CHAPTER-1

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1.1. Tea: an overview

Tea beverage is an infusion of the dried leaves of the *Camellia sinesis* (L.) O. Kuntze plant. It is the second most commonly drank liquid on earth after water. It is being consumed socially and habitually by people since 3000 BC. From time immemorial, tea is regarded as a healthy beverage. 'Lost Property of Medicinal Herbs', an ancient book in China's Chang Dynasty recorded that while various medicines are the cure of different diseases, 'green tea is the cure to all' (Sharangi, 2009). Green, oolong and black tea are all made from the same plant species, but differing in their appearance, organoleptic taste, chemical content as well as flavour due to their respective fermentation process. It is consumed in the form of fermented (black tea), semi-fermented (oolong) or non-fermented (green tea). Tea has been reported to have a wide range of beneficial physiological and pharmacological effects such as anti-inflammatory effect, anti-microbial and anti-oxidant properties, strengthening of capillaries, and a favourable role in cardiovascular ailments (Hamilton-Miller, 1995). Green tea is rich in catechins which are strong antioxidants. In addition, presence of certain minerals and vitamins increases the antioxidant potential of tea. Tea constituents inhibit carcinogenesis of the skin, lungs, oral cavity, esophagus, stomach, liver, prostate and other organs as revealed by animal studies (Lambert and Yang, 2003; Parmar *et al.*, 2012).

The discovery of indigenous tea in Assam in 1823 led to the origin of the tea industry in India. However, much earlier to that, Sir Joseph Bank recorded the existence of indigenous tea growing wild in Coochbehar and Rangpur districts of Bengal in 1788 and suggested the cultivation of this plant. The wild teas of Coochbehar confirmed the first discovery of indigenous tea in India (Karmakar and Banerjee, 2005). The genus of *Camellia*, believed to comprise more than 300 species, is considered to be genetically instable and of high out breeding nature (Hall, 2000). According to conservative estimation, there are more than 30,000 cultivated varieties of ornamental *Camellia* worldwide (Mondal, 2014). Because of extensive internal

hybridization between different *Camellia* taxa, several intergrades, introgressants and putative hybrids had been found. They were arranged in a gradient based on morphological characters that extended from China types through intermediates to those of Assam types (Banerjee, 1992; Mondal, 2014). Besides this natural diversity, the different organizations such as the tea research institutes as well as dedicated planters had further developed a number of varieties with better yield, quality and traits such as tolerance to drought, diseases, etc. More than 1,200 such commercial cultivars of tea have been developed and released for cultivation worldwide and many of them have special characters. Currently, India is the largest producer of black tea as well as the largest consumer of tea in the world. It is the only industry where India has retained its leadership over the past 150 years offering a variety of products, from original orthodox to CTC and now green tea, Darjeeling tea, Assam tea and Nilgiris tea (Selvakumar and Jeyaselvam, 2012).

1.2. Economic importance of tea

Owing to its increasing demand, tea is considered to be one of the major components of world beverage market. The global market for hot beverage (coffee and tea) is predicted to reach US$ 69.77 billion in value and 10.57 million tons in volume terms by the year 2015 (http://www.strategyr.com/Hot_Beverages_Coffee_and_Tea_Market_Report.asp). Presently, India contributes to 23% of total world production and consumes about 21% of total world consumption of tea. Almost 80% of the tea produced in India is consumed within the country. Tea industry plays a pivotal role in Indian national economy with a total annual turnover of Rs.10000 crores. India occupies 1.016 million acres of tea growing land which is 16.4% of the total tea growing areas of the world. In terms of employment, it is the second largest industry by employing more than a million people directly and 2 million people indirectly, of which 50% are women. The tea industry, to a large extent, drives the economies of the regions where the tea gardens are concentrated, for example Assam. Over the last 20 years, India's world ranking as an exporter has come down from number one to number four, in the face of stiff competition from Sri Lanka, Kenya and China (Basu Majumder *et al.*, 2010).

