

Research Article

## INVESTIGATION OF SHADE TREE SPECIES USED IN TEA GARDEN IN BANGLADESH

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### ABSTRACT

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. For this persists, a floristic exploration of shade trees was carried out at fifteen tea gardens in Chattogram and Moulvibazar District of Bangladesh from November 2017 to December 2018. During the investigation, a total of 44 species of Angiosperm representing 31 genera of 9 families was enlisted. For every species, scientific name, vernacular name, status, and necessary photographs are mentioned. In the assessment, 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. Further investigations, however, are required to find out the right type of shade tree species on the growth and yield of tea plants in tea cultivation areas of Bangladesh.

**Keywords:** Tea, Tea garden, Shade tree species, Fabaceae

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## INTRODUCTION

Tea (*Camellia sinensis* L.) is one of the most popular and favored beverages (nonalcoholic) in the world. It plays an important role in Bangladesh economy. There are 162 tea estates and 746 small cultivators having about 59,018 hectares of tea plantation generating about 85.05 million kg of over tea per annum with an average yield of about 1,587 kg per hectare in Bangladesh (BTB, 2017). It is now ranked 8th, 10<sup>th</sup>, and 12<sup>th</sup> position in the world in respect of the area, production, and export respectively (ITC, 2015). The tea industry of Bangladesh is frolicking a major role in fulfilling the domestic consumption as well as an important source of export earnings and contributing about 0.8 percent of the total GDP of the country (Rahman, 2016). Tea gardens and smallholding tea cultivators in Bangladesh have created employment for about 1,33,000 people every year (Rahman, 2016).

The tea plant is traditionally grown under the shade condition as they are shade-loving plants. Planting of shade trees has become an integral component of tree plantation and management in India, Sri Lanka, Indonesia, Bangladesh and some parts of Africa. The shade trees provide 50 % to 70 % of diffused solar insolation to the tea cultivation area (Sana, 1989). It results in improves the quality of the tea leaves due to an increase in the concentration of amino acids with lowers the content of catechin in the plant and it also inhibits the concentration of flavonoid (Ku et al., 2010; Wang et al., 2012). Barua (1979) reported that tree shade can increase photosynthetic rate and yield by 10 to 30 percent, especially during hot summer in north-eastern India. Shade trees not only used as shade provider, but it also produces fuel wood timber, conserve soil from erosion, the impact of rainfall drop, enrich soil fertility, support diverse flora and fauna, producing foods (leaves, pods or flowers) for people, creation of tannins, gums, medicines and services like living fences, ornamentals and environmental protection (FAO, 1987).

Tea cultivation is one of the important Agroforestry systems well known in Bangladesh, which was started in the 19<sup>th</sup> century. The shade trees play an important role in increasing the productivity of the tea under the environment of Bangladesh. 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 (Kalita et al., 2014). The right type of shade trees and their proper management is possibly one of the most well-investigated research problems in all tea cultivation areas of Bangladesh. Therefore, the present study was undertaken to investigate the shade tree species in the tea gardens of Bangladesh.

## MATERIALS AND METHODS

### *Study area*

The present study was conducted in fifteen tea gardens of Chattogram and Moulvibazar District of Bangladesh (Table 1). This study was conducted in several tea estates from September 2017 to December 2018.

Table 1. Investigated tea estates in Bangladesh

SL no.	Name of tea garden	Location	District
1.	Ramgarh tea estate	Fatikchari	Chattogram
2.	Dantmara tea estate	Bhojpur, Fatikchari	Chattogram
3.	BTRI substation	Ooadalia, Fatikchari	Chattogram
4.	Ooadalia tea estate	Katirhat, Fatikchari	Chattogram
5.	Bhojpur tea estate	Bhojpur, Fatikchari	Chattogram
6.	Naseha tea estate	Dantmara, Fatikchari	Chattogram
7.	Haldavalley tea estate	Najirhat, Fatikchari	Chattogram
8.	Neapchun tea estate	Narayanhat, Fatikchari	Chattogram
9.	Panchabati tea estate	Bhojpur, Fatikchari	Chattogram
10.	Aasia tea estate	Bhojpur, Fatikchari	Chattogram
11.	Majan tea estate	Datmara, Fatikchari	Chattogram
12.	Andhar manik tea estate	Chikancherra, Fatikchari	Chattogram
13.	BTRI main campus	Srimangal	Maulvibazar
14.	BTRI Bilashchara Experimental Farm	Srimangal	Maulvibazar
15.	Finlay tea estate	Srimangal	Maulvibazar

### *Specimen collection and plant identification*

During the study, a large number of fertile specimens of different shade trees have been collected for taxonomic identification. The collected specimens were identified consulting with the experts of (Bangladesh Forest Research Institute) BFRI Herbarium (BFRIH) and pertinent literature (Ahmed et al., 2009; Pasha and Uddin, 2013; Hooker, 1872-1897; Prain, 1903; Brandis 1906; Kanjilal et al., 1939, 1940; Heining, 1925). Also, we compared identified samples with specimens preserved at Bangladesh Forest Research Institute Herbarium (BFRIH) Chattogram, Bangladesh.

## **RESULTS AND DISCUSSION**

During the present investigation, mainly two types of shade trees viz., permanent shade trees, and temporary shade trees were found in all investigated tea gardens of Bangladesh. Permanent shade trees are planted for a longer period (about 40 years). It takes a long period to be established with their full canopy. That's why at the initial stage of plantation temporary shade trees along with the permanent shade trees are planted to protect the tea plants from direct sunlight. When the permanent shade trees become established after 5/6 years, the temporary shade trees are removed. In the present assessment, a total of 44 species representing 31 genera of 9 families of angiosperms were enlisted (Table 2). The Morphological characteristics of shade tree species at investigated tea estates are presented at Table 3.

