STUDY ON SHADE TREE AND SOIL CHARACTERISTICS OF TEA GARDENS IN SYLHET

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CERTIFICATE

*This is to certify that the thesis entitle, "***STUDY ON SHADE TREE AND SOIL CHARACTERISTICS OF TEA GARDENS IN SYLHET"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of research work carried out by* ***OBAIDUN NAHAR URMI,*** *Registration No.***11-04374** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Prof. Dr. Nazmun Naher
Supervisor

Dated: June, 2020
Dhaka, Bangladesh

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CHAPTER 1

INTRODUCTION

Agroforestry is a potential solution to bridge biodiversity conservation as well as increasing agricultural productivity in tropical countries. Nowadays traditional forest practices and Agroforestry systems are spreading all over the world due to their multifunctional contributions. Generally, the most complete definition of Agroforestry is the one given by the Food and Agriculture Organization (FAO) which resumes the International Council for Research and Technology (ICRAF). The layers of vegetation largely according to the different heights to which their plants grow is termed as vertical classification. On the basis of vertical stratification, temporal sequence and main considerations Tea Agroforestry system may be termed as double layered, coincident commercial Agroforestry system (AFS). Benefits of intercropped shade trees in tea garden are proposed to range from microclimate regulation (Beer *et al.,* 1998) to alternative income sources for farmers (Tscharntke *et al.,* 2011) or improved nutrient cycling efficiency (Schroth, 1995). Tea Agroforestry System maintains a multistoried composition with good association of extensively managed tea, temporary and permanent shade trees. At present, more than 58 countries around the world produce tea. The total world tea production in 2018 was 5,896,644 tons (ITC, 2019). According to statistics of Bangladesh Tea Board, total tea production in 2018 was 82.13 million kg and ranked 9th among the tea producing countries of the world.

Bangladesh has 159 tea estates and many of the world's largest working plantations. Bangladesh tea industry established at 1840 when a pioneer tea garden was established on the slopes of the hills in Chittagong (Nasir *et al.*, 2011). First commercial tea plantation in Bangladesh was established in 1854 at Malnicherra Tea Estate near Sylhet town (Mamun *et al*., 2011). There are over 150 tea gardens in Sylhet such as Malnicherra tea garden, Lakkatura tea garden, Tarapur tea garden, Ali Bahar tea garden etc. Tea is a shade loving plant and 50-70% diffused sunlight is needed for better tea production (Sana, 1989). Daily five hours sunlight is optimum for tea growth considering the intensity and duration of sunlight, (Amin, 2003). If the intensity of sunlight is reduced, production increases to 40% (Amin, 2003). As cloudy sky is not favourable for tea growth, and intense sunlight, excess temperature or too much cold may stunt the growth of tea plant. Tea is grown under a canopy of trees that's providing partial shade to tea compartment. These tree species conserve soil from erosion and the impact of rainfall drops, enrich soil fertility and organic matter content through leaf litter and support diverse flora and fauna especially many bird species. Tea is a perennial evergreen shrub. Tea growing soils are usually acidic in nature. Soil acidity is further aggravated by the extended use of nitrogenous fertilizers (urea and ammonium sulphate) to obtain higher yield. The maintenance of an optimal soil pH (4.5-5.5) is important in tea cultivation (Natesan, 1999). Adjustment of soil pH and addition of organic matter are the most common methods of decreasing P deficiencies in tea soils; it also improves soil fertility status (Zhang *et al.,* 1997). Nutrient requirements for commercial tea production are high as the harvestable portions of tea contain the largest percentage of nutrients in the plant. Nitrogen is the most important nutrient element for tea cultivation because it is required in large quantities. The next important nutrients are potassium and phosphorus respectively for tea plantation (Kamau, 2008; Ranganathan and Natesan, 1985).

Nowadays Bangladesh is producing tea under marginal climatic and soil conditions. A moderate shade about 50-70% sunshine in the plantation is necessary for the optimum growth of tea in Bangladesh. So, right type of shade trees and their proper management is important for successful tea culture. A large number of jungle trees have been tried in the past as shade trees but a few of them proved suitable finally (Chowdhury and Kibria, 1977). The use of leguminous species as shade tree for tea is common in Bangladesh, India and Sri Lanka. Leguminous species are preferred because they help in conservation of soil moisture by reducing the evaporation rate and maintain a humid atmospheric condition under the canopy. Soil moisture conditions also help the growth and physiological activity of the root system and subsequent utilization of mineral nutrients. Tea Agroforestry systems, with tea plants and shade trees, sequester significant amount of carbon dioxide. They can support the implementation of conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (REDD+) programmes and serve as an additional income source on account of their environmental services. The right type of shade trees and their proper management is a prerequisite for successful tea crop growing as well as production. Increased plant species diversity has been directly linked to spatial and temporal resource partitioning and improved functional complementarity (Hooper and Vitousek, 1997; Van Ruijven and Berendse, 2005). However, intercropped trees in agroforests might also compete with crops for nutrients or light resources. There was no thorough investigation about the tea gardens of Sylhet. So this study was conducted to fulfill the following objectives:

Objectives

i. To identify the dominant shade trees and tea plantation in the studied tea gardens and

ii. To determine the soil characteristics of tea garden of Sylhet Sadar.

CHAPTER 2

REVIEW AND LITERATURE

In this chapter, an attempt has been performed to review the information about the tea based Agroforestry system, tea gardens in Sylhet district, different shades trees and soils in the tea garden.

2.1 Agroforestry

There are many definitions of Agroforestry have been proposed world-wide and it has now become an accepted land use system. Some of the definitions are as follows:

Lundgren and Raintree (1983) has reported that ICRAF defines Agroforestry as a collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in either a spatial arrangement or a temporal sequence, there being both ecological and economical interactions between the different components.

Bene *et al*. (1977) reported that Agroforestry as a sustainable management system for land that increases overall production, combines agriculture crops, forest plants and tree crop and/or animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of a local population.

King and Chandler (1978) defined Agroforestry is a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.

Nair (1979) has stated that Agroforestry as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers.

2.1.1 Classification of Agroforestry

Nair (1985) studied that structurally Agroforestry system can be grouped as Agrisilviculture (crops including tree/shrub crops and trees, Silvopastoral (pasture/animals + trees) and Agrosilvopastoral (crops + pasture/animals + trees) and based on their component composition, into Agrisilvicultural, Silvopastoral and Agrosilvopastoral (or any other specialized) systems.

2.1.2 Scenario of tea production and marketing in Bangladesh and around the world

Workman (2019) stated that the largest tea-exporting countries in 2017 were China (USD 1.6 billion), Sri Lanka (USD 1.5 billion) and Kenya (USD 1.4 billion) while the largest importing countries were Pakistan (USD 550 million), Russia (USD 525 million) and the United States (USD 487 million).

According to FAO (2017) total tea production accounted for 5.98 million tonnes of which approximately 35 per cent was exported, worth USD 8 billion.

Ethical Tea Partnership (2019) reported that tea was grown in 48 countries in 2016, including 12 Low Human Development Countries (LHDCs). Tea production employs 13 million people, 9 million of whom are smallholder farmers while the remainder work in tea estates; in China, Sri Lanka and Kenya, which account for half of the world's tea production, the majority of tea is produced by smallholder farmers.

Sen (2008) observed that Assam is the largest tea producing state in India and contributes about 60 per cent of the total production of India.

BTRI (2003) reported that tea cultivation in Bangladesh developed concurrently with the northeast Indian tea during early part of 19th century. Bangladesh tea grows in the three fairly divergent ecological zones, namely Surma valley in greater Sylhet, Halda valley in Chittagong and Karatoa valley in Panchagarh district.

Mamun *et al*. (2011) has reported that first commercial tea plantation in Bangladesh was established in 1854 at Malnicherra Tea Estate near Sylhet town.

2.2 Shade tree

Leguminous or non-leguminous trees, which are used in the tea, coffee, and cacao gardens for providing shade to the main crop, are called shade trees.

Anon (1984) stated that selection and management of proper shade trees are needed to reduce the rate of evaporation of the soil moisture and thus maintain a suitable humid atmospheric condition.

Chowdhury and Kibria (1977) observed that a large number of jungle trees have been tried in the past as shade trees but only a few of them proved suitable in the long run.

Sana (1989) said that shade tree is planted at the starting period of tea cultivation in the garden. It is better to plant the shade one year before the planting of tea. Permanent shade trees take a long time to provide optimum shade. For this reason, temporary shade is planted for first 4-5 years.

Barua (1960) has found that preliminary experiments using overhead mechanical shade of split bamboo laths to reduce light intensity by about half showed that growth, yield and weight of prunings of teas under the bamboo screens were significantly higher than those under full sun.

2.2.1 Cultivation of shade tree

Barua (2007) reported that since the later part of 20th century planting of shade trees among tea bushes became a practice in plains of North East India, *Albizia chinensis* was the first tree used as shade tree.

Verbist *et al.* (2005) found that cultivating coffee under varieties of shade tree species is one of local wisdoms that has long been practiced in the District of Sumberjaya, West Lampung.

Evizal *et al*. (2012) found that technical shade trees are legume trees planted on coffee plantations, not to harvest the yield but to provide shade for the coffee plants. In West Lampung, technical shade trees most widely grown are *Erythrina subumbrans* and *Gliricidia sepium.*

Wang and Lin (2012) studied that organic tea gardens should be constructed in mountain areas where the ecological environment is superior, biodiversity is rich and where places surrounding the base and tuyere are away from residential areas, upstream rivers, industrial and mining areas.

Ran *et al.* (2012) stated that organic agriculture and organic cultivation system emphasizes the application of production technology to keep the ecosystem stable and sustainable and not using varieties improved by chemical fertilizer, chemical pesticides and genetic engineering.

Redwan (2003) found that in Rasidpur tea estate of Dinajpur, in the lower slope the average height *Albizia chinensis* was 13.91 m, average diameter was 28.10 cm, average volume per tree was .6776 m^3 while average volume per hectare was 218.0 m^3. In the upper slope, the average height was 13.17 m, the average diameter was 27.32 cm, and average volume per tree was 0.6065 m3 while average volume per hectare was 215.10 m^3.

2.2.2 Function and use of shade tree

Pangging and Mandal (2017), Ahmed *et al*. (1993) said that Fabaceae type of shade trees not only provide shade to tea plants but also helps in replenishing nitrogen loss and controls insect pest due to biopesticide properties of the tree.

Tscharntke *et al.* (2011) stated that management of agroforestry systems in a sustainable manner requires conservation and proper management of MPTS strata. Shade trees in coffee plantations can be technical shade trees, wood trees, or MPTS. Determining the composition of shade trees is important to maintain the balance of the ecological functions and the coffee agro-ecosystem productivity.

Hassan and Chowdhury (1964) have found that generally *Albizia lebbek* are used as shade trees in most tea gardens of Bangladesh. *Albizia chinensis* is a fast growing shade tree and produce excellent shade but it is more susceptable to canker disease than any other species of *Albizia*.

Mamani-Pati *et al.* (2012) said that understanding the diversity, characteristics and functions of shade trees as well as its strata is important in efforts to improve the sustainability of coffee agro- ecosystem.

Lopez-Rodriguez *et al.* (2015) reported that ecological functions of the shade trees in coffee agroforestry system are as environmental services such as recycling nutrients.

Lin (2007) observed that shade trees also improve local climatic conditions and reduce variability in microclimate and soil moisture and maintain soil nutrient.

According to FAO (1987) shade trees not only used as shade provider but it also produces fuel wood timber, foods (leaves, pods or flowers) for people fodder, production of tannins, gums, medicines and services like erosion control, living fences, ornamentals, environmental protection.

Kibria (1986) has observed that another vital use of trees is they can be used as windbreaks. Single row windbreaks are considered to be better than multi row windbreaks since the farmer gives protection against wind velocity for a greater distance.

Pandey (2002), Yadava (2010), Kumar and Nair (2011) stated that the tree components in Agroforestry systems can be significant sinks of atmospheric carbon due to their fast growth and high productivity.

Albrecht and Kandji (2003) found that tree species and system management can influence carbon storage in Agroforestry systems.

Redwan (2003) stated that shade trees not only contribute directly to the maintenance of even temperatures and soil moisture control but also by their natural leaf fall, or by pollarding provide vegetable mulch. The mulch gives even more intimate protection than the foliage canopy and also makes a contribution to soil conservation by impeding soil wash. Mulch prevents the “running” of erosive soils. Shade trees with a more robust root system are capable of overcoming the resistance of physically bad soils.

2.2.3 Importance of shade tree

Schroth *et al*. (2000) observed that unshaded cacao can rapidly degrade in the absence of anti-mirid insecticides seen, for example, on the African islands of Fernando Po´ and Sa˜o Tome´ as well as in Ghana.

Schroth *et al.* (2000), Rice and Greenberg (2000) said that shaded cacao agroforestry suffers less problems from insect pest although pathogens such as the black pod disease *Phytophtora sp.* may profit from the higher humidity under planted shade trees.

Barua and Dutta (1961) said that mature tea shaded by *Albizia. chinensis* and manured with 84 kg N per ha as ammonium sulphate is conducive to the growth of a higher proportion of feeding roots, during the growing season (April to October) than those exposed to full sun and this may well be a premium against drought damage.

