CHAPTER II
REVIEW OF LITERATURE

Tea is a perennial monocultural crop. Its lifespan extends over 100 years. During this period, the plant is prone to many diseases, leading to moderate to severe crop loss and in certain cases even the death of the bushes. On a global basis the crop loss due to diseases has been estimated to be 10 to 15% (Chen and Chen, 1990) and it mainly depends on the nature of the pathogen and geographical area.

The diseases of tea occurring in different countries vary according to the geographical location. The major diseases in south east Asian countries such as India, Sri Lanka, Indonesia and Malaysia are blister blight and root rot, while in China and Japan it is brown blight and anthracnose. In the southern part of China and Taiwan blister blight is a serious problem. In African countries root rot diseases are of major concern. Several treatises are available on the diseases of tea in various countries like Japan (Hamaya, 1981), south east Asia (Arulpragasam, 1986; Satyanarayana, 1987; Semangun, 1987) and Africa (Rattan, 1992). Apart from these, regional treatises are also available (Venkataram, 1964; Satyanarayana and Barua, 1975; Agnihothrudu, 1995). Our knowledge on tea diseases in India is mainly based on the contributions from Petch (1923), Gadd (1949), Hainsworth (1952) and Sarmah (1960). Recently Muraleedharan and Chen (1997) reviewed the important pests and diseases of tea and their management worldwide.

Agnihothrudu (1964) has reported 385 species of fungi associated with tea, of which a large number were saprophytic. On the
other hand, Chen and Chen (1989) recorded a total of 507 fungi. Later they described around 400 pathogens associated with tea (Chen and Chen, 1990). Recently, Chandramouli (1994) enlisted 58 pathogens along with the common names of the diseases they cause. Among various groups of pathogenic fungi in tea, Ascomycetes form a major group causing many root and stem diseases. Among these, *T. aculeata* of Loculoascomycetidae causing thorny stem blight is of major concern (Agnihothrudu, 1961; Chandramouli and Parthiban 1992; Arulpragasam, 1992).

Thorny stem blight was first recorded in Sri Lanka (Petch, 1906). Subsequently, the disease was reported from Darjeeling hill area and plains of Assam (Tunstall, 1940; Tunstall and Sarmah, 1947). In southern India, this disease was first noticed in Nilgiri-Wynaad (Anon., 1963) and later on from High Range, Karnataka, Wynaad, Central Travancore, High Wavys and the Anamallais (Chandramouli and Parthiban, 1992). The disease is known to occur in Malawi, Zimbabwe, Indonesia and Colombia (Rattan, 1990).

The disease affects stem and branches of the tea bush. In some cases, the fruiting body appears on the root just below the ground level. The disease starts from the pruning cuts, where one could notice fresh infection with the development of typical thorns (Agnihothrudu, 1961; Chandramouli and Parthiban, 1992). From the pruning cut the infection slowly spreads down, killing the branches one by one until it reaches the collar and finally the roots, causing the death of the bush (Chandramouli, 1999). The disease is characterized by the development
of black thorns on completely dead wood. These thorny projections constitute the apices of the stroma of the fungus. The area surrounding the thorns is often raised and cracked.

The perithecia (fructifying body) are immersed in cortical tissue, carbonaceous and aggregated in groups up to five in number. The perithecial cavities are depressed and open into a common conical ostiolum (beak) which projects through the bark as a thick ‘thorn’. The thorns give a rough pustular surface to the infected part. (Agnihothrudu, 1961; Rattan, 1988).