Table 2. Types and abundance of shade trees at investigated tea estates

Scientific Name	Tea garden name	Habits	Vernacular Name	Family	Status
Permanent shade trees					
<i>Acacia auriculiformis</i>	RMG, DM, BP, HV, NPC, AS, ADM	Tree	Akashmoni	Fabaceae	Less common
<i>A. hybrid</i>	BP, MJ, DM	Tree	Acacia hybrid	Fabaceae	Rare
<i>Albizia chinensis</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Chakua koroi	Fabaceae	Most common
<i>A. lebeck</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Sirish	Fabaceae	Most common
<i>A. lucidor</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Potka Siris	Fabaceae	Most common
<i>Acacia mangium</i>	BP, HV, NPC, PACB	Tree	Mangium	Fabaceae	Rare
<i>Albizia moluccana</i>	RMG, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM	Tree	Moluccan sau	Fabaceae	Less Common
<i>A. procera</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Silkoroi	Fabaceae	Most common
<i>A. richardiana</i>	ODL, NPC, AS, MJ	Tree	Gagan shiris	Fabaceae	Rare
<i>A. falcataria</i>	RMG, DM, ODL, BP, NDFC, HV, NPC, AS, ADM, BEFBTRIS, FLA	Tree	Malakana Koroi	Fabaceae	Less Common
<i>Adenanthera pavonina</i>	RMG, ODL, BP, HV, NPC, AS, MJ, ADM	Tree	Rakta Kambal	Fabaceae	Less common
<i>Albizia odoratissima</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Kali Sirish	Fabaceae	Most common
<i>Alstonia scholaris</i>	RMG, DM, ODL, BP, HV, PACB, AS, MJ, ADM	Tree	Chatim	Apocynaceae	Less common
<i>Artocarpus chaplasha</i>	DM, ODL	Tree	Chapalish	Moraceae	Rare
<i>Azadirachta indica</i>	RMG, DM, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM	Tree	Neem	Meliaceae	Less common
<i>Bauhinia purpurea</i>	DM, ODL, BP, AS, MJ	Tree	Rakta kanchan	Fabaceae	Rare
<i>Butea monosperma</i>	DM, ODL, AS	Tree	Palash	Fabaceae	Rare
<i>Cassia fistula</i>	RMG, BP, NDFC, HV, NPC, AS,	Tree	Badar lathi	Fabaceae	Less

Scientific Name	Tea garden name	Habits	Vernacular Name	Family	Status
	MJ, ADM				common
<i>Cassia siamea</i>	BP, NDFC, HV, AS	Tree	Minjiri	Fabaceae	Rare
<i>Chukrasia tabularis</i>	DM, BP, AS	Tree	Chikrassi	Meliaceae	Rare
<i>Dalbergia assamica</i>	RMG, DM, NPC	Tree	Mouhita	Fabaceae	Rare
<i>Dalbergia sericea</i>	RMG, DM, ODL, BP, HV, NPC, PACB, AS, MJ, ADM	Tree	Silky Dalbergia	Fabaceae	Less common
<i>Dalbergia sissoo</i>	RMG, ODL, BP, , NPC, PACB, AS, MJ, ADM	Tree	Shisu	Fabaceae	Less common
<i>Delonix regia</i>	DM, BP, AS, MJ	Tree	Gulmohar	Fabaceae	Rare
<i>Derris robusta</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Tree	Miringa	Fabaceae	Most common
<i>Erythrina variegata</i>	RMG, ODL, HV	Tree	Madar	Fabaceae	Rare
<i>Eucalyptus robusta</i>	DM, ODL, AS	Tree	Eucalyptus	Myrtaceae	Rare
<i>Eucalyptus camaldulensis</i>	DM, ODL	Tree	Red gum	Myrtaceae	Rare
<i>Gravillea robusta</i>	RMG, DM, ODL, BP	Tree	Silky oak	<u>Proteaceae</u>	Rare
<i>Lagerstroemia speciosa</i>	RMG, BP, AS, MJ	Tree	Jarul	Lythraceae	Rare
<i>Leucaena leucocephalla</i>	DM, ODL, NDFC, HV, NPC, AS, MJ, ADM	Tree	Ipilipil	Fabaceae	Less common
<i>Mangifera indica</i> L.	RMG, BP, AS	Tree	Aam	Anacardiaceae	Rare
<i>Melia azedarachta</i>	DM, ODL, BP, AS	Tree	Ghora neem	Meliaceae	Rare
<i>Phyllanthus emblica</i>	DM, ODL	Tree	Amlaki	Phyllanthaceae	Rare
<i>Samanea saman</i>	DM, ODL	Tree	Shirish/Rain tree	Fabaceae	Rare
<i>Swietenia macrophylla</i>	RMG, BTRISS, ODL, BP, MJ, ADM	Tree	Mahagoni	Meliaceae	Rare
<i>Toona ciliata</i>	AS, MJ	Tree	Tun	Meliaceae	Rare
Temporary shade trees					
<i>Indigofera teysmannii</i>	RMG, DM, BTRISS, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM, BTRIMCS, BEFBTRIS, FLA	Shrubs	Indigofera	Fabaceae	Most common

Scientific Name	Tea garden name	Habits	Vernacular Name	Family	Status
<i>Cajanus cajan</i>	RMG, DM, ODL, BP, NDFC, HV, NPC, PACB, AS, MJ, ADM,	Shrubs	Arhor	Fabaceae	Common
<i>Tephrosia candida</i>	AS, MJ	Shrubs	White tephrosia	Fabaceae	Rare
<i>Gliricidia sepium</i>	RMG, DM, ODL, BP, NDFC, HV, NPC, AS, MJ, ADM	Shrubs	Gliricidia	Fabaceae	Less common
<i>Erythrina lithosperma</i>	RMG, ODL	Small tree	Dadap	Fabaceae	Rare
<i>Desmodium gyroides</i>	RMG, BP, NPC	Medium size tree	Tick clover	Fabaceae	Rare

RMG- Ramgarh; DM-Dantmara; BTRISS- BTRI substation, Fatikchari; ODL- Oodalia; BP- Bhojpur; NDFC- Naseha; HV- Haldavalley; NPC- Neapchun; PACB- Panchabati; AS- Aasia; MJ- Majan; ADM- Andhar manik; BTRIMCS- BTRI Main campus, Srimangal; BEFBTRIS- Bilashchara Experimental Farm, BTRI, Srimangal; FLA- Finlay tea estate, Srimangal.