Danthanaryana and Ranaweer (1972) observed that damaged due to tea mites is more severe on unshaded rather than shaded tea. Just the opposite effect has been reported from Sri Lanka.

Kalita *et al.* (2014) reported that without shade trees, the yield of tea is limited. Thus, to increase tea yields, a large number of shade tree species are planted in various tea gardens of Bangladesh.

2.3 Soil characteristics of tea garden

Zhang *et al*. (2013) found that soil porosity suitable for growth of Guizhou king bird tea was between 48% and 56%, consistent with the soil porosity of organic and ecological tea garden at different depths.

Peng *et al*. (2006) have shown that the growth of crops is favored when soil noncapillary porosity is between 20% and 40% and the soil cannot guarantee good ventilation when soil noncapillary porosity is less than 10% and many crops cannot normally grow when less than 6%.

It has found by Deng *et al.* (2012) that cedar has a significant effect on improving soil water content and porosity and reducing soil bulk density and organic tea gardens are more suitable for tea tree growth than ecological tea gardens.

Carr (1971) found that a soil relative water content from 70% to 90% was the most suitable condition for growing tea and tea development and that tea tree roots are retarded when the water content is less than 50% or higher than 110%.

Han *et al.* (2002) reported that the soil organic matter contents of the organic and ecological tea gardens are both more than 2.0% whereas the non-ecological tea garden is relatively low and not good for growth and yield.

2.4 Environmental factors for tea production

2.4.1 Effects of light on tea production

Mohotti and Lawlor (2002) observed that parameters such as photosynthetic light capture, electron transport, photochemical and non-photochemical energy quenching and carboxylation have shown that the entire photosynthetic apparatus of the tea plant is shade adapted. Tea leaf photosynthesis decreases due to photoinhibition when light intensity increases beyond 1400-1500 μmol m-^{2} s-^{1}.

Mohotti (2004) and Okano *et al*. (1995) reported that the net photosynthetic rate in fully expanded mature leaves of tea shows an asymptotic response to increasing light intensity and reported values for saturating light intensities range from 600-800 μmol $m^{-2}s^{-1}$ up to 1200-1500 μmol m^{-2} s^{-1} of photosynthetic active radiation (PAR).

Barua (1961) said that the optimum light intensity for maximum growth will then shift more and more towards full light as the difference in. leaf area between fun light and reduced light gradually diminishes. The yield of plucked shoots in all cultivars is generally maximum under 50 per cent light intensity - the relative values for the four light intensities being 50, 35, 100 and 20 percent.

Carpenter (1974) said that the best tea grows in the forest, on the hills facing the sun, with canopy cover.

Sana (1989) has reported that tea is a shade loving plant and 50-70% diffused sunlight is needed for better tea production.

Amin (2003) observed that considering the intensity and duration of sunlight daily five hours sunlight is optimum for tea growth.

Barua (1969), Carr (1972) and De Costa *et al.* (2007) has found that fluctuations in the yield of tea during the year, i.e. short-term variation within a growing season and variation between the seasons of the year are well documented phenomena in many environments.

Fordham and Palmer-Jones (1977) reported that the short-term fluctuations are due to successive cohorts of shoots reaching harvestable size at similar times after synchronization at the beginning of the season.

2.4.2 Effect of pH and temperature on tea production

Carr (1972) reported that tea grows well within an air temperature range of about 18-25ºC and air temperatures below 13ºC and above 30ºC have been found to reduce shoot growth.

Choudhury and Kibria (1977) observed that the range of pH values for the satisfactory growth of *Albizia chinensis* is 5.5 to 6.5 the optimum growth is found at pH 6.0. It prefers slightly to moderately acidic soil.

2.5 Pest of tea gardens

Hasan (1963) reported that shade trees also serve as potential source of root diseases, encourages -quick germination of disease spore, invite and harbour different insect pests as well as play a vital role for the transmission and transmigration of pests and diseases among different components of tea ecosystem**.**

It has found by Hazarika *et al.* (2009) globally, 1031 species of arthropods are associated with tea monoculture.

Ahmed (2005) has found that in Bangladesh tea, 25 species of insects, 4 species of mites and 10 species of nematodes are recorded.

Muraleedharan (1992) found that the tea plant is subjected to attack by at least 250 insect species and 380 fungal pathogens out of which 167 pests and190 fungi have been detected in N.E. India.

CHAPTER 3

MATERIALS AND METHODS

The study was done at four locations and the period of June 2018 to February 2019. The study area, season, soil, climate and weather, data collection, statistical analysis etc. were described briefly in this chapter.

3.1 Study area

3.1.1 Location

The study was conducted at four tea gardens of Sylhet sadar in Sylhet district. The area of Sylhet district (Sylhet division) area is 3490.40 sq km, located in between 24°36' and 25°11' north latitudes and in between 91°38' and 92°30' east longitudes. The studied tea gardens are Malnicherra tea garden, Lakkatura tea garden, Tarapur tea garden and Ali Bahar tea garden. The area of Sylhet sadar is 323.17 km^2.

3.1.2 Climate and soil

Sylhet lies on 35m above sea level. Sylhet's climate is classified as tropical. Rainfall is significant most months of the year and the short dry season has little effect. The average annual temperature is 24.8 °C in Sylhet. The annual rainfall is 3876 mm. At an average temperature of 28.1 °C, August is the hottest month of the year. January is the coldest month with temperatures averaging 18.5 °C. The soil pH of Sylhet is less than 6.5 and organic matter content ranges from 0.55 to 2.45%.

The morphological characteristic of Sylhet district is mentioned in appendix I and climatic parameters in appendix II.

Study area

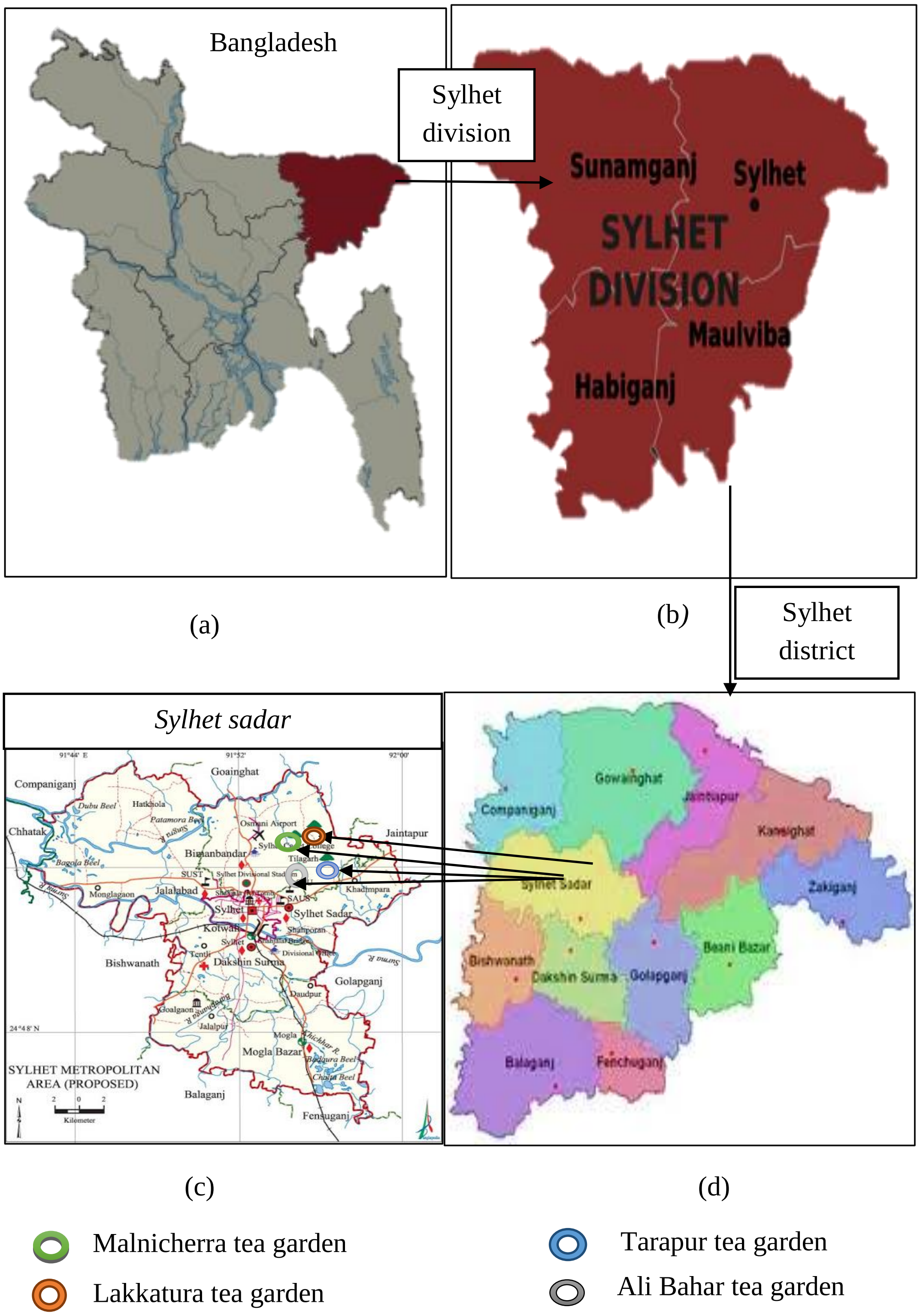


Plate 1. Stepwise location of the study area where (a) Bangladesh (b) Sylhet division (c) Sylhet district (d) Sylhet sadar

3.2 Description of the tea gardens in the study area

There are about 159 tea estates in Bangladesh which are spread over Sylhet, Srimongal, Surma-Valley, Zaintapur, Jaflong, Shamshernager, Juri, MonuDoloi, Kulaura, Naypara, Vanugas, Longla, Chunarughat, Laskarpur, Satgaon in Sylhet Division, at Brahmonbaria, Fatiqchari, Rangunia, Ramgar, Patiya (Kanchannagar), Dohazari-Sangu Valley Banshkhali (Chanpur-Balgoan) in Chittagong and Kapti (WaggaChitmorom) in CHTs There are gardens after gardens throughout this vast hilly region of Sylhet.

In this study four tea garden in Sylhet district was studied and their description have been given below:

3.2.1 Malnicherra tea garden

Malnicherra tea estate is the largest and oldest tea garden in Bangladesh and subcontinent. It is situated in Sadar upazila of Sylhet district in Bangladesh. It is the first commercial tea industry in Bangladesh which started in 1854. The establishment of Malnicherra tea garden in Sylhet covering an area of 1,500 acres. However, the coverage of the garden has now almost doubled. The Latitude of Malnicherra tea estate is $24^{0}93'$ N and Longitude $91^{0}86'$ E. The location of Malnicherra tea garden is next to Sylhet Airport Road. Besides tea, oranges and rubber are also cultivated in the Malnicherra tea garden.

Plate 2. Malnicherra tea garden

3.2.2 Lakkatura tea garden

Lakkatura is one of the largest and most scenic tea gardens in the country and covers a total of 3,200 acres. This estate was officially established in 1875 and it now produces an astounding 550 tons of tea each year. Lakkatura Tea Garden is located near Osmani Airport in Chaukidhenki Upazila of Sylhet district. The Lakkatura tea garden is an official tea garden under the National Tea Board.

Plate 3. Lakkatura tea garden

3.2.3 Tarapur tea garden

Tarapur tea garden is also very close to Sylhet city. It is in a shady environment of nature in Pathantula area on the way from Amberkhana to Medina Market. The garden has become well known among the tourists as the business branch campus of Jalalabad Ragib Rabeya Medical College Hospital and Madan Mohan College has been established in the adjoining area. The garden is almost always a tourist attraction.

Plate 4. Tarapur tea garden

3.2.4 Ali Bahar tea garden

It is located in Sylhet sadar of Sylhet district. Ali Bahar tea estate occupies less than 200 hectors. It includes 53% tea and 33% rubber trees and produces 1000000 kg tea annually.

Plate 5. Ali Bahar tea garden

3.3 Sampling procedure and data collection

Information was collected systematically one after another and was enlisted in the notebook for further assessment. Information was mainly on soil type, planting technique of shade trees, growth performance of shade trees to tea growth, spacing, pest management etc. The relevant information and data were collected from studied areas of Malnicherra tea garden, Lakkatura tea garden, Tarapur tea garden and Ali Bahar tea garden.

