CHAPTER-3

USE OF COPPER CONTAINING FUNGICIDES IN THE TEA GARDENS OF SUB-HIMALAYAN WEST BENGAL AND SOUTHERN ASSAM

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The annual loss to crops worldwide as a result of disease has been estimated at 25,000 million dollars. Thus control of phytopathogens plays an important role in determining the cost and amount of food produced thereby ensuring food safety. Early agriculturists from ancient times tried to prevent crop loss by using chemicals. The first record of plant disease control is in the writings of the Greek poet Holmer (1000 B.C.) who mentioned sulphur that is still used as an important component of fungicides (Mehrotra and Agarwal, 2003).

The first landmark in the control of phytopathogens is the discovery of Bordeaux mixture by P. M. A. Millardet in 1885. While working on downy mildew of grapevines, he noticed that vines treated with a mixture of copper sulphate and slaked lime to prevent the grapes from being stolen, retained their leaves whereas the untreated vines were defoliated. Millardet believed that the foliage on some of the vines had persisted because of the dabbing of the leaves with the lime-copper sulphate mixture. This suggested Millardet a way to control the disease and ultimately led to the discovery of Bordeaux mixture. This mixture has the reaction product of copper sulphate and calcium hydroxide. Spectacular results were obtained even in severe outbreaks leading to a rapid improvement in copper based fungicidal preparations. From the Bordeaux mixture developed the insoluble copper fungicides such as cuprous oxides or oxychlorides (Mehrotra and Agarwal, 2003). Copper based compounds thus emerged as the most important and successful fungicides and continued to remain so for many more years.

Tea is the major industrial sector in northeast India. Tea alone generates an annual turnover of 8 million USD. There are around 350 tea gardens in the North Bengal region alone that provides employment to about 3.5 lakh people working in the tea gardens. It produces around 200 million kg of tea of the total 830 million kg of tea produced in the country per annum. (Mandal *et al.*, 2012). The agro-climatic conditions of the north-eastern region of India provide an ideal situation for growing different types of teas.

Tea plant is an evergreen woody perennial grown mostly as monoculture. Occurrence of pests and diseases can cause serious damages in tea with significant impact on productivity and quality. All parts of the plant *i.e* leaf, stem, root, flower, and seed are susceptible to the pests and pathogens which may result in 7-10% annual crop loss, if left unchecked. Incidence and intensity of attack varies widely with variation in climate, elevation and the planting material (Barthakur, 2011). The tea plant is subject to attack from at least 250 insect species and 380 fungal pathogens out of which 167 pests and 190 fungi have been detected in northeast India (Das, 1965).

The tea planters are in general more concerned than growers of other crops about leaf disease, for the obvious reason that plant (bush) is cultivated for its leaves. The leaves are harvested usually at intervals of 5-7 days. Were it not for the planters' constant fight to protect their crop, the tea production would have been badly affected. The consumption of pesticides in India is one of the lowest in the world, about 0.5 kg/ha, but pesticide use in tea in general is said to be several times higher than in other crops (Barooah, 2011).

From the previous discussion it is clear that pests and diseases play an important role in economy of the tea gardens, and to control these diseases, regular spraying of huge amount of fungicides is inevitable. As this study aims to understand the effect of copper on tea plants, a survey work on fungicide usage by the tea gardens of the north eastern region of India was undertaken right at the beginning before indulging in any kind of experimental work. This was needed in order to estimate the actual threat to tea plants, if any.

3.1. MATERIALS AND METHODS

3.1.1. Study Area

The study area covers four districts of northern West Bengal and three districts of southern Assam which are part of the agro-climatic zone of north-east India. The West Bengal districts include Darjeeling, Jalpaiguri, Coochbehar and North Dinajpur (Fig. 3.1 and 3.2). Of these, Darjeeling is mainly hilly while the others are located in the foothills of the Eastern Himalayas (altitude: 90m to 1750m above sea level). It covers an area of