Table 3. Morphological characteristics of shade tree species at investigated tea estates

Shade trees species	Morphological characteristics
Akashmoni ( <i>Acacia auriculiformis</i> )	A medium-sized, heavily branched, evergreen tree that grows between to 15–30 m tall. Bark greyish brown, more or less smooth in young trees. Adults phyllodes alternate, straight or falcate, acute or subacute, 10-15 cm long and 1.2- 2.5 cm wide, glabrous. Flowers in a spike up to 7.5 cm long, many in pairs in the upper leaf-axils, golden colored. Fruit a pod, initially straight, but maturity become very much irregularly twisted and coiled. Seed elliptical, 3-5 x 2-3 mm, almost encircled by a long orange funicle.
Acacia hybrid ( <i>A. hybrid</i> )	The tree is a medium-sized. The tree is capable of reaching a height of 8–10 m and a diameter at breast height of 7.5–9.0 cm. Phyllode is about 4–6 cm wide and 15–20 cm long, with four veins. The flowers are creamy to whitish and arranged in a straight, or slightly bent, 8–10 cm spike. The pod (fruit) is usually very curly and twists. A pod holds 5–9 seeds (Fig. 4d).
Chakua koroi ( <i>Albizia chinensis</i> )	The tree is a deciduous or evergreen. Bark dark brown or greenish-grey with many vertical and horizontal fissures. Leaves bipinnate, rachis 7-30 cm long with a large gland near the base and sometimes one or more between the pinnae. Its flowers are stalked heads that aggregate into a yellow panicle. Flowers are sessile, yellowish white in pedunculated, terminal or axillary heads. The fruits are indehiscent pods (Fig. 3 e).

Shade trees species	Morphological characteristics
Sirish ( <i>A. lebeck</i> )	The tree can attain a height of 30 m and a diameter of 1 m. Bark yellowish grey to dark brown, almost blackish. Leaves bipinnate rachis 7-15 cm long, usually with a large gland near the base or between the upper pinnae. Flowers greenish white, very fragrant in peduncled heads, solitary or in fascicles of 2-4 from the upper leaf axils. Fruit a pod, 20-30 x 2.5-5 cm, very compressed and flat. Seeds 4-12 (Fig. 3 a).
Potka Siris ( <i>A. lucidor</i> )	A medium sized to large unarmed, glabrous evergreen or semi-deciduous tree with spreading branches. This tree species grows up to 40 m. Leaves dark green, bi-pinnae. The leaves are (single) pinnate, in 1-3 pairs. The seed pods are yellow and glabrous. Seeds 6-8, round (Fig. 3 f).
Mangium ( <i>Acacia mangium</i> )	It is a fast-growing evergreen tree with a dense, spreading crown. The bole is usually straight, often fluted near the base, free of branches. phyllode large, thick coriaceous, up to 25 cm long and 5-10 cm broad, whitish or yellowish green, glabrous. Flowers creamy white in a loose spike up to 10 cm long. Fruits is a pod, blackish brown and woody.
Moluccan sau ( <i>Albizia moluccana</i> )	It is about 30m tall tree in nature with a massive trunk and an open crown. Leaves are twice pinnately compound with small leaflets. Flowers are creamy white small flowers are faintly fragrant. Fruits are pods that fall from the trees when mature (Fig. 4a).
Silkoroi ( <i>A. procera</i> )	A large deciduous tree with tall cylindrical boles and rather small crown. Bark yellow shish brown to greenish white. Leaves bipinnate, pinnae 3-5 pairs, 12-25 cm long. Flowers sessile, yellowish white, in fascicled heads of 2-5, sometimes solitary, arrange in terminal and axillary pinnacles. Fruits a pod, flat, flexible, 7-12 x 1.2-2.5 cm. Seeds 6-12 (Fig. 3c).
Gagan shiris ( <i>A. richardiana</i> )	A lofty hand some evergreen tree with horizontal dichotomous branching which from a beautiful crown. Bark yellowish gray. Leaves bipinnate, 6-9 cm long, pinnae 8-14, stipules small. Flowers small, greenish white, sessile in axillary corymbose, much shorter than leaves. Fruits a pod, dull brownish grey, firm, flat about 10 x 2 cm, shortly beaked (Fig. 4b).
Malakana Koroi ( <i>A. falcataria</i> )	Tall deciduous tree to 30 m tall, 1 m in diameter. Leaves alternate, bipinnate, 23-30 cm long, rufose pubescent, the pinnae 20-24, 5-10 cm long, each with 30-40 paired leaflets, sessile, obliquely oblong, 6-12 mm long, 3-5 mm broad, shortly acute. Flowers sessile, white, ca 10-12 mm long. Pods 10-13 cm long, 2 cm wide, flat, acute, green, turning brown, papyraceous, dehiscent. Seeds 15-20 per pod.

Shade trees species	Morphological characteristics
Rakta Kambal ( <i>Adenanthera pavonina</i> )	A medium sized, unarmed, deciduous tree. Bark brown or greyish brown, corky. Leaves bipinnate, rachis 20-25 cm long, red; pinnae 4-6 pairs, 7-8 cm long, opposite; leaflets alternate, 12-20, elliptic, obtuse, base unequal, dark green and glabrous above. Flowers in long paniced racemes, greenish yellow, fragrant, minute. Fruit a pod, 15-24 x 1.5 cm, flat, linear, curved and much twisted when opening. Seeds 8-15.
Kali Sirish ( <i>Albizia odoratissima</i> )	A large semi deciduous or semi evergreen tree with spreading crown. Bark thick, rough yellowish brown. Leaves bi-pinnate, rachis up to 30 cm long with 3-8 pairs of pinnae and has a large gland at the base and 1-2 between the upper pinnae. Flowers small, sessile, yellowish in heads of compact corymbs, arranged in large terminal panicles. Fruit a pod, 15-20 x 2.5 cm, dehiscent, thin, flexible, tomentose. Seed 8-12 (Fig. 3d).
Chatim ( <i>Alstonia scholaris</i> )	A medium sized evergreen trees with copious white latex, trunk often fluted; branches whorled and twigs with white streaks of lenticles which are containing. Bark grey and smooth. Leaves in whorls of 4-8, oblanceolate or elliptic-oblong. Flowers greenish white in compact umbellately branched pubescent paniced cymes. Fruits of follicles, 30-60 cm long, pendulous, in clusters, terete.
Chapalish ( <i>Artocarpus chaplasha</i> )	A large deciduous tree with tall cylindrical bole and milky latex. Bark thick, greyish brown or ashy-gray with large white patches deep verticle furrows peeling off in rounded flakes. Leaves are juvenile, elliptic ovate 15-20 cm long, hispid, base-subcordate or rounded. Flowers monoecious, densely crowded on globose receptacles. Fruits a globes, tuberculate, syncarp, pubescent (Fig. 4c).
Neem ( <i>Azadirachta indica</i> )	A medium sized to large glabrous evergreen to semi deciduous tree with large spreading crown. Bark greyish to blackish color. Leaves imparipinnate, 18-45 cm long, crowded towards the end of branchlets. Flowers short, white, honey-scented, pentamerous, in axillary panicles shorten than leaves. Fruit a drupe, 1-15 cm long, ovoid, pericarp smooth.
Rakta Kanchan ( <i>Bauhinia purpurea</i> )	A small to medium sized, evergreen to semi evergreen tree. Leaves deeply cleft, leaf cleft halfway or more down. Flowers very fragrant, deep rose or lilac. Fruits a pod, 15-30 cm long, flat. Seeds 12-15, flattened, roundish, dark brown, smooth.
Palash ( <i>Butea monosperma</i> )	A small to medium size tree. Bark rough, bluish-grey, exfoliating in irregular pieces; inner bark fibirous, pinkish, exuding reddish juice when injured. Leaves pinnately 3-foliolate, common petiole 12-25 cm long, geniculate, pubescent, stipules short, tomentose. Flowers large, reddish-orange, in rigid axillary racemes, 10-15 cm long and crowded towards the ends of leafless branchlets. Fruits a pod, 10-15 x 3-4 cm, rigid, pendulous and borne in large clusters in the leafless branches. Seed oval, compressed, dark brown.