3.3.1 Shade tree

For studying growth performance of the shade trees in different locations data of height and girth of trees were taken from four tea gardens. Dominant species of shade trees *Albizia procera, Albizia lebbek, Acacia auriculiformis, Dalbergia sissoo and Leucaena leucocephala* were under consideration. Random plots were taken and collected data for height and girth from ten samples of every species in each garden.

i. Height of shade tree

Tree height was measured by stick method in meter. By holding the stick and align both the base of the tree with the top of the hand holding the stick and the top of the tree with the top of the stick. By moving toward or away from the tree, adjusting the stick length and by moving arm up and down. Once aligned, distance was measured from the top of your hand grasping the base of the stick to the eye. Distance was measured from the top of the hand to the top of the stick and measured the distance from the eye to the base of the tree. The yardstick was held straight up and down and the top of the tree was vertically over the base and the various measurements were still proportional and then height was measured of the tree using a simple formula: Tree height = (distance from eye to base of tree/distance from eye to base of stick) × length of stick

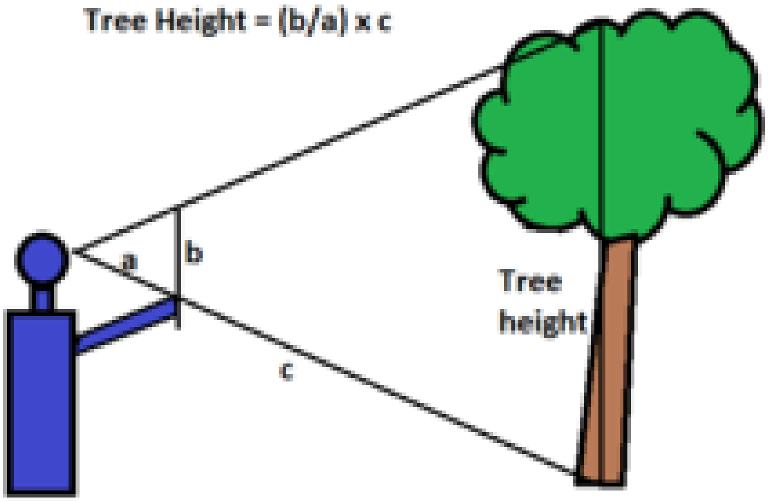


Figure 1. Measuring plant height by stick method

ii. Girth of shade tree

Shade tree girth was measured at 1.5 m height from ground in centimeter.

iii. Spacing of Shade tree and tea plant

Spacing was also calculated both for permanent and temporary shade tree by using measuring tape.

3.3.2 Tea plant

i. Age of tea plant

Data were collected randomly from sampled tea gardens according to their age. Randomly about fifty samples were collected in each tea garden.

ii. Height of tea plant

Tea height was measured by meter scale in centimeter.

iii. Girth of tea plant

Tea girth was measured by measuring tape in centimeter. Tea plant girth was measured at 6.35 cm from ground level. The collected data had been compiled for study.

3.3.3 Soil sampling procedure in the tea garden

In order to keep the soil sample representative, sampling points were located in places where the natural state of soil is good and various factors are relatively stable and representative. 'S' shaped points between rows of tea were used and ten samples in every tea gardens were collected randomly from depth 0-15 cm by auger. From each point and mixed every five samples into one and discarded excess soil using the four point method and retained a mixed sample of 1 kg. Samples were placed in sealed polythene bags and then transported to the laboratory for preparation and analysis. The composite samples were air dried and sieved through a 2 mm sieve and then 500 g each sample were stored for chemical analysis. There were three replications for each sample.

3.3.4 Soil sample analysis

Collected soil samples were analyzed for both physical and chemical properties and the soil sample were analyzed using the standard techniques as follows:

3.3.4.1 Textural class

Mechanical analysis of soil samples was done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the Marshall's triangular co-ordinate following USDA system (Marshall, 2003).

3.3.4.2 Soil pH

The soil pH was determined by glass electrode pH meter at a soil: water ratio of 1:2.5 as described by Jackson (1985).

3.3.4.3 Soil organic matter (OM) content

The organic carbon (OC) of the soil samples was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1985). The (OM) content was calculated by multiplying the content of organic carbon by Van Bemmelen's factor 1.73 (Piper, 1950).

3.3.4.4 Determination of nitrogen (N) in soil sample

Total N in the soil was determined by semi-micro Kjeldahl method by digesting soil sample with concentrated H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 10:1:0.1). The N in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in boric acid with 0.01N H_2SO_4 (Page *et al.*, 1982).

3.3.4.5 Determination of phosphorus (P) in soil sample

Available P was extracted by Olsen's method $SnCl_2$ as reducing agent. The extract was estimated colorimetrically following the blue color method and was analyzed by a spectrophotometer at 660 nm wavelength (Black *et al.,* 1965).

3.3.4.6 Determination of potassium (K)

Extracted by neutral ammonium acetate and determined directly by flame photometer (Black, 1965) at the wave length of 766.5 to 769.5 nm.

The exchangeable cations (Na) of soil were extracted with 1N NH_4OAC (pH = 7.0). The extract was analyzed for Na by Galenchamp Flame Photometer at 589 nm.

3.5 Statistical analysis of data

The analysis was performed using SPSS 16.0 version computer package programme.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Shade tree species used in tea garden

Leguminous or non-leguminous trees that are used in the tea, coffee and cacao gardens for providing shade to the main crop are called shade trees. The shade trees are an integral component of tea cultivation in Bangladesh. The shade trees are essential for modulating the environment of the tea ecosystem, enriching the soil fertility, reducing temperature and the evaporative capacity, conserve soil moisture and helps in the control of certain pests and diseases which are positively thermotropic in nature. The shade trees provide partial shade to the tea plants, which is important for improving the quality of the tea leaf. The right type of shade trees and their proper management is a prerequisite for successful tea crop growing. In the studied gardens various types of leguminous trees are planted as shade trees to provide optimum growing condition for the cultivation of tea plant which are more or less same in nature. It was noticed during survey that the legume trees are most dominating because of its compound leaf and bushy appearance in tea plantations areas. Leguminous species are preferred because they help in conservation of soil moisture by reducing the evaporation rate and thus maintain a humid atmospheric condition under the canopy. Soil moisture conditions also help the growth and physiological activity of the root system and subsequent utilization of mineral nutrients.

4.1.1 Types of shades tree

Shade tree is planted at the starting period of tea cultivation in the garden. Shade trees are of mainly of two types

1. Permanent shade tree and

2. Temporary shade tree

1. Permanent shade tree

Permanent shade trees are planted for a longer rotation (about 40 years). It takes a long period to be established and to provide optimum shade. So it is better to plant the shade tree one year before the planting of tea.

Plate 6. Permanent shade trees in Malnicherra tea garden

The dominant permanent shade trees used in the studied tea estates have been given below:

i. Sada koroi (*Albizia procera*)
ii. Kala koroi (*Albizia lebbek*)
iii. Chakua koroi (*Albizia chinensis*)
iv. Ipil-ipil (*Leucaena leucocephalla*)
v. Siris (*Albizia lucida*)
vi. Sissoo (*Dalbergia sissoo*)
vii. Minjiri (*Cassia siamea*)
viii. Babla *(Acacia nilotica)*
ix. Akashmoni (*Acacia auriculiformis*)
x. *Mangium* (*Acacia mangium*)

2. Temporary shade tree

In the initial stage of tea plantation, temporary shade trees along with the permanent shade trees are planted to protect the tea plants from direct sun light. When the permanent shade trees become established after 5/6 years, the temporary shade trees are removed. The dominant temporary shade trees used in the study tea estates have been given below:

i. Indigofera (*Indigofera sp.*)
ii. Arhor (*Cajanus cajan*)
iii. Pigeon pea *(Cajanus indicus)*
iv. Gliricidia *(Gliricidia sp.)*
v. Tick clover *(Desmodium gyroides)*

4.1.2 Growth performance of some dominant shade trees in the studied area

I. Sada koroi

English name: White siris

Scientific name: *Albizia procera*

Origin: Southeast Asia and India

Main wood use: Timber, fuel

Other uses: Medicinal use

Plate 7. Sada koroi (White siris)

Silvicultural description

Albizia procera is a tree which has open canopy up to 30 m tall and trunk of 35-60 cm in diameter. Bark is smooth, pale grey-green, yellowish-green, yellowish-brown or brown coloured with horizontal ridges. Under bark portion is green in color and changing to orange just below the surface and inner bark is pink or straw coloured. Branches are terete and glabrous. *Albizia procera* bears bipinnately compound leanes with 2-5 pairs of subopposite pinnae; 10-30 cm long glabrous rachis with a narrowly elliptical gland above the base. Pinnae 12- 20 cm long, glabrous, 5-11 pairs opposite asymmetrically ovate to subrhomboid leaflets presents per pinna. Inflorescence composed of pedunculate glomerules collected in an axillary, sparsely puberulous up to 30 cm long panicle. 2-5 peduncles of 1.5-2.3 cm long exists together. 15-30 sessile, uniform bisexual flowers present per glomerule. Fruits are rich red or reddish brown in colour. Pods are flattened, glabrous with distinct marks over the seeds and mature pods each containing 6-12 seeds usually remaining on the tree until the whole twig bearing the pods is shed. Seeds small, greenish-brown, and elliptical to round, flat, with a hard, smooth seed coat. During the dry season the tree becomes almost leafless for a short time.

II. Kalo koroi

English name: Black siris

Scientific name: *Albizia lebbeck*

Origin: Burma, India, Andaman Island

Main wood use: Fuel, timber

Other uses: Tannin, gum, ornamental, erosion control, shade tree

Plate 8. Kalo koroi (Black siris)

Silvicultural description

Albizia lebbeck favours mean annual temperature of 19-35 ºC and rainfall of 500-2500 mm for growth. *Albizia lebbeck* often attains height of 15-20 m and diameter of 50 cm. Tree bark is grey-violet with rusty brown breathing pores, rough and fissured. The tree bears bipinnate compound elliptic to circular leaves slightly hairy on the axis. Flowers appear shortly after new leaves during September-October. Flowers are white coloured, stalked and heavily scented. Pods pale straw to light brown at maturity, narrow-oblong, 15-26 × 3-5 cm, papery, leathery, flat and not raised or constricted between seeds. Mature pods remain on the tree for long periods and are available during May-July. Seeds are brown coloured, flat, orbicular or elliptic, transversely placed within each pod.

III. Sissoo

English name: Indian rosewood

Scientific name: *Dalbergia sissoo*

Origin: Indus to Assam, Himalayas

Main wood use: Timber, fuel, furniture, cabinet work

Other uses: Honey flora, erosion control, shade

Plate 9. Sissoo (Indian rosewood)

Silvicultural description

Dalbergia sissoo is a medium to large-sized fast growing deciduous tree commonly known as Indian Rosewood with wide spreading crown reaching 30 m in height under favourable environmental conditions with a bole diameter up to 80 cm (Parrotta, 1989), crown is wide spreading and thin. The bark is grey 10-15 mm thick with transverse fissures alternate, imparipinnate, bearing 3-5 petiolated more or less acuminate leaflets alternately inserted on a 10-15 cm long rachis. Inflorescence remains in axillary panicles 5-10 cm long, flowers pale white to dull yellow in colour. Flowering closely follows leaf flushing; leaves fall and young flower buds appear with new leaves followed by complete pod formation and maturity. Mature pods remain attached to the tree for 7-8 months. Pods are slender, oblong, flat, thin, light brown coloured and with 1-4 kidney shaped, thin and flat, light brown coloured seeds.

IV. Akashmoni

English name: Golden shower

Scientific name: *Acacia auriculiformis*

Origin: Queensland, Papua New Guinea

Main wood use: Timber, pulp, fuel

Other uses: Tannin, ornamental, erosion control, shade

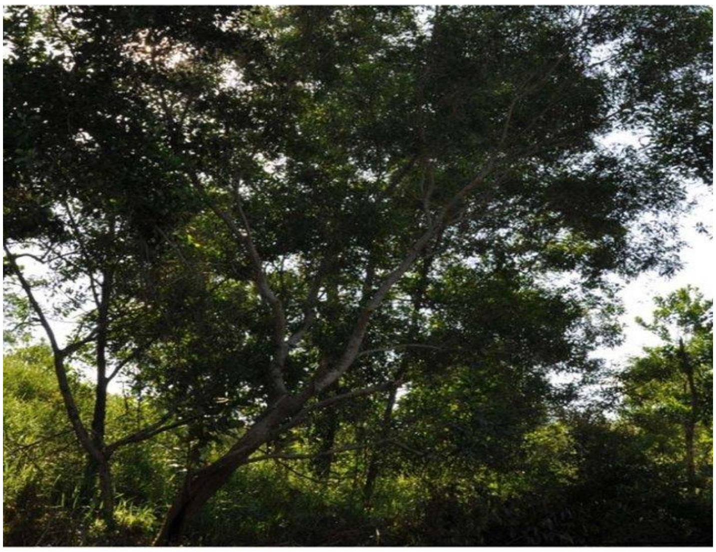


Plate 10. Akashmoni (Golden shower)

Silvicultural description

Acacia auriculiformis is commonly known as auri, earleaf acacia, earpod wattle, northern black wattle, Papuan wattle, and tan wattle, Akashmoni in Bengali. It is a fast-growing, crooked, gnarly tree. It grows up to 30m tall. *Acacia auriculiformis* has about 47000 seeds/kg. *Acacia auriculiformis* is an evergreen tree that grows between to 15–30 m tall, with a trunk up to 12 m long and 50 cm in diameter. The trunk is crooked and the bark vertically fissured. Roots are shallow and spreading. It has dense foliage with an open, spreading crown. Leaves 10–16 cm long and 1.5-2.5 cm wide with 3-8 parallel nerves, thick, leathery and curved. Flowers are 8 cm long and in pairs, creamy yellow and sweet scented. Pods are about 6.5 × 1.5 cm, flat, cartilaginous, glaucous, transversely veined with undulate margins. They are initially straight but on maturity become twisted with irregular spirals. Seeds are transversely held in the pod, broadly ovate to elliptical, about 4-6 × 3–4 mm. These birds also probably help in dispersal of seeds.

