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Natural Rubber Cultivation in Bangladesh: A Review

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Abstract

The rubber tree (*Hevea brasiliensis*) is considered one of the most important industrial plants. With a view of industrial essence, natural rubber production should be planned carefully because it is sustainable and renewable natural resources which cultivation creates positive impact to economic, social and environmental perspectives. Worldwide, the use of rubber products is huge and increasing its demand day by day. A huge amount of products have been made as their basic ingredient from rubber. The widely used items are car tires, shoes, rubber bottles, pencil erasers, resin, gum, children toys, industrial products, medical products etc. Research has shown that the demand for natural rubber has been increased by 3% every year. If this increasing demand is not addressed properly, it could be lose the financial returns as well as it will create more pressure on forests, biodiversity and agricultural land. Bangladesh has been started commercial cultivation of rubber since 1961. At present, about 1,03,004 acres of land is under rubber plantation in Bangladesh and annual production is about 20,000 metric tons against 30,000 metric tons country's total demand of natural rubber (NR). A major concern of Bangladesh rubber is its low yield production as well as the volatility of rubber price. Bangladesh is using traditional conditions of rubber plantations and our maximum production is about 506 kg/ha/year only. In order to ensure sustainability of rubber industry, it is needed to increase

the yield production. Therefore, the development and expansion of rubber, systematic research is essential to improve the present yield productivity. So, it is advised to manage good agricultural practices such as planting with certified high yield clones, reduce wastages through proper latex harvesting technology and ensure high quality of their product to meet the consumer demands. It is also important to address the current phase of industrial revolution. So, research and development must be intensified with emphasis on component of the industrial revolution especially in the downstream activities to increase consumption through manufacturing of rubber based products. In addition, the utilization of rubber wood in furniture and the building industry has been given extra benefits and also demands its priority.

সারসংক্ষেপ

রাবার গাছ (*Hevea brasiliensis*) প্রাকৃতিক রাবার উৎপাদনের জন্য একটি গুরুত্বপূর্ণ উদ্ভিদ। প্রাকৃতিক রাবার, একটি টেকসই এবং পুনর্নবীকরণযোগ্য প্রাকৃতিক সম্পদ যার চাষ অর্থনৈতিক, সামাজিক এবং পরিবেশগত দৃষ্টিকোণ থেকে ইতিবাচক ফল বহন করে। ক্রমবর্ধমান বিশ্ব জনসংখ্যা এবং গতিশীলতা বৃদ্ধিতে টায়ারের চাহিদা প্রাকৃতিক রাবারের সম্প্রসারণের উপর প্রভাব ফেলছে। চাহিদার এই বৃদ্ধি যদি যথাযথভাবে মোকাবেলা করা না হয় তবে এটি অনিবার্যভাবে বন, জীববৈচিত্র্য এবং কৃষি জমির উপর আরও চাপ সৃষ্টি করবে। বাংলাদেশ ১৯৬১ সাল থেকে বাণিজ্যিকভাবে রাবার চাষ শুরু করে। বর্তমানে বাংলাদেশে প্রায় ১,০৩,০০৪ একর জমি রাবার চাষের অধীনে রয়েছে এবং দেশের মোট প্রাকৃতিক রাবারের চাহিদা ৩০,০০০ মেট্রিকটন (NR) এর বিপরীতে

বার্ষিক উৎপাদন প্রায় ২০,০০০ মেট্রিকটন। বাংলাদেশ রাবারের একটি প্রধান উৎসের বিষয় হল এর কম ফলন এবং সেই সাথে রাবারের দামের অস্থিরতা। বাংলাদেশে রাবার চাষে প্রচলিত বা গতানুগতিক পদ্ধতি ব্যবহার করার ফলে রাবারের সর্বোচ্চ উৎপাদন বছরে মাত্র ৫০৬ কেজি/হেক্টর। রাবার শিল্পকে টেকসই করার জন্য উৎপাদন বৃদ্ধি করা প্রয়োজন। অতএব, বর্তমান ফলন এবং উৎপাদনশীলতা বৃদ্ধির জন্য রাবারের উন্নয়ন, সম্প্রসারণ এবং পদ্ধতিগত গবেষণা অপরিহার্য। ফলস্বরূপ উচ্চ ফলনশীল ক্রোন রোপণ, ল্যাটেক্স সংগ্রহ প্রযুক্তির সঠিক ব্যবহারের মাধ্যমে অপচয় কমানো এবং ভোক্তাদের চাহিদা মেটাতে পণ্যের উচ্চ গুণমান নিশ্চিত করার মতো উন্নত কৃষি ব্যবস্থাপনাজলি অনুশীলন ও পরিচালনা করা প্রয়োজন। পাশা-পাশি এখন যে শিল্প বিশ্ব খটছে সেটিকেও শুরুতে দেওয়া জরুরী। তাই, রাবারভিত্তিক পণ্য তৈরির মাধ্যমে ব্যবহার বাড়ানোর জন্য বিশেষত নিম্নধারার কার্বকলাপের উপর জোর দিয়ে গবেষণা ও উন্নয়নকে সম্প্রসারণ করতে হবে। এছাড়া উচ্চমূল্যে আসবাবপত্র এবং নির্মাণশিল্পে রাবার কাঠের ব্যবহারকে সর্বোচ্চ অগ্রাধিকার দিতে হবে।

Keywords: Bangladesh, Cultivation, Clones, Environment, Impact, Natural rubber, Prospect.

History and domestication of natural rubber

Hevea brasiliensis is one of the recently domesticated crops in the world. Before the commercial cultivation of *H. brasiliensis* started, the major sources of natural rubber were *Ficus elastica* and *Castilla elastica* which grew wild in the forests of Central and South America, India, Africa, Madagascar etc. In India, the major contribution was from *F. elastica* (Assam rubber). The rubber was promoted as a plantation agriculture crop in South East Asia to feed raw material for the rubber based industries located in Europe in late 19th Century (Thomas and Panikkar 2000). Attempts to domesticate *H. brasiliensis* in the South East Asia were started with the arrival of 2000 seeds, collected from the centre of origin at Kew gardens, Kew, during June 1873. The initial attempt to propagate these plants through cutting failed as the climate was unfavorable. Later a shipment of 1919 seedlings packed in portable greenhouses was sent to Ceylon of which 90% survived; of these 18 seedlings were sent to the Botanic

Gardens at Bogor, Indonesia and only two survived. Fifty seedlings were sent to Singapore and only one survived (Dean 1987). During 1876, seedlings from Kew Gardens were received in Sri Lanka, Java, Singapore and subsequently Malaya and another 22 plants were sent to Singapore in 1877 (Wycherley 1959). During the early days of rubber cultivation, Sri Lanka became the centre of activity with the Heneratgoda Botanic Gardens in Colombo being the major supplier of rubber seeds and seedlings for domestic distribution and for export.

Economic importance

Hevea brasiliensis is the major source of commercial natural rubber. Chemically, natural rubber is cis-1,4-polyisoprene, having molecular weight ranging from 200,000 to 8000,000 and with viscoelastic properties. Natural rubber produced in the milky cytoplasm (latex) of specialized cells called laticifers, is one of the most important biological macromolecule, used as industrial raw material for the manufacture of about 50,000 products. Although natural rubber has been found in the latex of over 2,000 plant species belonging to 311 genera of 79 families, *H. brasiliensis* remains the only cultivated species as commercial source of natural rubber because of its abundance in latex, high quality and convenience of harvesting. The higher strength, low heat buildup and better resistance to wear and flex cracking make natural rubber a suitable raw material for manufacture of automobile tyres. A major quantity of natural rubber produced is consumed by the automobile tyre industry. Natural rubber is a good insulator and can be easily manipulated. Being water resistant, it finds use in the manufacture of water proofing materials. In addition to automobile tyres, more than 50,000 rubber based products such

as hand gloves, toys, balloons, hoses, footwear, etc. are manufactured from rubber. It is also useful in soil stabilization, in vibration absorption, road surfacing etc. There is hardly any segment of life, which does not make use of rubber-based material. The economic production of latex is for about 30-35 years, after which the old rubber trees are felled and become a source of timber. Rubber wood has high environmental acceptability both in domestic and international markets. Processed rubber wood has a wide range of applications like furniture, panelling, table top, flooring, household articles etc. The estimated total availability of rubber wood was 2.30 million m³ during 2012- 2013, of which, stem wood accounted for 1.38 million m³. Rubber tree is also a source of nectar. It is found at the extra floral nectary glands at the end of the petiole where the leaflets join. Honey can be collected by maintaining hives in the rubber plantations. However, nectar is produced by the rubber plants only for a short period in a year, when refoliation occurs. Rubber seed is a minor source of non-edible oil in India. Seed production is not stable every year. An estimated 45,000 tons of seeds are produced in a year. But only a fraction of the seeds are collected and processed. About 10% of the collected seeds are used for raising stock seedlings.

Establishment of rubber plantations in Bangladesh

Bangladesh is a country of the north-eastern part of the South Asia. It lies between 20°34' to 26°38' N latitudes and 88°01' to 92°41' E longitudes (Rashid 2001). The country consists mostly of flood plains (80%) with some hilly areas (12%), with a sub-tropical monsoon climate (Islam 2003). It shares boundary on the west, the north and the

north-east side with India, in the Southeast with Myanmar, and the Bay of Bengal in the South. Bangladesh has an agrarian economy with 21.77% of GDP coming from the agriculture, forestry and fisheries sectors (BBS 2004). Major agricultural products are rice, jute, wheat, potato, pulses, tobacco, tea and sugarcane. The country is the largest exporter of jute and jute products in the world. Readymade garments occupy the topmost position among the exportable items. Tea frozen shrimps, fish, leather goods, flowers and vegetables, ceramic-ware and handicrafts are also major export commodities. Bangladesh has undergone a major shift in its economic philosophy and management in recent years. The government is working towards upgrading the living standard of the people by meeting their basic needs and is determined to ensure health for all within the shortest possible time. Considerable progress has been achieved in Bangladesh in the fields of health and family welfare. Primary healthcare has been expanded throughout the country. Infant mortality rates have come down dramatically. The annual GDP (Gross Domestic Product) growth rate of the country is 7.11 and per capita GDP is 1093.05 USD. ILO (2015) and UNDP (2015) observed that, poverty alleviation strategies and sustainable development plans especially in rural communities have become major challenges for many governments worldwide (Sythud *et al.* 2015). Hence for many countries especially in Southeast Asia, natural rubber (*H. brasiliensis*) cultivation in extensive plantations has been advocated as a means to alleviate poverty and foster rural development (Dwyer 2007; AFP 2009). AFP (2009) and Ziegler *et al.* (2009) described that, in Laos for instance; areas planted with rubber will skyrocket from approximately 27,000 hectare

(ha.) in 2007 to 195,000 ha in 2010, as a result of foreign direct investments (FDIs) from China and Vietnam. Additionally, Dwyer (2007) and AFP (2009) predicted that, the area of land dedicated to rubber and other farming systems could more than double or triple by 2050, replacing lands currently occupied by evergreen broadleaf trees and secondary vegetation growing in areas subjected to slash-and-burn farming.

Over the last decade, rubber cultivation has expanded rapidly throughout South-East Asia in order to meet demand for natural rubber, especially in expanding economies such as China and India (Ziegler *et al.* 2009; Sturgeon 2010). Asia continues to dominate the world supply of natural rubber, with 93% of total world production in 2013 (IHS 2014; Vongkhamheng *et al.* 2016). The three largest countries producing natural rubber in 2013 were Thailand, Indonesia and Vietnam. Thailand has been the world's largest producer of natural rubber since 1993, accounting for 34% of world production in 2013, with Indonesia accounting for 26% while Vietnam is the third-largest producer (IHS 2014). Malaysia, which accounted for 32% of world production in 1988 has shifted its emphasis to other crops and non-agricultural investment and produced only 6.9% of the world total by 2013 (IHS 2014; Vongkhamheng *et al.* 2016). Natural rubber plays an important role in economic growth and sustainable development of a country. The tree also serves as a source of timber, fuel and shade-tree on many farms. It is thus important in farm management and poverty alleviation for rural communities. Bangladesh, being a land of agriculture, could prosper in the plantation of rubber, since the climate provides a very appropriate base for producing natural rubber in the country. The British planters first introduced rubber in

Bangladesh in the early twentieth century. But commercial plantation was started in 1961 by the government in Chittagong and Sylhet hilly regions. Later on, plantations were expanded in Chittagong Hill Tracts and Madhupur by the government and public enterprises. The British and some other private companies also planted rubber in the fallow lands of tea estates. At present about 1,03,004 acres of land is under rubber plantation in Bangladesh, and annual production is about 20,000 metric tons against 30,000 metric tons country's total demand of natural rubber (NR). However, though the government has been encouraging plantations in the hilly areas since 1980 due to this favorable condition, so far, only about 45,000 acres of land have been allotted to the government sector and 32,500 acres to private owners for rubber plantations. Considering high productivity, storage, transportation and marketing facilities, the government encouraged its plantation with financial support; land allotment and foreign technical assistance. Public and private enterprises established plantations in different hilly regions and commercial exploitation started successfully within seventh years of plantation. The growth and latex flow is also very encouraging. Since maintenance and processing cost is relatively very low and a good price of rubber prevailed till 1996, it was considered an important crop with high potentiality.

In this study, it has been described the bright prospect of natural rubber cultivation in Bangladesh to improve the socio-economy of small holders while assessing its environmental impacts. Here considered some challenges and their probable solutions. It is observed that, with adequate and effective management and proper sustainable planning, rubber cultivation would be a way of breaking the poverty nexus and ecological impacts that

arise. The especial biophysical characteristics of rubber tree and its natural potentials were evaluated. After that the social and economic advantages/potentials of rubber cultivation were also reviewed. It was explored the probable socioeconomic and ecological impacts of rubber cultivation which is arise from the cultivation and establishment practices of natural rubber plantations.

Potential and prospect of natural rubber cultivation in Bangladesh

The prime source of commercial rubber, *Hevea brasiliensis* (Muell. Arg.) is a deciduous perennial tree of the family Euphorbiaceae. The constituent of natural rubber derived from *Hevea* is *cis*-1,4-polyisoprene (C₅H₈)_n, where n may range from 150 to 2,000,000 (Pushparajah 2001). In *H. brasiliensis*, rubber biosynthesis takes place on the surface of rubber particles suspended in the latex (the cytoplasm of laticifers). The laticifers are specialized vessels that are located adjacent to the phloem of the rubber tree. When severed during tapping, the high turgor pressure inside the laticifers expels latex containing 30-50% (w/w) *cis*-1,4-polyisoprene. The economic life period of rubber trees in plantations is around 32 years up to 7 years of immature phase and about 25 years of productive phase. The scientific advancement through the discovery of vulcanization by Good year in 1839 adjudged rubber as a prime industrial commodity which had been unknown to mankind for over 450 years, since Christopher Columbus gave the first description of rubber in the 15th century (Priyadarshan and Clément-Demange 2004). *Hevea* trees descended from seedlings transplanted from Brazil to South East Asia that have undergone several cycles of breeding are now the prime source of the modern world's natural rubber. Natural rubber

is produced in South East Asia (92%), Africa (6%), and Latin America (2%) (Venkatachalam *et al.* 2013). The main natural rubber producing countries are by descending order, Vietnam, Thailand (3.09 million tons in 2008), Indonesia, Malaysia, India, China and also Côte d'Ivoire, Liberia, Sri Lanka, Brazil, Philippines, Cameroon, Nigeria, Cambodia, Guatemala, Myanmar, Ghana, the Democratic Republic of Congo, Gabon, and Papua New Guinea, (Venkatachalam *et al.* 2013). First attempt to grow rubber in Bangladesh was made in 1952 when Forest Department planted some thousands of seed and budded stamps in Chittagong imported from Malaysia and Sri Lanka.

In 1959, FAO expert investigated the possibilities of producing rubber in large scale and recommended to cultivate rubber extensively. In the year 1959, Bangladesh Forest Industries Development Corporation (the then EPIDC) was established. In 1962 Forest Department handed over Rubber Planting Activities to BFIDC. Under the agreement signed between the Govt. of the then East Pakistan (now Bangladesh) and EPIDC (now BFIDC) on 13-04-1963 and BFIDC was mandated to get forest land on lease to raise Rubber Garden (BFIDC 2016). In Greater Chattogram, CHTs', Sylhet and Mymensingh areas, rubber plantations play a vital role in creating natural resources for economic development. Under BFIDC, from 45,000 acres of rubber plants in 16 rubber plantations produce rubber. About 32,500 acres have been distributed among small private entrepreneurs to organize rubber plantation (BFIDC 2016). The rubber cultivation areas are shown in Table 1. The rubber produced in Bangladesh can be used in making tires and tubes, sandals and shoes, hose pipes, washers etc. These products

Table 1. Total rubber cultivation in public and private sectors of Bangladesh.

Sl. No	Name	Location of rubber plantation	Area (acres)
1	State-owned companies	Chattogram, CHTs, Cox'sBazar, Sylhet, Mymensingh, Tangail	36,654
2	Private entrepreneurs	Chattogram, CHTs, Cox'sBazar	32,550
3	Chattogram Hill Tracts	Bandarban, Rangamati and Khagrachari	13,000
4	Tea state and smallholder farmers	Chattogram, Sylhet	20,800
Total =			1,03,004

of high quality can replace imported rubber products. The entrepreneurs therefore must be encouraged by bank loans, and proper training of the workers for production of rubber and processing. The Ministry of Environment, Forest and Climate Change of Bangladesh can inspire the entrepreneurs with proper government help to make rubber a leading product in country and also for exports. The rubber production of Bangladesh in government sector has been shown in Table 2. It should be mentioned here that, natural rubber is the raw material for tyres and tubes of automobiles, bi-cycle and rickshaw, footwear, belts and hoses, latex foam, cables and wires, battery boxes, gloves, coats and aprons, air bags, life jackets and life buoys, adhesives, balloons and toys etc. and it is also essential for processing synthetic rubber. Therefore, the future of rubber is very bright in terms of rubber industry. Besides, rubber plants have many other uses: its timber is a good source of high valued furniture. In this respect, Bangladesh Forest Research Institute

(BFRI) developed some noble technologies for treatment of rubber wood to maximize its uses in furniture industries. The technologies have been transferred among the government and private stakeholders. Bangladesh Forest Industry Development Corporation (BFIDC) has been using this technology for rubber wood treatment. Rubber seed kernel is used for extraction of oil, which is abundantly used as lubricant, and for soap and paint industries and the cake as a good fertilizes and poultry feed. Bangladesh Forest Research Institute also developed the technologies for extraction of oil from rubber seed as well as it can be used as a good food for poultry farm. Mature rubber plantations are the potential source of honey. Honeybees collect large quantities of nectar from extra floral nectarines at the swollen tip of the petiole. Affluent or latex processing wastes and residues can be used as fertilizer and making biogas for power. Every year fallen leaves add 6 to 7 tons per hectare of biomass (Rahman 2006). Moreover, rubber

Table 2. Natural rubber production in Bangladesh.

Year	Total/MT*	Sell /MT*	Amount /BDT*
20 14 -20 15	4,837	4,518.44	48,51,69,266.00
20 15 -20 16	6,752	4,977.49	68,87,62,209.00
20 16 -20 17	6,940	5,967.85	78,37,15,147.00
20 17 -20 18	5,992	5,649.36	67,73,95,767.00

*MT=Metric tons, *BDT=Bangladesh currency in taka

Source: Bangladesh Forest Industries Development Corporation (BFIDC)

roots make a very good net spreading in the top soil up to a depth 1 to 1.5 m and increase the porosity of the soil. Rubber is a very useful crop preferred as a fast growing multi-purpose species for quick afforestation. Rubber plant is capable of storing carbon in a higher rate in comparison to many other tree species. In Bangladesh, the rubber plantations can be a remarkable source of carbon trading. Overall, rubber planting generates the highest economic and social benefits in terms of profitability, employment, foreign exchange savings, land use and a positive environmental impact. Properly managed plantations are self-sustainable ecosystems and could maintain a fair degree of biodiversity. Rubber plantations do support different plant species as well.

1. Socio-economic impact of the sector

Rubber cultivation can generate significant increases of household income and reduce the poverty of local communities. Three types of rubber producers in Bangladesh such as state-owned companies, private entrepreneurs and smallholder farmers. Smallholders comprise 99.19% of the growers as the total number 5204 (Table 3). Smallholders comprise between 20 and 40% in Laos, Cambodia and Vietnam, 50% in China and about 90% in Myanmar and Thailand (Fox and Castella 2013). All small holders are playing active role in the value chain of rubber production.

According to BFIDC, in 2012, Bangladesh produced 24,000 tons of rubber, out of which 60% (worth BDT 334 core) was consumed by the local market and the rest 9600 tons were exported for a sum of BDT 220 core. According to the Export Promotion Bureau (EPB), from July 2013 to January 2014, the rubber export revenue was USD 10.06 million, whereas the expected figures were USD 5.71 million.

2. Environmental impact

The rubber plantation can be considered as a significant contributors towards reducing global warming through carbon sequestration (Cheng *et al.* 2007). Rubber plantations establishment could result in a significant reduction in carbon biomass, desiccate the region's water systems. Properly managed rubber plantations that are supplied with sufficient amounts of fertilizer have a high potential to act as a continuous sink for atmospheric carbon dioxide. This is mainly due to their high sequestration rates and the fact that there is a constant export out of the production system by means of tapping. A 30 years lifetime carbon sequestration of rubber plantation is about 574 ton/ha/30 (Cheng *et al.* 2007). Comparing this to the sequestration rates of rain forests and secondary forests on the high productivity of a rubber plantation

Table 3. Current structure of rubber industry in Bangladesh.