Shade trees species	Morphological characteristics
Badar lathi ( <i>Cassia fistula</i> )	A small to medium sized deciduous tree, often with crooked bole. Young shoots and leaves silky. Bark greenish to ash grey. Leaves pinnate, 24-40 cm long; rachis slightly hairy; stipule minute, hairy, early falling; Flowers yellow, in pendulous, lax, axillary, 20-60 cm long racemes. Fruit a pod, 30-60 cm long and about 25 cm across, calendric, indehiscent, smooth, dark brown to black when ripe. Seeds 40-100, flattened, ovoid, about 1 cm across, embedded in a dark brown or black sweetish pulp.
Minjiri ( <i>Cassia siamea</i> )	A medium size to large, fast growing, evergreen or semi deciduous tree. Bark ash grey or blackish brown. Leaves pari-pinnate, 15-30 cm long. Flowers Sulphur colored, in stout corymbose racemes arranged in a large pyramidal terminal panicles, often 60 cm long. Fruit a pod, flat, ribbon like, thickened at sutures, 10-25 cm long; greenish brown velvety when mature. Seeds many, pentagonally elliptical, flat, blackish brown, glossy.
Chikrassi ( <i>Chukrasia tabularis</i> )	A tall, handsome (due to beautiful foliage), deciduous tree with tall cylindrical bole and spreading crown; branchlets lenticellate. Bark thick, rusty brown. Leaves pinnately compound, 30-50 cm long; softly pubescent when young, rachis terete. Flowers white in terminal, panicles, shorten than leaves, slightly hairy. Fruit a capsule, ellipsoidal, woody, brown or blackish outside, speckled with white lenticels. Seeds numerous, transversely and closely packed, elliptic, flat with dark brown wings.
Mouhita ( <i>Dalbergia assamica</i> )	<i>D. assamica</i> is a tree with a spreading crown; it can grow 7 - 10 metres tall. Branches horizontally spreading. Leaves 25-30 cm; stipules caducous, large, leaflike, ovate to ovate-lanceolate; leaflets 13-21; Flowers 6-8 mm. Legume broadly ligulate or oblong to strap-shaped, 5-9 × 1.2-1.8 (-2.5) cm, leathery, base attenuate, cuneate, apex acute, inconspicuously reticulate opposite 1 or 2(-4) seeds. Seeds reniform, compressed, ca. 6 × 2.5 mm.
Silky Dalbergia ( <i>Dalbergia sericea</i> )	Dalbergia is a medium to large-sized trees, 40-60 m tall; trunk up to 2 m. Leaves are imparipinnate, alternate, 14-22 cm long. Flowers are borne in silky-hairy, dense-flowered panicles, 3-4 cm long, in leaf axils. Pods are elliptic-oblong or oblong, 2.2-6 x 0.5-0.7 cm, acute-obtuse at tip, tapering towards base into a 3-4 mm long slender stalk, flat, glabrous, reticulately nerved especially on seed portion.
Shisu ( <i>Dalbergia sissoo</i> )	A medium sized to very large deciduous tree often with curved bole or crooked bole. Bark thick, grey or light brown, reticulately and longitudinally furrowed. Leaves imparipinnate, 10-20 cm long, rachis zigzag. Flowers yellowish white, in 2.5-4.0 cm long cymose racemes. Fruit a pod, strap-shaped, pale brown, 5.8 x 0.7-1.2 cm. Seeds flat, kidney shaped.