Petch (1906) described the pathogen as *Aglaospora aculeata* and included *A. aculeata* under *Phragmosporus spheriaceae*. He mentioned that the ascospores are septate at maturity. Based on Petch’s description, Wehmeyer (1941) erected the genus *Phragmodiaporthe* and included *A. aculeata* under this genus as *Phragmodiaporthe aculeata*. After a detailed study Agnihothrudu (1961) concluded that the ascospores are not septate but only pseudoseptate at maturity. Based on the ascus morphology, spore character and the conical ectostroma, Agnihothrudu (1961) erected a new genus and named it as *Tunstallia aculeata* (Petch) Agni. At present this is the internationally recognized nomenclature. There are two varieties in this species, *T. aculeata* with four ascospores in the ascus and *T. aculeata* var. *kesabii* with eight ascospores (Agnihothrudu 1961). The species recorded in southern India is *T. aculeata* (Chandramouli, 1993), while in northern India both species have been recorded (Devnath, 1985).
Ultrastructure studies have been used in the classification of fungi (Cole and Samson, 1979). Recently, Gehlot and Purohit (2001) used scanning electron microscope (SEM) and transmission electron microscope to understand the characteristic features of *Colletotrichum capsici*. SEM studies have helped to find out several unique features of fungal species (Alexopoulos and Mims, 1989).

Isolation and pure culturing of *T. aculeata* was done from ascospores obtained from infected stems collected from field (Devnath, 1985; Chandramouli and Parthiban, 1992). Growth characteristics of the fungus on different solid media were also described (Devnath, 1985). The fungus took 56 days to complete its life cycle under laboratory conditions on sterilized tea stem bits (Chandramouli and Parthiban, 1992). Wijesundera and Kalatunga (1993) have reported the variation in growth rate of three isolates of branch canker pathogen (*Poria hypolateritia*) of tea and this has been correlated with the virulence of the isolates.

Plant diseases occur under specific environmental conditions. Seasonal discharge of spores, depending on weather conditions has been reported in many pathosystems (James and Sutton, 1982; Roberts and Boothroyd, 1987; Alexopoulos and Mims, 1989). Hershman and Perkins (1995) monitored the seasonal discharge pattern of ascospores of *Leptosphaeria maculans* and correlated it with weather factors. In a large number of Ascomycetes, ascospores are forcibly ejected from the ascus by a puffing action. Wind, water, insects or other agencies can also disseminate the spores (Ingold, 1971; Fitt et al., 1989). In *T.*
aculeata, ascospores are disseminated through air, which are considered to be the primary source of inoculum (Arulpragasam, 1992). But Agnihothrudu (1961), Satyanarayana (1987) and Barthakur (1994) reported that the dissemination of spores from bush to bush takes place through pruning knives.

Under favourable conditions ascospores germinate by producing one or more germ tubes that develop into septate mycelium. A relative humidity of more than 80% and a temperature around 20°C are ideal for the germination of ascospores (Alexopoulos and Mims, 1989).

2.1. Nutritional requirement / pathogen physiology

T. aculeata is a wood parasite infecting the main stem and branches, mainly through the pruning cuts. Structurally, the major component of wood is cellulose, a linear polymer of D-glucose in β (1-4) linkage. Another important constituent is lignin but this constitutes only 25% (Lehninger, 1975). Parasitism of a pathogen involves a nutritional inter relationship with the host from where it derives its entire nourishment (Starr, 1945). Preference of glucose and sucrose by many pathogenic fungi is well documented (Grover and Chona, 1960; Kumar and Grover, 1967; Papavizas, 1967; Tandon, 1967; Thind and Madan, 1967; Onsando, 1987; Bilgrami and Verma, 1992). Fungi generally prefer hexose sugars than pentose sugars (Bilgrami and Verma, 1992).

Starvation i.e., exhaustion of carbon and/or nitrogen is known to
cause conidiation in fungi. *T. aculeata* has been reported to have sexual cycle and asexual cycle is not known (Chandramouli and Parthiban, 1992). Evaluation of nutritionally rich and poor media may show some light on different life cycles (Dicker et al., 1969).

In addition to the nutritional requirements, the fungi require optimum physical conditions such as pH, temperature, moisture, etc. for their growth and reproduction. Growth of the fungi is an overall cumulative expression of a variety of metabolic activities including a large number of enzymatic reactions, each of which requires its own physical conditions. Successful *in vitro* growth of the fungi is possible by understanding these optimum conditions.