1.3. Abiotic stress response in plants

Abiotic stress is defined as the negative impact of non-living factors on the living organisms in a specific environment. The non-living parameter must influence the environment outside its normal range of deviation in order to adversely affect the physiology of the individual organism to a significant level (Vinebrooke *et al.*, 2004). While a biotic stress includes living disturbances like pathogenic fungi, bacteria or harmful insects; abiotic stress factors are naturally occurring, and are essentially unavoidable. Abiotic stress affects animals, but plants are particularly dependent on environmental factors, so it is principally hindering to normal existence. Abiotic stresses such as drought, salinity, heavy metal excess, nutrient defiency, water excess and others are the most harmful factors concerning the growth and productivity of crops worldwide (Gao *et al.*, 2007). Research has also shown that abiotic stressors are most harmful when they occur together, that is in combinations of several stress elements (Mittler, 2006).

Plants must respond and adapt to abiotic stresses in order to survive in various soil and climatic conditions. Plants have acquired mechanisms for stress tolerance, which are essentially the different processes involving adaptive physiological and biochemical changes that may also result in morphological changes (Urano *et al.*, 2010). Similar kinds of responses are often manifested at the cellular and molecular level to different environmental stresses occurring in a plant. This is because, the impacts of the different stress signals trigger similar strains and downstream signal transduction chains in the plant. Abiotic stresses on plants can cause germination inhibition, growth reduction, premature senescence, reduction in productivity, reduction in water uptake, altered transpiration uptake, reduction in photosynthesis, altered respiration, decrease in nitrogen assimilation, metabolic toxicity, accumulation of growth inhibitors, altered gene expression, breakdown of macromolecules, reduced activity of vital enzymes, decreased protein synthesis and disorganization of membrane systems (Yruela, 2005; Shanker *et al.*, 2005; Maksymiec, 2007; Olteanu *et al.*, 2013).

Long exposure of plants to soil contaminated with an excess of various metals may lead to the accumulation of metals in plant organs and

organelles and to the induction of defense mechanisms. Plants possess several mechanisms by which they protect themselves from the deleterious effects of metals such as: exclusion, inactivation and storage as complexes with various natural compounds called phytochelators in the vacuole (Brune *et al.*, 1994; Zenk, 1996). One important feature of metal toxicity in plants is the disruption of redox homeostasis because of an increased production of reactive oxygen species (ROS), together with a response in antioxidative metabolism (Prasad *et al.*, 1999; Rao and Sresty, 2000; Bonnet *et al.*, 2000; Schutzendubel and Polle, 2002). Excessive metal accumulation in the cells may lead to collapse of the plant's detoxification capacity thereby causing oxidative damage to cellular components such as DNA, proteins and membrane lipids resulting in cell death (Tappel, 1973; Didierjean *et al.*, 1996; Casano *et al.*, 1997; Yun *et al.*, 1999; Sgherri *et al.*, 2003).

1.4. Objectives

The hilly regions of Assam and sub-Himalayan West Bengal are among the major tea growing areas in India and a large population of these areas depend on tea for their livelihood. Tea plantations are very prone to attack by several fungal pathogens which results in major economical losses. Diseases of tea such as blister blight, brown blight, grey blight, black rot, cercospora leaf spot, pink disease and thread blight cause severe loss to the industry (Tripathi, 2006). Several fungal pathogens such as *Exobasidium vexans*, *Pestalotiopsis theae*, *Colletotricum camelliae*, *Rhizoctonia solani* and *Lasiodiplodia theobromae* attacks the tea plants round the year resulting in substantial reduction in the yield. This requires regular use of fungicides which are mostly based on copper because they are cheap and highly effective. Several reports suggest that copper fungicides are used for a long time in tea gardens of North East India including Assam and sub-Himalayan West Bengal (Sarmah, 1960; Barua, 1988; Singh, 2005). The excess accumulation of Cu^{2+} may have adverse effect on the tea plants which normally have a productive life-span of 25 years. Therefore, it is necessary to study the effect of copper on different cultivars of tea plants commonly grown in India. The present study proposes the following objectives for investigating the effect of copper in tea plants:

1. Studies on morphological changes in different tea varieties following application of copper in different concentrations.
2. Investigations on biochemical changes in different tea varieties in response to copper stress.
3. Studies on enzymatic antioxidants in response to copper stress.
4. Cytochemical localization of related copper induced enzymes in affected tissues.