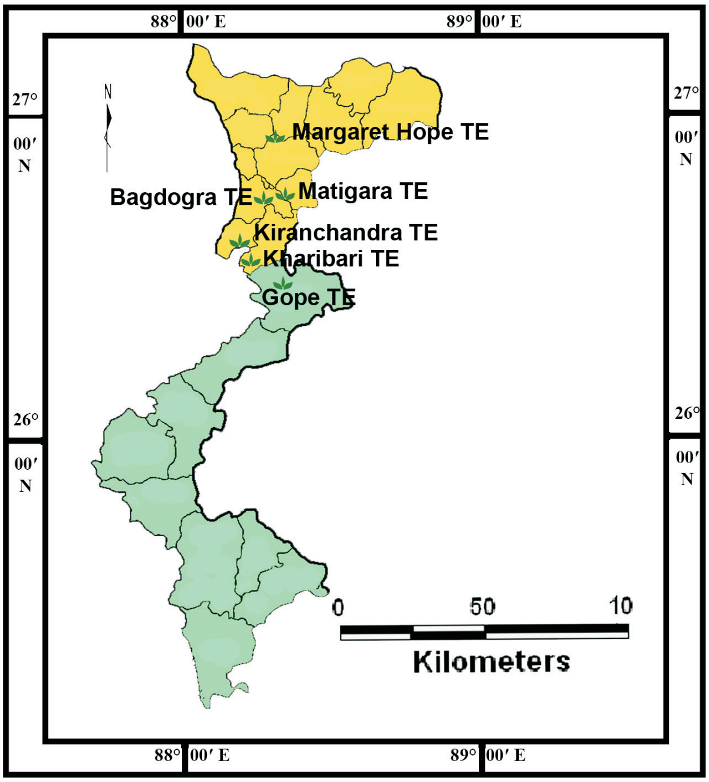

Fig. 3.1: Map of Darjeeling and Uttar Dinajpur districts of West Bengal showing the geographical locations of surveyed tea estates (TE).

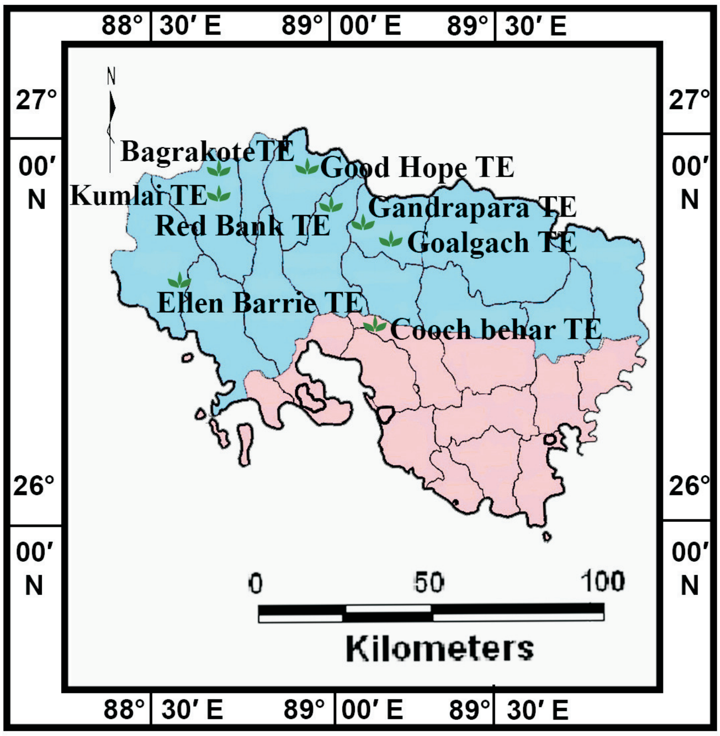

Fig. 3.2: Map of Jalpaiguri and Coochbehar districts of West Bengal showing geographical locations of surveyed tea estates (TE).

8800 km^2 and is situated between 25°58' and 27°45' North latitudes and 89°08' and 89°59' East longitudes. It is bounded in the North by Himalaya, to the East by river Sankosh, to the West by river Teesta and to South by Bangladesh and Gangetic plain. It is a transitional zone between the Himalayan Mountain and fertile alluvial Teesta–Brahmaputra plains commonly known as the "Dooars" region. The districts of Assam include Cachar, Hailakandi and Karimganj under Barak Valley Zone (Fig. 3.3). It covers an area of 6922 km^2 and is situated between 24°22' North and 25°08' East latitudes and 92°24' East and 93°15' East longitudes. This zone is bounded in the north by North Cachar hills, in the east by Manipur hills, in the south by the hills of Mizoram, and in the west by Bangladesh and Tripura. The region lies around 36.5 m above sea level. The entire topography is crisscrossed with several rivulets and rivers along with substantial forest cover comprising of semi-moist-deciduous vegetation.