Sl. No.	Items	No./Value
1	Number of farmers	5204
2	Percentage (%) of smallholders	99.19%
3	Number of traders	13
4	Number of factories processing TSR/Centrifuged Latex/RSS	70
5	No. of groups and cooperatives involve in rubber trading/processing/manufacturing	27
6	Number of rubber products manufacturing units	120
7	Number of auto-tyre manufacturing units	14

becomes discernible. Nevertheless, more than 57% of the sequestered carbon ends up in easily decomposed litter. This decomposition process returns considerable amounts of carbon back to the atmosphere, up to 50% of the total carbon content in the first year (Anderson and Swift 1983; Cotter *et al.* 2009). As part of carbon strategies, Bangladesh must adhere to the Kyoto Protocol mechanism (Wulf 2000) which takes into consideration the effects of carbon sinks and sources, as well as for addressing issues related to fossil fuel emissions. Rubber trees can absorb carbon three times more than any other tree- a tool which can be used to earn foreign currency worth billions of dollars from the Global Carbon Trading and Environmental Fund (Zahir 2015).

3. Biodiversity conservation in rubber dominated landscapes

Biodiversity conservation in rubber dominated landscapes is expanding through land sharing, land sparing and ecological restoration. Referring to rubber cultivation, this approach includes options of intercropping to promote system diversity. Types of diversified rubber-based production systems are monoculture rubber, representing the most common type, temporarily intercropped rubber plantations, with annual crops (e.g. upland rice, corn, pineapple) established between young rubber trees before canopy closing, rubber plantations of multiple species and layers of shrubs and perennial herbaceous, plants such as tea, coffee, cardamom and vanilla (Wu *et al.* 2001). Mixed rubber plantations with perennial plants including tea, coffee, fruit trees, bamboo and bananas, which are mainly established in aging rubber plantations. Rubber plantation plays an important role on soil fertility conservation. With increasing age

of the rubber plantation stand, soil organic matter, NO_3^- and soil moisture significantly increases. Soil pH, total N, exchangeable K and Ca, OM, NO_3^- , soil moisture and soil microorganisms tend to increase with the increasing age of rubber trees, while the soil bulk density tends to decrease (1.48g cm^{-3}) (Kiriya and Sukanya 2019). Similar results of decreases in available P from 12.88-6.50 ppm. The P is easily absorbed onto the surface of oxides of Fe, Al, Mg and hydroxides and becomes a nutrient, which is difficult to be utilized by plants, often causing the shortage of P. The leaf coverage provided by rubber trees and their root system regulates the microclimate, allowing a range of secondary plants to flourish and providing protection of soil against dehydration and the erosive effect of rain (Kox 2000). In addition, rubber trees also provide a habitat for a great variety of fauna. It has also been reported that biodiversity remains remarkably high in rubber plantations, in marked contrast to most other forms of monoculture (Jones 1997). Soil microorganism are at highest levels in the 11 and 22 years old rubber tree plantations and the community of actinomycetes, bacteria and fungi varies between the different aged rubber tree plantations (Kiriya and Sukanya 2019). The composition of the soil microbial community is closely related to soil properties and vegetation at different stages growth of rubber tree. There are also some merits of rubber plantation. The large leaf area index, the biomass production per unit land area and rate of photosynthesis is higher for rubber plantations. For that reason, such tree is more very effective candidate for more afforestation of lands and also for precluding degradation of soils. Rubber plantations are also beneficial in improving the chemical (nutrient availability), physical (bulk density,

porosity), and biological (soil microbes) properties of the soil. Less amount of chemical fertilizers compares to field crops, low intensity agriculture care, and intake of lower quantity of inputs (like water, insecticides and pesticides) are some other benefits of rubber. Rubber plantation has been useful for the restoration of the degraded forestlands and also the possible source of income. Rubber plantation also is the source of fuel wood and timber. Soil binding and reducing the erodibility of soil is another benefit of rubber tree. It helps for reducing the soil temperature which further helps for reduced oxidation of soil organic (Chuan 2003; Panda and Sarkar 2020). In immature rubber plantation through intercropping crops, like banana and pineapple are grown and rubber planters can earn some extra income by bee keeping for honey, because honeybee attracts for extra floral nectaries in the rubber tree (Chaudhuri *et al.* 2013; Panda and Sarkar 2020). Rubber plantation helps for growth of shade loving plants (like as orchids, medical plants etc.) but many plants cannot grow inside of mature rubber plantation due to lack of lights (Mahmoud *et al.* 2005; Panda and Sarkar 2020).

Problem identification and strategy of the solutions

i. Yield and productivity

Bangladesh started rubber cultivation commercially since 1961. At present, about 98,000 acres of land is under rubber plantation in Bangladesh and annual production is about 20,000 metric tons against 30,000 metric tons country's total demand of natural rubber (NR). Bangladesh using traditional conditions of rubber plantations where the maximum achievement is about 506 kg/ha/year only (Fig.1). Whereas in Malaysia, the success of the rubber breeding programme can be seen from the multifold yield increase, from about 500 kg/ha/year for unselected seedlings to about 3,000 kg/ha/year in the modern clones (Anem 2013). Different factors are affecting the low yield production of natural rubber in Bangladesh. One of the main causes is the lack of research and technological backup from the very beginning to improve the crop as well as the field management. However, the selection of clones, low productive stand per hectare, high tapping interference, lack of uniform productive stand, prolong dry season and cultivation practices are important factors

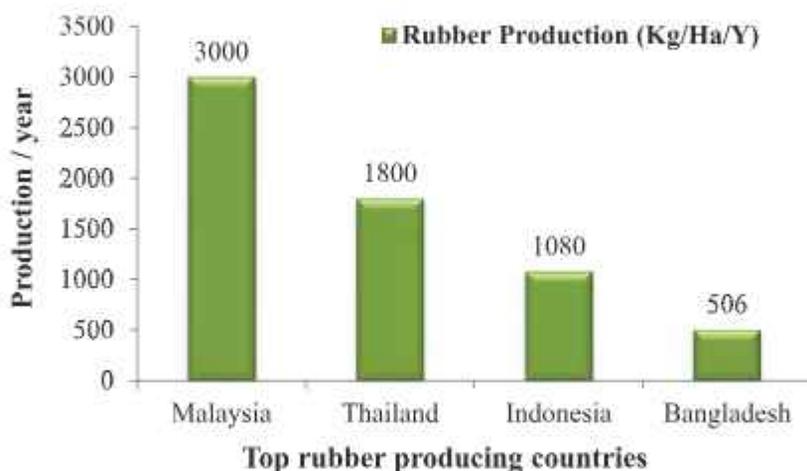


Figure 1. Comparative yield production of top rubber producing countries.

for low yield production. Rubber plants were introduced in Bangladesh from Malaysia for commercial plantation. Both seed and grafted saplings of different clones e.g. GT 1, PB 235, RRIM 600 and TJIR etc. were imported and planted directly without any field experiment in our condition (Rahman 2006). Moreover, RRIM 600 became dominated although it is not widely accepted for large scale planting due to susceptibility to *Phytophthora* sp. and low yield production (Rahman 2006). Since then due to the lack of research feedback there is no improvement activities of existing rubber clones as well as to introduce improved clones for future plantation. Whereas the member countries of International Rubber Research Development Board (IRRDB) including Malaysia have been developed high yielding and quality latex clones like RRIM 3001, RRIM 928, RRIM 929 and PB 350. According to the secretariat of IRRDB, 49 high yielding rubber clones have been exchanging among the

member countries under the multilateral clone exchange programme. Bangladesh as a new member of IRRDB has the opportunity to participate in the clone exchange programme for quick improvement of its natural rubber industry.

ii. Crop management

Appropriate crop management practices with developed technologies are essential for sustainable yield production. It could be through the adaptation and practice of latex harvesting technologies like as stimulation, low intensity tapping system and mechanization in latex harvesting. However, emphasis has been given on integrated farming, agro-forestry and appropriate agricultural practices (Fig. 2).

iii. Crop improvement and protection

Natural rubber is produced by the rubber trees *H. brasiliensis*. The latex yield of the wild rubber trees is low, so it is uneconomical to



(A) Elephant foot yam



(B) Pineapple



(C) Aloe vera



(D) Banana

Figure 2. Inter cropping in rubber plantation (A, B, C & D).

commercially cultivate. It is the obligation of the crop improvement and protection to produce new rubber clones with increasing latex yield. The clones are selected for high latex and timber yield, vigorous growth, good tree morphology, resistance to wind, diseases and brown blast, and other secondary characters such as thick bark. The current targets of the breeding programmes is to produce clones which can produce more than 3500 kg/ha of latex and also yield more than 1.5 cubic meter of total rubber wood/tree. A well-managed plantation in the traditional zone can produce 3 tons rubber per hectare. The average yield of rubber is about 1.6 tons in India. But under the non-traditional condition Bangladesh achieved about 0.5 ton/ha only (Rahman 2006). Unfortunately, the industry suffered badly in the last decade with the decreasing price in the international market, and import of low priced natural and synthetic rubber through free market economic policy. Moreover, low productivity due to lack of proper cultural practices and appropriate processing facilities aggravated the situation further more. The technique of tissue culture is being harnessed to meet the needs of genetic transformation of *H. brasiliensis*. The main objective of genetic transformation is to enhance crop productivity by improving selected agronomic traits of the rubber tree. Two characteristics of the rubber tree that could benefit from transgenic are in girth increment for timber production and in resistance to diseases, particularly *Corynespora* leaf disease. In this context, Silviculture Genetics Division of BFRI has been carried out research studies on *in vitro* plant regeneration and genetic improvement of selected rubber clones. For development and expansion of rubber, systematic research and protection of market price were not done in Bangladesh. As a result, the rubber industry was facing destruction although there was a great demand for NR in Bangladesh. In this

situation, the government should take necessary measures to save the plantation industry considering its contribution in land utilization, afforestation, and development of environment and in national economy. However, the situation has been changed now, the price of rubber has been increased at least three-folds, at a very encouraging level. Now rubber is one of the most profitable commodities in the present market. Therefore, it is the right time to think forward for further development revising the policy and rectifying the faults through applied research and appropriate technology to achieve highest productivity and profit.

iv. Scarcity of skilled tappers

In recent years, the global consumption of natural rubber is steadily increasing and the production has also to be increased so as to meet the demand. Further, many of the recently developed high yielding *Hevea* clones are susceptible to one or more of the undesirable traits such as tapping panel dryness (TPD) a physiological disorder which causes due to the unskilled tapping. Due to uneven distribution of crop, a common standard for payment of wages still cannot be achieved, as it is done in the rubber producing countries like Malaysia, Thailand and Sri Lanka of the traditional zones. Very limited training facilities for the tappers, still exist in Bangladesh. Only a training institute is located in Chattogram Hill Tracts for the government gardens, which should be more organized with modern equipment's and facilities. Proper arrangement for training is urgently needed for the private sectors. However, keeping extra tappers at least 5% can minimize absenteeism problem, but during the acute scarcity it is advisable to use yield stimulants e.g. ethephon, ethrel and edbroza etc., which will reduce the tapping frequency and can minimize the tappers' requirement (Rahman 2006).

v. Processing facilities

Bangladesh is situated in non-traditional rubber production zone where more than 4 months are dry or with very little or no rains. Therefore, in this period dry rubber content (DRC) decreases as low as 15% (Rahman 2006). On the other hand, during the rainy season June to August tapping is greatly affected by heavy down pour although DRC is above 30% in that period. It is practically observed that, more than 50% of total production is achieved within the period of 3 months October to December. This uneven distribution of crop seriously affects management of work force and in latex processing especially accommodation of latex and smoked drying of sheets. Moreover, scarcity of wood fuel for smoke drying is also an acute problem (Rahman 2006). By adopting simple techniques the above problems can easily be solved and the production cost can be reduced significantly. Hot air drying by natural gas, biogas or coal followed by 8 to 10 hrs of smoking in double chambers will reduce the smoking cost at 15% (Rahman 2006). Efficient temperature maintenance, proper heat insulation and occasional turning of sheets can reduce the drying period and will increase the quality of the sheets. Marketing of hot air drying sheets should also be encouraged. Although it is advised by some experts to switch over to other latex processing methods e.g. technically specified rubber (TSR) or block rubber and latex concentrates by centrifuging. It should be remembered that, initial big investment, processing capacity and use of electricity do not favor for establishment and running these factories. It is also not economically viable here at the present situation. The major rubber producing countries like Thailand (total NR production 2.59 million tons in 2002) and India (total NR production 649,435 tons in 2002-2003)

produced TSR 17 and 11.53% respectively (Rahman 2006). The production share of latex concentrates is also about 10%. Moreover, uneven flow of latex in different seasons does not assure economic running of TSR and latex concentrates plants. However, introduction of advance technologies is always preferred; after careful feasibility study that can only be implemented (Rahman 2006).

vi. Marketing

The global demand of natural rubber (NR) grew 7.6% from 3.123 million tons during January-March, 2017 to 3.361 million tons during Q1 2018. The world production of NR recorded a 3.3% growth to 3.152 million tons during 1st quarter of 2018 as compared to 3.051 million tons produced during same period last year. This figure also accounted the 9% of production share from non-ANRPC (Association of Natural Rubber Producing Countries) member countries. An increase in production in China, Philippines, Thailand and Cambodia has contributed for the spurt in NR production, said a report by ANRPC (MRB 2018). Therefore, it is predicted that the price will increase significantly in the world market. In this situation, the government should adopt a policy on import and on the use of off-grade rubber, at the same time production of good quality rubber (Prime grades: RSS 1, RSS 2 and RSS 3 should be more than 80%) in the country, must be ensured (Rahman 2006). The poor quality rubber is generally produced due to the lack of cleanliness in latex collection, handling and coagulation, inadequate addition of chemicals and improper drying, which is sold in ungraded. Rubber based industries; especially automobile-tyre industry should be installed. Marketing of field coagulum (FC) or cup lump is getting importance for increased uses

in the footwear industries. Trading of both FC and smoked dried rubber should be made through registered agencies to prevent illicit channeling of rubber from the gardens (Rahman 2006).

Future of Bangladesh rubber

Bangladesh became as the member of International Rubber Research and Development Board (IRRDB) and the Association of Natural Rubber Producing Countries (ANRPC) very recent. It has the opportunity to get support from the two organizations in respect to crop improvement and management for raising average yield production as well as to improve quality and strengthen the supply chain of rubber sector in country. The global supply of NR 90% of which is fulfilled through ANRPC members is

annually. The areas of rubber plantations in government sector have been extend through replanting and new plantations. The future plan of rubber plantation in Government sector has been shown in Table 4. However, for sustained growth of a plantation industry the positive margin between the cost of production and the sale price of the products is mandatory, otherwise the effect will be negative. It will also affect the national economy as the initial investment, maintenance before and after maturity and other cost in management of a garden e.g. in employment, disaster recovery, productivity etc. will be a poor show in such a losing concern. Although price of rubber was very low in the international market, which influenced the domestic market price earlier but now the problem no more, exists; still there must be some sort of mechanism or

Table 4. Future plan of rubber plantation in government sector of Bangladesh.

Rubber Plantation (in acre)						
Year	Vacant land /new land	Area of matured trees	Total	Nursery	Area to be replanted	New area for plantation
2012-14	4365	2822	5822	60	1000	2000
2014-16	12500	3322	15822	70	1500	2000
2016-18	10500	3322	13822	80	1500	2500
2018-20	8000	3322	11322	90	1500	3000

Source: BFIDC

set to rise 4.5% this year to 13.8 million tons in 2018, the association said. It is well-established fact that natural rubber is superior to synthetic rubber in all respects. In consideration to environment, health and safety, bio-degradation and waste disposal factors it is also more acceptable. The tyre industry is the largest consumer of natural rubber and its demand is increasing with the increase of wheeler vehicles. The demand of natural rubber is increasing at the rate of 3.3%

regulation to control the domestic market price to protect the plantation industry. As a plantation crop, there is no permanent or continuous crisis, but thinking all other aspects: like timber, environment, soil and improvement etc. domestic price control by the government is essential to save the plantation industry and to fetch the good price of rubber in the coming days by improving the yield and quality, meeting the country demand and exporting quality rubber.

Conclusion

Rubber is an important industrial crop of Bangladesh. A major concern of Bangladesh rubber is its low yield production as well as the volatility of rubber price. In order to ensure sustainability of industry, it is needed to increase the yield production. As a result, it is advised to practice good agricultural management such as planting with certified high yield clones, reduce wastages through proper latex harvesting technology and equally important to ensure high quality of their produce to meet consumer demands. It is also important to address the industrial revolution (IR) which is moving on. It can be utilized the potential outcome of rubber industry to face the upcoming challenges at different dimensions. Therefore, research and development must be intensifying with emphasis on component of the industrial revolution especially in the downstream activities to increase consumption through manufacturing of rubber based products. In addition, the utilization of rubber wood in high value furniture and the building industry should be given high priority.

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Assisted Natural Regeneration (ANR) involving Local Communities in Hill Forests of Bandarban Hill District, Bangladesh

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Abstract

Assisted Natural Regeneration (ANR) is known as a cost-effective method to restore forest landscapes compared to conventional reforestation methods. The study was completed in two Mro villages, namely Bagan Para and Sitapahar Nutun Para area of Bandarban Hill District. Total number of seedlings at the top and bottom part of the hill at ANR plots in Bagan Para is 363 and 221 seedlings at NR (Natural Regeneration) plots. Also in the Sitapahar Nutun Para plots of ANR, 245 seedlings are found on the top part of the hill, and 127 on the bottom part. The number of regenerated seedlings in ANR plots is 1.93 times higher ($t=11.96$, $P<0.05$) compared to the NR plots. Total number of seedlings per hectare at Sitapahar Nutun Para is 1500 and 800 in ANR and NR plots respectively. The number of regenerated seedlings in ANR plots is 1.64 times higher ($t=3.20$, $P<0.05$) compared to the NR plots in Bagan Para. Number of seedlings per hectare at Bagan Para is 1200 and 700 in ANR and NR plots respectively. Results showed that regeneration of 41 species was recorded from ANR plots in 2017 followed by 47 species in 2018 and 48 species in 2019. Similarly, 46 species were found in NR plots in 2017 followed by 32 species in 2018 and 19 species in 2019 at Bagan Para. As well as the Sitapahar Nutun Para, in 2017, 32 plants were recorded to regenerate on ANR plots, followed by 51

species in 2018 and 53 species in 2019. Similarly, 34 species were found in NR plots in 2017 followed by 29 species in 2018 and 23 species in 2019 at Sitapahar Nutun Para. Results showed that regeneration rate, seedling survival percentage, seedling heights are higher at both paras in ANR plots in comparison to NR plots. Considering the trends, the ANR method of regeneration may be considered a sustainable technology for conserving plant diversity in the VCF areas of hill districts in Bangladesh.

সারসংক্ষেপ

বনভূমি পুনরুদ্ধার এর প্রচলিত পদ্ধতির তুলনায় প্রাকৃতিক পুনর্জন্ম পদ্ধতি অনেক ব্যয় সাশ্রয়ী পদ্ধতি। বান্দরবন পার্বত্য জেলার বাগান পাড়া এবং সীতা পাহাড় নতুন পাড়া এলাকায় গবেষণা স্টাডিটি সম্পন্ন করা হয়েছে। বাগান পাড়ার এএনআর প্লটে পাহাড়ের উপরে এবং নীচের অংশে মোট চারার সংখ্যা ৩৬৩টি এবং এনআর প্লটে মোট চারার সংখ্যা ২২১টি। সীতা পাহাড় নতুন পাড়ার এএনআর প্লটে পাহাড়ের উপরে এবং নীচের অংশে মোট চারার সংখ্যা ২৪৫টি এবং এনআর প্লটে মোট চারার সংখ্যা ১২৭টি। সীতা পাহাড় নতুন পাড়ার এএনআর প্লটের তুলনায় এএনআর প্লটে পুনর্জন্মকৃত চারার সংখ্যা ১.৯৩ গুণ বেশি ($t=11.96$, $P<0.05$)। এএনআর এবং এনআর প্লটে সীতা পাহাড় নতুন পাড়ায় প্রতি হেক্টরে চারার সংখ্যা যথাক্রমে ১৫০০ এবং ৮০০। বাগান পাড়ার এএনআর প্লটের তুলনায় এএনআর প্লটে পুনর্জন্মকৃত চারার সংখ্যা ১.৬৪ গুণ বেশি ($t=3.20$, $P<0.05$)। এএনআর এবং এনআর প্লটে বাগান পাড়ায় প্রতি হেক্টরে চারার সংখ্যা যথাক্রমে ১২০০ এবং ৭০০টি। গবেষণা ফলাফলে

দেখা যায় যে, বাগান পাড়ায় এএনআর প্রটে ২০১৭ সালে (৪১টি), ২০১৮ সালে (৪৭টি) এবং ২০১৯ সালে (৪৮টি) প্রজাতির পুনর্জন্মকৃত উদ্ভিদের সংখ্যা রেকর্ড করা হয়েছে অন্যদিকে বাগান পাড়ার এএনআর প্রটে ২০১৭ সালে (৪৬টি), ২০১৮ সালে (৩২টি) এবং ২০১৯ সালে (১৯টি) প্রজাতির পুনর্জন্মকৃত উদ্ভিদের সংখ্যা রেকর্ড করা হয়েছে। সীতা গাহাড় নতুন পাড়ায় এএনআর প্রটে ২০১৭ সালে (৩২টি), ২০১৮ সালে (৫১টি) এবং ২০১৯ সালে (৫০টি) প্রজাতির পুনর্জন্মকৃত উদ্ভিদের সংখ্যা রেকর্ড করা হয়েছে, অন্যদিকে বাগান পাড়ার এএনআর প্রটে ২০১৭ সালে (৩৪টি), ২০১৮ সালে (২৯টি) এবং ২০১৯ সালে (২৩টি) প্রজাতির পুনর্জন্মকৃত উদ্ভিদের সংখ্যা রেকর্ড করা হয়েছে। ফলাফল বিশ্লেষণে দেখা যায় যে, পুনর্জন্মের হার, চারা বেঁচে থাকার হার এবং চারার উচ্চতা এএনআর প্রটের তুলনায় এএনআর প্রটে বেশি। গতিবিধি বিবেচনায় দেখা যায়, বাংলাদেশের পূর্বতম জেলার ভিসিএফ এলাকায় উদ্ভিদ বৈচিত্র্য সংরক্ষণের জন্য পুনর্জন্মের এএনআর পদ্ধতি একটি টেকসই প্রযুক্তি হিসেবে বিবেচিত হতে পারে। ফলাফল এএনআর পদ্ধতি উদ্ভিদ বৈচিত্র্য সংরক্ষণের জন্য একটি টেকসই প্রযুক্তি।

Keywords: Assisted Natural Regeneration, Natural Regeneration, Native trees, Regenerating potentials, Restoration.