Shade trees species	Morphological characteristics
Gulmohar ( <i>Delonix regia</i> )	A medium sized handsome, deciduous or evergreen tree with spreading, dome shaped or flat-top crown. Leaves bi-pinnate, 15-40 cm long, pinnae 11-18 pairs. Flowers large, 7-10 cm across, scarlet. Fruit a sessile pod, 30-60 cm long, flat, linear, obliquely acuminate, woody when dry but dehiscent. Seeds many, oblong, slightly compressed, about 1.5 cm long; brown and white variegated, bony when dry.
Miringa ( <i>Derris robusta</i> )	A medium sized deciduous tree with tall cylindrical bole and dichotomous branching at the top. Bark greyish white. Leaves pinnately compound, 7-20 cm long. Flowers white in slender axillary pubescent racemes, 12-25 cm long; pedicles filiform, grey downy. Fruits a pod, 2.5-7 x 3 cm, linear, narrowed at both end. Seeds brown, orbicular, compressed (Fig. 3 b).
Madar ( <i>Erythrina variegata</i> )	A small to medium sized armed, deciduous tree. Bark smooth, yellowish or greenish grey, peeling off in thin. Leaves tri foliate, common petiole 15-20 cm long, unarmed, terete. Flowers showy, scarlet red, in 15-25 cm long racemes. Fruit a pod, 10-12 cm long, cylindrical with constrictions. Seeds kidney shaped, large, deep red.
Eucalyptus ( <i>Eucalyptus robusta</i> )	It is a medium to large tree with a dense crown and long, spreading branches when grown in open ground. The bark is rough and persistent to the small branches, thick, held in coarse, soft, spongy, elongated slabs with deep longitudinal furrows, grey or reddish grey-brown. The juvenile leaves are petiolate, ovate, up to 19 × 8 cm, strongly discoloured, green, opposite for several pairs, then alternate. The inflorescence is axillary, 9-15 flowered, the peduncles are strongly flattened, up to 3 cm in length. The fruit is a woody capsule, with prominent stalk, cylindrical, 1.8 × 1.1 cm
Red gum ( <i>Eucalyptus camaldulensis</i> )	A large boled, medium sized to tall evergreen tree. Bark smooth white, grey, buff, reddish patches. Leaves bluish green; juvenile alternate, petiolate, broad lanceolate. Flowers in axillary, 5-10 flowered umbels on a slender, terate, 0.5-2.5 cm long peduncles. Fruits a capsule, pedicellate, ovoid or tuncate globular, 0.3 – 0.6 x 0.4-1 cm disc broad. Seeds smooth yellow.
Silky oak ( <i>Gravillea robusta</i> )	A medium sized to tall, semi deciduous tree with pyramidal or conical crown. Bark dark grey to blackish, furrowed, lenticelate. Leaves alternate, pinnately compound, petiolate, graceful and fin like, pinnatifid, divided with 11-23 primary segments. Flowers bright orange or orange yellow glabrous, in one sided 7-10 cm long racemes and borne in dense cluster on short leafless branches. Fruit boat shaped 2 seeded follicles, compressed and oblique and tipped with a slender persistent style. Seed brown, flat with a shiny centre surrounded by a light brown papery wing.

Shade trees species	Morphological characteristics
Jarul ( <i>Lagerstroemia speciosa</i> )	A medium sized to large much branched deciduous tree. Bark greyish to brown, smooth, peeling off in thin irregular flakes, blaze whitish. Leaves opposite, elliptic or oblong-lanceolate, 10-20 cm long, acuminate, glabrous on both surface. Flowers large, showy, mauve purple, 5-7 cm across, in ample terminal panicles, ultimate branches mostly 1-3 flowered. Fruit a capsule, sub globes, smooth, seated on accrescent woody. Seeds pale brown, 3 angular, laterally expanded into an oblong wing.
Ipilipil ( <i>Leucaena leucocephala</i> )	A medium sized to tall, large, unarmed, deciduous tree. Bark light brownish grey, smooth. Leaves bipinnate, 7-18 cm long; pinnae 8-16 cm long; leaflets 20-30, about 12 cm long, glaucous, linear, acute, finely hairy. Flowers dirty white or yellowish in auxillary or sub terminal, dense globose heads. Fruit a pod, produced very copiously, straight, 7-15 x 1.0-1.4 cm flat, glabrous, shiny brown when mature. Seeds 15-20, lenticular, shiny.
Aam ( <i>Mangifera indica</i> L.)	A medium-sized to large evergreen tree with a large dense crown and rather short buttressed trunk. Bark brown or ashy-grey, vertically cracked, exfoliating in scales. Leaves crowded at the end of branchlets, oblong-lanceolate, 15-20 cm long, bluntly acuminate, coriaceous, glossy, green above, paler beneath, entire with a undulated margin. Flowers in erect pubescent panicle. Fruit a drupe, ovoid or globose, laterally compressed.
Ghora neem ( <i>Melia azedarachta</i> )	A medium-sized to large glabrous evergreen to semi-deciduous trees with large spreading crown. Bark greyish brown to blackish with longitudinal and oblique furrows and many scattered tubercles, blaze greenish pink with characteristic smell. Leaves imparipinnate, 18-45 cm long, crowded towards the end of branchlets. Flowers short, white, honey-scented, pentamerous, in auxillary panicles shorter than leaves. Fruit a drupe, 1-1.5 cm long, ovoid, pericarp smooth, greenish yellow when ripe enclosing white visid pulp and a smooth whitish stony endocarp almost 1-seeded.
Amlaki ( <i>Phyllanthus emblica</i> )	A small to medium sized deciduous tree. Bark of young tree grey-smooth, in older trees exfoliating in irregular rounded pieces and in long strips. Leaves not compound, although individual small leaves look very much like the leaflets of pinnately compound leaf, light green, bluntish, 0.6-1.3 cm long, glabrous, paler beneath with appressed pubescence, closely arranged in two rows on opposite side of twigs. Flowers small, greenish yellow, monoecious, in axillary clusters, usually crowded towards the lower naked portion of branchlets, male flowers on short, slender pedicles; female flowers sub-sessile. Fruit a drupe, globose, about 2.5 cm across, obscurely 6-lobed, 3 celled. Seeds dark brown, trigonous.