Temperature plays an important role in the growth of fungi by influencing the activity of enzymes in various metabolic processes. Cartwright and Findlay (1934) reported cardinal temperatures required by a large number of wood decaying fungi. Several reviews on the effect of temperature on fungal growth are available (Hawker, 1950; Cochrane, 1958; Deverall, 1965).

pH is another important factor. Fungi in general are more tolerant to acid ions (H\(^+\)) than of basic ions (OH\(^-\)). However, most of the fungi grow at pH between 4 and 8 (Bilgrami and Verma, 1992). pH of the medium exerts profound influence upon the availability of metallic ions, nitrogen, cell permeability, enzyme activity, etc. Reports on the optimum pH for various fungi are available (Lilly and Barnett, 1951; Cochrane, 1958; Narasimhan, 1969; Bilgrami and Verma, 1992).
2.2. Disease assessment and economic importance

Crop loss assessment requires collection of a large amount of data in order to understand the interaction between various factors that affect yield. These data need to be ‘quantitative’, and most often are collected through survey and field experiments (Bowen and Teng, 1987; Gaunt, 1995). Methods to quantify the relationship between disease intensity and yield loss have been described (Vanderplank, 1963; Teng, 1987). Yield loss models aid in decision making on disease control. The effect of diseased plants on yield of healthy plants in population is well known in several pathosystems. Hughes (1990) and Gaunt (1995) estimated the variation in individual plant yield in the population due to ‘space reducers’. They have explained that healthy plants compensate the yield loss due to dead plants, to some extent in wheat and several other annual crops.

Variation in disease susceptibility of tea clones is known. In case of blister blight disease of tea the existence of resistant clones in different locations in southern India has been documented (Anon, 1960; Baby and Premkumar, 2000). Differences in susceptibility of tea clones to collar canker disease (Phomopsis theae) have been reported from southern India (Baby et al., 2001).

2.3. Cultural operations vs. disease

Most of the species of higher plants are either immune or resistant to majority of microorganisms with which they come in
contact (Gaumann, 1950). This resistance may be genetic or non-genetic. The tendency of non-genetic factors to make plants susceptible to disease is called predisposition (Yarwood, 1959). According to Ward’s concept of predisposition (Ward, 1901) any disturbance in the ‘normal’ state may predispose plants to disease; therefore any deviation from environmental conditions optimum for expression of disease resistance could be considered as stress. Thus, factors like drought, defoliation, flooding, frost, etc can be a stress. Common effects of stress on diseases caused by obligate and facultative parasites were well illustrated (Schoeneweiss, 1975). He demonstrated that abiotic stress leads to reduced defense response in host plants leading to disease development by non-aggressive facultative parasites (Fig. 2). When the stress is removed the host plants resist further invasion of such pathogens.

Improved crop varieties are characterized by their high yield potential. Translocation of carbohydrates from source to sink depends on the sink capacity. Large sink capacity removes excessive quantities of sugars and leads to its depletion in leaves and stem, thereby making them susceptible to plant diseases (Vanderplank, 1984). This concept of low sugar diseases was elucidated in cotton (Batson et al., 1970), kentucky blue grass (Lukens, 1970), finger millet (Vidyasekaran, 1974), tomatoes (Horsfall, 1975) and maize (Dodd, 1980). Vanderplank (1984) coined the term sink induced loss of resistance to the above phenomena. He concluded that low sugar diseases are usually associated with necrotrophs and that of high sugar diseases with biotrophs. Necrotrophs are able to take the advantage of low sugar
Fig. 2. Common effects of stress on infectious diseases caused by obligate and facultative parasites (Schoeneweiss, 1975).
conditions and develop themselves by killing the host tissue with the help of enzymes produced by them. Biotrophs on the other hand support the production of antibiotic substances that are essential for establishment of the parasitic relationship.