Introduction

Degradation of forests continues to cause serious problems worldwide and deforestation now is the second largest anthropogenic source of GHG emissions (IGES 2009). Natural regeneration is a natural biological process of forest resource reproduction in a forest ecosystem where the assessment of regeneration is an authentic tool to know the overall condition of the forest (Yang *et al.* 2014; Rahman *et al.* 2019). Recently, Assisted Natural Regeneration (ANR) is known as a cost-effective method to restore forest landscapes compared to conventional reforestation methods. It is considered one of the most viable methods to restore degraded tropical forestlands and convert them into more productive forests (Carandang *et al.* 2007; Shono *et al.* 2007). It aims to accelerate natural succession in forests by reducing or eliminating obstacles such as weeds competing with available resources, fire and grazing disturbances, and marginal soil conditions (Shono *et al.* 2007). Assisted

Natural Regeneration stimulates the growth of natural regenerations. The need for effective and low-cost forest and biodiversity restoration and rehabilitation methods is now highlighted in the face of climate change and the global phenomenon of rapid loss of forests and biodiversity.

Recognizing the success of community-based restoration of degraded forests in other countries of Asia, especially the Indian subcontinent, Bangladesh recently started adopting ANR in degraded natural forests. Bandarban Hill District is the second largest district of Chattogram Hill Tracts with an area of 4,502 sq. km. A Village Common Forest (VCF) is a natural forest outside of the government forest that is managed to meet the daily needs of the ethnic communities. Village common forest is managed as a common property resource by the villagers. VCFs are generally managed by the village community under the leadership of the mouza headmen. In these forests, traditional resource management patterns are used, and jhuming is not permitted. These forests are common forests, and all the adjacent community members have equal rights over the resources under certain guidelines. The study has been carried out at Sitapahar Nutun Para and Bagan Para VCF at Bandarban sadar upazila in Bandarban hill district. Sitapahar Nutun Para was established in 2008 and is 36 kilometres away from Bandarban town. The para is situated beside the Chimbuk-Thanchi road near Peak-69. The Murang community (130 people with 22 families) came here from Sualock. Whereas, Bagan para is just 25 kilometres away from Bandarban Sadar and nearby Chimbuk Hill. Both paras are rich in floral diversity. But, the forests are degrading day by day due to the development of road communication, lack of awareness of biodiversity, forest encroachment and shifting

cultivation. Community reserve forest meets the demand for bamboo, timber, medicinal plants, fuel wood and other minor forest products of many indigenous people (Chakma 2005). Therefore, the protection and preservation of community reserve forests become crucial for the livelihood, environmental, medicinal, cultural and religious needs of indigenous communities (Misbahuzzaman and Marma 2008). The indigenous culture, lifestyle and livelihood are mostly related to forest and forest resources. In a study conducted by Hossain *et al.* (2013), overexploitation of forest resources has caused severe damage to the forest ecosystem which led to rapid loss of biodiversity. Unfortunately, over the past several decades, unsustainable use of these resources has led to the loss of biodiversity. As a result, forest resource-oriented indigenous communities face several crises for their subsistence requirements. Conventional plantations are expensive and are difficult to establish in community areas. Since natural regeneration is promising and less expensive, the study has aimed to restore

the degraded forests for biodiversity conservation through ANR methods involving the local community.

Materials and Methods

Study area

The study was carried out at by two *Mro* village namely; Sitapahar Nutun Para and Bagan Para area of Bandarban sadar upazila in Bandarban Hill District (Fig. 1). Geographical position of Sitapahar Nutun Para is 22°00'N and 92°29'E. On the other hand, Bagan Para lies between 22°05'N and 92°26'E which are covered by hilly areas (Banglapedia 2018). Both paras are situated at Bandarban-Thanchi road about 36km and 25km away from Bandarban district town. There are village common forests (VCFs) adjacent to the villages in both paras. Tropical climates exist in the study areas. The average temperature of the study areas rises to the highest point of 32°C from April to October and the average temperature falls to the lowest point of 15°C in January. The average rainfall

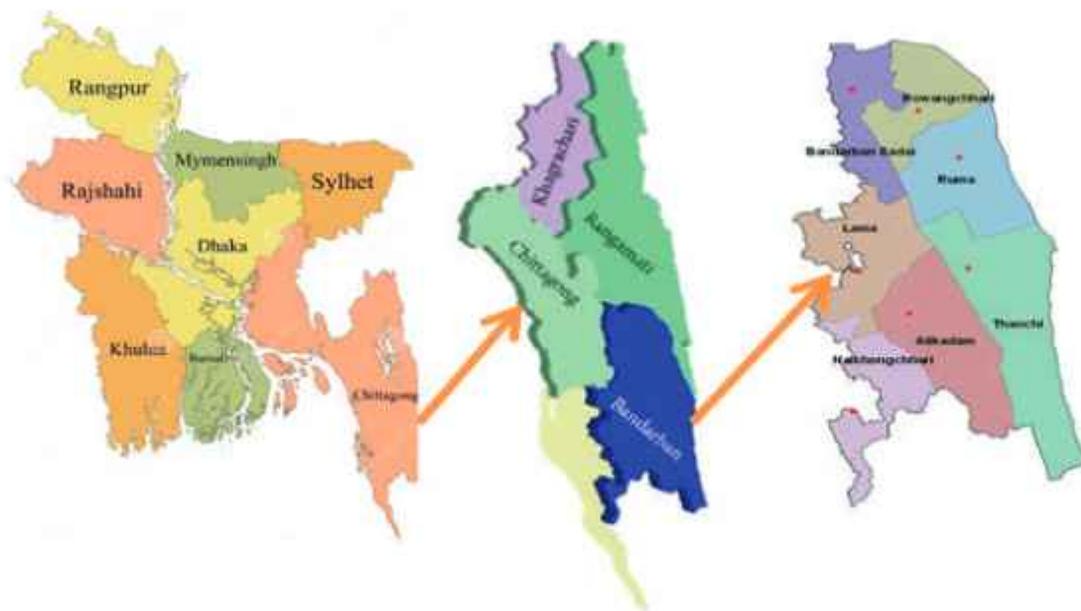


Figure 1. Location map of the Bagan Para and Sitapahar Nutun Para at Bandarban district.

of the study areas may rise to the highest peak of 435mm in July. Rainfall may fall in to the lowest point of 0-5mm from December to January. From May to September, average rainfall occurs more than 100mm. The soils types of the study areas are yellow-brown to strong brown permeable friable loamy, very strongly acidic and low in moisture holding capacity. In general, soil patterns are complex due to local variations in sand, silt, and clay contents of sedimentary rocks, as well as erosion levels. Brown soils are the predominant general soil type of the area (BBS 2018) The vegetation types of the study area are semi-evergreen (deciduous) to tropical evergreen dominated by tall trees belonging to euphorbiaceae, mimosaceae, moraceae and rubiaceae. All of the population of the research area is from the Mro ethnic community and belongs to Christianity and Crama by religion.

Sampling procedure and survey

At first discussed with Karbari (local community leader) of two paras to know about the idea of vegetation composition and accessibility of the whole study area prior to the selection of sampling procedures (Fig. 2). Assisted Natural Regeneration is a simple, low-cost restoration method that can effectively enhance the productivity and ecosystem functions of deforested or degraded lands. As a result of this method, natural succession is accelerated rather than replaced by removing or reducing barriers to natural regeneration, including soil degradation, weed competition, and recurring disturbances.(e.g. fire, grazing and wood harvesting). Assisted Natural Regeneration method of forest restoration is simple and low cost, so a certain number of ANR and NR (control) demonstration plots have been set up in the VCF. Comparison between ANR and NR plots has been shown by setting up

demonstration plots and it has been shown that forest restoration is simple and low-cost by applying the ANR method. It was compared with the conventional afforestation method. All the naturally regenerating seedlings with $\geq 5\text{cm}$ to 150cm in height were identified, counted and tagged inside each ANR and NR plots. All the woody species regeneration without tags or numbers within each plot at the final measurement were identified and counted. All competing vegetation, such as grasses and vines within at least a 0.5m radius around the stem of the marked seedlings were removed in the ANR plots. The NR plots were kept untreated without any management. Survival percentage of seedlings in ANR and NR plots was determined. A total number of 60 random quadrat sample plots, each of 10m x 10m size were taken from Bagan Para VCF in the top and bottom hill portion (Fig. 3). Of these plots, 30 are ANR and 30 are NR plots. On the other hand, a total of 32 quadrat sample plots each of 10m x 10m size were taken from Sitapahar Nutun Para VCF, out of which 16 are ANR and 16 are NR plots. Each NR sample plot was selected adjacent to ANR plots area having approximately similar vegetation conditions. The area of each plot was demarcated by measuring tape and rope. Focus group discussions were conducted with the community people with the aim to raising awareness of the potential of the ANR method for biodiversity conservation.

Statistical analysis

In this study, seedlings were defined as plants up to 15cm in height. A total number of seedlings was counted and recorded for each species in the sample plots. T-test were conducted (at 5% level of significance) to test significance of difference in regeneration between the ANR and NR plot areas. Botanical samples were collected from two



Figure 2. Discussion meeting with the leader of local community at Bagan para and local Mro people at Sitapahar Nutun Para.



Figure 3. Data collection of ANR and NR from Bagan Para and Sitapahar Nutun Para.

VCF sample plots of two paras. Common plant species were identified directly in the field. Their respective local name, scientific name, habitat and habit were documented. Herbarium specimen of unidentified plant samples with fertile material (flower, fruit and seed) were collected and prepared for identification after necessary processing. Herbarium specimens were identified by consulting with plant taxonomist and comparing them with authentic herbarium samples of Bangladesh Forest Research Institute Herbarium (BFRIH), Chattogram and Bangladesh National Herbarium (BNH), Dhaka as well as recognized references, e.g. Prain (1903), Heinig (1925), Siddiqui *et al.* (2007) and Ahmed *et al.* (2008). Finally the voucher specimens were preserved in the BFRI herbarium.

Results

A total of 50 regenerating tree species belonging to 26 families were recorded from Bagan Para ANR and NR plots. Among the families, Euphorbiaceae (6 species) comprises the highest number of species followed by Rubiaceae (4 species), Anacardiaceae (3 species), Bignoniaceae (3 species), Mimosaceae (3 species) and Verbenaceae (3 species) and the rest of the families comprise one or two species (Table 1). In Sitapahar Nutun Para total 61 regenerating plant species belonging to 29 families were recorded from ANR and NR plots. Among the families Euphorbiaceae was the highest (11 species) number of species followed by Moraceae and Sterculiaceae each are 4 species. Families Areaceae, Combretaceae, Rubiaceae and Verbenaceae were 3 species each. The remaining families were 1 or 2 species each (Table 2).

Table 1. Regenerating tree seedlings recorded from Bagan Para ANR and NR plots in the years 2017, 2018 and 2019.

Family	Scientific name	Local name	Bagan Para					
			ANR			NR		
			17	18	19	17	18	19
Anacardiaceae	<i>Mangifera indica</i> L.	Am	+	+	+	+	+	-
	<i>Mangifera sylvatica</i> Roxb.	Uriam	-	+	+	-	-	-
	<i>Holigarna caustica</i> (Dennst) Oken	Barela	-	+	+	+	-	-
Apocynaceae	<i>Holarrhena antidysenterica</i> (L.) Wall. ex Decne.	Kurchi	+	+	+	+	+	+
Araliaceae	<i>Trevesia palmata</i> (Roxb. ex Lindl) Vis.	Bon papay	+	+	+	+	+	+
Arecaceae	<i>Areca triandra</i> Roxb. ex Buch.-Ham.	Bon supari	+	+	+	+	+	-
Bignoniaceae	<i>Stereospermum suaveolens</i> (Roxb.) DC.	Parul	+	+	+	+	-	-
	<i>Stereospermum colais</i> (Buch.-Ham. ex Dillw.) Mabberley	Dharmara	+	+	+	+	+	-
	<i>Oroxylum indicum</i> (L.) Benth. ex Kurz	Khona	-	+	+	+	-	-
Bombacaceae	<i>Bombax insigne</i> Wall.	Pahari tula	+	+	+	+	+	+
Burseraeae	<i>Protium serratum</i> (Wall. ex Colebr.) Engl.	Gutguttya	+	+	+	+	-	-
	<i>Garuga pinnata</i> Roxb.	Shil bhadi	+	+	+	+	+	-
Combretaceae	<i>Anogeissus acuminata</i> (Roxb. ex DC.) Guill. & Perr.	Echri	+	+	+	+	+	+
	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Bohera	-	+	+	+	+	-
Dipterocarpaceae	<i>Dipterocarpus turbinatus</i> Gaertn.	Garjan	+	+	+	+	+	-
Ebenaceae	<i>Diospyros montana</i> Roxb.	Bon gab	+	+	+	+	-	-
Euphorbiaceae	<i>Suregada multiflora</i> (A. Juss.) Baill.	Maricha	+	+	+	+	+	+
	<i>Mallotus philippensis</i> (Lam.) Muell.- Arg.	Sindur	+	+	+	+	+	+
	<i>Sapium baccatum</i> Roxb.	Bolos	+	+	+	+	-	-
	<i>Aporosa wallichii</i> Hook. f.	Kechua	+	+	+	+	+	-
	<i>Aporosa dioica</i> (Roxb.) Muell.-Arg.	Kechua	+	+	+	+	-	-
	<i>Mallotus roxburghianus</i> Muell.-Arg.	Noon-Kocho	+	+	+	+	-	-
Elaeocarpaceae	<i>Elaeocarpus floribundus</i> Blume	Bon jalpai	+	+	+	+	+	-
Flacourtiaceae	<i>Hydnocarpus kurzii</i> (King) Warb.	Chalmoogra	-	+	+	+	-	-
	<i>Flacourtia jangomas</i> (Lour.) Raeusch.	Painnya gula	+	+	+	+	+	+
Lauraceae	<i>Litsea monopetala</i> (Roxb.) Pers.	Menda	+	+	+	+	+	-
Lythraceae	<i>Lagerstroemia speciosa</i> (L.) Pers.	Jarul	+	+	+	+	+	+
Tiliaceae	<i>Grewia nervosa</i> (Lour.) Panigrahi	Asar	+	+	+	+	+	+
Mimosaceae	<i>Albizia chinensis</i> (Osbeck) Merr.	Chakua koroi	-	+	+	+	+	+
	<i>Albizia procera</i> (Roxb.) Benth.	Sil koroi	+	+	+	+	-	-
	<i>Albizia odoratissima</i> (L.f.) Benth.	Tetua koroi	+	+	+	+	+	+
Moraceae	<i>Artocarpus lacucha</i> Buch.-Ham.	Barta	+	+	+	+	+	-
	<i>Streblus asper</i> Lour.	Sheora	+	+	+	+	+	+
	<i>Ficus hispida</i> L.f	Dumur	+	+	+	+	+	+
Myrsinaceae	<i>Maesa indica</i> (Roxb.) A. DC.	Maricha	+	+	+	+	+	-
Myrtaceae	<i>Syzygium fruticosum</i> DC.	Puti jam	+	+	+	+	+	+

Family	Scientific name	Local name	Bagan Para					
			ANR			NR		
			17	18	19	17	18	19
Rubiaceae	<i>Mitragyna parvifolia</i> (Roxb.) Korth.	Dakroom	-	+	+	+	-	-
	<i>Ixora nigricans</i> R. Br. ex Wight & Arn.	Rongma	+	+	+	+	+	+
	<i>Pavetta indica</i> L.	Kathchapa	+	-	-	-	-	-
	<i>Gardenia coronaria</i> Buch.-Ham.	Kannyari	+	+	+	+	+	-
Rutaceae	<i>Micromelum minutum</i> (G. Forster) Wight & Arn.	Pislaphula	+	+	+	+	+	+
	<i>Murraya paniculata</i> (L.) Jack.	Kamini	+	+	+	+	-	-
	<i>Clausena suffruticosa</i> (Roxb.) Wight & Arn.	Kalo maricha	+	-	-	+	-	-
Sapindaceae	<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	Baro Harina	+	+	+	+	+	+
Sterculiaceae	<i>Pterospermum acerifolium</i> (L.) Willd.	Moos	+	-	+	+	+	+
	<i>Sterculia villosa</i> Roxb. ex Smith.	Fashya-udal	-	+	+	-	-	-
Theaceae	<i>Schima wallichii</i> (DC.) Korth.	Kanak	+	+	+	+	-	-
Verbenaceae	<i>Vitex glabrata</i> R. Br.	Goda	+	+	+	-	-	-
	<i>Gmelina arborea</i> Roxb.	Gamar	+	+	+	+	+	-
	<i>Callicarpa macrophylla</i>	Bormala	+	+	+	+	+	+
			41	47	48	46	32	19

*Note: + = Present, - = Absent

Table 2. Regenerating tree seedlings recorded from Sitapahar Nutun Para ANR and NR plots in the years 2017, 2018 and 2019.

Family	Scientific name	Local name	Sitapahar Nutun Para					
			ANR			NR		
			17	18	19	17	18	19
Anacardiaceae	<i>Swintonia floribunda</i> Griff.	Civit	-	+	+	-	+	-
Apocynaceae	<i>Holarrhena antidysenterica</i> (L.) Wall. ex Decne.	Kurchi	+	+	+	+	+	+
Arecaceae	<i>Areca triandra</i> Roxb. ex Buch.-Ham.	Bon supari	+	+	+	+	+	-
	<i>Calamus guruba</i> Buch.-Ham. ex Mart.	Jali bet	+	+	+	+	+	+
Bignoniaceae	<i>Stereospermum suaveolens</i> (Roxb.) DC.	Parul	+	+	-	+	+	-
	<i>Stereospermum colais</i> (Buch.-Ham. ex Dillw.) Mabblerley	Dharmara	-	+	+	-	+	-
	<i>Oroxylum indicum</i> (L.) Benth. ex Kurz	Khona	-	+	+	+	-	-
Burseraceae	<i>Protium serratum</i> (Wall. ex Colebr.) Engl.	Gutguttya	-	+	+	-	-	-
Caesalpiniaceae	<i>Tamarindus indica</i> L.	Tetul	+	+	+	+	+	+
	<i>Saraca asoca</i> (Roxb.) de Wild.	Ashok	+	+	+	-	-	-
Combretaceae	<i>Anogeissus acuminata</i> (Roxb. ex DC.) Guill. & Perr.	Echri	+	+	+	+	+	+
	<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	Arjun	-	+	+	-	+	+
	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Bohera	-	+	+	-	-	-

Family	Scientific name	Local name	Sitapahar Nutun Para					
			ANR			NR		
			17	18	19	17	18	19
Dipterocarpaceae	<i>Dipterocarpus turbinatus</i> Gaertn.	Garjan	+	+	+	+	-	-
	<i>Hopea odorata</i> Roxb.	Telshur	-	+	+	-	-	-
Euphorbiaceae	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	Sindur	+	+	+	+	-	-
	<i>Bischofia javanica</i> Blume	Kanjil badi	+	+	+	+	+	+
	<i>Suregada multiflora</i> (A. juss.) Baill.	Ban-nariga	+	+	-	+	+	+
	<i>Aporosa dioica</i> (Roxb.) Muell.-Arg.	Kechua	+	+	+	+	-	-
	<i>Aporosa wallichii</i> Hook. f.	Kechua	+	+	+	+	+	+
	<i>Sapium baccatum</i> Roxb.	Bolos	-	+	+	+	-	-
	<i>Macaranga denticulate</i> (Bl.) Muell.- Arg.	Bura	+	+	+	+	+	+
	<i>Baccaurea ramiflora</i> Lour.	Lotkan	-	+	+	-	-	-
	<i>Antidesma acidum</i> Retz.	Elena	+	+	+	+	+	+
	<i>Glochidion lanceolarium</i> (Roxb.)Voigt.	Kechchua	+	+	+	+	-	-
	<i>Phyllanthus emblica</i> L.	Amloki	-	+	+	+	+	+
Elaeocarpaceae	<i>Elaeocarpus floribundus</i> Blume	Bon jalpai	-	+	+	-	-	-
Fabaceae	<i>Erythrina stricta</i> Roxb.	Mander	+	+	+	+	+	+
Fagaceae	<i>Lithocarpus elegans</i> (Bl.) Hatus. ex Soepad	Jat Batna	-	+	+	+	-	-
	<i>Quercus gomeziana</i> A.Camus	Sil batna	+	+	-	-	-	-
Flacourtiaceae	<i>Flacourtia jangomas</i> (Lour.) Raeusch.	Painnya gula	+	+	+	+	+	+
Clusiaceae	<i>Garcinia cowa</i> Roxb. ex DC	Kao-gola	-	-	+	-	+	-
Juglandaceae	<i>Engelhardtia spicata</i> Leschen.ex Blume	kicra bhadi	-	-	+	-	-	-
Lauraceae	<i>Litsea monopetala</i> (Roxb.) Pers.	Menda	+	-	-	+	-	-
Leeaceae	<i>Leea indica</i> (Burm. f.) Merr.	Hoti gach	-	+	+	+	-	-
Lythraceae	<i>Lagerstroemia speciosa</i> (L.) Pers.	Jarul	-	-	+	-	-	-
Magnoliaceae	<i>Michelia champaca</i> L.	Champa	-	+	+	-	-	-
Tiliaceae	<i>Grewia nervosa</i> (Lour.) Panigrahi	Asar	+	+	+	+	+	+
Meliaceae	<i>Melia azedarach</i> L.	Ghora nim	-	+	+	-	-	-
	<i>Chukrasia tabularis</i> A. Juss.	Chikrasi	-	-	+	-	-	+
Mimosaceae	<i>Albizia procera</i> (Roxb.) Benth.	Sil koroi	-	-	+	-	-	-
	<i>Samanea saman</i> (Jacq.) Merr.	Rain tree	-	+	-	-	-	-
Moraceae	<i>Artocarpus chama</i> Buch.-Ham. ex Wall.	Chapalish	+	+	+	-	-	-
	<i>Ficus nervosa</i> Heyne ex Roth.	Pania Dumur	+	+	+	+	+	+
	<i>Streblus asper</i> Lour.	Sheora	+	+	+	+	+	+
	<i>Ficus hispida</i> L.f.	Dumur	+	+	+	+	+	+
Myrtaceae	<i>Syzygium fruticosum</i> DC.	Puti jam	-	+	+	-	+	+
	<i>Syzygium firmum</i> Thw.	Dhaki jam	-	+	+	+	-	-
Rubiaceae	<i>Mitragyna parvifolia</i> (Roxb.) Korth.	Dakroom	-	+	+	-	+	+
	<i>Ixora cuneifolia</i> Roxb.	Kamuchui	+	-	-	+	+	+
	<i>Hymenodictyon orixensis</i> (Roxb.) Mabberley	Bhui - kadam	+	+	-	-	-	-
Sapindaceae	<i>Litchi chinensis</i> Sonn.	Lichu	-	+	+	-	-	-
	<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	Rubharina	+	+	+	+	+	-