Shade trees species	Morphological characteristics
Shirish/Rain tree ( <i>Samanea saman</i> )	A very large, deciduous to semi-deciduous tree with spreading crown and large bole. Bark rough, blackish-grey, exfoliated in old trees. Leaves bipinnate, pinnae 3-7 pairs, largest uppermost, shorter downwards with a gland between each pair of pinnae. Flowers in dense rose colored heads on pubescent peduncles, 1-3 together from the upper axils, and 5-8 cm long. Fruit a pod, 12-20 x 1.5 cm. indehiscent, suture thick, ripe pod blackish brown, smooth with septa between seeds and containing sweet sticky pulp.
Mahagoni ( <i>Swietenia macrophylla</i> )	A tall evergreen to semi deciduous tree. Bark greyish brown, rough and flakes off in small patches. Leaves paripinnate, up to 60 cm long; leaflets 6-16, ovate-lanceolate with oblique base, up to 20 cm long with a very short panicles. Fruit a woody capsule, erect, brown. Seeds deep brown, winged at one end only.
Tun ( <i>Toona ciliata</i> )	A medium to large deciduous tree. Bark greyish brown, exfoliating in irregular flakes when old. Leaves paripinnate, 30-60 cm long, somewhat crowded at the ends of branchlets; common petiole, glabrous, terete. Flowers white, sweet scented, in terminal pyramidal cymose panicle. Fruit a capsule, dark brown, smooth outside with white lenticles. Seed brown with lighter brownish wing at the ends.
Indigofera ( <i>Indigofera teysmannii</i> )	Erect shrub or small tree, up to 12 m tall. Branches subsericeous with minute brown or white, biramous, appressed hairs. Leaves imparipinnate; stipules linear, up to 8 mm long; leaflets 11-23, elliptical to ovate, 2-8 cm × 1-3 cm. Inflorescence an axillary, many-flowered raceme, 8-10 cm long; flowers about 0.5 cm long; calyx brown-sericeous, 2 mm long; corolla whitish, pink or dark purple; standard ovate, up to 5 mm × 4 mm, dorsally sericeous. Pod subcylindrical, 2.5-4.5 cm × 0.5 cm, glabrous, beaked, about 16-seeded. <i>I. zollingeriana</i> occurs mainly on coral strands and sandy beaches, up to 850 m altitude (Fig. 4 e).
Arhor( <i>Cajanus cajan</i> )	The plant is an erect, short-lived perennial leguminous shrub that usually grows to a height of about 1-2 m, but can reach up to 2-5 m high. It quickly develops a deep (2 m depth) poisonous taproot. The stems are woody at the base, angular and branching. The leaves are alternate and trifoliate. The leaflets are oblong and lanceolate, 5-10 cm long x 2-4 cm wide. Leaves and stems are pubescent. The flowers (5 to 10) are grouped in racemes at the apices or axils of the branches. The flowers are papilionaceous and generally yellow in colour. They can also be striated with purple streaks. The corolla is about 2-2.5 cm. The fruit is a flat, straight and pubescent pod, 5-9 cm long x 12-13 mm wide. It contains 2-9 seeds that are brown, red or black in colour, small and sometimes hard-coated.

Shade trees species	Morphological characteristics
White tephrosia( <i>Tephrosia candida</i> )	<i>Tephrosia candida</i> is a deciduous Shrub growing to 3 m (9ft) by 3 m (9ft) at a medium rate. Leaves alternate, 17-25-foliolate; rachis 15-25 cm, including petiole; leaflets oblong, 3-6 × 0.6-1.4 cm, abaxially densely sericeous, adaxially glabrous, secondary veins 30-50 on each side of midvein. Flowers ca. 2 cm. Calyx ca. 5 × 5 mm; teeth equal, ca. 1 mm, apex rounded. Petals white, rarely yellow or pale pink; standard densely sericeous. Ovary tomentose, with numerous ovules. Fruit linear, 8-10 cm × 7.5-8.5 mm, straight, brown tomentose with a mixture of long and short trichomes, apex truncate and with a straight ca. 1 cm beak; seeds 10-15 per legume, olive-green with dark patches, ellipsoid, ca. 5 × 3.5 mm, smooth.
Gliricidia ( <i>Gliricidia sepium</i> )	A small to medium-sized, deciduous tree with a short trunk and long slender branches at first tend to rise almost vertically from the base. Bark soft, grey or ashy with longitudinal cracks. Bark of branches brownish-grey speckled with white spots like lenticels. Leaves imparipinnate, to 30 cm long. Flowers mauve pinkish; produced in great clustered racemes on leafless branches. Fruit a pod, to 20 x 2 cm, flat without wing and dehiscent seeds up to 10 or more (Fig. 4 f).
Dadap ( <i>Erythrina lithosperma</i> )	The plant is deciduous growing to 20 m (65ft) by 20 m (65ft) at a fast rate. The branches and the branchlets stout and armed with short, few to many sharp prickles. Leaflets are broadly ovate and 8 to 18 centimeters long, with pointed tip and broad base. Racemes are terminal, hairy, dense, and up to 2.5 centimeters long. Flowers are papilionaceous, large and numerous. Calyx is about 4 centimeters long and minutely 5-toothed at the tip, the mouth being very oblique. Petals are bright red and shorter than the calyx, the standard being 7 to 9 centimeters long and the wings and keels subequal. Stamens are 10, upper filaments free nearly to the base or more or less connate with others. Ovary many-ovuled, style incurved. Racemes terminal, hairy, dense and up to 2.5 cm long. Fruits are pods, 10 to 25 centimeters long, 1.5 to 2 centimeters in diameter, and distinctly constricted between the seeds.
Tick clover ( <i>Desmodium gyroides</i> )	Leaves are compound. Leaflets are hairy, more densely hairy along major veins on the underside, to 3 inches long and 1 inch wide with a rounded or slightly tapering base and blunt point at the tip. Flowers are pea-shaped, about ½ inch long, pink to purple with 2 yellow spots near the base of the broad upper lobe. The stamens and pistil form a curving tube that protrudes from the center, between the 2 lateral petals. The calyx behind the flower and the short flower stalk are reddish green and hairy. Fruit is a flat pod 1 to 2½ inches long with 3 to 5 sections, the sections convex on the upper edge and well rounded on the lower, and each containing a single seed. Seeds are kidney-shaped, about 4 mm long, and mature to brown. The pod is densely covered in tiny hooked hairs that latch onto anything that passes by.

Among the collected species, Fabaceae shows the highest percentage with 31 species comprising 19 genera (61.29%) followed by 5 species of Meliaceae comprising 5 genera (16.12%) and 2 species of Myrtaceae comprising 1 genus (3.22%) (Fig. 1 and 2). Apocynaceae, Moraceae, Protaceae, Lythraceae, Anacardiaceae, and Phyllanthaceae each family show the one species of one genera (Fig. 1 and 2).

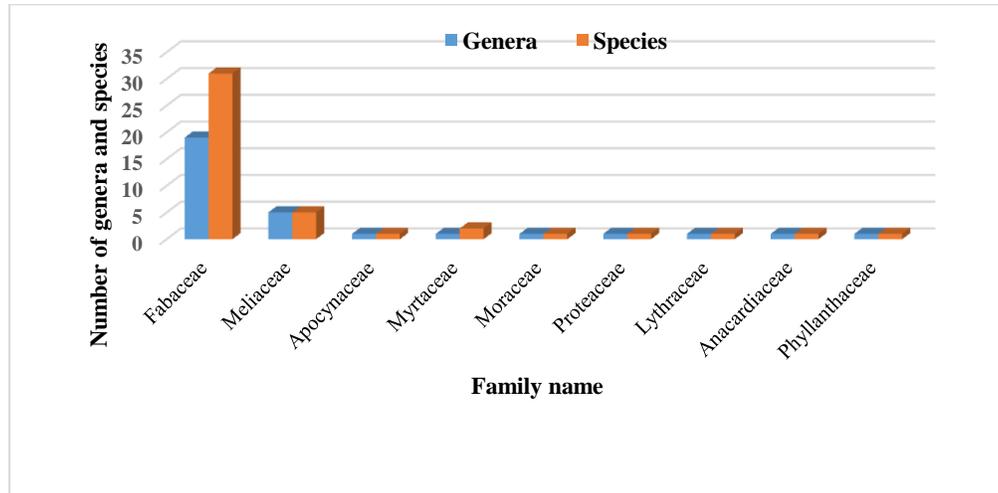


Figure 1. Family wise showing the number of genera and species of shade trees at the surveyed tea garden.