In tea, the vegetative shoot forms the harvest. This is essentially a process of defoliation. Loss of foliage during the growing season may predispose plants to attack by pathogens. This has been well established in certain plant-pathogen interactions (Stanley, 1965; Siddique et al., 1968; Stephens, 1971; Stephens and Hill, 1971; Schoeneweiss, 1975, 1981). Defoliation affects photosynthesis leading to reduced production and accumulation of photosynthates. The principal storage sugar in woody perennials is starch. During prolonged defoliated conditions the starch reserves breakdown to simple sugars, which are utilized by the plant for their energy needs. Thus defoliation decreases the starch content in stem and root tissues (Hodges and Lorio, 1969; Parker, 1970; Parker and Houston, 1971; Wargo, 1972; Wargo and Houston, 1973). The role of maintenance foliage in tea and effect of harvesting methods on bush health and root carbohydrate levels have been reported (Manivel, 1978; Sharma, 1983; Satyanarayana and Sharma, 1984; Barua, 1989; Barman, et al., 1992; Marimuthu et al., 1994).

The woody stem of the tea plant is protected by the living cells of the bark and under normal circumstances offer resistance to invasion by parasitic and other fungi. But the practice of pruning exposes the woody tissue to a variety of fungi. They invade the tissue through cut surfaces and/or through sun scorch damage on the bark.
Pruning is an essential cultural operation to keep the plants at convenient height for harvesting and induce vegetative growth. The recommended pruning time in southern India is March / April and July / August (Swaminathan et al., 1995). It is established that during these periods there will be enough starch reserves in the root to ensure good recovery from pruning (Marimuthu et al., 1996).

Many tea plant pathologists have reported that the entry of TSB pathogen takes place through the wounds, mainly the pruning cuts. Pruned cuts provide ideal surface for spore germination (Arulpragasam, 1992). *T. aculeata* is a weak parasite and affects the tea plants, which are debilitated due to moisture stress, pest attack (mites) and intensive harvesting (Petch, 1906; Tunstall and Sarmah, 1947; Gadd, 1949; Agnihothrudu, 1961; Devnath, 1985; Chandramouli and Parthiban, 1992; Barthakur, 1994).

The effects of mineral nutrients on plant growth and yield are usually explained in terms of the functions of these elements in plant metabolism. However, mineral nutrition may also exert unpredictable influences on the growth and yield of crop plants by effecting changes in plant morphology, anatomy and physiology. In this context, mineral nutrition of plants can be considered as an environmental factor that can predispose plants to diseases. Although frequently unrecognized, this factor has always been an important component of disease development (Huber and Wilhelm, 1988). It may either increase or decrease the resistance/tolerance of the plants to pathogens (Marschner, 1995).
The relationship between nutrition and susceptibility to parasitic and non-parasitic diseases in plants has been discussed (Boning, 1976). Among the various plant nutrients, nitrogen is well known to increase the susceptibility, whereas potassium induces disease resistance. On the other hand, a balanced fertilizer dosage of nitrogen and potassium protects plants from disease (Goodman *et al.*, 1967; Huber, 1980; Stack, *et al.*, 1986; Rangaswami, 1988; Sinha, 1998). Comprehensive reviews on this subject are available (Fuchs and Grossman, 1972; Huber and Watson, 1974; Perrenoud, 1977; Graham, 1983; Huber, 1989). Severity of branch canker disease of tea was influenced by nitrogen and potassium levels. Size of cankers increased with increasing levels of nitrogen but with increased levels of potassium, the severity reduced (Shanmuganathan and Bopearatchy, 1972b). *Armillaria* root rot symptoms in prunus trees were reduced by 65% with increased levels of potassium (Anon., 2000).

Response of nitrogen and potassium fertilizer levels to yield is also documented (Ishigaki, 1978; Grice and Malenga, 1985; Ranganathan and Natesan, 1985; Jain, 1988; Manivel, 1999). Since vegetative parts (leaf) are continuously harvested, the nitrogen and potassium requirement of tea plant is high. A NK ratio of 1:1 is recommended for tea under harvesting and a higher level of potassium, up to 1:2 is recommended in first year fields, based on the pruning height (Verma, 1997).
2.4. Disease management

Fungicidal protection is the prime strategy in the control of plant diseases (Maloy, 1993). In tea, the maximum fungicide usage was for the control of leaf diseases such as blister blight, anthracnose and grey blight (Muraleedharan and Chen, 1997).