The entire region is characterized by a sub-tropical and humid type of climate. The average annual humidity is 71%-98%. The average maximum temperature is 37-38°C and the average minimum temperature is 9-15°C depending on the altitude. The average annual rainfall of sub-Himalayan West Bengal is 2500 mm and that of the Barak valley zone is 3500 mm with an average of about 150-200 rainy days per year.

3.1.2. Data Collection

A simple but very basic work plan was adopted for this survey work. At first various government departments like Agriculture Department, Panchayat Offices, etc. were approached for getting information about checklist of tea gardens with relevant demographic information and to get detailed information about government guidelines about fungicide usage, if any. Relevant information was also collected from the data uploaded on various government websites and from those of some of the tea gardens (http://dae.portal.gov.bd/sites/default/files/files/dae.portal.gov.bd/page/). On the basis of that information, a plan of work was chalked out for our survey. Then extensive survey was conducted during the period of July, 2007 to December, 2007 and some of the places were revisited again during July to December of 2010.

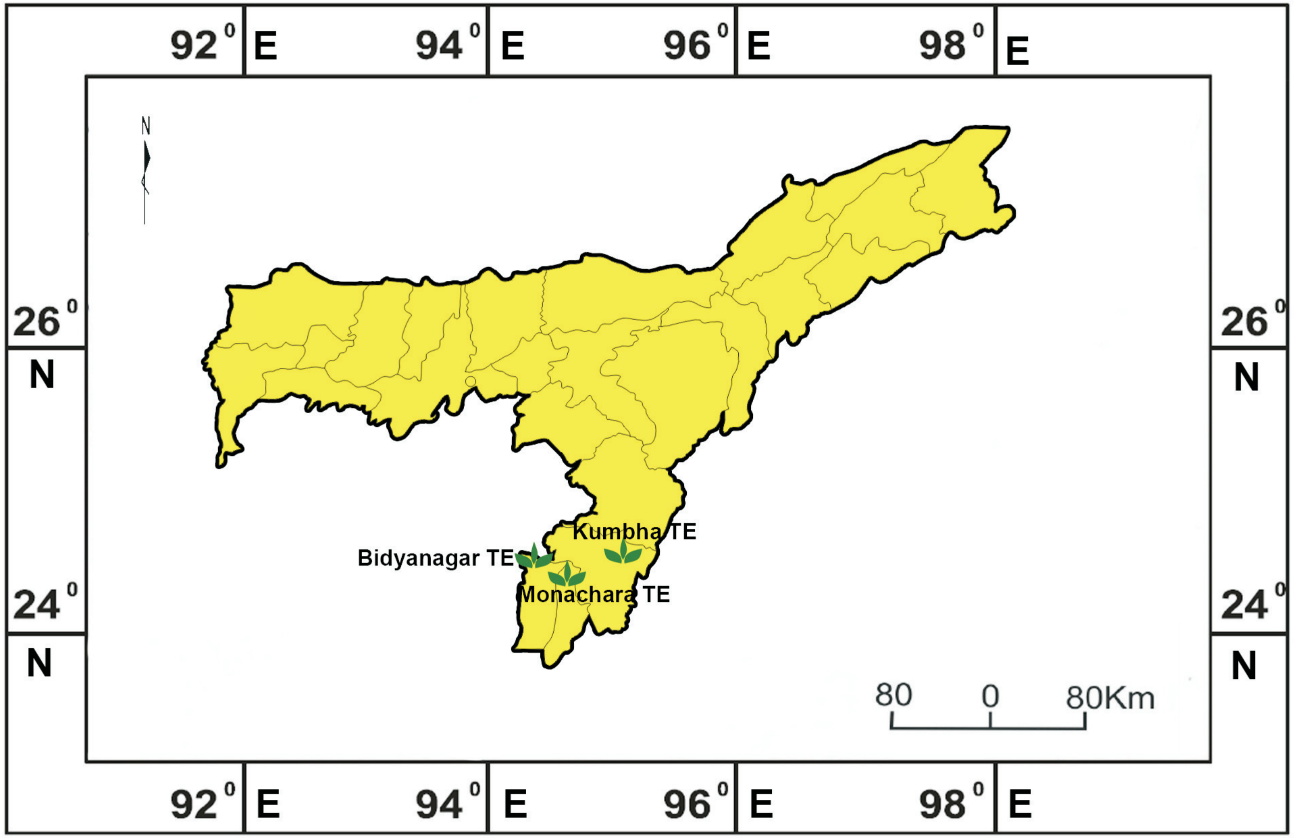

Fig. 3.3: Map of Assam showing locations of tea estates (TE) included in survey. The concerned tea estates are located in the Barak Valley region covering the districts of Cachar, Hailakandi and Karimganj.