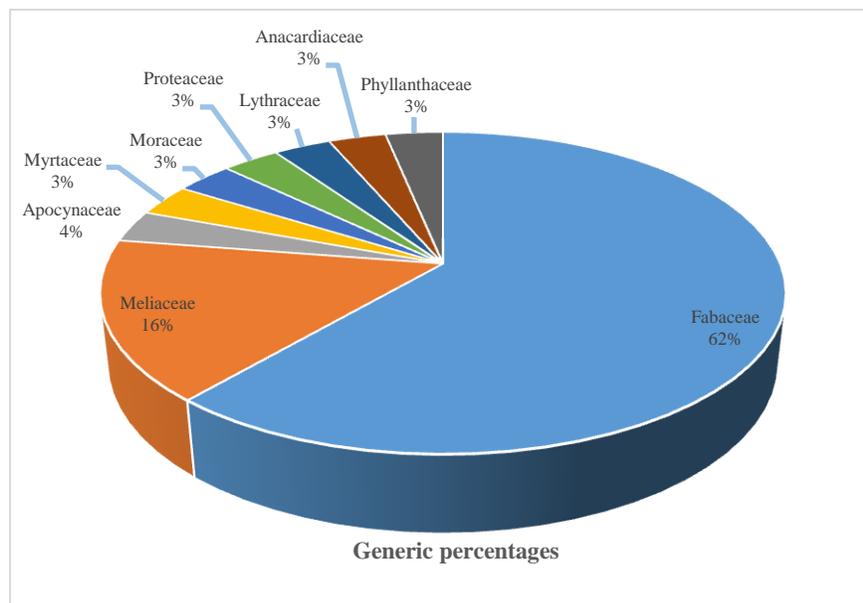


Figure 2. Family wise generic percentage of available shade trees of the study areas.

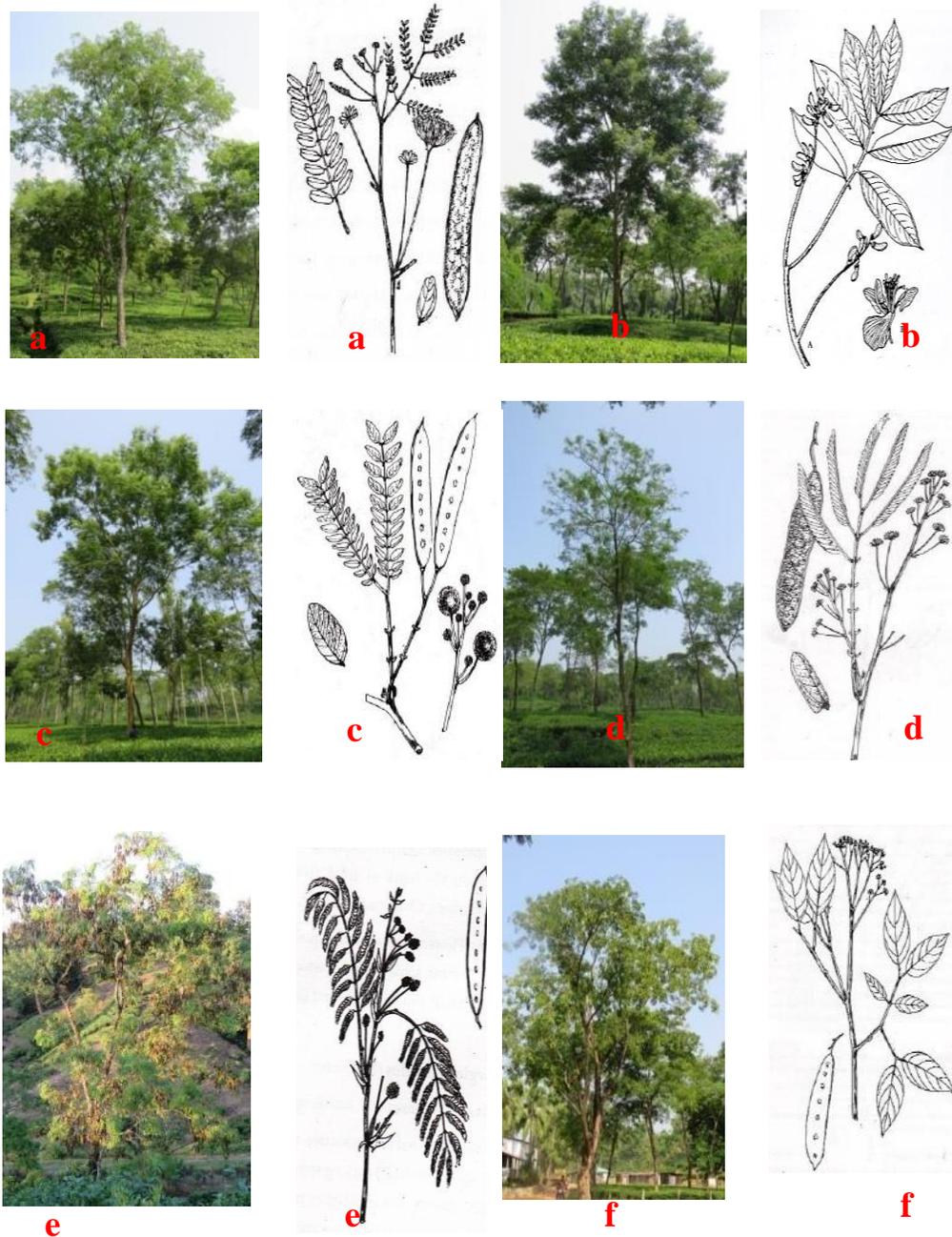


Figure 3. Morphological and leaf characteristics of different types of shade trees at investigated tea gardens in Bangladesh. a, b, c, d, e and f indicates *Albizia lebbeck*, *Derris robusta*, *A. procera*, *A. odoratissima*, *A. chinensis* and *A. lucidor*.