Information on chemical control of tea stem diseases is meagre. Soil application of benomyl effectively controlled stem canker caused by *P. theae* (Shanmuganathan and Bopearatchy, 1972a). Efficacy of benlate *in vitro* and *in vivo* in controlling wood rot caused by *H. serpens* is also known (Onsando 1986; Onsando and Langet, 1989; Othieno, 1996). It was found that the efficacy was superior when fungicide treatments were given after surgical removal of diseased wood. Venkataram (1976) has reported similar results from southern India. Although pruning is also used as an important tool in the eradication of stem diseases of tea, this can be ineffective if the pathogen is deep seated in the collar region (below ground level). On the other hand, height of pruning from ground level plays a major role in yield. Lower yield due to collar pruning in comparison to cut across pruning has been reported (Venkataram, 1976; Onsando and Langet, 1989; Sharma and Satyanarayana, 1994). They attributed this to longer period required for the recovery and development of branches. But Venkataram (1976) concluded that in the long term, collar pruning results in higher yield due to superior disease control.

Chandramouli and Parthiban (1992) emphasized on the physical
removal of diseased wood to control TSB. Application of a mixture of copper oxychloride and linseed oil on the pruned cut was also recommended as a control measure. In cases where infection spread below the collar region, uprooting of the bushes and infilling the vacancies was suggested as a way to manage the disease. Since TSB pathogen was known to enter the plant through pruning cut, sterilization of pruning knife with copper oxychloride (0.2%) or post prune application of copper oxychloride (0.2%) at the rate of 1000 l ha$^{-1}$ was also recommended (Satyanarayana, 1987). Soil drenching with copper oxychloride was found effective to control citrus *Phytophthora* disease of kinnow mandarin (Thind *et al*., 1999).

There are several successful examples of fungicidal control of woody perennials using systemic fungicides. Benomyl, carbendazim and thiabendazole were found effective in managing Dutch elm disease through proper application technology and dosage (Hock *et al*., 1970; Biehn and Dimond, 1971; Prasad and Travnick, 1972; Smalley, 1972; Erwin, 1973). Successful management of apricot dieback caused by *Eutypa armeniaca*, through the protection of pruned cut has been reported (Moller and Carter, 1970). High volume sprays of benomyl (0.025%) after pruning reduced infection by more than 50%. They also found that the wounds were susceptible to infection only for eight weeks from pruning. Carbendazim was reported to be effective in the control of *Corticium sasakii*, the causal organism of rice sheath blight disease (Roy and Saikia, 1976). Prolonged persistence of carbendazim in soil has also been reported (Sinha *et al*., 1980). *Rhizoctonia solani*, the collar rot pathogen of coffee was inhibited *in vitro* by tridemorph
Dust formulations of carbendazim and tridemorph were found effective in controlling powdery mildew (Oidium heveae) and dry rot (Ustulina deusta) of rubber (Jacob et al., 1996; Joy and Jacob, 2000).

Another important group of systemic fungicides is triazole. They inhibit the growth of fungal pathogens by interfering with the biosynthesis of sterols. These fungicides are effective against a wide range of fungal diseases caused by Ascomycetes, Basidiomycetes and Deutromycetes (Nene and Thapliyal, 1993). Tridemorph effectively controlled the pink disease of Hevea caused by Corticium salmonicolor (Wastie, 1976). Jacob and Edathil (1983) reported the efficacy of propiconazole in managing the pink disease of rubber through trunk injection. Similarly, Helton and Kochan (1968) reported the efficacy of triazoles as chemical paints in managing Cytospora canker of Prunus domestica. Systemic uptake and translocation of Panoram and Vitavax has been reported in sorghum (Shah and Mariappan, 1989). Systemic activity of tridemorph and several triazoles against blister blight of tea was also documented (Venkataram, 1974 and Premkumar, et al., 1998).