During field survey, each enlisted tea-garden (Table 3.1) was approached through personal visits and detailed information on prevalent diseases, types and methods of fungicide usage, spray schedules, amount used, conditions of application etc. were collected from authorized persons of the tea estates. Information was collected through well-structured pretested questionnaires (Fig. 3.4) and discussions among the informants often in their local language.

Table 3.1:Geographic Information System (GIS) locations of the tea estates

Name of the tea estate	Location		GIS Location (Latitude, Longitude)
	District	State	
Bagdogra T. E.	Darjeeling	W. B.	26°42'N/88°18'E
Bidyanagar T. E.	Karimganj	Assam	24°31'N/92°29'E
Bagrakote T.E.	Jalpaiguri	W. B.	26°53'N/88°35'E
Coochbehar T. E.	Coochbehar	W. B.	26°57'N/89°05'E
Ellen Barrie T. E.	Jalpaiguri	W. B.	26°63'N/88°33'E
Gandrapara T. E.	Jalpaiguri	W. B.	26°78'N/89°20'E
Goal Gach T. E.	Jalpaiguri	W. B.	26°52'N/89°12'E
Good Hope T. E.	Jalpaiguri	W. B.	26°58'N/88°56'E
Gope T. E.	Uttar Dinajpur	W. B.	26°37'N/88°31'E
Kharibari T. E.	Darjeeling	W. B.	26°33'N/88°11'E
Kiranchandra T. E.	Darjeeling	W. B.	26°49'N/88°22'E
Kumbha T. E.	Cachar	Assam	24°56'N/92°59'E
Kumlai T. E.	Jalpaiguri	W. B.	26°90'N/88°40'E
Margarets Hope T. E.	Darjeeling	W. B.	26°55'N/88°17'E
Matigara T. E.	Darjeeling	W. B.	26°43'N/88°23'E
Monachara T. E.	Hailakandi	Assam	24°44'N/92°32'E
Red Bank T. E.	Jalpaiguri	W. B.	26°88'N/88°90'E

T. E.: Tea Estate; W. B.: West Bengal

1. Name of the Tea Estate
2. Address
3. Date of visit
4. Time of visit
5. Resource personnel of Tea Estate (Name)
6. Address
7. Information collected:

i) Status of diseases prevalent in the garden

a) Name of the disease

b) Time and duration of occurrence

c) Severity level

ii) Whether chemical fungicides are used (yes/no)

iii) Whether organic fungicides are used (yes/no)

iv) If answer to questions (ii) and (iii) are both "yes" then what proportion of chemical fungicides are applied.

v) If only answer (ii) is "yes"

a) Name(s) of chemical fungicides used

b) Conditions of application (such as disease outbreak, preventive application etc.)

c) Amount of chemical fungicides used under each condition

d) Spray schedule under each condition

Fig. 3.4: Format of the questionnaire for collecting information regarding fungicide usage routine of the tea gardens of sub-Himalayan West Bengal and Barak Valley region of Assam

3.2. RESULTS

The results of the survey work are summarized in Table 3.2. It was found that several fungal diseases such as blister blight, black rot, die back, stem rust, leaf blight (grey blight, brown blight), root and stem blight, stem canker, damping off, collar rot, thread blight, stem rot, leaf spot etc. are prevalent in the tea gardens of sub-Himalayan West Bengal and Barak Valley zone of Assam. In order to control the diseases, 12 different types of fungicides were found to be used. All of these were either simple copper salts or compounds that are complexes or mixtures of different salts of Cu (Table 3.2). Of these, copper oxychloride was found to be the most common fungicide that was used in several tea gardens under different trade names such as Blitox, Acmecop, Emivit, Bicoxy, Capvit, MS Vit, Delight and Coxy 50.

Almost all the tea gardens surveyed were found to apply copper oxychloride 50% w/p on a regular basis. Some of the gardens, for instance Kumbha TE in Southern Assam was found to use Blitox as well as MS Vit, both of which are chemically copper oxychloride. Smilarly, Bagdogra TE in the Darjeeling district of West Bengal was found to use Emivit, Blitox and Acmecop all of which were copper oxychloride. Maximum spraying at short intervals is practiced during the monsoon months from June to September at a dose of 2.80 Kg per hectare. This application is done irrespective of disease development or appearance of disease symptoms.