Family	Scientific name	Local name	Sitapahar Nutun Para					
			ANR			NR		
			17	18	19	17	18	19
Sterculiaceae	<i>Pterospermum acerifolium</i> (L.) Willd.	Moos	-	-	+	-	-	-
	<i>Sterculia villosa</i> Roxb. ex Smith.	Fashya-udal	-	+	+	-	-	-
	<i>Firmiana colorata</i> (Roxb.) R.Br.	Uddal	+	+	+	+	+	+
	<i>Pterospermum semisagittatum</i> Buch.-Ham. ex Roxb.	Lana assar	+	-	-	+	+	+
Theaceae	<i>Schima wallichii</i> (DC.) Korth	Kanak	+	+	+	+	-	-
Verbenaceae	<i>Vitex glabrata</i> R. Br.	Goda	-	-	+	-	-	-
	<i>Gmelina arborea</i> Roxb.	Gamar	-	+	+	-	-	-
	<i>Callicarpa macrophylla</i> Vahl.	Bormala	+	+	+	+	+	-
			32	51	53	34	29	23

*Note: + = Present, - = Absent

Studies using the ANR method in the two paras have shown that the number of plant species in the ANR plots is much higher than the NR plots. The average number of ANR and NR plots in Bagan Para and Sitapahar Nutun Para is given in Table 3.

Table 3. Different parameters of ANR and NR plots for Bagan Para and Sitapahar Nutun Para.

Name of paras	Parameters	ANR plots	NR plots
Bagan Para	Total no. of seedlings	363	221
	Mean per plot	12	7
	Seedlings per ha.	1200	700
Sitapahar Nutun Para	Total no. of seedlings	245	127
	Mean per plot	15	8
	Seedlings per ha.	1500	800

The number of regenerated seedlings in ANR plots is 1.93 times higher ($t=11.96$, $P < 0.05$) compared than the NR plots in Sitapahar Nutun Para. Number of seedlings per hectare at Sitapahar Nutun Para in ANR and NR plots is 1500 and 800 respectively. The table value of 't' is 5% larger than the appropriate limit value, so the value of 't' is very significant. The number of regenerated seedlings in ANR plots is 1.64 times higher ($t=3.20$, $P < 0.05$) compared than the NR plots in Bagan Para. Number of seedlings per hectare at Bagan Para in ANR and NR plots is 1200 and 700 respectively. The table value of 't' is 5% larger than the appropriate limit value, so the value

of 't' is significant. Regenerating seedling was found more in ANR plots than in NR plots. However, due to properly take cared and increases awareness, the rate of regeneration in ANR plots in Sitapahar Nutun Para is much higher than in ANR plots in Bagan Para. In both paras the rate of regeneration of ANR plots is much higher than NR plots. Kurchi (*Holarrhena antidysenterica*) regeneration is highest in ANR plots in Sitapahar Nutun Para and followed by Itchri (*Anogeissus acuminata*), Khona (*Oroxylum indicum*), Putijam (*Syzygium fruticosum*) and Jarul (*Lagerstroemia speciosa*). Also Echri (*Anogeissus acuminata*) regeneration is highest in ANR plots in Bagan Para and followed by Kurchi (*Holarrhena antidysenterica*), Bonsupari (*Areca triandra*), Kalomaricha (*Clusena suffruticosa*), Kechua (*Aporosa wallichii*) and Rubharina (*Lepisanthes rubiginosa*). In the ANR plots of Bagan Para and Sitapahar Nutun Para, the survival percentage of seedlings were found 78% and 89%. But in NR plots that were 56% and 67% respectively (Fig. 4). The application of ANR treatment reduces the competition with other species and allows them to collect food from the soil with adequate sunlight. As a result, the growth and survival rate of the seedlings is higher. So, ANR treatment increases the number of seedlings. For the

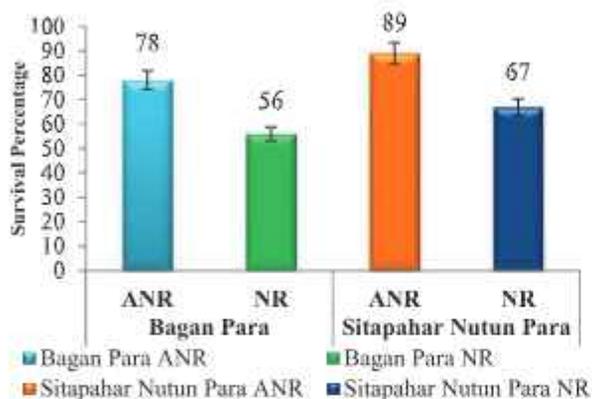


Figure 4. Survival percentage at Bagan Para and Sitapahar Nutun Para in ANR and NR plots.

improvement of regeneration, it is necessary to carry out ANR programme. Assisted Natural Regeneration treatments at the start of rainy season so that seeds and seedlings will have the full growing seasons of faster germination and growth. Regeneration studies between ANR and NR reveal the potential for natural regeneration by ANR treatment.

Discussion

Assisted Natural Regeneration has played a very important role in expanding forest resources, controlling soil erosion, delaying the process of desertification, improving the ecological environment and improving the living conditions of farmers (Sannai 2003). Sannai (2003) also reported, ANR will henceforth play a more important role in the process of afforestation and improvement of environmental conditions in China. The basic ecological principles of community succession involved in ANR were described by Sajise (1989). It has the potential to contribute significantly in addressing the region's forest rehabilitation challenges (Walpole 2003). It is the more cost-effective method for carbon restoration (Evans *et al.* 2015) and recognized as a cost-effective forest restoration method that can restore biodiversity and ecosystem services in areas of intermediate levels of degradation, while also providing income for rural livelihoods

(Chazdon 2008; Ma *et al.* 2014). Assisted Natural Regeneration in China, Indonesia, Cambodia, Philippines and Thailand for forest restoration and reproducing nature in Brazil, are a few examples of this principle being implemented (Sajise 1989). In Indonesia, ANR techniques are applied for forest reforestation. Motivate the people for conserved the remaining natural regeneration forest by using ANR method (Soegiri and Pramono 2003). It indicate positive feedbacks among soil and water conservation, biodiversity protection, and biomass accumulation and there by enhances ecosystem services (Yang *et al.* 2018). From the results of this study showed that, the ANR method is a sustainable technology for conserving natural plant diversity. Assisted Natural Regeneration method is a new technology in Bangladesh. Not many research activities were conducted in Bangladesh on ANR method before. At present the Forest Department is using ANR system to conserve natural forests. Rahman (2011) conducted a study on ANR in Sundarban Bangladesh. The study reveals that total number of seedlings for all the species including sundri together and sundri alone were significantly higher in ANR areas compared with Pure Natural Regeneration areas (Rahman 2011). Significant potential of ANR as well as the need for further research have been noted by tropical restorationists (Elliot *et al.* 2000).

Conclusion

Implementation of rehabilitation programmes in deforested areas and degraded lands is primarily pursued through plantation establishment instead of ANR. To increase awareness and appreciation of ANR, there should be more publications, demonstrations, research plots and workshop-study tours. These initiatives will encourage foresters to study and gain a deeper understanding of ANR. In addition to conventional plantation establishment, foresters will be more motivated to consider alternative strategies

and methods to help combat deforestation with increased knowledge. Research has also shown that the application of ANR methods has significantly increased the rate of regeneration. It can be recommended that ANR should be practiced in the areas where undergrowth is dense and regeneration is inadequate and forest health is not satisfactory.

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Effectiveness of Disodium Octaborate Tetrahydrate (DOT) as Rubber Wood Preservative

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Abstract

Rubber (*Hevea brasiliensis*) wood is very quickly affected by wood decay agents due to the presence of huge amounts of starch. This starch is very much favorable for fungi and wood decay agents. Because of that, it cannot be used without preservative treatment. The service life of rubber wood is extended by applying the preservative treatment. Disodium Octaborate Tetrahydrate (DOT) is used to increase the service life of rubber wood. It contains the highest amount of boron that is effective against wood-destroying fungi. The experiment was under taken to investigate the retention of 10% DOT aqueous solution in treated wood by applying the pressure method. The assessment was applied for 1, 2 and 3 hours and the pressure of 10, 30, 50, 70, 90, 110, 130, 150 and 170 psi. All the experiment was carried out at different pressure with same three different times and same preservative concentration. The experiment was conducted for the pressure of 10, 30 and 50 psi at 1, 2 and 3 hours. Among the three treatments, the highest retention was found 45.41 kg/m³ at 3 hours with 50 psi pressure. The experiment was conducted for the pressure of 70, 90 and 110 psi at 1, 2 and 3 hours. The highest retention was found 46.12 kg/m³ at 3 hours with 110 psi pressure. Then, the experiment was conducted for the pressure of 130, 150

and 170 psi at 1, 2 and 3 hours. The Maximum retention was found 41.97 kg/m³ at 3 hours at 130 psi pressure. All over the experiment, the highest retention was recorded 46.12 kg/m³ applying 110 psi pressure for 3 hours which is suitable for rubber wood treatment.

সারসংক্ষেপ

রাবার কাঠে প্রচুর পরিমাণে স্টার্চ থাকার কারণে কাঠ ধ্বংসকারী এজেন্ট দ্বারা খুব দ্রুত নষ্ট হয়। এই স্টার্চ ছদ্মক এবং কাঠ ধ্বংসকারী এজেন্টদের জন্য খুব অনুকূল। যে কারণে, এটি ট্রিটমেন্ট ছাড়া ব্যবহার করা যায় না। সংরক্ষণী প্রয়োগের মাধ্যমে কাঠের ব্যবহারিক আয়ুষ্কাল বৃদ্ধি করা যায়। ডাই-সোডিয়াম অক্টাবোরেট টেট্রাহাইড্রেট (ডিওটি) রাবার কাঠের ব্যবহারিক আয়ুষ্কাল বৃদ্ধির জন্য ব্যবহার করা হয়েছে। ডিওটিতে সর্বোচ্চ পরিমাণে বোরন থাকে যা কাঠ ধ্বংসকারী ছত্রাকের বিরুদ্ধে কার্যকর। চাপ প্রয়োগ পদ্ধতিতে ১০% ডিওটির জলীয় দ্রবণ দ্বারা ট্রিটেড রাবার কাঠের ধারণ মূল্যায়নের জন্য স্ট্যাডিটি নেওয়া হয়েছিল। ১, ২ এবং ৩ ঘণ্টা সময় ধরে ১০, ৩০, ৫০, ৭০, ৯০, ১১০, ১৩০, ১৫০ এবং ১৭০ পিএসআই চাপ প্রয়োগে এ পরীক্ষাটি করা হয়। সকল পরীক্ষণের ক্ষেত্রে একই ঘনত্বের সংরক্ষণী এবং তিনটি ভিন্ন সময়ের জন্য ভিন্ন ভিন্ন চাপ প্রয়োগ করা হয়। ১, ২ এবং ৩ ঘণ্টা সময়ের জন্য পৃথক পৃথকভাবে ১০, ৩০ এবং ৫০ পিএসআই চাপ প্রয়োগ করা হয়। তিনটি পরীক্ষণের মধ্যে ৩ ঘণ্টা সময় এবং ৫০ পিএসআই চাপ প্রয়োগে সর্বোচ্চ ধারণ ৪৫.৪১ কেজি/ঘনমিটার পাওয়া গেছে। ১, ২ এবং ৩ ঘণ্টা সময়ের জন্য পৃথক পৃথকভাবে ৭০, ৯০ এবং ১১০ পিএসআই চাপ প্রয়োগ করা হয়। ৩ ঘণ্টা সময় এবং ১১০ পিএসআই চাপ প্রয়োগে সর্বোচ্চ ধারণ ৪৬.১২

কেজি/ঘনমিটার পাওয়া গেছে। অতপর, তিনটি ভিন্ন সময়ের জন্য পৃথক পৃথকভাবে ১৩০, ১৫০ এবং ১৭০ পিএসআই চাপ প্রয়োগ কর হয়। ৩ ঘণ্টা সময় এবং ১৩০ পিএসআই চাপ প্রয়োগে সর্বোচ্চ ধারণ ৪১.৯৭ কেজি/ঘনমিটার পাওয়া গেছে। সর্বোপরি, ৩ ঘণ্টা সময় এবং ১১০ পিএসআই চাপ প্রয়োগে সর্বোচ্চ ধারণ ৪৬.১২ কেজি/ঘনমিটার রেকর্ড করা হয়েছে যা রাবার কাঠ ড্রিটমেন্ট করার জন্য উপযুক্ত।

Keywords: Concentration, Disodium Octaborate Tetrahydrate, Pressure method, Retention, *Hevea brasiliensis*.

Introduction

Rubber trees (*Hevea brasiliensis*), indigenous to the Amazon Valley of South America, were introduced to India in the latter half of the 19th century (Edwin *et al.* 2006). The trees are now widely cultivated in 20 countries around the world, including Bangladesh, for natural rubber (Latex). The rubber plant is found almost everywhere in Bangladesh. Particularly, Cox's Bazar, Chattogram, Chattogram Hill Tracts, Sylhet, Tangail, etc. are the most suitable place for rubber tree plantation. The plantation of rubber trees has been started in Bangladesh about five decades back. The present tree is covered with a rubber plantation area of about 27,500 acres. Latex production decreases gradually from the old-aged plant. Bangladesh has already attained the stage of old-aged plantation and extracting latex from that plantation is uneconomic. This plantation, therefore, requires replanting. Rubber trees are replanted every 25–30 years when they are uneconomical for latex production (FAO 2010). During the process, a considerable quantity of rubber wood is obtained. *Hevea brasiliensis* is a common exotic species in Bangladesh. The attractive features of rubber wood are its creamy color and good wood working properties. This has prompted many industries to use rubber wood as a substitute for highly priced timber. In fact, rubber wood has carved a niche for itself and has become the timber used in many wood products (Teoh *et al.* 2011). Rubber wood is also very prone to

attacks by fungi and wood borers in green and dry conditions. According to George, staining fungi can seriously attack rubber wood as soon as within 1 day of felling. An example is *Botryodiplodia theobromae*, which occurs together with the surface mold *Aspergillus sp.* *Penicillium sp.* also cause considerable loss of strength in rubber wood. Apart from this, wood rotting fungi such as *Lenzites palisotii* and *Ganoderma applanatum* can also rapidly destroy rubber wood (George 1985). As reported by a few researchers, the high carbohydrate (e.g., sugar and starch) reserves deposited in the parenchyma are major factors governing the high decay susceptibility of rubber wood. In view of the high severity of the decay problem, there is a need for prompt preservative treatment against the attack of bio deteriorating organisms (Teoh *et al.* 2011).

Research report of Commonwealth Scientific Industrial Research (CSIR) (Du Toit 1988) indicated that average sapwood retention levels are required for adequate protection of poles against wood rot, and termite attacks preservative treatment of wood modifies its properties making it dimensionally stable and durable for efficient utilization (Winandy 1991). The commercial potential of borate treatments was first identified in the 1930s. Interest in standalone borates as wood preservatives first arose in Australia and New Zealand where borates were recommended for insect control (Drysdale 1994). Borax-Boric acid (BB) solutions (10%) are used to increase the service life of non-durable wood and bamboo for indoor use. This solution is also used by Bangladesh Forest Industries Development Corporation (BFIDC) for the treatment of rubber wood according to BFRI instructions. Boron is a vital active ingredient of BB and Disodium Octaborate Tetrahydrate (DOT) which function against insects and

fungi. It is a stable, white, odorless, powdered chemical substance that is not flammable, combustible, or explosive and has low acute oral and dermal toxicity. The product itself is a flame retardant. It is sold under TIM-BOR ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) and or BORA CARE (40% DOT in ethylene glycol) brands in the United States. It has a higher solubility than borax and boric acid. It contains more boron or B_2O_3 than borax and boric acid as per unit mass. Inorganic borates are diffusible, and with appropriate treating practices, can achieve excellent penetration in species that are difficult to treat with other preservatives. However, the borate in the wood remains water soluble and hence they are standardized by the American Wood Protection Association (AWPA) for only indoor applications not directly exposed to liquid water. The Effectiveness of preservative chemicals depends on the climatic condition of that country. The weather condition of Bangladesh is different from the other countries of the world. Activities of wood decay agent depend on the high and low temperature. So, the research study has been taken to investigate the performance of DOT in rubber wood in Bangladesh. Typical examples of satisfactory building construction use of DOT would be studs, rafters, sill plates (Nicholas and Preston 1988). It is more effective than boric acid and borax against decay fungi because it contains a higher proportion of boron and the borate ion is more readily available (Jonge 1987). 17.48% boron (B) content comes from boric acid (H_3BO_3), 11.34% boron (B) content comes from Borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) but 20.96% boron (B) content comes from DOT ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$). 1.65 BAE (Boric Acid Equivalence) comes from 2 mol Borax Boric acid whereas 2.39 BAE comes from 2 mol DOT. It has a pH of 8.3 at 20°C as a 3%

solution and a pH of 7.6 as a 10% solution. It is considered non-corrosive (Freeman *et al.* 2011) and has the most widespread commercial use in North America. It has higher water solubility allowing the use of higher concentrations and increasing mobility in wood. All borates convert to boric acid when they dissolve in acidic media such as in wood (pH 4-5). Boric acid in a 1% solution contains 0.56% B_2O_3 ; 1% borax contains 0.37% B_2O_3 while DOT (as TIMBOR) contains 0.67% B_2O_3 (Freeman *et al.* 2011). Disodium Octaborate Tetrahydrate is an insecticide and effective against a wide variety of wood destroying insects including: powderpost beetles (Lyctidae) (Williams 1977); furniture beetles (Anobiidae); old house borers: longhorn beetles (Cerambycidae); subterranean termites (Reticulitermes, Coptotermes, Heterotermes) (Tokoro and Su 1993; Grace and Yamamoto 1992). It may be more effective and economically profitable and may use DOT alternative of BB because of vital active ingredient of boron is higher than the BB. The toxicokinetics and toxicological effects of boric acid, disodium tetraborate, boric oxide (B_2O_3) and disodium octaborate tetra hydrate are likely to be similar on a boron equivalents basis (Assessment Report, 20 February 2009 Annex I – the Netherlands). This study will be undertaken to determine the treatment schedule of DOT to increase the service life of wood. Bangladesh Forest Industry Development Corporation (BFIDC) has about 12 lac rubber trees that have lost their life cycle in various plantations from which 1 crore 20 lac cubic feet of rubber wood will be obtained. If these large quantities of wood can be treated with effective preservative DOT, the pressure on natural forests will be reduced on the other hand, it will be economically profitable.