V. Ipil-ipil

English name: Lead tree

Scientific name: *Leucaena leucocephala*

Origin: S. W. Mexico and Central Guatemala

Main wood use: Fuel

Other uses: Leaves as fodder

Plate 11. Ipil-ipil (Lead tree)

Silvicultural description

Ipil-ipil is a small tree growing up 8 meters high. Leaves are compound 15 to 25 centimeters long with hairy rachis. Pinnae are 8 to 16 and 5 to 8 centimeters long. Leaflets are 20 to 30 linear oblong and 7 to 12 millimeters long. Heads are solitary, at the axils of the leaves, long-peduncled, globose and 2 to 5 centimeters in diameter with many flowers. Flowers are whitish in dense globule heads, 2 to 3 centimeters in diameter. Fruit is an oblong or linear pod, strap-shaped, 12 to 18 centimeters long, 1.4 to 2 centimeters wide, papery, green turning to brown and splitting open along two edges when mature and several fruits developing from each flower head. Each pod contains 15 to 25 elliptic, compressed, shining, brown seeds, each 5 to 8 millimeters long, 3 to 5 millimeters wide.

Barua (2007) reported that since the later part of 20^{th} century planting of shade trees among tea bushes became a practice in plains of North East India, *Albizia chinensis* was the first tree used as shade tree. *Albizia odoratissima*, *Dalbergia sissoo*, *Erythrina indica* etc. were also introduced simultaneously in different tea gardens. A floristic exploration on shade trees at different tea gardens of Sub-Himalayan Terai and Duars of West Bengal was carried out time since 2013. A total of 45 species of Angiosperm representing 34 genera of 15 families were recorded from the study areas.

Leguminosae shows the highest number of shade trees comprising 13 genera and 22 species. For each and every species correct name, field status, flower and fruiting and necessary photographs has been given (Chowdhury *et al*., 2015). They also reported that Nowadays some spice plants like *Cinnamomum verum*, *Piper nigrum* are also planted within the tea gardens of this region as alternative crops. Some medicinal or cereal plants like *Justicia adhatoda*, *Cajanus cajun*, *Jatropha curcas* etc. are planted as fencing along with roadsides or marginal areas. The waste lands of tea gardens are very rich in dense bushes with various weeds and important wild medicinal plants that are frequently used treat various diseases by tribal tea garden workers. In a floristic assessment in Chattogram and Moulvibazar District of Bangladesh by Rahman *et al*. (2020) it was found that the Fabaceae family shows the highest number of shade trees comprising 19 genera and 31 species. The most common permanent shade tree species among the tea gardens are *Albizia odoratissima*, *A. chinensis*, *A. lebbeck*, *A. lucidior*, *A. procera*, and *Derris robusta*. *Indigofera teysmannii* is frequently using as a temporary shade species in all investigated tea gardens. *Cajanus cajan, Tephrosia candida, Tephrosia candida, Gliricidia sepium, Erythrina lithosperma* and *Desmodium gyroides* species are also used as temporary shade trees in many tea gardens. Fabaceae type of shade trees not only provide shade to tea plants but also helps in replenishing nitrogen loss and controls insect pest due to biopesticide properties of the tree (Pangging and Mandal, 2017; Ahmed *et al*., 1993). Mulugeta (2017) reported that *Albizia chinensis*, *Aleurites fordii* and *Calophyllum elantus* species can be used as shade trees for the successful establishment of a new tea plantation.

4.1.3 Girth and height of shade trees

Table 1. Descriptive statics for girth and height distribution of different shade tree species

Parameter	Species	Maximum	Minimum	Average	S.D.	CV (%)
Height(m)	*Albizia procera*	22.01	10.25	14.20	3.49	24.51
	Albizia lebbeck	19.29	3.54	11.19	4.5	44.59
	Dalbergia sissoo	15.53	9.25	11.74	2.12	18.06
	Acacia auriculiformis	16.53	9.54	11.20	1.91	16.96
	Leucaena leucocephala	6.29	4.25	5.10	0.56	10.78
Girth(cm)	*Albizia procera*	152.8	47.9	108.93	27.58	25.72
	Albizia lebbeck	138	15	53.25	41.22	77.41
	Dalbergia sissoo	53.9	35.3	43.05	6.29	14.61
	Acacia auriculiformis	43.3	25.9	34.10	5.27	15.46
	Leucaena leucocephala	25.8	7.9	16.30	5.39	33.07

Tree height across different shade tree species exhibited ranged between 3.54 m and 22.01 m. In case of *Albizia procera*, *Albizia lebbeck*, *Dalbergia sissoo, Acacia auriculiformis, Leucaena Leucocephala* maximum height were 22.01 m, 19.29 m, 15.53 m, 16.53 m and 6.29 m respectively. Minimum height was observed for *A. procera, A. lebbeck*, *Dalbergia sissoo, Acacia auriculiformis, Leucaena Leucocephala were* 10.25 m, 3.54 m, 9.25 m, 9.54 m and 4.25 m respectively (Table 1). Average tree height were 14.20 m, 11.19 m, 11.74 m, 11.20 m and 5.10 m respectively of *A. procera*, *A. lebbek*, *D. sissoo*, *A. auriculiformis* and *L. leucocephala.*

Standard deviation for height of *Albizia procera*, *Albizia lebbeck*, *Dalbergia sissoo, Acacia auriculiformis, Leucaena Leucocephala* were 3.49, 4.5, 2.12, 1.91, 0.56 respectively and coefficient of variation were 24.51%, 44.59%, 18.06%, 16.96% and 10.78% respectively (Table 1).

Tree girth across different shade tree species exhibited ranged between 7.9 cm and 152.8 cm. In case of *Albizia procera*, *Albizia lebbeck*, *Dalbergia sissoo, Acacia auriculiformis, Leucaena Leucocephala* maximum girth were 152.8 cm, 138 cm, 53.9 cm, 43.3 cm and 25.8 cm respectively. Minimum girth was observed for *A. procera*, *A. lebbeck*, *Dalbergia sissoo, Acacia auriculiformis, Leucaena Leucocephala were* 47.9 cm, 15 cm, 35.3 cm, 25.9 cm and 7.9 cm respectively (Table 1). Average tree girth were 108.93 cm, 53.25 cm, 43.05 cm, 34.10 cm and 16.30 cm respectively of *A. procera*, *A. lebbek, D. sissoo*, *A. auriculiformis* and *L. leucocephal* (Table 1).

Standard deviation for girth of *Albizia procera*, *Albizia lebbeck*, *Dalbergia sissoo, Acacia auriculiformis*, *Leucaena Leucocephala* were 27.58, 41.22, 6.29, 5.27 and 5.39 respectively and coefficient of variation were 25.72%, 77.41%, 14.61%, 15.46% and 33.07% respectively.

The highest average girth was found in the *Albizia procera* which was about 4.15 m, followed by *Melia azedarach* (3.21 m) and *Albizia lebbeck* (1.02 m) (Pangging and Mondal, 2017). *Albizia odoratissima* showed more growth in smaller girth class and gradually declined with increased girth size. The mean annual girth increment in Albizia lebbeck was 2.97 cm and 3.09 cm and *Albizia odoratissima* was 1.81 cm and 2.27 cm for 2011and 2012 (Ashesh *et. al*., 2014). There is as such no published information on the girth increment of shade trees in tea agroforestry system although similar studies are available for shade trees in coffee agroforestry systems (Nath *et al.*, 2011) in India.

4.1.4 Arrangement of the shade tree species in the garden

In all the studied gardens two types of planting system were found. Generally, two permanent shade trees are found in plain or fairly slope land and three permanent species are found in slope land region.

4.1.4.1 Tea and shade square planted

a. Two permanent shade species (where A, B, C are tea tree and X is shade tree)

A B C

XX XX

B C A

Two trees of a single species are adjacent to each other in this system.

Plate 12. Arrangement of the shade tree species in the Malnicherra tea garden

b. Three permanent shade species (where A, B, C, D are tea tree and X is shade tree

A B C D

X XX

D C A B

X XX

C A B D

Three permanent shade trees of a single species are adjacent to each other for this dispersion. The importance of shade pattern and selection of shade trees were carried out by several workers like Visser (1961), Hadfield (1974) and Mohotti (2004).

Plate 13. Arrangement of the shade tree species in Lakkatura tea garden

4.1.5 Spacing of shade tree and tea plant

The shade trees provide partial shade to the tea plants, which is important for improving the quality of the tea leaf. The right type of shade trees and their proper management is a prerequisite for successful tea crop growing. So the spacing of shade tree and tea plant vary from garden to garden for topography and tea plantation type.

Table 2. Distribution of spacing for tea, permanent and temporary shade trees

Name of Garden	Tea spacing (cm)	Permanent Shade tree Spacing (m)	Temporary Shade tree spacing (m)
Malnicherra	132.08×66.04	5.16×6.5	2.25×3.50
Lakkatura	121.92×60.96	4.23×5.25	2.15×3.30
Tarapurtea	120.60×60.30	3.90×5.15	2.10×3.20
Ali Bahar	91.44×45.72	3.25×4.96	2.11×3.30
Average	**116.51×58.23**	**4.14×5.47**	**2.16×3.33**
SD	**17.49×8.74**	**0.79×0.70**	**0.07×0.13**

It was found that in Malnicherra tea garden, for permanent shade trees spacing varied from 5.16×6.5 to 10.55×12.83 meter square and temporary shade trees 2.25×3.50 meter square. In case of tea plant, it was varied from 132.08×66.04 cm square. In Lakkatura tea garden, for permanent shade trees spacing varied from 4.23×5.25 to 8.46×10.50 meter square and temporary shade trees 2.15×3.30 meter square. In case of tea plant, it was varied from 121.92×60.96 cm square. It was found in Tarapur tea garden, for permanent shade trees spacing varied from 3.90×5.15 to 7.80×10.25 meter square and temporary shade trees 2.10×3.20 meter square. In case of tea plant, it was varied from 120.60×60.30 cm square. In case of Ali Bahar tea garden, for permanent shade trees spacing varied from 3.25×4.96 to 6.50×9.92 meter square and temporary shade trees 2.11×3.30 meter square. In case of tea plant, it was varied from 91.44 × 45.72 cm square (Table 2). The average spacing was 4.14×5.47 and 2.16×3.33 meter square between the permanent and temporary shade trees respectively and the Standard deviation were 0.79×0.70 and 0.07×0.13 respectively. In case of tea plant, average spacing was 116.51×58.23 cm square and Standard deviation was 17.49×8.74 (Table 2).

In case of standard tea garden of Bangladesh, temporary shade trees, the spacing may vary from 3 to 4.6 meters. In case of permanent trees, it may vary from 3×3 to 5×5 meter square (Sana, 1989). The seedling population of Bangladesh tea consists of a hybrid and mixed population varying from one extreme to the other. However, the majority of the population belongs to the dark leafed type. In the 1960s, spacing of 120 cm × 75 cm to 120 cm × 60 cm depending on topography and a population range of 11,000 to 14,000 ha and three and four year pruning cycles were the conventional recommendations. As in many other tea growing countries, long term trial results have led nowadays to spacing from 120 cm × 75 cm to 90 cm × 60 cm with a population load of 15,500 to 18,000 (Banglapedia).

4.2 Tea plant in the studied garden

Tea is a popular beverage. It is made from the leaves of evergreen shrub or tree *Camellia sinensis*, family Theaceae. Tea is predominantly an agro-based export-oriented evergreen crop in Bangladesh and a perennial crop grown as a monoculture on large contiguous areas. Under natural conditions, a tea plant grows to a small tree but it is configured into a bush by sequential pruning and other silvicultural practices.

4.2.1 Tea plantation

Tea grows best in misty, rainy regions at altitudes of 2,000 to 7,000 feet in the tropics and lower elevations in temperate regions. The best tea is produced in regions which have dry days and cool nights. Tea grows best on sloping terrain and tea plants on mountains and hills rest on carefully constructed terraces that trap water and prevent erosion. Sometimes trees are also planted for shade and windbreaks. Plants grow in low regions are ready to harvest after three years and in high regions are ready to harvest after five years. The planters harvest the tea leaves from March to Mid-November. Though there are four flushes or seasons for Assam tea, one can get the better quality tea on the first two flushes. The first flush or the spring flush starts in late March. The second flush occurs during end of May to June.