Another fungicide that was also found to be used often by many of the surveyed tea gardens is copper hydroxide. This was also used by different trade names such as Superex, Champion and Kocide. Matigara TE was the only tea garden that was found to rely entirely on copper hydroxide. The garden used Kocide at 1 kg/ha and Champion at 2.24 Kg per hectare. In other gardens, this was used along with copper oxychloride. For instance, Khoribari TE used Superex 77 w/p at 750 g per hectare along with Blitox 50. The third type of fungicide that was found to be used was blue copper. This was used by three of the surveyed tea gardens. Of these, Goal Gach TE and Margaret Hope TE used all the three types of fungicides. Goal Gach used Blitox 50 at 2.80 kg/ha, blue copper at 2 kg/ha, superex 77 w/p at 750 g per hectare and Margaret Hope used blitox 50 at 2.80 kg/ha, Kocide at 1 kg per hectare. Good-Hope TE used copper oxychloride along with blue copper. In all cases, fungicide spraying is done regularly even under asymptomatic stages.

Table 3.2: Use of copper fungicides in Tea Estates of North East India

Name of the Tea Estates	Prevalent diseases	Fungicides used	Amount
Bagdogra T.E.	Blister blight, Black rot, Damping-off, collar rot.	Acmecop w/p, Emivit 50% w/p, Blitox-50.	2.80 kg/ha 2.80 kg/ha 2.80 kg/ha
Bidyanagar T.E.	Dieback, Black rot.	Capvit 50 w/p, Blue copper.	2.80 kg/ha 2 g/ha
Coochbehar T.E.	Stem rust, Black rot, Dieback, Leaf blight.	Biocoxy, Blue copper.	2.80 kg/ha 2 g/ha
Duncans Bagracote T.E.	Black rot, Stem canker.	Kocide 101R, Blitox-50, Acmecop w/p.	1 kg/ha 2.80 kg/ha 2.80 kg/ha
Ellen Barrie T.E.	Black rot, Red blight, Damping off.	Capvit 50 w/p, Acmecop w/p.	2.80 kg/ha 2.80 kg/ha
Gandrapara T.E.	Black rot, collar rot, Leaf blight.	Blitox 50, Superex 77 w/p, Capvit 50 w/p.	2.80 kg/ha 750 g/ha 2.80 kg/ha
Gope T.E.	Black rot, Stem canker.	Kocide 101R, Blitox.	1 kg/ha 2.80 kg/ha
Goal Gach T.E.	Black rot, Dieback.	Blitox, Blue copper, Superex 77 w/p.	2.80 kg/ha 2 kg/ha 750 g/ha
Good Hope T.E.	Blister blight, Black rot, Leaf blight.	Blitox50, Blue copper, MS Vit 50 w/p.	2.80 kg/ha 2 kg/ha 2.80 kg/ha
Kiranchandra T.E.	Black rot, Damping off, collar rot.	Kocide 101R, MS Vit 50 w/p.	1 kg/ha 2.80 kg/ha
Kharibari T.E.	Dieback, Black rot, Damping off.	Superex 77 w/p, Blitox 50.	750 g/ha 2.80 kg/ha
Kumlai T.E.	Leaf blight, Stem blight.	Copper 50 w/p, Blitox 50.	2.80 kg/ha 2.80 kg/ha
Kumbha T.E.	Dieback, Black rot.	MS Vit 50 w/p, Blitox 50.	2.80 kg/ha 2.80 kg/ha
Margarets Hope T.E.	Blister blight, Black rot, Collar rot.	Blitox 50, Kocide 101R.	2.80 kg/ha 1 kg/ha
Matigara T.E.	Blister blight, Leaf blight.	Champion w/p, Kocide 101R.	2.24 kg/ha 1 kg/ha
Monachara T.E.	Dieback, Black rot.	Coxy 50 w/p, Blue copper.	2.80 kg/ha 2.80 kg/ha
Red Bank T.E.	Thread blight, Dieback.	Delight 50, Blitox.	2.80 kg/ha 2.80 kg/ha

3.3. DISCUSSION

Since the discovery of Bordeaux mixture, copper has been an important component of different types of fungicides. The use of copper sulphate that was highly toxic was known even before the discovery of Bordeaux mixture. But it was Millardet who reduced the toxicity of copper sulphate by mixing it with lime. This discovery has doubtless been the greatest boon to plant protection since copper fungicides was used extensively in Europe and USA for many years for the control of numerous diseases. A literature study shows that copper has been successfully used as fungicides against several crops including rice (Chaudhary *et al.*, 2012), grapes (Pietrzak and McPhail, 2004; Viti *et al.*, 2008), olive (Viti *et al.*, 2008), cocoa (Aikpokpodion *et al.*, 2013), citrus (Hardy *et al.*, 2007), broccoli, lettuce, tomato and squash (http://extention.psu.edu/plants/vegetables-fruits/news/2013/copperfungicides-for-organic-disease-management- in vegetables).

