. It has about 50 species distributed around the world for the aesthetic value of their bright purple flowers. Several have the capacity to become woody, and have become noxious weeds in Hawaii and other countries (Forest Starr *et al.*, 2006).

*Polygonum* is a genus in the buckwheat family, Polygonaceae. Common names of *Polygonum* species include knotweed, knotgrass, bistort, tear-thumb, mile-a-minute. They vary widely from prostrate herbaceous annual plants under 5 cm high, others erect herbaceous perennial plants growing to 3-4 m tall. The smooth-edged leaves vary greatly in shape between species, and can be narrow lanceolate, oval, broad triangular, heart shaped or arrowhead shaped, they range from 1-30 cm long. The stems are often reddish or red-speckled. The flowers are small, pink, white or greenish, forming in summer in dense clusters from the leaf joints or stem apices (Bussmann, 2006). Natural products isolated from plant appear to be one of the alternatives as they are known to have minimal environmental impact and danger to consumers in contrast to synthetic pesticides (Varma and Dubey, 1999).

Air is the carrier but not the medium of growth for microbes. Atmospheric fungal spores form an essential part of the aerobiological flora. Fungal spores occur numerously in the air and, on account of their dimensions (several micrometers), are classed as bioaerosols. They are always observed in natural air and their concentration changes depending on the environmental conditions. Numerous airborne organisms, their fragments as well as particles of biological origin passively float in the atmosphere. Small insects, bacteria, viruses, plant pollen, diasporaes, fragments of tissues and talli, and such organic compounds as mycotoxins or allergens can be found in the air. Fungi produced varied forms of spores which behave differently, i.e. actively or passively released (blown away, rinsed off or shaken out); however their subsequent fate usually depends on the wind (Edmonds, 1979; Hirst, 1991; Ingold, 1971; Cartney, 1994).

The wind is a blind vector; hence an abundant production of spores is necessary for the fulfillment of the biological functions (Edmonds, 1979). Because of their size, fungal spores can cover enormous distances with air currents (Hjelmroos, 1993). The
distant transport is unimportant for the development of the fungus unless its spores are viable (Edmonds, 1979; Ingold, 1971). Fungal spores are capable of becoming airborne by virtue of their efficient dispersal mechanism. The incidence and diversity of fungal spores highly depend upon the topographical diversity, climatic conditions of the particular study sites, meteorological parameters, vegetation types, air pollution, agricultural, industrial and other human activities. The extreme climatic conditions are unfavourable for the concentration of fungal spores in the atmosphere (Agarwal and Shivpuri, 1974).

Aerobiological studies are of great importance as they provide with the qualitative and quantitative information about the airborne fungi of a given region. They are essential for understanding the survival of microbes in the soil, leaf surface and air. A single record of the succession of fungal spores, which invade the atmosphere of any given localities, furnishes valuable information regarding the fungal calendar. The presence of spores of specific plant pathogenic fungi near the crop fields may suggest when appropriate measures should be taken against any particular disease (i.e. disease forecasting).

The phyllosphere may be defined as that part of the leaf serving as the interface between the plant organ and the environment. Although the phyllosphere has been referred to as a relatively “hostile environment”, a number of macro and microorganisms successfully exploit this niche; thus it serves as a microcosm for a complete series of multitrophic interactions (Jose, et al., 2009). The surfaces of aerial plant parts provide a habitat for epiphytic micro organisms, many of which are capable of influencing the growth of the pathogens. The relationship of epiphytic microorganisms to plant disease has been previously discussed by Leben (1965). The microbial diversity of phyllosphere communities is influenced by plant ages, species, micro- and macro habitat, changes to environmental regimes and position of leaf on the plant (Kinkel, 1997; Talley, et al., 2002; Behrendt, et al., 2004). Plant genera growing in close proximity have their own characteristics mycota (Kinkel, 1997) which is conditioned by nature of the plant exudates, microclimate and by other members of the mycota (Goodman, et al., 1986; Lucas and Knights, 1987; Osono and Mori, 2004).
The mycoflora present in the air, phyllosphere and soil of tea plantations may be interlinked and they may play important positive and or negative role in relation to disease development or control. Toxin producing organisms if any can be regarded under the negative role; on the otherhand biological control measures of some specific tea diseases may be possible by using some of the mycoflora trapped from the atmosphere of tea plantations (i.e. from the air and phyllosphere). Biological control using microorganisms can be economic, self perpetuating and usually free from residual side effects (Vidhya Pallavi, et al., 2011). Biological control therefore holds a promise as a strategy for disease management and at the same time it is environment friendly.

Mycoparasitism, the direct attack of one fungus on another, is a very complex process that involved sequential events, including recognition, attack and subsequent penetration and killing of the host. Higher growth rate and greater competitive ability of the selected strains are the indicative of their better antagonistic potential. The antagonists may exert direct biocontrol by parasitizing a range of fungi, detecting other fungi and growing towards them (Harman, et al., 2004). They may be attach to the pathogen, with cell wall carbohydrates that bind the pathogen’s lectin. Once they are attached, it coils around the pathogens hyphae, which facilitates the entry of their hyphae into lumen of the parasitized fungus and form the appressoria. The following consists of the production of various cell wall degrading enzymes and peptaibols (Howell, 2003).

Although use of biocontrol agents could reduce chemical application to a limited extent, it is less reliable and less efficient (Monte, E. 2001). Integrated Pest Management (IPM) is an approach involving the use of biological, physical and chemical control measures to manage pest and pathogen populations in a cost effective ecological way. Within these complex plant protection strategies, one may need to combine biocontrol agents with chemicals to achieve the target (Kredics, L. et al., 2003). The combined use of biocontrol agents and chemical pesticides has attracted much attention as a way to obtain synergistic or additive effects in the control of pathogens (Locke, et al., 1985).
Apple (1977) suggested that the word “control” evokes the notion of finality, of having controlled or permanently solved a problem. In nature diseases and pests are inherent to agroecosystems. It is practically impossible to control diseases and pests. Operations to minimize the loss due to these enemies have to be a continuous process every year. Management is based not on the principle of only eradication of the pathogens but mainly on the principle of maintaining the loss or damage to the minimum possible level. Integrated disease or pest management aims at the integration of all the available methods directed in favor of the host, against the pathogen (i.e. chemical control, biological control, treatment with plant extracts, antibiotics, trace elements) and for the modification of the environment i.e. cultural practices. Keeping the above in view the present work was undertaken to control some of the leaf and stem diseases of tea prevalent in the Tea Estates of Barak valley involving Integrated Disease Management (IDM) strategy with the help of chemical, biocontrol agents and botanical pesticides (plant extracts).