4.2.2 Structure and composition (Phytophysiology) of tea compartment

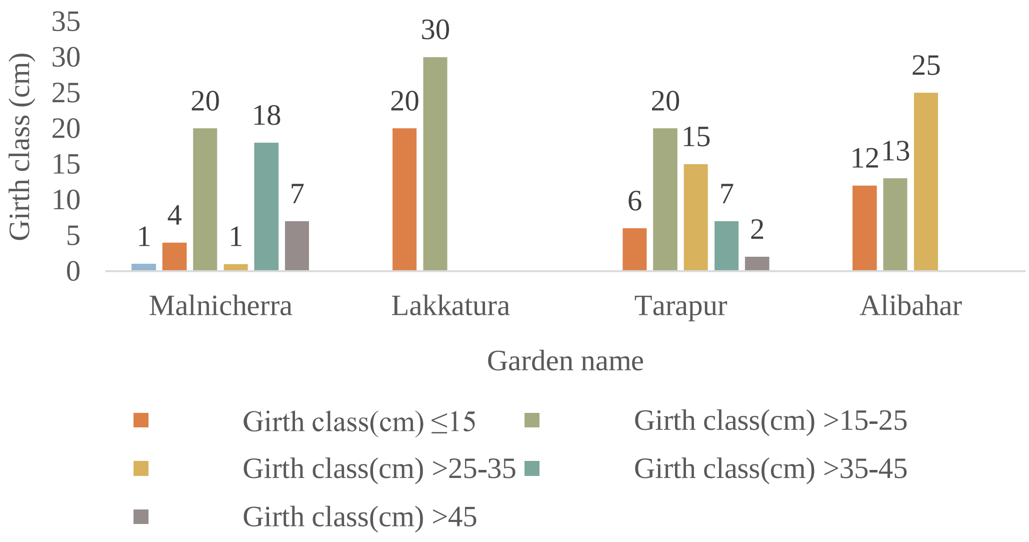


Figure 2. Distribution of tea gardens according to their girth class

In the sampled plots a total of 50 individual tea plants from each garden were measured for dendrometric parameters. In Malnicherra garden among 50 tea plants, 20 plants were belonged to the girth class >15-25 cm, 18 plants were belonged to

>35-45 cm and 7 plants were belonged to >45 cm. In Lakkatura tea garden of the sampled population 30 plants were belonged to >15-25 cm and 20 plants were belonged to ≤15 cm. In case of Tarapur tea garden, 20 plants were belonged to >15-25 cm, 15 plants were belonged to >25-35 cm and 7 plants were belonged to >35-45 cm. Among 50 plants 25 plants were belonged to >25-35 cm, 13 plants were belonged to >15-25 cm, 12 plants were belonged to ≤15 cm in Ali Bahar (Figure 2).

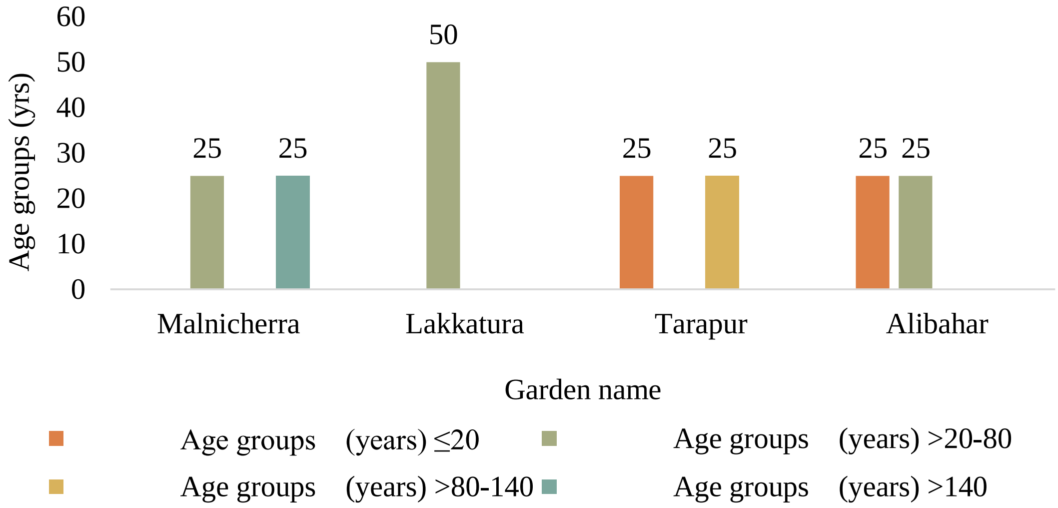


Figure 3. Distribution of tea gardens according to age group

In the sampled plots a total of 50 individual plants from each garden were measured for dendrometric parameters. Among the different age groups, in Malnicherra tea garden, 25 tea plants were belonged to >20-80 years group and 25 plants were belonged to >140 years group. In Lakkatura tea garden, among all supplied samples all were belonged to >20-80 years group. In case of Tarapur tea garden, 25 plants were belonged to ≤20 years groups and 25 plants were belonged to >80-140 years group. 25 plants were ≤2o years group and 25 plants were belonged to >20-80 years group (Figure 3).

Table 3. Distribution of tea gardens according to tea plant height

Garden name	Total number of tea plants	Height(cm)			
		>60-70	>70-80	>80-90	>90
Malnicherra	50	13	18	13	6
Lakkatura	50	8	22	13	7
Tarapur	50	5	19	15	11
Alibahar	50	14	17	15	4

In the sampled plots a total of 50 individuals from each garden were measured for dendrometric parameters. Among the different height classes, In Malnicherra tea garden, 13 plants were belonged to >60-70 cm, 18 tea plants were belonged to >70-80 cm, 13 plants were belonged to >80-90 cm and 6 plants were belonged to >90 cm. In case of Lakkatura tea garden, 8 plants were belonged to >60-70 cm, 22 tea plants were belonged to >70-80 cm, 13 plants were belonged to >80-90 cm and 7 plants were belonged to >90 cm. In case of Tarapur tea garden, 5 plants were belonged to >60-70 cm, 19 tea plants were belonged to > 70-80 cm, 15 plants were belonged to >80-90 cm and 11 plants were belonged to >90 cm. 14 plants were belonged to >60-70 cm, 17 tea plants were belonged to > 70-80 cm, 15 plants were belonged to >80-90 cm and 4 plants were belonged to >90 cm in Ali Bahar tea garden (Table 3).

Table 4. Descriptive statistics for tea plant girth distribution of different tea gardens

Parameter	Garden name	Mean	Minimum	Maximum	S.D.	CV(%)
Girth(cm)	Malnicherra	29.91	10.16	55.80	**14.15**	**47**
	Lakkatura	14.74	12.70	17.78	**1.98**	**13**
	Tarapur	24.47	12.70	58.42	**11.03**	**45**
	Ali Bahar	25.96	10.16	40.64	**12.27**	**47**

Tea plant girth was measured at 6.35 cm from ground level. Across different garden tea girth measurement values ranged between 10.16 cm and 58.42 cm. Mean girth showed maximum value in Malnicherra (29.91 cm) followed by Ali Bahar (25.96) and Tarapur (24.47 cm). The lowest plant girth was found in Lakkatura. Tea girth (14.74) and standard deviation were for Malnicherra, Lakkatura, Tarapur, Ali Bahar were 14.15, 1.98, 11.03, 12.27 and CV were 47%, 13%, 45% and 47% respectively (Table 4).

Table 5. Descriptive statistics for tea plant height distribution of different tea gardens

Parameter	**Garden name**	**Mean**	**Minimum**	**Maximum**	**S.D.**	**CV(%)**
Height(cm)	Malnicherra	77.61	66.04	96.52	**8.75**	**11**
	Lakkatura	75.48	55.88	91.44	**10.67**	**14**
	Tarapur	84.48	68.58	101.60	**12.21**	**14**
	Ali Bahar	74.78	60.96	86.36	**7.15**	**10**

Across the different tea plant height measurement values ranged between 55.88 cm and 101.60 cm. Mean height showed maximum value in Tarapur (84.48 cm) followed by Malnicherra (77.61 cm) and Lakkatura (75.48 cm). The lowest plant height was found in Ali Bahar tea garden (74.78 cm) and standard deviation were for Malnicherra, Lakkatura, Tarapur, Ali Bahar were 8.75, 10.67, 12.21, 7.15 and CV were 11%, 14%, 14% and 10% respectively (Table 5).

Table 6. Correlation between height of shade tree and height and girth of tea plant

Parameter	Shade height	Tea girth	Tea Height
Shade height	1		
Tea girth	0.998**	1	
Tea height	0.663**	0.792**	1

****** Correlation is significant at 0.01

The relation between shade tree height and tea girth and tea height was positive and highly significant at 1% level of significance, that means tea girth and height will increase with the increase of shade tree height. Similarly, the relation between tea girth and tea height and shade tree height was positive and highly significant that means with the increase of tea girth and height shade tree height will increase (Table 6).

4.3 Major pests and diseases in tea garden

In the tea gardens there were many pests that attack the garden during the plantation period. These were Tea Mosquito, Bug, Aphids, Thrips, Jassids, Lopper caterpillar, mites and different types of spiders. Many strategies are used in integrated pest management (IPM) strategy in tea plantation including cultural practices, biological control agents, chemical pesticides, pest-resistant varieties and physical barriers. Of all standard control strategies such as natural control like- Climatic factors, Topographic features, Predators and Parasites etc. Applied control like- cultural control, physical control, Mechanical control, Biological control, Microbial control, Regulatory control, Chemical control and Integrated control. Breeding of resistant agrotypes, Ionizing radiation, Chaemosterilant, etc. has been incorporated and population still to be continued because of protection of tea and various constraints to employ with different control methods (Muraleedharan, 1991). The various components IPM practices are enumerated below with a few specific examples, since the success stories with the use of IPM practices are numerous and increasing day by day.

Tea leaves are mostly affected by pathogens rather than other parts of tea plants. The major diseases found in tea gardens of Bangladesh were leaf blister blight, algal leaf spot. Besides that brown blight of tea, twig dieback, stem canker, black root rot etc. are common tea diseases in Bangladesh (Table 7)

Table 7. Major pests and diseases of the studied tea gardens

Name of the pest	**Name of the diseases**
Tea Mosquito, Bug	Tea brown blight
Aphids	Tea algal leaf spot
Thrips	Tea blister blight
Jassids	Twig dieback
Lopper caterpillar	Stem Canker
Flushworms, Leaf rollers	Black root rot
Red spider mites, Pink and purple mites	
Termites	
Nematodes	

4.4 Light intensity in the tea garden

Environmental and climatic conditions determine the rate of shoot expansion and tea yield. Various components of the environment influence the growth and productivity of tea to a different extent. Light, CO_2, temperature and water availability are the most important factors determining tea productivity. The net photosynthetic rate in fully expanded mature leaves of tea showed an asymptotic response to increasing light intensity. The light intensity was measured by Lux meter. The light intensity ranged in the Malnicherra garden, Lakkatura, Tarapur and Ali Bahar garden were 520-1030, 610-1200, 670-1370 and 550-1400 μmol m^{-2} s^{-1} respectively. The average light intensity was 520- 1400 μmol m^{-2} s^{-1} (Table 8).

Table 8. Light intensity in the tea gardens of the study area

Name of Tea garden	Light intensity range (μmol m^{-2} s^{-1})
Malnicherra	520-1030
Lakkatura	610-1200
Tarapur	670-1370
Ali Bahar	550-1400
Average	**520- 1400**

Tea plant originated as an understorey plant in tropical rainforests, its photosynthetic apparatus is adapted to function with maximum capacity under shade (De Costa *et al*., 2007). Photoinhibition occurs when these photoprotection mechanisms cannot efficiently quench excess excitation energy, resulting in damage to photosystems (Hajiboland, 2014). Because Tea leaf Pn decreases due to photoinhibition when light intensity increases beyond 1400-1500 μmol m-^{2} s-^{1} (Mohotti and Lawlor, 2002). Buds are predisposed to remain or become resting when dΦ/dt is negative, and are released from rest when dΦ/dt becomes positive (Matthews and Stephens, 1998b). The photoperiod influences shoot growth in two ways: by determining when a bud commences and finishes development, and by regulating its subsequent development and extension rate (Barua 1969, Tanton 1982). Mohotti (2004) and Okano *et al*. (1995) reported that the values for saturating light intensities range from 600-800 μmol m^{-2} s^{-1} up to 1200-1500 μmol m^{-2} s^{-1} of photosynthetic active radiation (PAR) in tea garden. In a greenhouse experiment, the optimum light intensity for CO_2 assimilation was lower for young leaves (250 μmol m^{-2} s^{-1}) than that for old leaves (500 μmol m^{-2} s^{-1}) (Hajiboland *et al*., 2011). Interestingly, abundant application of N fertilizers, e.g. 375 kg N ha^{-1} year^{-1}, minimizes photoinhibition in tea in the normal range of light intensities, i.e. up to 2000 μmol m-^{2} s^{-1} (Smith *et al*. 1993). Significant photoinhibition in tea has been observed on clear and sunny days, but not on cloudy days (Karunaratne *et al*., 2003). The optimum shading level for tea yield is 30-40% (Gamage *et al*., 2007). 50-70% diffused sunlight is needed for the optimum production of tea. Shades are used to provide that range of diffused sunlight in the cultivation of tea (Sana, 1989).

4.5 Soil characteristic of the studied tea gardens in Sylhet

The shade trees are an integral component of tea cultivation in Bangladesh. The shade trees are essential for modulating the environment of the tea ecosystem, enriching the soil fertility, reducing temperature and the evaporative capacity, conserve soil moisture and helps in the control of certain pests and diseases which are positively thermotropic in nature.

Table 9. Soil physiology of the studied tea gardens (0-15 cm)

Garden name	Topography	Sand%	Silt%	Clay%	Textural class
Malnicherra	Tillah	74	17	9	Loamy sand
Lakkatura	Medium flat	72	20	8	Loamy sand
Tarapur	High flat	61	30	9	Sandy loam
Ali Bahar	Medium flat	63	32	5	Sandy loam

The USDA textural class of the soils presented (Table 9) that soils of the studied gardens, loam and sandy are the dominant fractions. Malnicherra tea garden presented loamy sand textural class where sand was 74%, Silt was 17% and clay was 9%. Lakkatura tea garden presented loamy sand textural class where sand was 72%, Silt was 20% and clay was 8%. Tarapur belonged to sandy loam class where sand was 61%, silt was 30% and clay was 9% and Ali Bahar belonged to sandy loam class where sand was 63 %, silt was 32% and clay was 5%. Malnicherra and Lakkatura are the two oldest gardens than Tarapur and Ali Bahar in Sylhet sadar. Therefore, the soils had been converted from sandy loam to loamy sand due to passage of time. The textural class of the south Indian tea soils varies from sandy clay loam to clay while the tea soils in Bangladesh are predominantly loamy to sandy loam. Texturally, the tea soils in Bangladesh are predominantly loamy. Soils of Balisera, Monu-Doloi and Luskerpore circles are loamy to sandy loam from surface downwards, while loamy sand to loam in North Sylhet circle, but soils in Chittagong zone are mostly loamy (Biswas and Motalib, 2012).