Materials and Methods

The Wood Preservation Division of BFRI carried out the determination of the treatment schedule of DOT treated *H. brasiliensis* wood species. Rubber wood was collected from Shatgaon rubber garden, Sylhet helping by Bangladesh Forest Industries Development Corporation (BFIDC), Kalurghat, Chattogram. The age of the tree was 35 years. Then the logs were sawn and dried planks at a shed of BFIDC, Kalurghat using steam heated killon drier. The average moisture content was 75% when the wood was collected. Three-by-three factorial completely randomized design (CRD) were used for this experiment. Before treatment, wood samples were cut with the

moisture content for treatment. Moisture Content (MC) of treated and untreated rubber wood specimens was determined by an FMC moisture detector. All samples were taken for treatment by applying the pressure method. Measured the weight of specimens before treatment. 10% DOT aqueous solution was used in the pressure method. If the percentage is less than 10%, then retention rate become lower than the standard level. If the percentage is higher than 10%, and then retention rate become higher than the standard level but treatment cost rapidly increase, which is not economically viable. Wood will be treated by water-borne preservatives solution for obtaining required retention and reducing experimental period. 5% boric acid



Figure 1. Untreated rubber wood. A. (2.54 × 5.08 × 50.08cm), B. (7.62 × 10.16 × 20.32cm) and C. (10.16 × 10.16 × 20.32cm)

following three dimensions eg. 2.54cm × 5.08cm × 50.08cm (Fig. 1A), 7.62cm × 10.16cm × 20.32cm (Fig. 1B) and 10.16cm × 10.16cm × 20.32cm (Fig. 1C). The samples were free of knots and showed no visible evidence of infection by mold, stain, or wood-decaying fungi. A total number of 270 wood samples were prepared for the experiment. Then, all specimens were allowed to dry for reducing moisture content up to fiber saturation point (FSP) at 25–30%

and 5% borax aqueous solution were used for rubber wood treatment by pressure method (Akter *et al.* 1994). It will be cost-effective and entrepreneurs can apply the concentration of the solution commercially. For a long time, BFIDC has been using 10% BB solution to treat rubber wood under pressure method. The physical and mechanical properties of wood increase after treatment using 10% CCB aqueous solution (Shanu *et al.* 2015). So that, the solution (10% DOT AS) was selected and used for better result in this study. For the

pressure method, a total number of 81 samples of three sizes were treatment into 10% DOT aqueous solution for 1, 2 and 3 hrs duration and 10, 30 and 50 psi pressure applied (Fig. 2). Then, a total number of 81 samples of three sizes were immersed into 10% DOT aqueous solution (10 kg DOT mixed with 90 liters water) for 1, 2 and 3 hrs duration and 70, 90 and 110 psi pressure was applied. Finally, 81 samples of three sizes were treated by DOT aqueous solution for 1, 2 and 3 hrs duration and 130, 150 and 170 psi pressure was applied. Rests of the untreated 27 samples of three dimensions were kept in the preservation laboratory for service test (Fig. 3). After treatment, all the samples have been taken



Figure 2. Pressure treatment plant at BFRI.

out from the pressure treatment cylinder. Again the samples were dried. Dry samples were cross-sectioned for determination of penetration. Then, solution-1 and solution-2



Figure 3. 10% DOT treated rubber wood samples.

were applied in splits wood samples which reaction with DOT preservatives. The reddish color indicates the penetration of treated samples. Depth intensity of reddish color indicates the penetration range and treatability group of treated samples. Penetration of DOT aqueous solution in rubber wood samples was determined according to the standard test method. Here, 100ml ethanol 10gm. turmeric powder was used for making solution-1. 100ml ethanol, 30ml concentrated hydrochloric acid and 15gm salicylic acid was used for making solution-2. The results revealed that full penetration of the boron component was present in all treated samples. Boron (DOT) component reacted with curcumin and formed a rosocyanine complex which shows the red color in wood (Fig. 4 & Fig. 5) (Sivrikaya *et al.* 2016). Then the absorption and retention of immersed samples were determined by weighing the samples. The treatment of specimens

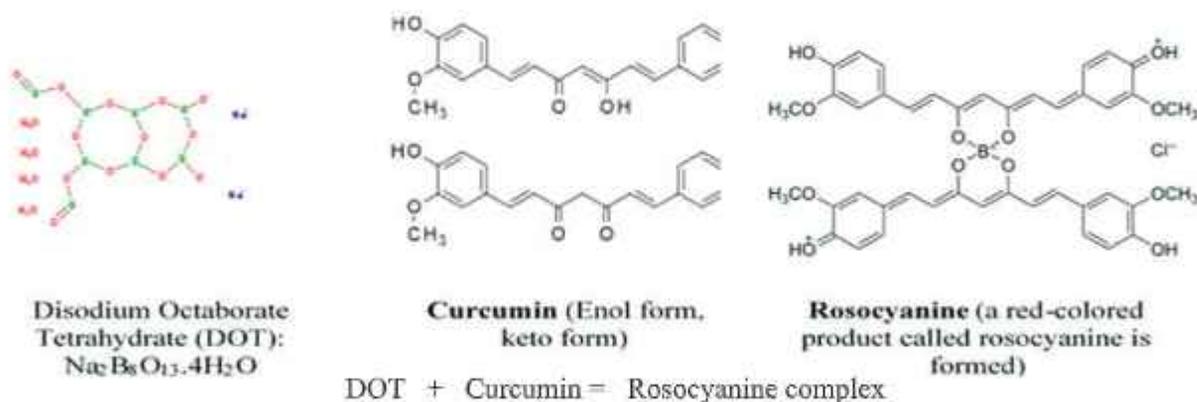


Figure 4. Disodium Octaborate Tetrahydrate reaction with curcumin and form rosocyanine complex.



Figure 5. Penetration of DOT treated wood samples tested by solution 1 and solution 2.

was carried out by traditional vacuum pressure method based on the principles of the full-cell process at the concentration of 10% DOT aqueous solution. The amount of active compound absorbed by the wood sample, also known as chemical retention, was calculated by the following equation. The retention of the treated wood specimens was determined based on the formula given below (Sivrikaya *et al.* 2016):

$$\text{Retention} = \frac{G \times C}{100 \times V} \text{ kg/m}^3$$

Where,

G = Uptake of the preservative solution (kg)

C = Concentration of the solution (%)

V = Volume of the sample (m³)

The numbers of wooden samples were in total 270 including treated and untreated of the three dimensions of this wood species for

indoor exposure. All the specimens were orientated horizontally in the wood preservation laboratory for the determination of service life. Treated and untreated samples were deployed at BFRI campus (22°22'25" N, 91°49'38" E). Finally, the penetration and retention of these specimens were measured.

Statistical analysis

The experiments were carried out in a completely randomized design (CRD) with 3 replications. SPSS statistical software was used for the data analysis. Analysis of variance (ANOVA) and least significant difference (LSD) test were carried out to evaluate the significance of differences among the different retentions of treated specimens.

Results

In this study, three different times and nine pressures have been applied under two parameters. The results of the experiment are presented in three separate tables to avoid the difficulties of showing one table. Retention of DOT in rubber wood was recorded 19.19, 29.51 and 31.43 kg/m³ when 10, 30 and 50 psi pressure was applied for 1 hr; 25.34, 35.72 and 45.41 kg/m³ when 10, 30 and 50 psi pressure applied for 2 hrs and 29.90, 34.27 and 45.90 kg/m³ when 10, 30 and 50 psi pressure applied for 3 hrs respectively (Table 1). Retention of

Table 1. Retention of the preservatives in treated rubber wood applied by pressure method using different times and pressures (10, 30 and 50 psi).

Treatment Period (hrs)	Retention (kg/m ³) of DOT			Remarks
	10 psi	30 psi	50 psi	
1	19.19±2.50	29.51±2.68	31.43±2.41	Full penetration has been found in all specimens
2	25.34±2.71	35.72±2.90	45.41±2.88**	
3	29.90±2.16	34.27±1.11	43.9±2.06	
*F-value	5.69	0.71	1.21	-
p-value	0.14	0.49	0.39	-

*The data is significant for a 5% probability level ($F > p$).

** Maximum retention was found at 45.41 kg/m³ at 2 hrs and 50 psi pressure.

DOT in rubber wood was recorded 33.11, 37.07 and 44.55 kg/m³ when 70, 90 and 110 psi pressure was applied for 1 hr; 35.90, 42.51 and 45.57 kg/m³ when 70, 90 and 110 psi pressure applied for 2 hrs and 37.27, 43.73 and 46.12 kg/m³ when 70, 90 and 110 psi pressure applied for 3 hrs respectively (Table 2). Retention of DOT in rubber wood was

psi pressure. Accordingly, this treatment schedule may be used for wood treatment to protect from rot termite attack. Retention of DOT in Rubber wood was recorded when different pressure applied for 1 hr. The lowest retention was found 19.19 kg/m³ in this species when 10 psi pressure was applied. The rate of retention of DOT was increased rapidly

Table 2. Retention of the preservatives in treated rubber wood applied by pressure method using different times and pressures (70, 90 and 110 psi).

Treatment Period (hrs)	Retention (kg/m ³) of DOT			Remarks
	70 psi	90 psi	110 psi	
1	33.11±0.47	37.07±0.42	44.55±0.09	Full penetration has been found in all specimens
2	35.90±2.45	42.51±2.56	45.57±0.05	
3	37.27±0.74	43.73±0.37	46.12±0.14**	
*F-value	199.47	142.62	4929.741	-
p-value	0.0050	0.0069	0.0002	-

*The data is significant for 5% probability level ($F > p$).

** Maximum retention was found at 46.12 kg/m³ at three 3 hrs and 110 psi pressure.

recorded at 29.51, 32.45 and 37.57 kg/m³ when 130, 150 and 170 psi pressure was applied for 1 hr; 41.62, 31.22 and 36.99 kg/m³ when 130, 150 and 170 psi pressure was applied for 2 hrs and 41.97, 27.98 and 32.62 kg/m³ when 130, 150 and 170 psi pressure applied for 3 hrs respectively (Table 3). The

at the pressure of 10, 30, 50, 70, 90 and 110 psi. But, the retention declined when 130, 150 and 170 psi pressure were applied. Maximum retention was found 44.55 kg/m³ at 1 hr and 110 psi pressure (Fig. 6). Retention of DOT in rubber wood was recorded when the mentionable nine numbers of pressure were

Table 3. Retention of the preservatives in treated rubber wood applied by pressure method using different times and pressures (130, 150 and 170 psi).

Treatment Period (hrs)	Retention (kg/m ³) of DOT			Remarks
	130 psi	150 psi	170 psi	
1	29.51±2.12	32.45±3.30	37.57±2.01	Full penetration have been found in all specimens
2	41.62±1.75	31.22±1.57	36.99±1.60	
3	41.97±1.12**	27.98±4.69	32.62±3.15	
*F-value	126.9321	2007.019	1846.603	-
p-value	0.007786	0.000498	0.000541	-

*The data is significant for 5% probability level ($F > p$).

** Maximum retention was found 41.97 kg/m³ at 3 hrs 130 psi pressure.

findings of the present study prove that penetration and retention level can be maximized the preservatives by applying 110

applied for 2 hrs. The lowest retention was found 25.34 kg/m³ in this species when 10 psi pressure was applied. The retention of DOT

increased rapidly at the pressure of 10, 30 and 50 psi but maximum retention was found at the pressure of 110 psi. Then, the retention declined when the higher pressure (130, 150 and 170 psi) was applied (Fig. 6). The rubber wood of Bangladesh is a medium-density wood which specific Gravity is 0.54 kg/m³ in air dry condition (Sattar *et al.* 1999). 130-170 psi pressure is very much high for this species. This pressure may be suitable for higher density wood. Normally, latex stay in the rubber wood pore. When the higher pressure applies, the hole of the xylem can be rupture. May be, natural rubber (latex) and preservative chemical (DOT) slightly out from specimen's due to high pressure. As a result, the retention of rubber wood declined gradually. Retention of Disodium Octaborate Tetrahydrate in rubber wood was recorded when 9 numbers of pressure applied for 3 hrs (Fig. 6). The lowest retention was found 29.90 kg/m³ in this species when 10 psi pressure was applied. The retention of DOT increased rapidly at the pressure of 10, 30 and 50 psi but maximum retention was found at the pressure of 110 psi. Then, the retention was declined when applied 130, 150 and 170 psi pressure. Maximum retention was found 46.12 kg/m³ at 3 hrs and 110 psi pressure (Fig. 6). Nine (9) different

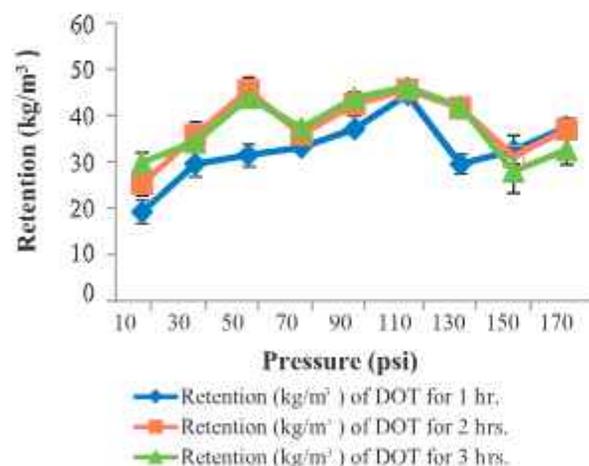


Figure 6. Retention (kg/m³) of DOT in wood samples using the pressure method for 1, 2 and 3 hours.

pressures and three (3) different treatment durations were applied in this experiment. A total number of 27 retentions were present in this investigation. All over the experiment, the highest retention was found 46.12 kg/m³ at 3 hrs and 110 psi pressure (Fig. 6).

Discussion

According to Bangladesh Standard and Testing Institute (BSTI), timbers in direct contact with ground or water, especially in outside locations, such as poles, piles, fence-posts, etc. the required retention for Chromated-Copper-Arsenic (CCA) preservative chemical is 8-16 kg/m³ (Anon 1975). In the present study, maximum retention of DOT was recorded at 46.12 kg/m³ in rubber wood for 110 psi pressure and three hrs time which can be supported with BSTI. According to the BDS code, the required retention of Chromated-Copper-Boron (CCB) is 8-16 kg/m³ (Anon 1975). The end penetration is higher than side penetration for wood (Salam *et al.* 2019). In this study, the retention results at 3 hrs are acceptable with the preservatives. According to the Bangladesh Standards and Testing Institution (BSTI), 46.12 kg/m³ retention of DOT in Rubber wood specimens can meet the objective of the study. Chandra and Gupta (1972) stated that 16 kg/m³ of dry salt were necessary for the effective preservation of the poles in contact with the ground. In the experiment, the minimum retention was found 19.19 kg/m³ which almost matched Chandra and Gupta (1972); the maximum retention was found 46.12 kg/m³ which is over Chandra and Gupta (1972). Untreated rubber wood samples were completely damaged after 8 to 9 months but treated samples are in good condition after 3 years. 0.28 pounds per cubic feet (pcf) Boron, the same retention approved by the Honolulu Building Department for use as a

preservative treatment in Hawaii. This test is very severe in that the test units are located directly on top of active FST (Formosan Subterranean Termite) colonies. It should also be noted that because of the warmer temperatures, the termite pressure in Hawaii is thought to be ~3x as severe as that in Japan, so that a 6 years exposure in Hawaii is considered to be comparable to ca. 18 years exposure at the Japanese test site in Kagoshima Prefecture (Island of Kyushu) (Tsunoda *et al.* 2002). The study reveals that, the maximum retention of DOT was found 46.12 kg/m³ at 3 hrs and 110 psi pressure in rubber wood which is over the standard (8-16 kg/m³) and matched with Chandra and Gupta (1972).

Conclusion

The treatment schedule of DOT is only used for interior wood treatment. Usually, Borax-Boric acid (BB) preservatives are applied for indoor use. So, DOT can be used as an alternative to BB wood preservatives. Subsequently, the DOT can be used commercially also. It is mentionable that untreated rubber wood samples were affected by insects, fungus, etc. within a short time but fully damaged after 8 to 9 months. Till now, the treated samples are in good condition after 3 years in indoor condition.

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Growth and Development of Rattan inside raised Coastal Plantation at Rangabali under Patuakhali District, Bangladesh

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Abstract

The study was conducted in 2017, 2018 and 2019 at Rangabali islands of Patuakhali district of Bangladesh to determine the feasibility and growth performance of *Calamus tenuis* (Jali bet) and *Calamus viminalis* (Kerak bet) inside the *Sonneratia apetala* (Keora) plantation. The mean survival, mean height and total shoot/clump were found 44%, 2.68m and 5.91nos respectively at the age of 3.5 years for *C. tenuis* in the 2017 plantation years. In the 2018 years plantation, the mean survival, mean height, and mean number of total stem/clump were found 86%, 1.35m and 3.93nos respectively for *C. tenuis* and 76%, 0.85m and 1.51nos respectively for *C. viminalis* at the age of 2.5 years. For height and collar girth a significant difference was found between *C. tenuis* and *C. viminalis* (P value is 0.041 and 0.034) at 5% level in the plantation year 2018. At the age of 1.5 years the mean survival, mean height and mean number of total stem/clump were found 87%, 1.35m and 2.77 nos respectively for *C. tenuis* and 84%, 0.84m and 1.51nos respectively for *C. viminalis* in the plantation year 2019. Now shoot initiation was found 100% for *C. tenuis* and 51% for *C. viminalis* at age of 2.5 years. After 1.5 years new shoot initiation was found 100% for *C. tenuis* and 35% for *C. viminalis*. Considering survival, height and shoot production, the *C. tenuis* and *C. viminalis* can be planted inside older *S. apetala* plantation in the west coastal belt of Bangladesh.

সারসংক্ষেপ

কেওড়া বনের অভ্যন্তরে জালি ও কেরাক বেত চাষের সম্ভাব্যতা ও বর্ধনহার নিরূপণের জন্য ২০১৭, ২০১৮ এবং ২০১৯ পর্বত পটুয়াখালী জেলার রাঙ্গাবালী দ্বীপাঞ্চলে গবেষণাটি পরিচালনা করা হয়। ফলাফলে দেখা যায় যে, ২০১৭ সনের জালি বেতের ৩.৫ বছর বয়সি পরীক্ষামূলক বাগানে গড় বাঁচন হার ৪৪%, গড় উচ্চতা ২.৬৮মিটার এবং ঝাড় প্রতি গড় বেতের সংখ্যা ৫.৯১টি পাওয়া যায়। অপরদিকে ২০১৮ খ্রি. উত্তোলিত জালি বেতের ২.৫ বছর বয়সি পরীক্ষামূলক বাগানে গড় বাঁচন হার ৮৬%, গড় উচ্চতা ১.৩৫মিটার এবং ঝাড় প্রতি গড় বেতের সংখ্যা ৩.৯৩টি। অন্যদিকে কেরাক বেতের গড় বাঁচন হার ৭৬%, গড় উচ্চতা ০.৮৫মিটার এবং ঝাড় প্রতি গড় বেতের সংখ্যা ১.৫১টি পাওয়া যায়। ২.৫ বছর বয়সি জালি ও কেরাক বেতের উচ্চতা ও collar girth (P -এর মান ০.০৪১<০.০৫ এবং ০.০৩৪<০.০৫) তাৎপর্যপূর্ণ পার্থক্য পরিলক্ষিত হয়। আবার ২০১৯ খ্রি. উত্তোলিত ১.৫ বছর বয়সি জালি বেতের গড় বাঁচন হার ৮৭%, গড় উচ্চতা ১.৩৫ মিটার এবং ঝাড় প্রতি গড় বেতের সংখ্যা ২.৭৭টি এবং কেরাক বেতের ক্ষেত্রে গড় বাঁচন হার ৮৪%, গড় উচ্চতা ০.৮৪মিটার এবং ঝাড় প্রতি গড় বেতের সংখ্যা ১.৫১টি পাওয়া যায়। জালি বেতের ২.৫ বছর বয়সি পরীক্ষামূলক বাগানে নতুন বেত গজানোর হার শতভাগ ঝাড়ে এবং কেরাক বেতের ৫১% পাওয়া যায়। অন্যদিকে ১.৫ বছর বয়সি পরীক্ষামূলক বাগানে জালি বেতে শতভাগ ঝাড়ে নতুন বেত গজাতে দেখা যায় কিন্তু কেরাক বেতে ৩৫% ঝাড়ে নতুন বেত গজানো পরিলক্ষিত হয়। পরীক্ষামূলক বাগানগুলোর বেতের বাঁচন হার, উচ্চতা এবং নতুন বেত গজানোর হার বিবেচনা করে পশ্চিম উপকূলীয় এলাকার কেওড়া বনের অভ্যন্তরে জালি ও কেরাক বেত চাষ করা বেতে পারে।

Keywords: Coastal raised land, *Calamus tenuis*, *Calamus viminalis*, Growth performance, Stem production.

Introduction

Rattan is thorny and climbing palms belong to the family Arecaceae (Siddiqi *et al.* 2007). This plant is growing in primary rain and monsoon forest as a predominant species and it has a huge range of ecological adaptations, ranging from sea level to over 3000m elevation (Dransfield and Manokaran 1993). It has high economic value in Southeast Asia and considered next to timber and bamboos. Rattan has been utilized commonly for binding, basketry and other domestic purposes. It has also uses for furniture, handicrafts and building materials. Rattans are important source of income and employment for millions of people all over the world (Alam and Haider 2020). There are about 550 species of rattan under 12 genera globally (Dransfield *et al.* 2008). In Bangladesh 15 species of rattans were recorded (Alam 1990; Basu 1991; Ali 2003). Ara (2005) found only 10 species of rattans under two genera. All the species are found to grow naturally in the forests area except *Calamus tenuis* and *Calamus guruba* (Islam *et al.* 2015). In Bangladesh rattans are generally found to grow at the north-eastern hill forests of Sylhet, Chattogram, Cox's Bazar, and Chattogram Hill Tracts. The climate of Bangladesh is very favorable for rattan and sometimes it grows well without any special care (Islam *et al.* 2015).

Calamus tenuis Roxb. is an evergreen climbing palm. It is thin, stem cluster-forming, perennial plant up to 20m long and 2.5cm diameter (Peters and Henderson 2014). Rai and Shukla (2015) reported that *C. tenuis* is a vigorous, climbing prickly palm with slender stems girth size about 3-4cm. that can be 100 meters or more long. In Bangladesh it occurs in plain to foothill slopes, river banks, wet, damp and shady areas (Alam 1990). It grows also at the edge of water and marshy places in village groves and in natural forests

of Bangladesh (Ara 2008). It is considered as multifunctional raw materials for handicrafts and cottage industries due to its flexibility, durability and lightness characteristics (Islam *et al.* 2015). Its fruits and young shoots also edible and some parts are use as an herbal medicine (Ahmed *et al.* 2014; Saikia and Khan 2011). The plant also serves as soil binder; hedge and wildlife habitat (Islam *et al.* 2015). The population of *C. tenuis* is reducing day by day due to habitat destruction, opening of the natural forest, urbanization and over exploitation. Now it is listed amongst threatened species in many forest areas (Rai and Shukla 2015).