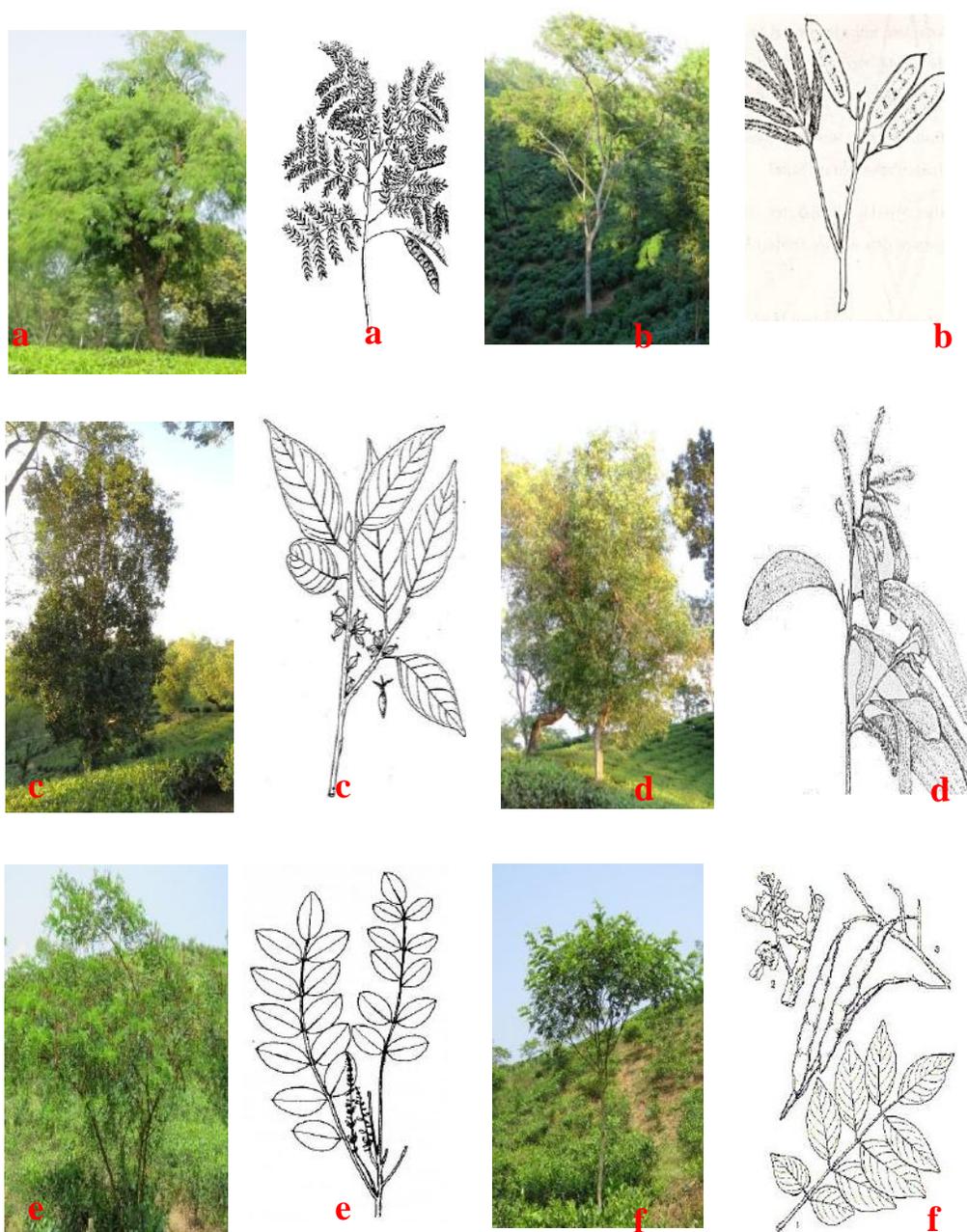


Figure 4. Morphological and leaf characteristics of different types of shade trees at investigated tea gardens in Bangladesh. a, b, c, d, e and f indicates *A. moluccana*, *A. richardiana*, *Artocarpus chaplasha*, *A. hybrid*, *Indigofera teysmannii* and *Gliricidia sepium*.

Apocynaceae, Moraceae, Protaceae, Lythraceae, Anacardiaceae, and Phyllanthaceae shows 3.22% generic components of the entire tree flora of the tea plantations areas (Fig.2). The popular permanent shade trees among the tea gardeners area. *odoratissima*, *A. chinensis*, *A. lebbeck*, *A. lucidior*, *A. procera*, and *D. robusta* (Fig. 3 and 4). *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. This finding shows that Fabaceae is the dominant family in all investigated tea garden of Bangladesh. These types 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). In a similar study, Chowdhury et al. (2015) were enlisted 45 species of angiosperm representing 34 genera of 15 families of shade trees in the tea garden of West Bengal, India. In their assessment, the Leguminosae family showed the highest number of shade trees comprising 13 genera and 22 species and the most dominant shade tree species were *Albizia odoratissima*, *Albizia chinensis*, *Albizia lebbeck*, *Albizia procera*, *Erythrina indica*, *Dalbergia sissoo*, and *Melia azedarach*. Likewise, Pangging and Mandal (2017) investigated shade tree species and socioeconomic status around the Banderdewa forest range, Arunachal Pradesh, India. The common shade trees found in tea estate around the Banderdewa forest range, Arunachal Pradesh was *Melia azedarach* L., *Albizia procera* (Roxb.) Benth. and *Albizia lebbeck* (L.) Benth. Fabaceae was the most dominant family. 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.

### CONCLUSION

A total of 44 species of Angiosperm representing 31 genera of 9 families was enlisted at fifteen tea estates of Bangladesh. Among the estates, Fabaceae family shows the highest number of shade trees comprising 19 genera and 31 species. Further investigations, however, are required to find out the appropriate shade tree species on the growth and yield of tea plants and improvement of quality of made tea.

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