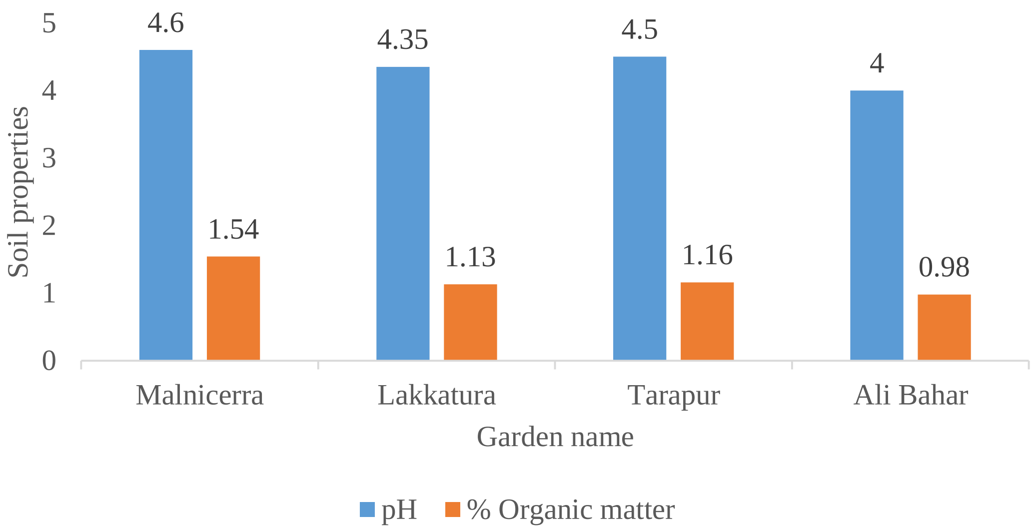


Figure 4. Distribution of pH and organic matter content in the soil profile of four tea gardens (S.D. for pH and OM was 0.27 and 0.24, S.E. for pH and OM was 0.13 and 0.12 respectively)

Soil pH

The pH for studied gardens varied from 4.00 to 4.60 and the average pH was 4.36 which was strongly acidic. From the table, it was found that soils of Ali Bahar was the most acidic among all the gardens (Figure 4). Soil pH ranging from 4.5 - 5.8 is known as favourable for tea cultivation (Hasan *et al*., 1974). Natesen (1999) reported that soil pH of 4.5 – 5.5 is considered to be optimum for the utilization of nutrients especially nitrogen and the growth of tea (Sandanam *et al*., 1978). Fertilization that causes soil acidity, especially excessive nitrogen fertilizer. Thenmozhi *et al.* (2012) reported that continuous use of ammonium N fertilizers in tea fields leads to a lower soil pH. The root metabolism of the tea tree itself was also causes acidification of tea garden soil. Therefore, tea soils are highly weathered, extremely acidic and of low fertility status. But the long-term rainfall infiltration leaded to the soil being weakly acidic. In

Bangladesh most of the tea soils of Balisera, Lungla and Monu-Doloi circles are below 4.5(Biswas and Motalib, 2012). Natesan (1999) reported that the maintenance of an optimal soil pH (4.5-5.5) is important in tea cultivation and generally lime and dolomite is applied to soil as an amendment when the pH is <4.5. Soil acidity increased with increasing tea cultivation period. Soil pH in tea plantations decreased by 1.37, 1.62 and 1.85 after 13, 34 and 54 years, respectively, compared to the soil of an unused land (Wang *et al*., 2010).

Organic matter (OM)

Organic matter percentage was high in Malnicherra tea garden (1.54) and lowest in Ali Bahar (0.98) tea garden. The average Organic matter was found 1.2% (Figure 4). Han *et al*. (2002) found the soil organic matter contents of the organic and ecological tea gardens are both more than 2.0%; while that of the non-ecological tea garden is relatively low and not good for growth and yield. Ping *et al.* (2014) showed that soil organic matter is greatly affected by the type of tea garden, the soil organic matter of the organic tea garden at different depths varies, indicating that this characteristic is greatly affected by soil depth. Tea soils of Bangladesh are generally medium textured with low organic matter. South Indian tea soils contains 1- 8% organic matter while tea soils of Bangladesh contain 1.0-1.2% (Biswas and Motalib, 2012). Alam (1999) stated that tea soils of Bangladesh, organic matter varies from 1.0 to 1.2 percent respectively and the critical values have been fixed at 1% for organic matter.

Table 10. Distribution of available N, P, K^+ and Na^+ content in the soil of four tea gardens

Garden name	Depth (cm)	%Total Nitrogen	Phosphorus (mg/kg)	Potassium Ion(meq/100 g soil)	Sodium Ion (meq/100g soil)
Malnicherra	0-15	0.07	26	0.14	0.18
Lakkatura	0-15	0.09	29	0.23	0.16
Tarapur	0-15	0.06	31	0.42	0.80
Ali Bahar	0-15	0.11	20	0.21	0.93
Average		**0.08**	**26.5**	**0.25**	**0.51**
CV (%)		**25**	**18.11**	**48**	**78.43**

Total Nitrogen

Among all studied gardens, the total nitrogen percentage for studied gardens varied from 0.06 to 0.11 (Table 10). The average nitrogen percentage was 0.08 and CV was 25%. Ali Bahar showed the highest nitrogen percentage content (0.11). On the other hand, Tarapur showed lowest amount of nitrogen percentage (0.06). In tea soils of Bangladesh, an overall content of nitrogen varies from 0.07 to 0.09 percent and the critical values have been fixed at 0.1% for nitrogen (Alam, 1999). The requirement of young tea plants for inorganic fertilizer can be reduced by the use of poultry manure, while the requirement of mature tea plants for chemical fertilizer can be minimized or avoided by the use of cow dung, as mature tea plants require more N and P compared to the younger ones (Sultana *et al*., 2014).

Phosphorus

The amount of phosphorus varied from 20 to 31 milligram per kilogram. The average phosphorus content was 26.5 milligram per kilogram and CV was 18.11%. Tarapur showed highest amount of phosphorus content (31 mg/kg) and Ali Bahar showed lowest amount of phosphorus content (20 mg/kg). The amount of potassium ion varied from 0.14 to 0.42 milliequivalent per hundredgram soil (Table 10). Tea soils of south India contain large amounts of free sesquioxides and phosphorus fixation is very strong (Biswas and motalib, 2012). The amount of available phosphorus, magnesium and base-saturation is low. The minimum level (critical limit) of nutrient status of tea soil should be 10μg/g for P (Alam,1999). In North-Sylhet circle pH, organic matter and available Ca content of the soils of khan tea estate were above the critical limit but total N, available P, K and Mg were below the critical limits. In the case of Habibnagar tea estate, soil pH, organic matter, available P and Ca were above the critical limits but total N, available K and Mg were below the critical limits (Biswas and Motalib, 2012).

Potassium Ion

The average potassium ion content was 0.25 meq/100g soil and CV was 48%. Tarapur showed highest amount of potassium ion content (0.42 meq/100g soil) and Malnicherra showed lowest amount of potassium ion content (0.14 meq/100g soil) (Table 10). The minimum level (critical limit) of nutrient status of tea soil should be 80 mg/g for K (Alam, 1999). After nitrogen, the next important nutrients are K and P respectively for tea plantation (Kamau, 2008; Ranganathan and Natesan, 1985). The determination of soil basic agrochemical characteristics of the representative tea garden in Zhejiang, Anhui and other provinces show that soil total potassium at 0-40 cm ranges from 0.27-3.91% (Hang *et al.*, 2002). Comparison of total potassium in surface soil and heart soil found the same rule that the organic and non-ecological tea gardens were low (Ping *et al.*, 2014).

Sodium Ion

The amount of sodium ion varied from 0.16 to 0.93 meq/100g soil. The average sodium ion content was 0.51 meq/100g soil and CV was 78.43%. Ali Bahar showed highest amount of sodium ion content (0.93 meq/100g soil) and Lakkatura showed lowest amount of sodium ion content (0.16 meq/100g soil) (Table 10). The amount of sodium ions adsorbed were in the range 0.6 to 1.5 meq; in this case, 2 meq of sodium ions were added to 100 g of soils and incubated 2 days at 30°C under the moisture condition of 70 per cent of water holding capacity. The soils began to show bad permeability and high dispersibility even in acidic medium if the exchangeable sodium ions occupied from 10 to 15 or more per cent of cation exchange capacity. The amounts of silicic acid extracted with distilled water from the soils with exchangeable sodium ions equivalent to about 13 per cent of their cation exchange capacities were twice of those of the control soils with only 6 per cent of exchangeable sodium (Keizaburo Kawaguchi and Tomoo Hattori, 1955).

CHAPTER 5

SUMMARY AND CONCLUSION

SUMMARY

Tea Agroforestry system maintains a multistoried composition with tea and shade trees. The study was undertaken in four tea gardens of Sylhet sadar which were Malnicherra tea garden, Lakkatura tea garden, Tarapur tea garden, Ali Bahar tea garden to identify the shade trees, tree plantation types and soils of tea gardens during the period of June 2018 to February 2019. Data were collected by random sampling process. Various types of shade tree were planted here like *A. lebbek, A. procera, A. auriculiformis*, *L. leucocephala* etc. Among all *Albizia procera* had the highest height and girth among all the shade tree in those tea gardens. It was found that Ali Bahar and Tarapur contained higher height of tea plants than Malnicherra and Lakkatura tea garden. Tea and shade tree were square planted with two or more shade trees in the gardens. Average spacing was maintained in case of tea plant, permanent and temporary shade tree which were 116.51×58.23 square cm, 4.14×5.47 and 2.16×3.33 square meter respectively.

Across different gardens, tea girth measurement values ranged between 10.16 cm and 58.42 cm. Mean girth showed maximum value in Malnicherra (29.91 cm) followed by Ali Bahar (25.96 cm) and Tarapur (24.47 cm). The lowest plant girth was found in Lakkatura (14.74 cm). Standard deviation for tea girth for Malnicherra, Lakkatura, Tarapur, Ali Bahar were 14.15, 1.98, 11.03, 12.27 and CV were 47%, 13%, 45% and 47% respectively. Across different tea plant height measurement values ranged between 55.88 cm and 101.60 cm. Mean height showed maximum value in Tarapur (84.48 cm) followed by Malnicherra (77.61 cm) and Lakkatura (75.48 cm). The lowest plant height was found in Ali Bahar tea garden (74.78 cm) and standard deviation were for Malnicherra, Lakkatura, Tarapur, Ali Bahar were 8.75, 10.67, 12.21, 7.15 and CV were 11%, 14%, 14% and 10% respectively. The relation between shade tree height and tea girth and tea height was positive and highly significant that means tea girth and height will increase with the increase of shade tree height and it was similar in case of shade height with tea girth and height.

The soil of Malnicherra and Lakkatura gardens belonged to loamy sand and Tarapur and Ali Bahar gardens belonged to sandy loam textural class. The study revealed light and pH performed a vital role for tea production. Tea plant originated as an understorey plant in tropical rainforests, its photosynthetic apparatus is adapted to function with maximum capacity under shade. The use of IPM practices are numerous and increasing day by day for the protection from insects and pests. Tea mosquitoes, aphids, bugs, thrips, lopper caterpillar etc. were very common to tea gardens. The major diseases found in tea gardens of Bangladesh were leaf blister blight, algal leaf spot. Besides that it was found that Ali Bahar tea garden had the highest pH and total nitrogrn among the studied gardens. Ali Bahar had the highest organic matter content and Tarapur contained highest amount of ion. The average nitrogen, phosphorus, potassium and sulphur content were 0.08%, 26.5mg/kg, 0.25 and 0.51 meq/100g soil respectively in the tea gardens. The study revealed that shade producing trees which are intercropped with tea helped in increasing soil fertility and also helped in reducing soil erosion.

CONCLUSION

The present study in four tea gardens of Sylhet sadar represented structural and physiological composition of shade trees and tea gardens. It also included that the environmental effects on tea gardens and also major pests in the tea gardens. It was shown that spacing varied gardens to gardens. The soil properties were observed that mentioned the fertility status of soil. However, the following conclusion can be drawn based on the present study:

i. Sampled area contained various dominant shade trees named *Albizia lebbek*, *Albizia procera, Leucaena leucocephala,* etc. which have positive relation with tea height and girth.

ii. The average pH, total nitrogen, phosphorus, potassium and sulphur content were 4.36, 0.08%, 26.5 mg/kg, 0.25 and 0.51 meq/100g soil respectively in the tea gardens.