Another important rattan species is *C. viminalis* Willd. It is very common and economically important. This species is clustered, climbing or often forming thickets to 35m long and 4cm in diameter (Peters and Henderson 2014). In Bangladesh, it occurs on the dry hill slopes of Chattogram, Cox's Bazar and the Chattogram Hill tract. It is also found in village of the northern districts like Mymensingh, Tangail, Gazipur and Dhaka (Siddiqi *et al.* 2007). It produces a good quality cane used in making basket, furniture and walking sticks. Leaves are used for fencing crop fields in the Chattogram and Cox's Bazar districts and in many other parts of the country (Siddiqi *et al.* 2007). The shrinking of forestry area and over exploitation of wild rattan, the natural population is reducing drastically in Bangladesh. The demand of raw materials is increasing day by day but existing resource of rattan is not enough to meet the present demands. The plantations of rattan in Bangladesh are not enough both in forest and village homesteads (Islam *et al.* 2015). The scientific knowledge of rattan cultivation should be improved to maximize growth and yield. Bangladesh is a pioneer country in

coastal afforestation (Siddiqi and Khan 1990; Spalding 1997). Afforestation program along the coastal belt was initiated in 1966 with the primary objective to protect the lives and properties of coastal communities from the cyclone and tidal surges (Das and Siddiqi 1985). Bangladesh is one of the leading countries of coastal afforestation programs with different mangrove species (Miah and Moula 2020). A total of 0.192 million hectares of accreted land were afforested with mangrove species in the coastal regions till 2013 (Hasan 2013).

Sonneratia apetala Buch.-Ham is the most successful and *Avicennia officinalis* L. is the second most successful planted species of the coastal mangrove plantations (Siddiqi 2001a). The mortality of planted seedlings of this species in the coastal areas is also high (Siddiqi and Das 1988; Miah *et al.* 2014). Huge gaps are created inside *S. apetala* plantations. Most of these areas are now raised with limited inundation ranging from 3 to 5 months only in full moon and new moon periods. As a result these raised lands become unsuitable for the growth of *S. apetala* species. Other mangrove species also do not grow and survive in this situation (Siddiqi 2001b). Islam *et al.* (2014) found seven mainland species are suitable for this raised land. Rattan can also be introduced inside the *S. apetala* plantation to increase the productivity of this vast raised coastal forest. So, a feasibility study for assessing rattan plantation inside the raised older coastal forest was highly desirable. Therefore, the present study was undertaken to assess the survival and growth performance of rattan inside the older *S. apetala* plantation.

Materials and Methods

The Plantation Trial Unit Division (PTUD) of Bangladesh Forest Research Institute carried out an experiment with two rattan species

namely; *C. tenuis* and *C. viminalis* at two locations of the western coastal belt of Bangladesh since 2017 to 2019. Experimental plots were established at Char Kashem and Char Nazir (Char Augasti) of Rangabali Island under the Patuakhali district. Char Kashem lies between latitude 21°54'561 N and longitude 90°27'227 E. Char Nazir lies between latitude 21°58'066 N and longitude 90°30'344 E (GPS=3m) respectively. The mean annual rainfall is 2377mm and mean maximum and minimum temperature is 25.3°C and 12.2°C (BBS 2013). Soil pH was found 6.8 at Char Kashem and 6.1 to 6.8 at Char Nazir. Soil is alluvium, non-calcareous and salinity varies from 1.1 - 9.9dS/m (SRDI 2010). The experimental sites were inundated about 3-5 months. Char Nazir site was fully inundated up to 4 months from July to October in the month of June only in new moon and full moon period. Char Kashem was inundated normally 3 months in new moon and full moon time from July to September. The experimental sites were established inside the older *S. apetala* plantation. The most common propagation method for large scale plantation of rattan by seed. *Calamus tenuis* seeds were collected from previous experimental plots of Rangabali Island and *C. viminalis* seeds were collected from Chattogram. In these experiments seedlings were raised from seeds in the nursery. Phenotypically superior rattan plants were selected and then matured seeds were collected from those trees. Fruits were soaked in water for 48 hours immediately after collection. After soaking fruits were rubbed in water by using wire mesh to remove pulp of fruits. Seeds were then sown in seed bed. The seed bed was prepared by pure Sylhet sands and maintained by regular watering and weeding. Germination was started after 28 days of seed sowing and continued up to 40 days. Seedlings were uprooted carefully from the seed bed and

transplanted to the polybags of size 25cm × 15cm filled with mixed powdered loamy soils and cow dung at 3:1 ratio when the first seedling leaves were fully expanded. Seedlings were then kept under shed for 1 week and then placed on normal nursery beds and maintained for another 3-12 months. The experiment was laid out inside 30 years old *S. apetala* plantations in randomized complete block design (RCBD) with 12 replications. Three months old polybag rattan seedlings were planted in 2018 only and rest of experimental plantation raised by 12 months older seedlings with 2m × 2m spacing in May-June. In each plot 100 (10 × 10) seedlings were planted every year. Three months old seedlings of *C. tenuis* was planted at Char Kashem in 2017. Twelve months old seedlings of *C. tenuis* and *C. viminalis* were planted in 2018 and 2019 respectively at Char Nazir. Data on survival, height, collar girth, number of stems, number of new stems/clump etc. were collected from the experimental plantation at 6 months and 1 year interval up to December 2020.

Statistical analysis

All these data were analyzed using SPSS-version 20.

Results

Survival and growth performance of *C. tenuis* planted in the year 2017 at Char Kashem showed in Table 1. The survivability was

found 81.44 %, 57.83 %, 44.00 % and 44.00% at the age of 0.5, 1.5, 2.5 and 3.5 years respectively. The survivability was found decrease to with the increase of age. The highest mean height and collar girth was recorded 2.68m (Fig. 1) and 4.27cm at the age of 3.5 years. The maximum height and collar girth were recorded 10m and 6.0cm respectively. The mean number of new stems per clump and mean total stem per clump was recorded 3.76 and 5.91 at the age of 3.5 years.

In the plantation year 2018, the mean survivability, mean height, mean collar girth, mean number of new stem and mean number of total stem/clump were found 86%, 1.35m, 2.70cm, 2.28, and 3.93 (Fig. 2) respectively for *C. tenuis* at the age of 2.5 years (Table 2). On the other hand, survivability, mean height, mean collar girth, mean number of new stem and mean number of total stem/clump were found 76%, 0.85m, 4.07cm, 0.51 and 1.51 respectively for *C. viminalis*. For height there is a significant difference between *C. tenuis* and *C. viminalis* (P value is 0.041) at 5% level. In case of collar girth there is a significant difference between *C. viminalis* and *C. tenuis* (P value is 0.034) at 5% level. The height growth of *C. tenuis* is higher than *C. viminalis* and collar girth of *C. viminalis* is higher than *C. tenuis*. But there is no significant difference between *C. tenuis* and *C. viminalis* in relation to survivability, mean number of new stem and mean number of total stem/clump at 5% level.

Table 1. Growth performance of different ages of *C. tenuis* planted in 2017 at the coastal raised land of Rangabali island under Patuakhali district.

Plantation Age (Year)	Survival %	Height (m)	Maximum Height (m)	Collar Girth (cm)	No. of new stems /clump	Total stems/ clump
0.5 year	81.44±0.47	0.28±0.01	0.70	0.00	0.00	1±0.00
1.5 years	57.83±5.15	0.96±0.26	1.49	0.00	0.00	1± 0.00
2.5 years	44.00±1.49	1.42±0.63	3.00	1.85±0.85	1.57±1.15	2.65±1.06
3.5 years	44.00±0.52	2.68±1.62	10.00	4.27±0.73	3.76±1.20	5.91±1.18



Figure 1. Rattan (*C. tenuis*) experimental plantation inside Keora (*S. apetala*) forest planted in 2017 (3.5 years age) at Char Kashem.



Figure 2. Rattan (*C. tenuis*) experimental plantation inside Keora (*S. apetala*) forest planted in 2018 (2.5 years age) at Char Nazir.

At the age of 1.5 years the mean survivability, mean height, mean collar girth, mean number of new stem and mean number of total stem/clump were found 87%, 1.35m (Fig. 3), 2.78cm, 1.73 and 2.77 respectively for *C. tenuis* in the plantation year 2019 (Table 2).

For *C. viminalis* survivability, mean height, mean collar girth, mean number of new stem and mean number of total stem/clump were found 84%, 0.84m, 2.32cm, 0.52, and 1.51 respectively. There is no significant difference between *C. tenuis* and *C. viminalis* in relation to survivability, mean height, mean collar

girth, mean number of new stem and mean number of total stem/clump at the age of 1.5 years. In the plantation year 2018 new shoot initiation was found 100% for *C. tenuis* and 51% for *C. viminalis* at the age of 2.5 years (Fig. 4). After 1.5 years shoot initiation was found 100% for *C. tenuis* and 35% for *C. viminalis* in the plantation year 2019 (Fig. 5).

There is a difference of shoot initiation percentage between the plantation year 2018 and 2019. This is due to seedling age. In 2018, 3 months old seedlings and in 2019, 1 year old seedlings were planted. Shoot initiation percentage of *C. tenuis* is higher than *C. viminalis*.



Figure 3. Rattan (*C. tenuis*) experimental plantation inside Keora (*S. apetala*) forest planted in 2019 (1.5 years age) at Char Nazir.

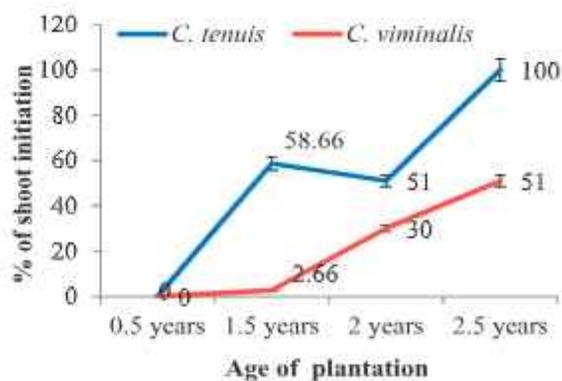


Figure 4. Percentage of new shoot initiation for *C. tenuis* and *C. viminalis* with age of plants in the plantation year 2018.

Table 2. Growth performance of *C. tenuis* and *C. viminalis* planted in 2018 (2.5 years age) and 2019 (1.5 years age) in the coastal raised land of Rangabali island under Patuakhali district.

Plantation year with age	Parameter	Species		T value	P value
		<i>C. tenuis</i>	<i>C. viminalis</i>		
2018 (2.5 years)	Survival%	86.00±3.70	76.00±7.02	2.188	0.951
	Height(m)	1.35±0.45	0.85±0.37	1.293	0.041
	Collar girth(cm)	2.70±0.53	4.07±1.25	-3.114	0.034
	No. of new stems/clump	2.28±0.99	0.51±0.50	9.262	0.090
	Total stems/clump	3.93±1.87	1.51±0.50	9.892	0.075
2019 (1.5 years)	Survival%	87.00±3.88	84.00±8.27	0.681	0.402
	Height(m)	1.35±0.49	0.84±0.12	8.177	0.059
	Collar girth(cm)	2.78±0.46	2.32±0.90	5.715	0.193
	No. of new stems/clump	1.73±0.74	0.52±0.57	31.03	0.219
	Total stems/clump	2.77±0.96	1.51±0.57	24.161	0.329

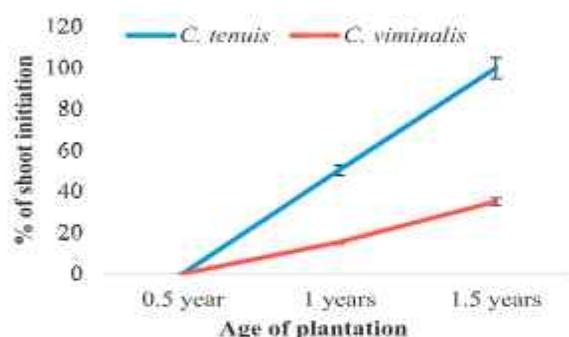


Figure 5. Percentage of new shoot initiation for *C. tenuis* and *C. viminalis* with the age of plants in the year 2019.

Discussion

Rattans are found to grow naturally in the forest except few species. In the present study trials were carried out with two rattan species like *C. tenuis* and *C. viminalis* inside older *S. apetala* plantation in the western coastal belt of Bangladesh. The result of the present study differ higher height growth and lower shoot production with study of Islam *et al.* (2015) for *C. tenuis* may be due to site condition (coastal raised land vs coastal homestead). Islam *et al.* (2015) carried out an experiment of *C. tenuis* at the coastal homesteads of Bangladesh and found an average seedling survival 36.75% and 40.50% at the age of 4.5 years and 3.5 years respectively. Average height, diameter of main

shoot, number of shoot per clump was found 8.0m, 1.40cm and 17.44 nos at the age of 4.5 years. At the age of 3.5 years the average height, diameter of main shoot, number of shoot per clump was found 7.69m, 1.23cm and 9.86nos in the homesteads of four coastal districts. Siddiqi *et al.* (1996) reported 95.6% survival of *C. tenuis* at the age of 6 months after planting in BFRI Campus, Chattogram. They also reported that average height 1.10m and shoot production 3.34 nos for *C. tenuis* at the age of 18 months. Siddiqi *et al.* (2000) found the height of *C. tenuis* 6.5m, 7.7m, 5.0m 7.9m respectively at Sylhet, Chattogram, Dhaka and Tangail districts at the age of 8 years. The shoot production per clump was 33, 23.5, 19 and 18.4nos at Sylhet, Chattogram, Dhaka and Tangail district respectively. The diameter at breast height was found 1.1cm, 1.7cm, 1.3cm and 1.1cm at Sylhet, Chattogram, Dhaka and Tangail district respectively. Rai and Shukla (2015) reported 1.95 m shoot length of planted *C. tenuis* at the age of 2 years in Meerut District of Uttar Pradesh of India. *C. tenuis* showed luxuriant growth with an average height of 8.0 m after 8 years of planting at Dehradun Forest Research Institute Campus, India (Gulati and Sharma 1983). Kuldilok and Boonyuen (2002) found

97.22% survivability for *C. viminalis* after 5 years planted under rubber plantation at Songkhi Silvicultural Research Station, Rattaphum district, Songkhla province of Thailand. They also reported 0.52, 1.70, and 2.99m height at the age of 3, 4 and 5 years respectively. In the present study the height growth of *C. viminalis* is higher and total stem production is lower than the study of Kuldilok and Boonyuen (2002) may be due to different site condition. The number of shoot per clump was recorded 1.77, 3.34 and 5.42nos after 3, 4 and 5 years respectively. Peters and Henderson (2014) found 1.39 m average growth rate per year at the age of 4 years for *C. viminalis* in Vietnam. On the basis of survival, height, collar girth and shoot production, shoot initiation %, the results of present study conducted in 3-5 months of inundated raised land coastal belt of Bangladesh in 2017, 2018 and 2019 showed promising performance of *C. tenuis* and *C. viminalis* species inside the *S. apetala* plantation. However, low seedling survival was found in 2017, due to biotic interference, as the experimental plot was without fencing. The new planted seedlings were damaged and uprooted by cattle, wild boar and bandicoot rat in the plantation year 2017.

Conclusion

C. tenuis and *C. viminalis* is a commercially important species in Bangladesh. The growth performance of these two species is found promising inside older *S. apetala* plantation. *C. tenuis* and *C. viminalis* may be a good species for raising plantation inside the coastal raised *S. apetala* forest. Plantation of these two rattan species may also create an employment opportunity and source of income generation for the rural people of the coastal areas. Therefore, for the development of rattan population and to fill up the gaps of raised coastal keora forest, plantations program with these two rattan species can be initiated inside raised keora forest.

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Physical and Mechanical Properties of Medium Density Fiberboard made from Borak (*Bambusa balcooa*) Bamboo

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Abstract

The global demand for medium density fiberboard (MDF) is rising day by day; as a result industries are facing a shortage of raw material supply. This study was conducted to examine the suitability of MDF boards made from Borak (*Bambusa balcooa*) bamboo fiber. In this experiment, single-layer MDF boards were formed in six different densities at 650, 700, 750, 800, 850 and 900 kg/m³ using urea formaldehyde (UF) resin as the binding agent. The physical characteristics including water absorption and thickness swelling, as well as mechanical properties such as modulus of rupture and internal bond strength of the MDF boards were assessed by the Indian Standard (IS 2380:1977) specification. All the test results were compared with the Indian (IS 12406: 2003), British (BS EN 622-5:2009) and American National Standards Institute (ANSI A208.2-2002) MDF specifications. The fiberboards of 850 kg/m³ density had the highest modulus of rupture and internal bond strength properties compared to other experimental single-layer MDF boards. Since bamboo is a species with a high yield, it has the potential to be a renewable and alternative raw material source for the wood composite industry.

সারসংক্ষেপ

মাঝারি ঘনত্বের ফাইবারবোর্ডের (MDF) বৈশ্বিক চাহিদা দিন দিন বৃদ্ধি পাচ্ছে; ফলে কম্পোজিট শিল্পগুলো কাঁচামাল সরবরাহের ঘাটতির সম্মুখীন

হচ্ছে। বোরাক বাঁশের ফাইবারের সাথে ইউরিয়া ফরমালডিহাইড আঠা ব্যবহার করে মাঝারি ঘনত্ববিশিষ্ট ফাইবারবোর্ডের ব্যবহারিক উপযুক্ততা যাচাই করার উদ্দেশ্যে এই গবেষণাটি পরিচালিত হয়। যেখানে বোরাক বাঁশের ফাইবার ঘনত্ব এক তরবিশিষ্ট ৬টি বিভিন্ন মাঝারি ঘনত্বের (৬৫০, ৭০০, ৭৫০, ৮০০, ৮৫০, ৯০০ কেজি/মি.^৩) ফাইবারবোর্ড তৈরি করা হয়েছিল। পরবর্তীতে তৈরিকৃত মাঝারি ঘনত্বের ফাইবারবোর্ডগুলোর পরীক্ষণীয় নমুনা হতে তাদের ভৌত ও যান্ত্রিক শক্তির মান নির্ণয় করা হয়। বোরাক বাঁশ থেকে তৈরিকৃত ফাইবারবোর্ডগুলোর ভৌত ও যান্ত্রিক বৈশিষ্ট্যাবলী ইন্ডিয়ান স্ট্যান্ডার্ড (IS ২৩৮০: ১৯৭৭) অনুসারে পরীক্ষা করা হয়। গবেষণার অংশ হিসেবে বোর্ডগুলোর মডুলাস অব রাপচার, অভ্যন্তরীণ বন্ধন শক্তি, জল শোষণ ক্ষমতা এবং পুরুত্বের ফ্রিক্তি পরিমাপ করা হয়েছিল। পরে বোর্ডগুলোর উপযুক্ততা যাচাইয়ের জন্য তাদের ভৌত এবং যান্ত্রিক বৈশিষ্ট্যের ফলাফলগুলো ইন্ডিয়ান (IS ১২৪০৬: ২০০৩), ব্রিটিশ (BS EN ৬২২-৫:২০০৯) এবং আমেরিকান (ANSI A208.2-2002) স্ট্যান্ডার্ড এর সাথে তুলনা করা হয়। উচ্চ পরীক্ষায় প্রতীয়মান হয় যে, বোরাক বাঁশের ৮৫০ কেজি/মি.^৩ ঘনত্বের ফাইবারবোর্ডের গুণগত মান তার অন্যান্য মাঝারি ঘনত্বের ফাইবারবোর্ডের গুণগত মানের তুলনায় উন্নত; যেহেতু বাঁশ দ্রুত বর্ধনশীল একটি প্রজাতি, তাই কম্পোজিট শিল্পে এর একটি নবায়নযোগ্য ও বিকল্প কাঁচামালের উপস্থাপন হওয়ার ব্যাপক সম্ভাবনা রয়েছে।

Keywords: *Bambusa balcooa*, Mechanical properties, Medium density fiberboard, Physical properties, Urea formaldehyde.

Introduction

Medium Density Fiberboard (MDF) stands out as a major wood-based panel that is widely

used in the manufacture of various building and housing components, especially furniture units intended for interior applications (Ye *et al.* 2007). The production of all types of fiberboard was enhanced from 2010 to 2014. During this period, fiberboard manufacturing increased by 31%. However, the majority of this expansion was concentrated in MDF manufacturing, which accounted for 81% of the total. Global MDF production has been rising by 6–10% annually since 2010, with China being the main contributor (FAO 2015). The average density of the standard form of MDF ranges between 600 and 900 kg/m³ (IS 12406, 2003). It is a typical production process that involves reducing wood or bamboo into small chips, which are then thermally softened and mechanically refined into fibers, and finally mixed with a synthetic resin binder. The resinated fibers are shaped into a mattress that is prepared for pressing. At last, the mattress is compressed in a hot press machine to the required thickness (Anon 2014). Medium Density Fiberboard is frequently used in furniture applications. It is also used for interior door skins, moldings, flooring substrates, and interior trim components (Cai *et al.* 2006). In Bangladesh, MDF boards are mostly used in furniture applications. Most of them are imported from different countries. A few industries, like Akij Particle Board Mills Limited and MRS Industries Limited produce MDF boards locally, which is much less than the demand.