Enhancement in yield after fungicide treatment is well known in several plant-pathogen interactions. This is chiefly attributed to reduced disease severity both as preventive and curative effects. Othieno (1996) recorded significant yield increase after treating wood rot (H. serpens) of tea with benomyl. Similarly Rajib et al. (2000) noticed increased seed yield with carbanzim soil application to control Fusarium wilt of lentils.
Chemical control of diseases occurring on the foliage and green stems was found successful in many cases (Campbell, 1989; Hofte, 1999). Soil borne diseases and diseases of the woody stem require large quantities of fungicides because of restricted translocation, degradation by a variety of microorganisms and some times by the host plant itself. In these cases chemical control is expensive and also leads to environmental pollution. Biological control holds much promise in such situations.

In the standard work on biological control of plant pathogens, Baker and Cook (1974) considered “biological control as the reduction of inoculum density or disease producing activities of a pathogen or parasite in its active or dormant state, by one or more organisms, accomplished naturally or through manipulation of the environment, host, or antagonist, or by mass introduction of one or more antagonists”. The first part of the definition “manipulation of the environment, host or antagonist’ can be achieved by traditional approaches such as crop rotation, green manuring and organic amendment. Most research on biological control, however, deals with the application of selected microorganisms to affected crops.

Biological control has been most successful against diseases of woody plants (Campbell, 1989). This can be explained because of the suitability of woody stem for inoculation with antagonists and their successful establishment due to lesser competition by other microorganisms. Traditionally there was very little breeding for resistance in trees, and pesticides developed specifically for tree
diseases were very few. This facilitated the development of biological control as a viable alternative in the control of tree diseases, especially those affecting woody stem.

In recent years a lot of progress has been made in understanding the biology of interactions between pathogen and biocontrol agents, that result in disease suppression. Many recent reviews dealing with mechanisms involved in biological control are available (Goldman et al., 1994; Handlesman and Stabb, 1996). The general modes of action are competition for nutrients and place (Elad, 1996), production of antibiotics, mycoparasitism, and induced resistance (Chet, 1987; Baker, 1988; Fravel, 1988; Hofte, 1999).

The work on biocontrol of tea diseases is limited. *In vitro* antagonism of *Trichoderma* spp. and *Gliocladium virens* to root rot pathogens has been reported (Baby and Chandramouli, 1996). *Trichoderma viride* and *T. harzianum* had inhibitory activity against *Poria hypobrunnea* causing stem canker (Das and Barua, 1990). They found that the decrease in infection was as high as 89% and 77% after 12 and 24 months of treatment, respectively. Attempts were made to control TSB using tea wood pellets colonized by *T. viride* and *T. harzianum* (Borthakur and Dutta, 1992).

The mechanism of protection of pruned cuts by inoculating a competitor or an antibiotic-producing microorganism at the time of pruning has been elucidated (Cook and Baker, 1983). Grosclaude et al. (1973) inoculated plum trees with *T. viride* spore suspension through
pruning shears at the time of pruning. Two days later, the pruned cuts were inoculated with the spore suspension of silver leaf pathogen *Stereum purpureum*. Inoculation of *T. viride* completely prevented the occurrence of silver leaf disease compared to 75% infection in control. The efficacy of *T. viride* against *S. purpureum* was further confirmed by Burges (1981). Richard (1983) investigated the biocontrol of Dutch elm disease with *T. viride* and *T. harzianum* pellets. Not only preventive but also curative effect has been reported with biocontrol agents (Dubos and Richard, 1974).

*Pseudomonas* spp. is a well known biocontrol agent against many plant pathogen interactions. *Pseudomonas* spp. effectively controlled Dutch elm disease caused by *Ceratocystis ulmi* (Scheffer, 1989) and take-all disease of wheat caused by *Gaeumannomyces graminis* var. *tritici* (Weller and Cook, 1983; Cook et al., 1988; Cook, 1993). Antagonism of *Pseudomonas aeruginosa* on *Fusarium* and *Pythium* spp. and its mode of action have been explained (Anjaiah, et al., 1998). Antifungal metabolites produced by *Pseudomonas* spp. and their role in biocontrol was reviewed recently (Thomashow and Weller, 1996).