CHAPTER 6

REFERENCES

Ahmed, M., Haq, M., Haq, M.I. and Ali, M.A. (1993). Influence of shade on the incidence of pests in Tea plantation in Bangladesh. Proc. Tea Sci. & Human Health: Tea tech., TRI, Kolkata, India. Pp. 326-329.

Ahmed, M. (2005). Tea Pest Management. Evergreen Printing and Packaging. Dhaka. Pp. 101.

Albrecht, A. and Kandji, S.T. (2003). Carbon sequestration in tropical Agroforestrysystems. *Agric. Ecosyst. Environ*. **99**: 15-27.

Amin, R.K. (2003). Cha Shilpe Bangladesh. (Bengali) Dainik Azadi, 11 September. Ann. Rep. Pest management Div., BTRI. 1981-1987.

Anon, (2003). Cha Bagane Vezosho Udvid Chaser Parikolpana. Daily Inqilab; 27 July.

Ashesh K.D., Rinku, M.K. and Arun, J.N. (2014). Comparative study on growth performance of two shade trees in tea agroforestry system. *J. of Environ. Bio*., India. ISSN: 0254-8704.

Barua, D.N. (1960). Soil fertility and illumination response of tea bushes. *Rep. Tocklai Exp. Station*, **1959**: 64-68.

Barua, D.N. (1961). Effect of shade and shade trees. Two Bud.**8**: 4 -12.

Barua, D.N. and Dutta, K.N. (1961). Root growth of cultivated tea in the presence of shade trees and nitrogenous manure.*Emp. J. Exp. Agric*. **29**: 287-298.

Barua, D.N. (1969). Seasonal dormancy in tea (*Camellia sinensis L*.). Nature, **224**: 514.

Barua, D.N. (2007). Science and Practice in Tea culture. Ed (1), Tea Research Association, Assam.

Beer, J.W., Muschler, R.G. and Somarriba, E., Kass D (1998). Shade management in coffee and cacao plantations-a review. *Agrofor. Syst*. **38**: 139-164.

Bene, J.G., Beall, H.W. and Côte, A., (1977). Trees, food and people. International Development Research Centre, Ottawa, Canada. Pp.52.

Biswas, A. and Motalib, M.A. (2012). Comparative study on tea soils of South india and Bangladesh. *Tea J. Bangladesh*, **41**: 27-36.

Black, C.A., Evans, D.D., Ensminger, E.E., White, J.L. and Clark, F.E. (1965). Methods of soil analysis: Part 2. Chemical and microbiological properties. *American Society of Agron. Inc. Wisconsin*, USA. Pp. 67.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of soils. *Agron. J.*, **54**:464-465.

BTRI (2003). Report; Bangladesh Tea Research Institute, Government of People's Republic of Bangladesh, Srimangal, Moulvibazar, Bangladesh. Pp. 94-98.

Carpenter, F.R. (1974). Introduction and translation of Lu Yu's Tea Sutra (The Classic of Tea) (1st ed.). Boston, M.A., USA: Little, Brown and Company.

Carr, M K.V. (1971). The internal water status of the tea plant (*Camellia sinensis*): Some results illustrating the use of the pressure chamber technique. *Agricultural Meteorolog*y. **9**: 447-160.

Carr, M.K.V. (1972). The climatic requirements of the tea plant: A review. *Exp*. *Agric*. **8**: 1-14.

Chaudhury, S.H. and Kibria, G. (1977). Relationship between soil reaction and the growth of shade trees used in tea gardens. Effect of liming and pH on the growth of Albizia chinensis (stipulate) shade tree. *Tea J. Bangladesh* **13**(1-2): 3-9.

Chowdhury, A., Sarkar, S., Roy, P., Mondal, S. and Chowdhury, Dr. M. (2015). Inventory of Shade Trees in Tea Gardens of Sub-Himalayans Region of West Bengal, *India. Int. J. Sci. and Tech*. **3**(12): 164-168.

Danthanaryana, W. and Ranaweera, D.J.W. (1972). The effect of rainfall and shade on the occurrence of three mite pests of tea in Ceylon. *Ann. Appl. Biol.***70**: 1-12.

De Costa W.A.J.M., Weerakoon, W.M.W., Chinthaka, K.G.R., Herath, H,M.L.K.and Abeywardena, R.M.I. (2007). Genotypic variation in the response of rice (*Oryza sativa L.*) to increased atmospheric carbon dioxide and its physiological basis. *J. Agron. Crop Sci.* **193**: 117-130.

De Costa W.J., Mohotti A. and Wijeratne M., (2007). Ecophysiology of tea. Braz. *J. Plant Physiol.***19**: 299- 332.

Deng, Y. H., Xia, Y. F. and Xi, J. (2012). Different age artificial Xiang Chun Lin effects on soil physical and chemical properties. Guizhou *Agric. Sci.* 40(**8**): 117-120.

Ethical Tea Partnership. (2019). Smallholder Tea Farmers Archives. Retrieved from http://www.ethicalteapartnership.org/category/key-areas/smallholder-tea-farmers/

Evizal R., Tohari, Prijambada I.D., Widada J. and Widianto D. (2012). Soil bacterial diversity and productivity of coffee - shade tree agro- ecosystems. *J. Trop. Soils.***17**: 181-187.

F. A. O. (1987/15). Nitrogen Fixing Trees. Regional Office for Asia and the Pacific (Rapa). Food and Agricultural Organization of the United Nations Bankok, Pp. 61-70.

Fordham R., Palmer-Jones R.W., 1977. Simulation of intra seasonal yield fluctuations of tea in Malawi. *Exp. Agric*. **13**: 33-42.

Gamage, A.J., Wijeratne, M.A. and De Costa, W.J., (2007). Role of shade trees in tea: A low-countryperspective. Proc. 215th Meeting of the Experiments and Extension Forum. Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka.

Hajiboland, R., Bastani, S. and Rad, S.B. (2011). Effect of light intensity on photosynthesis and antioxidant defense in boron deficient tea plants. *Acta Biol. Szeged*. **55**: 265-272.

Hajiboland, R., (2014). Reactive oxygen species and photosynthesis. In: Oxidative Damage to Plants, Antioxidant Networks and Signaling. Ahmad, P. (Ed.), Springer, New York, USA. Pp. 1-63.

Han, W.Y. *et al.* (2002). Tea garden soil nutrition main obstacle factors and fertilizer series of tea tree. *J. of Tea Sci.***22**(1): 70-74.

Hasan, K.A. (1963). Shade trees for tea. Part-I: Their functions and behaviour. *Tea J. Bangladesh.***1**(2): 9-16.

Hasan, K.A. and Chaudhury, S.H. (1964). Relationship between soil reaction and growth of shade trees used in tea gardens. Effect of pH on the growth of Derris robusta Benth. *Tea J. of Pakistan*. **2**(2): 4-10.

Hasan, K.A., Chadhury, S.H., Shome, K.M. and Rahaman, M.A. (1974). Nutrient status of the teasoils of Balisera Circle, Sylhet. Bangladesh Tea Research Institute, Srimangal, Moulvibazar. Pamphlet No. 2.

Hazarika, L.K., Bhuyan, M. and Hazarika, B.N. (2009). Insect Pests of tea and their management. *Annual Review of Entomology*. **54**: 267-84.

Hooper, D.U. and Vitousek, P. M. (1997). The effects of plant composition and diversity on ecosystem processes. *Sci*. **277**: 1302–1304.

ITC. (2015). Annual Bulletin of Statistics (Sept, 2015). International Tea Committee, London, U.K. Pp. 158.

Jackson, M.L. (1985). Soil chemical analysis - An advanced course (2nd ed). Department of Soil Science. University of Wisconsin. Madison, USA.

Kamau, D. M. (2008). Productivity and resource use in ageing tea plantations. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Karunaratne, P.M.A.S., Mohotti, A.J., Nissanka, S.P. and Gunasinghe, W.A.D.S.K. (2003). Effect of shade in minimizing photoinhibition of photosynthesis of high grown tea (*Camellia sinensis L*.) (O. Kuntze). *Trop. Agric. Res*. **15**: 133-143.

Kibria, A.K.M.G.a(1986). Factors regulating draught. *Bangladesh Tea Rehabilitation Project*, **1**(6): 16-20.

King, K.F.S. and Chandler, M.T. (1978). The waste lands: The programme of work of ICRAF. International Council for Research in Agroforestry, Nairobi.

Kumar, B.M. and Nair, P.K.R. (2011). Carbon sequestration potential of Agroforestry systems: Opportunities and challenges. Springer, Dordrecht Heidelberg London, New York. Pp. 310.

Lin, B.B. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. *Agric. For. Meteorol*. 2007, 144, 85–94.

Lopez-Rodriguez G., Sotomayur-Ramirez D., Amador J.A., Schroder E.D. (2015). Contribution of nitrogen from litter and soil mineralization to shade and sun coffee (*Coffea arabica L.*) *Agroecosystems. Trop. Ecol*. **56**: 155-167.

Lundgren, B. and Raintree, J.B. (1983). Sustained agroforestry. In B. Nestel (ed). Agricultural Research for Development: Potentials and Challenges in Asia. ISNAR, The Hague.

Mamun, M. S. A. and Ahmed, M. (2011). Prospect of indigenous plant extracts in tea pest management. *Int. J. Agril. Res. Innov. and Tech*. **1**(1-2): 16-23.

Mamani-Pati, F., Clay, D.E., Clay. S.A., Smeltekop, H. and Yujra-Callata, M.A. (2012). The influence of strata on the nutrient recycling within a tropical certified organic coffee production system. *ISRN Agron*. 2012: 1-8. DOI: 10.5402/2012/389290.

Marshall, T.J. (2003). Particle-size distribution of soil and the perception of texture. *Aust. J. of Soil Res*., **41**: 245-249.

Matthews, R.B., Stephens, W. (1998). CUPPA-TEA: A simulation model describing seasonal yield variation and potential production of tea. 1. Shoot development and extension. *Exp. Agric*. **34**: 369-389.

Mohotti, A.J. and Lawlor, D.W. (2002). Diurnal variation of photosynthesis and photoinhibition in tea: effects of irradiance and nitrogen supply during growth in the field. J. Exp. Bot. 53: 313-322.

Mohotti, A.J. (2004). Shade in tea: Is it beneficial? Sri Lank. *J. Tea Sci*. **69**: 27-39.

Muraleedharan, N. (1991). Pest Management in Tea, The United Planters' Association of Southern India. Pp. 130.

Muraleedharan, N. (1992). Pest Control in Asia. In "Cultivation to Consumption". (Eds. Wilson, K.C. and Clifford M. N.), Pp. 375-412. London: Chapman and Hall. Pp. 769.

Nair, P.K.R. (1979). Intensive Multiple Cropping with Coconuts in India: Principles, Programmes and Prospects. Verlag Paul Parey, Berlin (West).

Nair, P.K.R. (1985). Classification of Agroforestry Systems. Agroforestry Systems. **3**: 97-128.

Nasir, T. and Shamsuddoha, M. (2011). Tea productions, consumptions and exports: Bangladesh perspective. *Inter*. *J. Educat. Res*. **2**(1): 68-73.

Natesan, S. (1999). Tea Soils. In: Global advances in tea science, Jain, N.K. (Ed). Aravali Books International Pty Ltd, New Delhi. Pp. 519-532.

Nath, T.N. (2013). Status of macronutrients in some selected tea growing soils in Dibrugarh Sivasagar Districts of Assam, India. *Int. J. Sci. Res.***2**: 273-275.

Okano, K., Komaki, S., Matsuo, K., Hirose, D. and Tatsumi, J. (1995). Analysis of canopy photosynthesis in mature tea (*Camellia sinensis L*.) bush at late autumn. *Jap. J. Crop Sci*. **64**: 310-316.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). Agroforestry Database: A Tree Reference and Selection Guide Version 4.0. World Agroforestry Centre, Kenya.

Page, A.L., R.H. Miller and Kenny, D.R. (1982). Methods of soil analysis. Part 2: Chemical and microbiological properties (2nd Ed). American Society of Agronomy Inc. Wisconsin, USA. Pp. 1203.

Pandey, D.N. (2002). Carbon sequestration in Agroforestry systems. Climate policy, 2, 367-377.

Pangging, G. and Mandal, S. (2017). Assessment of shade trees and socio-economic condition of the Tea workers: a case study of tea estate around Banderdewa forest range. *Bull. Arunachal Forest Res*. **32**(1&2): 62-65.

Peng, D., Zhang, H. A. and Yang, J. Z. (2006). Guangdong Province soil the capillary porosity distribution. *Guangdong Forestry Sci. and Tech*. 22(**1**): 56-59.

Ping, X., Liyun, Y., Moucheng, L. and Fei, P. (2014). Soil characteristics and nutrients in different tea garden types in Fujian Province, *China. J. Resour. Ecol.***5**: 356-363.

Piper, C.S. (1950). Soil and plant analysis. Adelaide University Press, Australia. Pp. 368.

Ranganathan, V. and Natesan, S. (1985). Potassium nutrition of tea. In: Munson, R.D. (ed). Potassium in Agriculture. ASA-CSSA-SSSA, USA. Pp. 981-1015.

Ran, L. X. *et al.* (2012). Different types of tea garden plant diseases and insect pests and prevention and control technology research. *Journal of Anhui Agric. Sci.***40**(27): 13358-13359.