Bamboo in its natural form is a cylindrical pole, or culm, and is part of the grass family (Sharma *et al.* 2015). Bamboo is the common name for a member of a particular taxonomic group of perennial grass with a large woody stem or culm belonging to the family Poaceae, subfamily Bambusoideae. There are about 1,200 species of bamboo within 50 genera worldwide (Chapman 1996). The major

morphological characteristics of bamboo are divided into the rhizome and the culm system (Zhang *et al.* 2002; Jiang 2007). The culm is the upper-ground part of bamboo that contains most of the woody material. Unlike trees, bamboo has no secondary thickening growth. Depending on the species, bamboo culms take 3–6 years to mature. Thus, bamboo grows faster than other trees of similar size in the world (Alam 2001). Normally, the culm is straight, hollow and cylinder-formed with nodes and internode parts. Bamboo timber production is also rapid, with an average rotation of 4 years compared to the normal 40 years for most wood species. The strength and ductility of bamboo are significantly higher than those of many wood species of similar density (Chen *et al.* 2020). Bamboo is designed to be a particularly useful and better substitute for wood composite products, including fiberboard, veneer board, plyboard, strip board, mat board and particleboard. Wood processing methods, technologies and tools cannot be applied directly to the use of bamboo. Therefore, more research is needed to understand the properties of bamboo, as well as cost-effective technologies and its management. Nowadays, bamboo is receiving more attention from the industrial sector, particularly as a raw material for wood-based composites. As a result, there are many opportunities for researchers in the bamboo-based composite product sector (Chaowana 2013). Urea-formaldehyde (UF) is mostly used as an adhesive in the wood furniture industry around the world (Anon 2009). The annual production of UF is about 20 million metric tons. The forest products sector uses more than 70% of this production for manufacturing laminated board, particleboard, MDF and plywood (Wikipedia 2019).

Urea-formaldehyde glue is cheap, easy to use and can act as a good binding agent for all kinds of woodwork. It is a thermosetting adhesive which forms cross-linked polymers that have high strength, rigidity and long-term static loads without deforming (Frihart and Hunt 2010). If it is possible to make fiberboard from *B. balcooa*, then the shortage of raw materials in the wood-composite sector can be reduced. This is why *B. balcooa* is of interest in this study. Accordingly, this study aimed to measure the physical and mechanical properties of MDF boards made from *B. balcooa* fibers under different density conditions for furniture applications.

Material and Methods

Fiber preparation

About 3-4 years old *B. balcooa* were collected from Chattogram, the southern part of Bangladesh. After that, these were divided into six-eight strips considering their diameter. The strips were then converted into chips with a hammer milling machine (WB6A, Montgomery Ward & Co., USA). The chips were then sieved through a twenty mesh screen to remove dust and fines and dried in a batch oven (GECO Electric Oven, C65H360, Gruenberg Electric Co.) at 70°C temperatures to 4-5% moisture content.

$$\text{Moisture content (\%)} = \frac{\text{Original weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

The chips were cooked at 120°C by steaming for 1 hr under 10 kg/cm² digester pressures in a stainless steel rotary digester and then refined in a single-rotating disk attrition mill for fiber.

MDF board fabrication

Fiberboards were fabricated in six different densities at 650, 700, 750, 800, 850 and 900

kg/m³. Five single-layer medium density fiberboards of each density were prepared in a laboratory hot press machine (160 Ton, Williams-White & Co., USA) using *B. balcooa* fiber. The dimensions of the fiberboards were 50cm × 50cm × 1.2cm having the mentioned target density. The temperature of the platens of the hot press was maintained at 160°C. Liquid UF (50% solid content) glue was used in the fiberboard preparation based on oven-dry fiber. The UF glue was catalyzed with 2% ammonium chloride (NH₄Cl). No water repellent was used in this preparation. Firstly, the mats of the board were formed manually in a wooden-fabricated bordered frame. After that, the mats of the fiberboard were pressed initially for 6 mins. These pressures were then lowered for 4 mins and then for 2 mins. The boards were then conditioned at 65±5% relative humidity and 20±2°C temperature before they were put to tests. The experimental flow diagram is shown in Fig. 1.

Test sample preparation

With five replications, this study was conducted using a completely randomized design (CRD). Fiberboards were cut into various test specimens to determine the modulus of rupture (MOR), internal bond (IB), thickness swelling (TS) and water absorption (WA) values of the fiberboards. The MOR and IB strength tests were carried out according to the specification of IS: 2380 (Anon 1977) with the help of a computerized universal testing machine (TENSON, MWW-10, China). The IB test specimens were adhered to 75mm × 50mm × 25mm wooden blocks with UF resin using a cold pressing. The thickness of the specimens was measured with platform-type thickness gauge with an accuracy of 0.01mm. The specimens

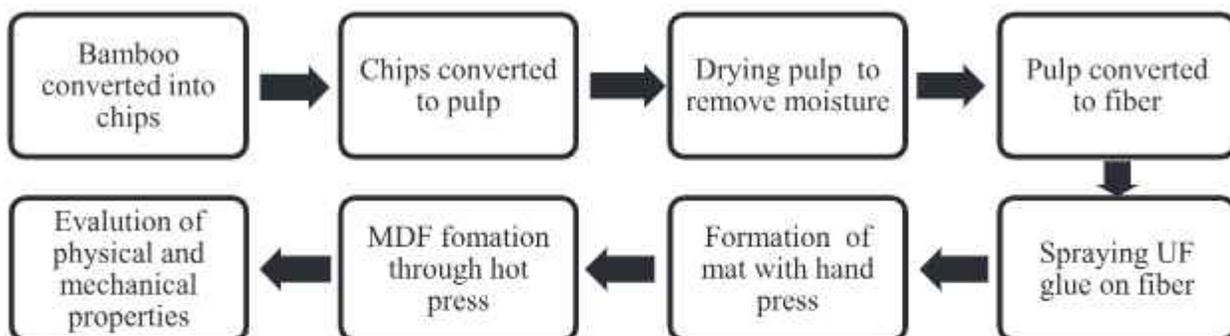


Figure 1. Flow diagram of the experimental process.

Table 1. Three standard specifications for MDF board.

Specification of some standards	Thickness (mm)	Density (kg/m ³)	MOR (kg/cm ²)	IB Strength (kg/cm ²)	% Thickness Swelling (24 hrs)	% Water Absorption (24 hrs)
IS 12406 (Anon 2003)	6-20	600-900	250.00	8.00	7	30
BS EN 622-5 (Anon 2009)	9-12		220.00	6.00	10	NA
ANSI A208.2 (Anon 2002)	6-19		240.00	6.00	15	NA

NA=Not applicable

were immersed in 25mm of water at ambient temperature for 24 hrs. At the end of 24 hrs, the test specimens were withdrawn from the water, wiped with a damp cloth, reweighed and re-measured for thickness as before. The percentages of WA and TS were then calculated. Then the values of the physical and mechanical properties of the MDF boards were compared with Indian (IS 12406: 2003), British (BS EN 622-5:2009) and American National Standards Institute (ANSI) MDF standard (A208.2-2002) to verify their suitability. The standard specifications are given in Table 1.

Statistical analysis

The collected data were analyzed as analysis of variance (ANOVA) to compare statistical differences among the treatments.

Results

The mean values of MOR and IB are given in Table 2 and the mean values of TS and WA properties for 24 hrs are presented in Table 3. The results illustrated that the different densities had significant effects ($p \leq 0.05$) on the MOR, IB, TS and WA properties. From Table 2, it is found that the MOR values of the MDF boards were different for six different densities. MDF boards containing 850 kg/m³ density had the highest MOR value compared to the other densities of fiberboards which fulfilled the British (BS EN 622-5:2009) standard specifications. But in the case of 900 kg/m³, the values of both properties decreased. The mean MOR value was 185 kg/cm² for 900 kg/m³ MDF boards which did not meet the Indian (IS 12406 -2003), British (BS EN 622-5:2009) and ANSI (A208.2-2002) standard specifications (Fig. 2). Measurements

Table 2. Mechanical properties of MDF boards made from *B. balcooa*.

Thickness of fiberboards (mm)	Density of fiberboard (kg/m ³)	MOR (kg/cm ²)	IB strength (kg/cm ²)
12.20	650	75.00 ± 5.21	2.48 ± 0.06
12.30	700	102.00 ± 8.46	3.28 ± 0.08
12.25	750	113.00 ± 4.09	3.88 ± 0.07
12.20	800	195.00 ± 6.35	4.24 ± 0.05
12.22	850	225.00 ± 3.12	6.76 ± 0.02
12.05	900	185.00 ± 7.16	5.92 ± 0.03
F-value		485.02	2302.17
Significant value		1.06E-21	8.06E-33

Note: Mean followed by standard deviation (± SD)

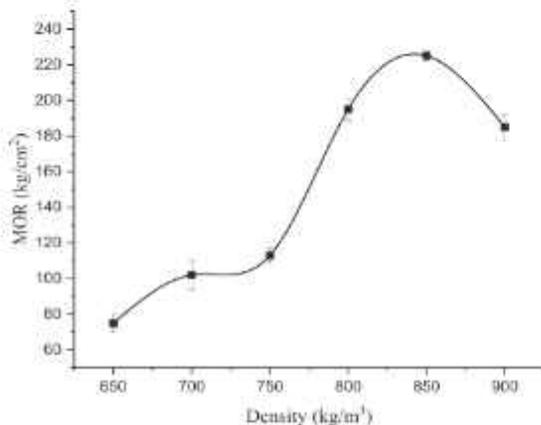


Figure 2. Relationship between the density of MDF boards and modulus of rupture (MOR).

of IB strength properties are presented in Table 2. It is observed that the IB values were different for different densities of fiberboards. Fiberboards containing a density of 850 kg/m³ had the highest IB strength values among all other densities of fiberboards. The value was 6.76 kg/cm² which satisfied both the British Standard (BS EN 622-5:2009) and ANSI (A208.2-2002) specifications. In the cases of 800 and 900 kg/cm² the IB values were lower as compared to 850 kg/cm². The mean values of IB for density 800 and 900 kg/cm² fiberboards were 4.24 and 5.92 kg/cm², respectively (Fig. 3). The TS and WA properties were evaluated for different densities of fiberboards made from bamboo fiber (Table 3). The test samples were soaked under water for 24 hrs, weight and thickness differences were measured for the

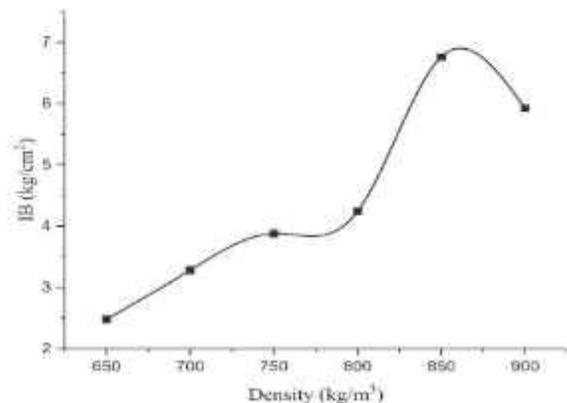


Figure 3. Relationship between the density of MDF boards and internal bond strength (IB).

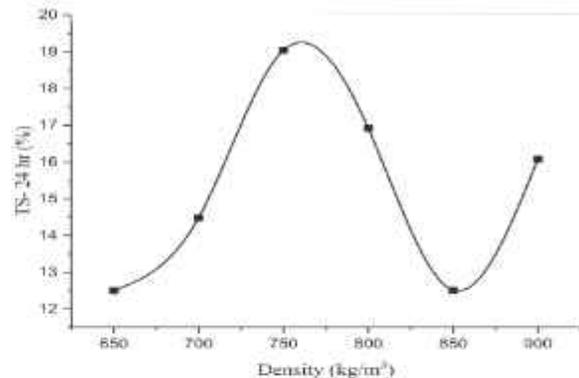


Figure 4. Relationship between the density of MDF boards and thickness swelling (TS) after 24 hours.

determination of TS and WA values (Fig. 4 & Fig. 5). The observed TS values of the different types of fiberboards were 12.02-19.04% after 24 hrs of water soaking. The WA values of the different types of fiberboards made from fiberboards ranged from 59.25 to 92.05% after 24 hrs (Table 3).

Table 3. Physical properties of MDF boards made from *B. balcooa*.

Thickness of fiberboard (mm)	Density of fiberboard (kg/m ³)	Thickness swelling (24 hr)	Water absorption (24 hr)
12.20	650	12.50 ± 0.03	77.82 ± 0.06
12.30	700	14.48 ± 0.05	81.22 ± 0.04
12.25	750	19.04 ± 0.04	92.05 ± 0.05
12.20	800	16.92 ± 0.02	67.82 ± 0.07
12.22	850	12.02 ± 0.03	59.25 ± 0.02
12.05	900	16.08 ± 0.01	64.11 ± 0.03
F-value		1456.45	1660.98
Significant value		1.68E-29	1.89E-30

Note: Mean followed by standard deviation (± SD)

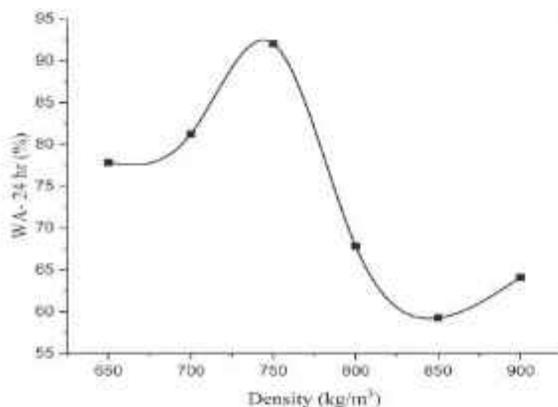


Figure 5. Relationship between the density of MDF boards and water absorption (WA) after 24 hours.

Discussion

According to Kollmann *et al.* (1975), MOR is the most essential mechanical characteristic of composite boards in terms of their use as interior components. After data analysis, there was found that, with the exception of 900 kg/m³, the MOR value increased as the board density increased. However, the extent of this growth was not proportional. Fiberboards containing a density of 850 kg/m³ had the highest MOR values than the other densities of fiberboards. The density of the fiberboards is one of the factors that affect the MOR value. As the MOR value decreases the bond between the boards weakens (Haygreen and Bowyer 1996). The fiberboard with a density of 850 kg/m³ exhibited the highest

MOR values (225.0 kg/cm²) in comparison to other densities. The mean MOR value gradually increases from 650 to 850 kg/m³ densities fiberboard, but it is decreased at 900 kg/m³ density fiberboard as compared to 850 kg/m³. At 900 kg/m³ density fiberboard, may be the silica of bamboo reduced the bonding. It may be there was an interaction between the resin binder and the silica of bamboo. Similar interactions were observed by Marinho *et al.* (2013). They found that the interactions were influenced by several parameters, including the fiber's characteristics (the anatomy of the fiber) and the resin's nature (physical-chemical properties), which lead to better penetration and moistening. This study revealed that the numerical values of IB strength properties differed for different densities of fiberboards. Fiberboards with a density of 850 kg/m³ had the highest IB strength values among the other boards. The mean IB strength value for 850 kg/m³ density fiberboards was 6.76 kg/cm² which met the British and ANSI Standard specifications. From this study it was found that the values of IB strength properties had increased between 600-850 kg/m³ fiberboards, but in the case of 900 kg/m³, the IB values had decreased. The IB strength is an indicator of resin penetration into the internal structure of any composite board. If the resin does not penetrate well, the internal bond in the center of the medium will

be weak and the surfaces will separate easily. The IB test is also used to measure the laminating strength between layers of a composite structure and determine how well they stick to each other (Hutten 2007). The IB strength property gives information about the structure of fiberboards, which ensures a fine adhesive property and dimensional stability of the fiberboard structure. The MOR value of 850 kg/m³ density fiberboard surpassed the requirements of the British Standard (BS EN 622-5:2009) specification. Whereas the IB strength value was above the British (BS EN 622-5:2009) and ANSI Standard (A208.2-2002) specifications, but lower than the Indian Standard (IS 12406:2003) specification. The TS or WA value of fiberboards is one of the basic properties that determine whether the panel will be used in dry or humid situations. When fiberboard is exposed to water contact, wood fibers swell and residual stress that is created during the board pressing process is released, which leads to an increase in the thickness of the panel. The strength characteristics of fiberboard are also reduced by both WA and TS properties. In this study it was observed that the TS and WA values of the fiberboards were not linear. The TS of the panels is related to the amount of WA, so higher WA contributes to higher swelling in thickness. The mean WA value of 850 kg/m³ fiberboard after 24 hrs of soaking was 28.95% lower than that of fiberboards having 800 kg/m³ densities. Moreover, fiberboards with densities of 900 kg/m³ had mean WA values that were 8.20% higher after 24 hrs of soaking than fiberboards with densities of 850 kg/m³. Perhaps there was some kind of interaction between the density of the MDF boards and the silica content of *B. balcooa*, resulting in a reduced thickness swelling as well as water absorption capacity of 850 kg/m³ density boards in comparison to other densities. TS and WA are essential characteristics that determine whether a panel will be used in dry

or wet conditions (Popovska *et al.* 2016). Bamboo fibers swell when fiberboard comes into contact with water, increasing the thickness of the panel. Accidental water exposure will not affect the durability of the panel or its qualities, as household furniture is kept away from water. Fiberboards are commonly used in the interior for household purposes. Household furniture is kept at a safe distance from water, although accidental water exposure will not reduce the durability of the panel and its properties. Kollmann *et al.* (1975) reported that the highest TS after 2 hrs of immersion in water should not exceed 6-10% of the original thickness. However, the addition of suitable additives may improve the properties of the fiberboards. Sihag *et al.* (2017) also found that the board's overall thickness swelling and water absorption were higher than the acceptable values for the Indian Standard specification (IS: 12406). They also stated that these properties of MDF boards could be controlled with appropriate treatment.

Conclusion

Medium Density Fiberboard made from *B. balcooa* with a density of 850 kg/m³ had the highest mechanical strength properties compared to other variants. However, other MDF boards derived from *B. balcooa* remain viable options for furniture materials. In this study, no water repellent was applied, suggesting potential for further improvement. Notably, the utilization of an alternative binding agent to UF could enhance the characteristics of the fiberboards. The exploration of *B. balcooa* as an alternative source of raw material for fiberboard production could contribute to the conservation of forest resources.

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Effect of Pre-sowing Treatment on Seed Germination and Seedling Growth Performance of *Sterculia foetida* L. (Box-badam) in Nursery and Field Conditions

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Abstract

The study investigates the germination behaviour of *Sterculia foetida* (Box-badam) seeds under five different pre-sowing treatments and seedling growth performance in nursery and field conditions. Seeds were i) soaked in tap water for 12 hours, ii) soaked in tap water for 24 hours, iii) soaked in tap water for 36 hours, iv) soaked in tap water for 48 hours and v) control (seeds were sown without any treatment). Growth performances of seedlings were determined by transferring the young seedling (with 4-6 leaves at 30 days) from the germination bed to poly bags filled with soil cow dung mixture (3:1) and out planting in the field at one year of age. Germination percentage was significantly ($P \leq 0.05$) enhanced by pre-sowing treatment in tap water for 36 hours in comparison to other treatments. The survival percentage of seedlings was highest (97%) in the field after 1 year at 2.0m x 2.0m spacing, and the average height was 212.6cm after 2 years of out planting. For the thriving plantation of *S. foetida*, pre-sowing treatment of seeds in tap water for 36 hours was found suitable for nursery rearing and seedlings for out planting at 2.0m x 2.0m spacing in the field.

সারসংক্ষেপ

নার্সারিতে ৫টি বপন-পূর্ব ট্রিটমেন্ট-এর মাধ্যমে *Sterculia foetida*-(বক্সবাদাম) এর বীজের অঙ্কুরোদগম হার পরীক্ষা করা হয় এবং নার্সারি ও মাঠ পর্যায়ে চারার বৃদ্ধি পর্যবেক্ষণ করা হয়। গবেষণায় ৫টি (১২, ২৪, ৩৬ ও ৪৮ ঘণ্টা ট্যাপের পানিতে ভিজিয়ে এবং কন্ট্রোল) ট্রিটমেন্ট প্রয়োগ করা হয়। অঙ্কুরোদগমের ৩০ দিন পরে ৪-৬টি পাতাসমৃদ্ধ চারা বীজতলা থেকে মাটি এবং গোবর (৩:১) ভর্তি পলিব্যাগে স্থানান্তর করে মাঠে ১ বছর বয়সী চারা রোপণ করা হয়। বীজের অঙ্কুরোদগম হার উল্লেখযোগ্যভাবে ($P \leq 0.05$) প্রাক-বপন ট্রিটমেন্ট দ্বারা প্রভাবিত হয়েছে এবং ৩৬ ঘণ্টা ট্যাপের পানিতে ভিজিয়ে বীজ বপন করলে সর্বোচ্চ অঙ্কুরোদগম পাওয়া যায়। মাঠ পর্যায়ে ২.০মি. x ২.০মি. দূরত্বে চারার বাঁচন হার সর্বাধিক (৯৭%) এবং ২ বছর পরে এদের গড় উচ্চতা ২১২.৬ সে.মি. হয়। বক্সবাদাম বীজের ক্ষেত্রে ৩৬ ঘণ্টা ট্যাপের পানিতে ভিজিয়ে বপন করা সর্বোত্তম কৌশল এবং সফল বাগান উল্লেখনের জন্য মাঠ পর্যায়ে ২.০মি. x ২.০মি. দূরত্বে চারা রোপণ করা উপযুক্ত বলে প্রতীক্ষমান হয়।

Keywords: Germination percentage, Growth performance, Pre-sowing treatment, *Sterculia foetida*.