Apart from biocontrol potential, *Trichoderma* spp. is known to stimulate plant growth through control of minor pathogens and production of growth regulating factors (Windham, et al., 1986; Baker, 1988; Hofte, 1999).

Integrated disease management can be defined as a system that
utilizes all suitable techniques and methods in a compatible manner as possible to maintain the disease incidence at levels below those causing economic damage. Successful development of integrated control depends on understanding of the epidemiology of the disease, sequence and/or combination of cultural, chemical, biological controls. Finally economics of the systems play an important role in its adoption.

Several canker diseases of tea can be eliminated by choosing resistant plant materials (Arulpragasam, 1992). Apple blotch (*Phylllosticta solitaria*) has been effectively managed by use of resistant varieties (Sutton, 1996). Host resistance contributed maximally in the management of rice blast caused by *Drechslera oryzae* (Kapoor *et al.*, 2000). Introduction of resistant cultivars against apple scab (*Venturia inaequalis*) and white root rot (*Dematophora necatrix*) has been highlighted as a key component in integrated disease management (Gupta, 2000). *Phytophthora* tolerant black pepper lines have been identified (Sarma, 2000). Integrated management of *Sclerotium* root rot of groundnut with *Trichoderma harzianum*, *Rhizobium* and carbendazim has been reported (Muthamilan and Jeyarajan, 1996). Phytosanitation, chemical control, biocontrol and host resistance have been found to be effective in combination to manage *Phytophthora* diseases of several plantation crops (Sarma, 2000). Foliar, stem and root diseases of apple can be managed by using forecasting tools, host resistance, fungicides and biocontrol agents (Gupta, 2000). Sutton (1996) emphasized the role of cultural, biological resistant genotypes and judicious fungicide application in achieving economic control of the diseases of deciduous fruits. Availability of several options in the
control of TSB such as harvesting method, fungicides, biocontrol agents, pruning cycle duration and host resistance has been reported (Chandramouli, 1999).

The scope of cultural practices like crop rotation, fallowing and uprooting for avoiding disease is limited in tea. However, integrated pest and disease management approaches have been envisaged in tea in north east India (Barbora et al., 1995).

2.5. Scope of the present investigation

Tea cultivation is characterized by intensive agronomic practices such as introduction of high yielding cultivars, application of high levels of nitrogenous fertilizers, use of toxic pesticides to control pests and diseases and intensive harvesting through continuous hand plucking and shearing. The harvesting practices are aimed at increased worker productivity and thereby maximizing production and profits. There is a growing awareness on the adverse effects of intensive harvesting on the health of the bushes, which lead to the development of many minor diseases into serious problems in recent years.

Review of literature indicated that information related to the biology and physiology of the pathogen, economic importance, cultural practices vis a vis TSB development and its control is scanty. Experiments were designed to fulfill these objectives. The survey conducted in various planting districts gave a picture on the severity of the disease in these areas and the clonal susceptibility. Even though
active spore dispersal takes place in *T. aculeata*, spread of the inoculum can also take place through the pruning knife. If pruning is done during actively sporulating period of the pathogen, the spread of disease is easy and rapid. To avoid this, an idea on the sporulating pattern with respect to weather condition is essential. An understanding of the clonal susceptibility/resistance will help to select resistant genotypes for planting programmes, while that of the development of disease on individual bushes and in a population will give an idea of the developmental stage and the crop loss accrued due to the disease.

The impact of cultural operations especially type of harvesting on the root carbohydrate levels in relation to disease development is evident from the study. The soothing effect of fertilizer doses on TSB development is also evident. These studies have left of practical implication in optimizing cultural operations for disease escape.

Conventionally, stem diseases are controlled by copper fungicides. In the present study, the scope of systemic fungicides and biocontrol agents in controlling TSB was evaluated. This will open a new arena in TSB management.

Further, public awareness of the pollution problems caused by pesticides and their failure due to resistance build-up stress the need for developing integrated disease management strategies through the integration of cultural, biological and judicious application of fungicides. This measure is eco-friendly and geared towards sustainable agriculture.