Nowadays, a considerable number of phytochemical companies offer numerous and different classes of fungicides, where copper fungicides according to their antifungal effects play an important role. The efficiency of copper fungicides, particularly aggressive in moist media, is caused by denaturation of protein structures (secondary and tertiary) of fungi and bacteria, and consequently the interruption of their functions. Our results showed undoubtedly that different types of copper fungicides are used extensively in the tea gardens of north-east India. At least 3 chemical types, *viz.* copper oxychloride, copper hydroxide and copper sulphate under 12 different trade names were found to be sprayed by the surveyed tea gardens on a regular basis.

The indiscriminate use of copper fungicides in Indian tea gardens was reported by Barooah (2011). According to him, residues of copper fungicides in made tea, 7 days after treatment, conform to Indian MRL but exceeds the EU MRL. During our survey, it was found that the fungicides were applied even in asymptomatic plants especially during the monsoon months when outbreaks of fungal diseases are common. A literature study reveals that copper sprays are protectant fungicides that must be applied evenly to the plant surface before the disease develops to prevent infection (Hardy *et al.*, 2007). Copper is not a systemic chemical and cannot be carried internally through the plant to kill the pathogen. Once the copper is applied, it sticks only where it hits and does not spread to a large extent across the fruit or leaf surface. The solubility of copper products increases as the pH drops due to exudates released by the plant. It slowly dissolves to release a small and constant supply of cupric ions (Cu^{+2}) as long as the water remains. Only one copper formulation (cuprous oxide) also releases cuprous (Cu^{+1}) ions, which also have fungicidal and bactericidal activity (Torgeson, 1967). These copper ions are picked up by spores or bacteria that come in contact with this surface water-travelling through the cell walls to eventually disrupt cellular enzyme activity (Hardy *et al.*, 2007).

Metal binding in soil is common through interaction of humic substances with oxides of Al, Mn and Fe and can accumulate in soil when used intensively (Aikpokpodion *et al.*, 2013). Tea is a plantation crop with a life span of 25-30 years. Thus the applied copper remains in the soil and accumulates through the years. Pesticide residue in tea has been a major challenge to the tea industry in recent times due to ever increasing global demand for quality (Barooah, 2005). It is well known that long term use of copper based fungicides leads to copper contamination especially in plantation crops. For instance, Aikpokpodion *et al.* (2013) found that Cu residues in cocoa beans cultivated in Nigeria exceeded the admissible limits even when recommended amounts of Cu fungicides were used. Similarly Hardy *et al.* (2007) observed that apart from causing blemishes and spots on leaves and fruits in the citrus plantations in Australia, use of copper based fungicides can also increase the copper levels in the soils and become toxic to citrus roots. They further stated that high levels of soil copper may also interfere with the uptake of other plant nutrients. It has been reported that the use of copper-based fungicides by Victorian vine growers has increased the total copper concentration in some vineyard soils to 250 mg/kg compared to background levels of approximately 10 mg/kg. This far exceeded the permissible limit of 60 mg/kg and this level was exceeded in 8 of the 14 vineyards investigated (Pietrzak and McPhail, 2004). Viti *et al.* (2008) observed that vines and olive orchards using copper fungicide had 5 to 10 times more copper in their soil than uncultivated forest soils and this causes toxicity to the microbial communities residing in the soil ultimately leading to a reduction in their diversity.

The area under the current survey covered the major tea growing belt of India. The selection of tea gardens was made randomly. However, since all tea gardens did not respond, or responded incorrectly, data from only 17 tea gardens could be actually presented here. Nevertheless, the consistency of data obtained from various tea gardens located at considerable distances from each other clearly shows the extent of the use of copper based fungicides throughout the region. To the best of our knowledge, no study was so far conducted to understand the effect of the accumulating copper in tea plants although the fact that copper was sprayed in the tea gardens almost from the beginning of tea cultivation in north east India was known. This prompted us to undertake the study of the effect of copper on tea plants under experimental conditions. This included the physio-biochemical and anatomical changes that occur in the process of adaptation/tolerance to excess copper.