Redwan, M. (2003). Management of shade trees in the tea gardens of Bangladesh with special reference to the Rasidpur and Kamaichora tea estate. B. Sc. (Hons.) thesis (Forestry), Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh.

Rice, R.A. and Greenberg, R. (2000). Cacao cultivation and the conservation of biological diversity. *Ambio.***29**: 167–173.

Sana, D. L. (1989). Tea Science, Ashrafia BoiGhar, Dhaka, Pp. 7-81.

Sandanam, S., Krishnapillai, S. and Sabaratnam, J. (1978). Nitrification of Ammonium Sulphate and Urea in acid red yellow Podzolic soil in Sri Lanka in relation to soil fertility. *Plant and Soil*. **49**: 9-22.

Schroth, G. (1995). Tree root characteristics as criteria for species selection and systems design in agroforestry. *Agrofor. Syst*. **30**: 125–143.

Schroth, G., Krauss, U., Gasparotto, L., Duarte Aguilar, J.A. and Vohland, K. (2000). Pests and diseases in agroforestry systems of the humid tropics. Agroforestry Systems. 50: 199–241.

Sen, B. B. (Eds.). (2008). Origin and Development of Tea, Guwahati, India, EBH Publishers, iii-v.

Smith, B.G., Stephens, W., Burgess, P.J. and Carr M.K.V. (1993a). Effects of light, temperature, irrigation and fertilizer on photosynthetic rate in tea (Camellia sinensis). *Exp. Agric.* **29**: 291-306.

Sultana, J., Siddique, M.N.A., Kamaruzzaman, M. and Halim, M.A. (2014). Conventional to ecological: Tea plantation soil management in Panchagarh District of Bangladesh. *J. Sci. Technol. Environ. Inform.***1**: 27-35.

Tanton, T.W. (1982). Environmental factors influencing the yield of tea (Camellia sinensis). II. Effects of soil temperature, day length, and dry air. *Exp. Agric.***18**: 53-63.

Thenmozhi, K., Manian, S. and Paulsamy, S. (2012). Influence of long term nitrogen and potassium fertilization on the biochemistry of tea soil. *J. Res. Agric*. **1**: 124-135.

TRFK (Tea Research Foundation of Kenya) (2012). Tea Cultivation Manual for Good Agricultural Practices. 1st ed. Nairobi, Kenya.

Tscharntke, T., Clough, Y., Bhagwat, S. A., Buchori D., Faust, H., Hertel, D., Holscher, D. H., Juhrbandt, J., Kessler, M., Perfecto, I., Scherber, C., Schroth, G., Veldkamp, E. and Wanger, T. C. (2011) Multifunctional shade-tree management in tropical Agroforestry landscapes. *J Appl Ecol*. 48: 619–629.

Van Ruijven, J. and Berendse, F. (2005). Diversity–productivity relationships: initial effects, long-term patterns, and underlying mechanisms. *Proceedings of the National Academy of Sci*. **102**(3): 695-700.

Verbist B., Putra A.E.D., Budidarsono S. (2005). Factors driving land use change: Effects on watershed functions in a coffee agroforestry system in Lampung, Sumatra. *Agric Syst*. **85**: 254-270.

Wang, H., Xu, R.K., Wang, N. and Li, X.H. (2010). Soil acidification of alfisols as influenced by tea cultivation in Eastern China. Pedosphere, **20**: 799-806.

Wang, J. Y. and Lin, F. J. (2012). The key technology of Dehua county development in organic tea garden. *Tea in Fujian*. (3): 12-15.

Workman, D. (2019). Tea Imports by Country. World's Top Exports. Retrieved from http://www.worldstopexports. com/tea-imports-by-country/

Workman, D. (2019). Tea Exports by Country. World's Top Exports. Retrieved from http://www.worldstopexports.com/tea-exports-by-country/

Yadava, A. K. (2010). Biomass production and carbon sequestration in different Agroforestry systems in Tarai region of Central Himalaya. *Ind. For*.**136:** 234-243.

Zhang, Y. L., Luo, S. H., Zeng Y. H. and Pengo P. Y. (1997). Study nutrient scale of sufficiency or deficiency in tea soils in Hunan province and fertilizing recommendation. *J. Tea Sci*. **17**(2): 161-170.

Zhang, J. C. *et al.* (2013). Different ecological regions in Guizhou king bird tea and tea quality soil characteristics correlation studies. Guangdong *Agric. Sci.***40**(8): 60-63.7.

Zhang, J. (2018). Research on the soil nutrient characteristics of tea plantation. IOP Conf. Ser.: *Earth Environ. Sci*. **208:** 012079.

https://www.atlasobscura.com/places/lakkatura-tea-garden

http://en.banglapedia.org/index.php?title=Tea

https://dailyasianage.com/news/185148/lakkatura-tea-garden

https://porzoton.com/malnicherra-tea-estate/

APPENDICES

Appendix I. Characteristics of soil of the studied field

Table A. Morphological characteristics of the studied field of Sylhet sadar, Sylhet

Morphological features	Characteristics
Location	Sylhet sadar, Sylhet
AEZ	AEZ-20, Eastern Surma-Kushiyara Floodplain
General soil type	Non-calcareous grey floodplain
Land type	High land
Soil series	Belaganj
Topography	Undulate with elevations

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from June 2018 to February 2019

Table B. Monthly records of air temperature, relative humidity and rainfall during the period from June 2018 to February 2019 of Sylhet sadar, Sylhet

Month	Air temperature (℃)		Relative humidity(%)	Rainfall (mm)
	Maximum	Minimum		
June	30.60	24.50	81	780
July	30.90	25.10	84	751
August	31.20	25.10	83	595
September	31.20	24.60	81	468
October	30.60	22.30	76	227
November	28.70	17.70	73	31
December	26.10	13.60	69	8
January	25	12.10	57	13
February	27.30	13.80	55	27

Source: Bangladesh Meteorological Department (Climate and Weather division), Agargaon, Dhaka-1212

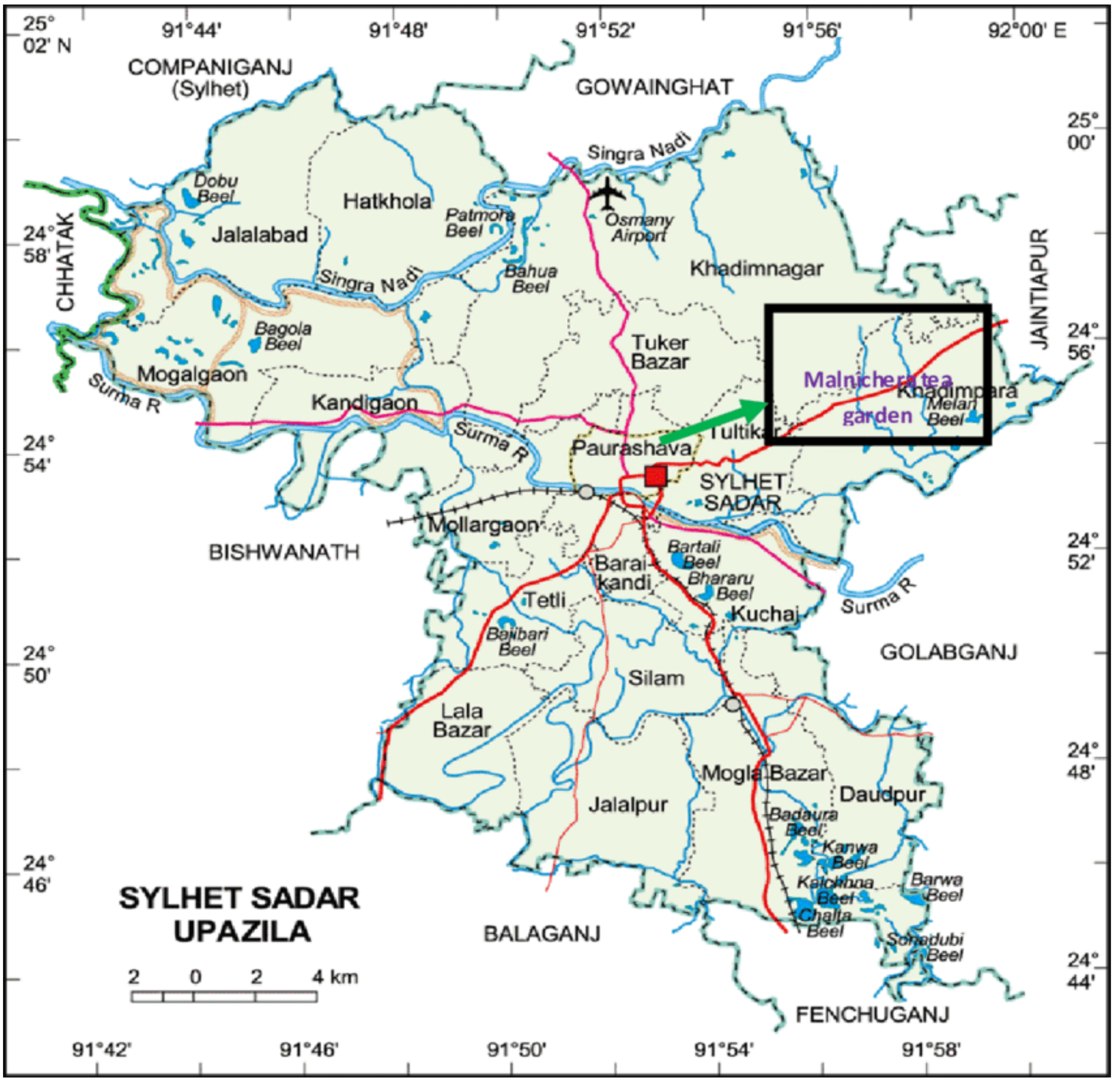
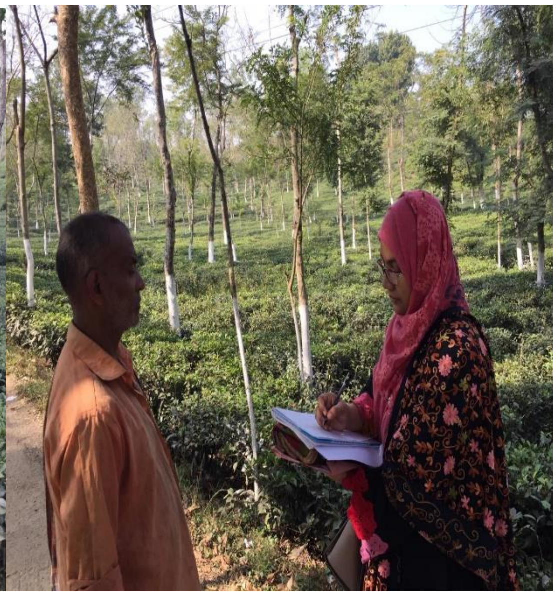


Plate 14. Location map of Malnicherra tea garden, Sylhet sadar, Sylhet

(a) (b)


(c) (d)

Plate 15. Photograph showing collection of data (a) Malnicherra tea garden, (b) Lakkatura tea garden, (c) Tarapur tea garden, (d) Ali Bahar tea garden

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STUDY ON SHADE TREE AND SOIL CHARACTERISTICS OF TEA GARDENS IN SYLHET

ABSTRACT

Agroforestry systems are spread all over the world and maintain a multistoried composition with good association of extensively managed tea and shade trees. The study was conducted at the four tea gardens in Sylhet district during June 2018 to February 2019. Data were collected following random sampling technique and analysis was done by SPSS 16.0 software. 50 shade trees and 50 tea plants were randomly selected for the study of height, girth and spacing. Soil sample were collected randomly from 0-15 cm depth in every garden to determine texture, pH, nitrogen, organic matter, phosphorus, potassium and sodium ion. The average pH, total nitrogen, organic matter, phosphorus content were 4.36, 0.08%, 1.20%, 26.5 mg/kg and potassium and sulphur content were 0.25 and 0.51 meq/100g soil respectively in the tea gardens. The soil of Malnicherra and Lakkatura garden belonged to loamy sand and Tarapur and Ali Bahar garden belonged to sandy loam textural class. Dominant shade trees named *Albizia lebbek*, *Albizi*a *procera* and *Leucaena. leucocephala* etc. which had positive significant relation with tea plant height and girth. Spacing of tea gardens was also observed including their arrangements with shade trees. Average spacing was maintained in case of tea plant and permanent shade tree which were 116.51×58.23 cm square and 4.14×5.47 meter square respectively and average light intensity was 520- 1400 μmol m^{-2} s^{-1} in the studied garden that increased photosynthesis rate.

ACRONYMS

% =Percent
^0C =Degree Celsius
AFS=Agroforestry systems
FAO=Food and Agriculture Organization
SAU =Sher-e-Bangla Agricultural University
REDD+=Reducing Emissions from Deforestation and forest Degradation
USD=United States Dollar
ICRAF=International Council for Research in Agroforestry
ETL=Economic Threshold Level
$\mu mol\ m^{-2}\ s^{-1}$=Micromole per second and square meter
m=Meter
cm=Centimeter
mg=Milligram
kg=Kilogram
meq=Milliequivalent
g=Gram
Lbs=Pound
viz. =Namely
W=West
N=North
E=East
S=South
Na^+=Sodium ion
K^+=Potassium ion
P=Phosphorus
N=Nitrogen
CV=Coefficient of Variation
SD=Standard Deviation
SE= Standard Error

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