Introduction

From ancient times to the present day, medicinal plants have been utilized as a source of pharmaceuticals for the treatment of a variety of health conditions around the world. Medicinal plants include about 250,000 species of flowering plants. The World Health Organization (WHO) enlisted 21,000 medicinal plant species (Penso 1980). Ghani (2000) reported that about 500 plant species in Bangladesh were identified as medicinal plants because of their therapeutic properties. Yusuf *et al.* (2009) wrote 747 plant species have therapeutic properties. *Sterculia foetida* L. is an important tropical medicinal tree species belonging to the family sterculiaceae, also known as the Java olive wild almond tree. In Bengali, it is known as Box badam, Letpan in Burmese, Vihroi in Hindi, Kepoh in Japanese, Kelumpang in Malay and Wild almond in English. *Sterculia foetida* is a large straight, deciduous tree growing to about 40-45m in height and 1.53m in circumference, with the branches arranged in whorls and spreading horizontally. It is found as a wild plant native to Australia, Southeast Asia, and Africa (Sudrajat 2005). However, *S. foetida* is mainly distributed in Indonesia, Bangladesh, Philippines, Uganda and Somalia (Vipunngeun and Palanuvej 2009; Kale *et al.* 2011). The plant has an average life span of over 100 years (Sudrajat 2005; Munarso 2010).

Typically, the kernel of a seed contains between 50 and 60% bland, light yellow fatty oil (Devan and Mahalakshmi 2009). It was also reported that the oil yield was about 350kg/ha compared to *Pongamia pinnata* 225kg/ha and rubber seed 120kg/ha (Atabani *et al.* 2012). It is found that the emissions are reduced to some extent when using biodiesel (Aliyu *et al.* 2011). Biodiesel as alternative fuel or substitution becomes to replace diesel. Biodiesel production using esterification and trans esterification process

has been proven worldwide as an effective way to reduce the viscosity and acid value of crude oil using refining stages as well as pretreatment procedure (Demirbas 2009; Atadashi *et al.* 2010; Leung *et al.* 2010; Silitonga *et al.* 2011; Atbani *et al.* 2012). Edible oils are obtained from the seed. Seed content is about 34% oil (Ram and Mehrotra 1993; Kirtikar and Basu 1999). The leaves of *S. foetida* are high in protein and phosphorus and can contain up to 2.66% calcium. The kernel meal has 31% crude protein content. The bark is velvety and grey. A cord is formed of fibers from the bark. The timber weighs 449kg/m³ and has a decent finish. It is relatively durable for interior work and used locally for doors of huts, dugout canoes, boat planking, guitars and carved toys etc. Good gum is collected from the trunk and branches, which are used for bookbinding. Bark has considerable medicinal value; seeds are taken as a laxative. Kernels sometime are used to degrade cacao. The tree plays a vital role in various fields, such as backyard planting, boundary markers, coastal protection, erosion control, environment management etc. Nutritional studies have proven one-quarter of the seed to be an oil with a high percentage of proteins (Burkill 1966). *Sterculia foetida* is an important tree species for local populations, forestry, biodiversity, and environment management (Kramer *et al.* 2011). It can play an essential role in the biodiversity conservation of forests. Due to habitat degradation and over exploitation, it has become rare in Bangladesh. Thus it is necessary to revamp the species in the country through a plantation program. A successful planting program depends on using the right nursery and plantation techniques and species management systems. Considering this fact, an effort has been made to study the effect of pre-sowing treatments on seed germination to recommend suitable pre-sowing treatments for *S. foetida*.

Materials and Methods

The study area

The study was conducted over 2 years period, from January 2017 to December 2018 at the nursery of Bangladesh Forest Research Institute (BFRI) in Chattogram, Bangladesh. Geographic position of the study area is situated between 22°22.27" and 22°29.0" North latitude and 91°46.30" and 91°46.30"



Figure 1. Map of Chattogram district in Bangladesh showing *S. foetida* at BFRI and the experimental plantation site of Hinguli forest research station.

East longitudes (Fig. 1). The study region has a tropical climate with hot, humid summers and chilly, dry winters. The maximum and minimum temperature in the area varies from 28.3-31.9°C and from 15.2-25.2°C (Hossain and Arefin 2012). The majority of the rainfall (3000mm) occurs June to September.

Seed collection and growing media

The seeds were collected from healthy mature trees of 30 years old from the Baldha Garden, Dhaka during the last week of February 2016. Seeds were dried in room temperature for 2-3 days and stored at dry and cold place. The collected seeds were sorted out to remove the discolored, damaged seeds. Healthy dried seeds were used for the experiment (Fig. 2). The number of seeds per kilogram was

325-360. The germination trial was carried out by sowing seeds in germination bed filled up with soil mixed with decomposed cow dung at the proportion of 3:1 by volume. Seeds were sown in the seed bed at the depth of 1.5-2.0cm.

Experimental design and pre-sowing treatments

The study employed a completely randomized design (CRD), incorporating three replications. To determine the effect of pre-sowing treatment on seed germination and seedling growth attributes, five different treatments were applied. The treatments were i) control (seeds were sown without any treatment), ii) soaking in tap water for 12 hrs, iii) soaking in tap water for 24 hrs, iv) soaking in tap water for 36 hrs and v) soaking in tap water for 48 hrs. A total of 750 seeds, 50 seeds per replication, were used for the germination trial. The seed trays were kept in nursery shade for a week before being partially exposed to sunlight. When needed, manual watering was done.

Assessment of seed germination and seedling growth performance

The study investigated the impact of pre-sowing treatments on seed germination and seedling growth through the counting of germinated seeds and the evaluation of seedlings initial growth performance. Cumulative germination was recorded in every alternate day of sowing and continued till ending the germination (9 days after sowing the seeds). All of the seedlings were measured above ground (from base to leaf tip) and their number of leaves was counted at one month of age in order to evaluate their growth performance. Ten seedlings from each replication, thus 30 seedlings from each treatment were randomly uprooted and measured for total length (root length and

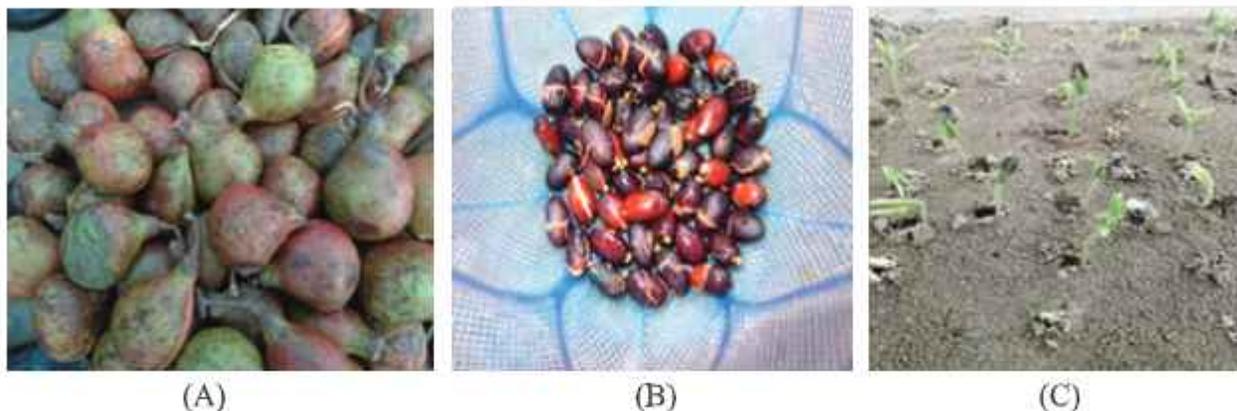


Figure 2. Fruits, seeds and germination stage of *S. foetida* (A), (B) and (C).

shoot length separately) for the assessment. Seedling vigor index (VI) was calculated according to Baki and Anderson (1973) as the germination percentage multiplied by total length of seedlings (i.e. sum of shoot and root length).

Assessment of seedling growth performance in the nursery and field level

To determine the seedlings growth performance in the nursery and the field, healthy seeds were first sown in the nursery bed with soaking in tap water for 36 hrs. When the seedlings were about 30 days old (with 4-6 leaves), they were transferred to the polybags (23cm × 15cm) filled with soil mixed with cow dung (3:1). After a week of complete shade, the polybags were moved into direct sunlight, where they were left to grow. At the start of the monsoon season (June–July), 225 seedlings were planted in the field when they were approximately a year old. Equal numbers of seedlings were allowed to grow in the nursery for 1 year more. These seedlings shoot length, root length, and leaf count was also measured at 3, 6, 12, and 24 months following their transfer into polybags. Seedlings in the field were planted at 2.0m × 2.0m, 2.5m × 2.5m and 3.0m × 3.0m spacing at Hinguli forest research station, Chattogram.

Seventy five (75) seedlings were planted in each replication, thus in three replications total 225 seedlings were planted for treatment. The soil was sandy-loam with a pH 5.7-6.0. Average rainfall of the area was about 3200 mm and average maximum and minimum temperature was 34.7°C and 20.7°C respectively. Weeding was done at every 4 months in first year and at every 6 months in second year in the field. Survival percentage of the planted seedling in the field was determined 1 year after planting and height of each plant were recorded at 6, 12 and 24 months after planting.

Statistical analysis

Data were analyzed with computer software IBM SPSS ver. 21 to determine the significant ($p \leq 0.05$) variations among the treatments. Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) were carried out to analyze the data.

Results

Seed germination

The germination period and germination percentage of *S. foetida* was influenced by different pre-sowing treatments. The seed soaking in tap water for 36 hrs, showed maximum germination (84%) and within

10-18 days after sowing (DAS). Seed soaking in tap water for 12 hrs showed 75% between the periods of 13-21 DAS. Seeds soaking in tap water for 24 hrs showed 77% germination between 11-19 DAS. Seeds soaking in tap water for 48 hrs showed 80% germination between 12-22 DAS. The lowest germination was recorded for control (62%) between 14-22 DAS (Fig.3A & Fig.3B). After being treated with tap water for 36 hrs, the germination percentage of the seeds was significantly ($P<0.05$) higher than that of the other treatments.

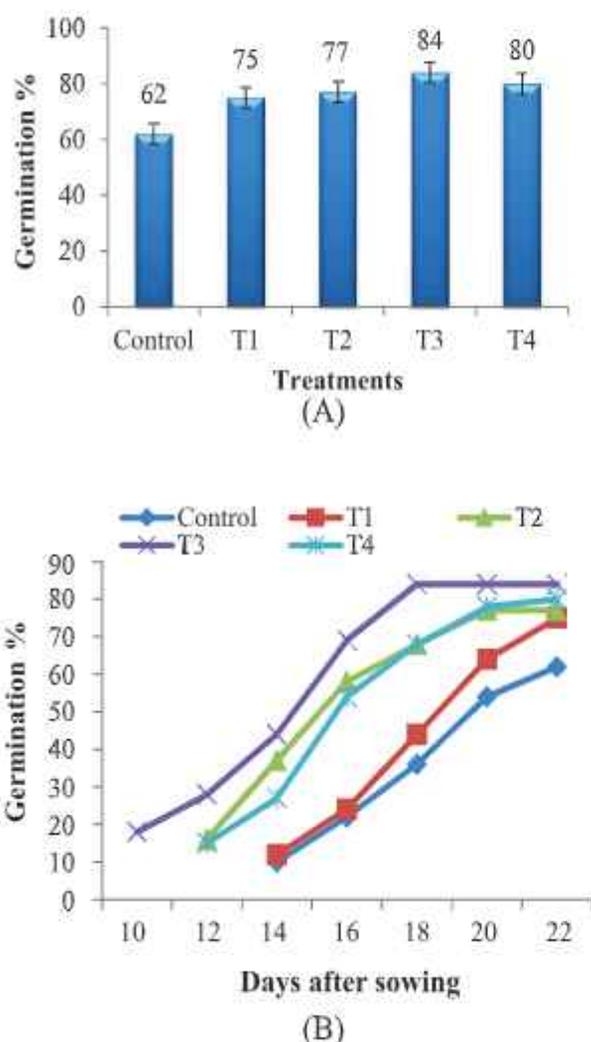


Figure 3. Germination percentage and the germination pattern of *S. foetida* (A) and (B).

Seedling growth performance in nursery condition

The early growth performance of *S. foetida* seedlings was influenced to some extent by pre-sowing treatment. The shoot length, root length, leaf number and vigor index are shown in Table 1. The maximum root length (11.80cm), shoot length (18.90cm), leaf number (5.40) and vigor index (2579) were marked with seeds treated with tap water for 36 hrs followed by seeds soaked in tap water for 48 hrs, seeds soaked in tap water for 24 hrs and seeds soaked in tap water for 12 hrs. The lowest length of root (10.12cm), shoot (18.60cm), leaf number (4.90) and vigor index (1939) were observed for seeds with control. Seeds soaked in tap water for 24 hrs or more showed significantly higher values for root length, shoot length and leaf numbers compared to seeds soaked in tap water for 12 hrs or control. The vigor index of the seedlings in the study was also increased remarkably from 1939 in control to 2579 in the treated seeds soaked in tap water for 36 hrs. The study reveals that there was marginal variation in seedlings length among the treatments but the germination percentage of seeds soaked in tap water for 36 hrs was much higher than the other treatment, which leads to a considerably high vigor index. The initial growth performance of these seedlings including seedling length and vigor index is also higher than those in the other treatments. Therefore, the seedlings developed with the tap water for 36 hrs were used for assessing the seedlings growth performance in the nursery and in the field. Nine hundred (900) seeds were sown in three blocks considering as replication of the nursery bed for the purpose. One month old seedlings having 4-6 leaves were transferred in the 15 × 23cm polybags filled with soils and cow dung (3:1) and allowed them to grow there (Fig. 4).

Table 1. Initial growth performance of *S. foetida* seedlings germinated with different treatments 1 month after germination.

Treatments	Root length (cm)	Shoot length (cm)	No. of leaf (nos.)	Vigor index
Control	10.12±0.25 ^b	18.60±3.42 ^b	4.90±2.10 ^b	1939
Soaked in tap water for 12 hrs	10.18±0.17 ^b	18.80±3.21 ^b	5.00±2.11 ^b	2174
Soaked in tap water for 24 hrs	10.55±0.12 ^a	18.87±2.88 ^a	5.20±1.85 ^{ab}	2280
Soaked in tap water for 36 hrs	11.80±0.19 ^a	18.90±2.65 ^a	5.40±2.22 ^a	2579
Soaked in tap water for 48 hrs	10.60±0.11 ^a	18.85± 2.29 ^a	5.30±2.09 ^a	2356

Note: Treatment values associated with same letters indicates no significant differences among the treatments at ($P \leq 0.05$); \pm indicates standard error of mean.

Following a year of transfer within the polybags, 225 seedlings were out planted in the field (Hinguli forest research station). Rest of the seedlings were grown in the nursery for one more year. The mortality of seedlings in the nursery bed, during and after transferring the seedlings to the polybag was about 2-4% which is very insignificant. Growth variation of seedlings was observed in the nursery in relation to age and the results are presented in Table 2. The seedlings reached to 52.67cm in height after 3 months, with an average root length of 16.27cm and nine leaves. The seedlings reached 98.50cm in height, an average root length of 21.47cm, and eleven leaves in just 6 months. At 1 year, the plant had an average height of 134.55cm, a root diameter of 29.12cm, and 17 leaves. At 24

months, the seedlings had grown to a height of 193.40cm, with a root length of 52.29cm and thirty one leaves.

Seedling survival and growth performance in the field

One year old seedlings of *S. foetida* raised in the polybags were out planted in the field. Survival was recorded at 12 months and seedlings growth performances were determined at 6, 12 and 24 months after planting in the field and shown in Table 3. Survival percentage varied from 94-97% among the treatments at 12 months after planting. The seedlings height varied from 108.7-120.0cm at 6 months, 101.9-155.4cm in 1 year and 166.7-212.6cm in 2 years among the treatments. The height growth of the



Figure 4. Seedlings of *S. foetida* at MFPD nursery at BFRI. (A), one month old (B), 12 months old and (C), 24 months old seedlings.

Table 2. Seedlings growth performance of *S. foetida* at different age (up to 24 months) in the nursery.

Age of seedlings (month)	Survival %	Average length of roots (cm)	Average length of shoot (cm)	Average number of leaves per seedling
3	98	16.27±0.40	52.67±0.90	9±0.70
6	98	21.47±0.11	98.50±0.82	11±0.11
12	96	29.12±0.21	134.55±1.21	17±0.19
24	96	52.29±0.41	193.40±1.49	31±0.39

Table 3. Survival percentage and seedlings growth performances of *S. foetida* in different spacing at Hinguli forest research station after out planting.

Age of seedling (Spacing used)	Survival (%)	Average height (cm)		
		6 months	12 months	24 months
2.0m x 2.0m	97±2.11 ^a	120.0±3.11 ^a	155.4±2.19 ^a	212.6± 2.11 ^a
2.5m x 2.5m	95±4.29 ^b	112.5±2.59 ^b	129.1± 2.01 ^b	179.5± 1.55 ^b
3.0m x 3.0m	94±4.57 ^b	108.7±1.61 ^b	123.9±1.89 ^b	166.7± 1.42 ^b

Note: Means followed by same letters are not significantly different at ($P \leq 0.05$), according to Duncan's Multiple Range Test (DMRT), \pm indicates the standard error of the mean.

seedlings was maximum (212.6cm) in 2m x 2m spacing in 2 years, 179.5cm in 2.5m x 2.5m and minimum (166.7cm) in 3m x 3m spacing (Table 3). The microclimatic conditions between the spacing may be the cause of the variation in the height growth of the seedlings. The survival percentage and height growth of the seedlings in the field were satisfactory in 2m x 2m. Considering the above-mentioned facts and the comparatively less land requirement, 2m x 2m spacing may be considered for planting seedlings in the field.

Discussion

The germination process and seed germination rate can be affected by seed treatments (Azad 2006a; Azad *et al.* 2011; Azad *et al.* 2012). The effect of pre-sowing treatments on seed germination of some tropical forest tree species has been reported by several authors (Ahmed *et al.* 1983; Matin and Rashid 1992; Koirala *et al.* 2000; Khan *et al.* 2001; Alamgir and Hossain 2005; Azad

et al. 2006b; Matin *et al.* 2006; Haider *et al.* 2014; Haider *et al.* 2016). According to Thapa and Gautam (2006) identification of suitable pre-sowing treatments is necessary for quicker and higher seed germination. Soaking the seeds in tap water helps in softening the coats, removal of inhibitors and reduces required time for germination and enhances percentage (Hartman *et al.* 2007). Gupta (2003) reported that overnight soaking of *Rauwolfia serpentina* seeds in cold water offered increased germination (86%) against control (62%). *Acacia catechu* seeds showed better germination (80%) against control (62%) when the seeds were soaked in cold water for 24 hrs (Haider *et al.* 2014). The germination percentage (84%) was almost similar to the previous studies. The findings of the present study are almost identical to those of the earlier research that are discussed here. However, there were significant differences in growth performance observed among the treatments at $p < 0.05$. Similar results were

reported by several authors and mentioned that pre sowing treatments enhance the seed germination and seedling growth performance in the nursery condition. The study reveals that seedlings out planted at 2m x 2m spacing in the field were found suitable for successful plantation raising for *S. foetida*. Similarly, Haider *et al.* (2014) mentioned that *Acacia catechu* seedlings showed satisfactory growth performance when they are planted at 2m x 2m spacing at the age of 6 months in the field. Haider *et al.* (2016) also mentioned that pre-sowing treatment of seeds in hot water (100°C) for 10 sec. for nursery raising and 1 year old seedlings for out planting at 2m x 2m spacing in the field were found suitable for successful plantation of *Sapindus mukorossi*.

Conclusion

The pre-sowing treatments of seed influence the germination percentage under nursery condition. Seeds start germination 9 days after sowing and complete within 10 days. Maximum germination and highest initial growth performance were perceived in seeds treated with tap water for 36 hrs, which was much higher than other treatments. Minimum mortality is ensured by pricking the seedlings from the nursery bed to the polybag 30 days after germination. The survival of the seedlings (97%) and growth performance of the seedlings in the field were satisfactory after out-planting 1 year old seedlings at 2m x 2m spacing. Therefore, pre-sowing treatment of seeds with tap water for 36 hrs is suitable for seedling raising in the nursery and seedlings out planting at 2m x 2m spacing may be suggested for the plantation program.

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Determination of Physical and Mechanical Properties of Gamar (*Gmelina arborea*), Mango (*Mangifera indica*) and Sil koroi (*Albizia procera*) Wood through Heat Treatment

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Abstract

Heat treatment is often used for improving the dimensional stability of wood. In the present study, determination of physical and mechanical properties of Gamar (*Gmelina arborea*), Mango (*Mangifera indica*) and Sil koroi (*Albizia procera*) through heat treatment were examined. Samples were exposed to temperature levels of 110°C, 130°C and 150°C for time durations 3, 6 and 9 hours respectively. Treated samples had higher mechanical properties compared to control samples. Based on the findings in this study, dimensional stability of all types of wood samples improved with heat treatment. It seems that properties of these wood evaluated in this investigation were more pronounced with increasing temperature and time durations.

সারসংক্ষেপ

কাঠের মাত্রিক স্থায়িত্ব উন্নতকরনে যথাযথ তাপ প্রয়োগের প্রভাব রয়েছে। এই গবেষণায়, তাপ প্রয়োগের ফলে গামার (*Gmelina arborea*), আম (*Mangifera indica*) ও শিলকড়ই (*Albizia procera*) কাঠের ভৌত ও যান্ত্রিক গুণাগুণের কিরূপ পরিবর্তন হয়েছিল তা নির্ণয় করা হয়। যথাযথ তাপমাত্রা (১১০ ডিগ্রী সে., ১৩০ ডিগ্রী সে. ও ১৫০ ডিগ্রী সে.) ও নির্দিষ্ট সময় ব্যবধানে (৩, ৬ ও ৯ ঘণ্টা) পর্যবেক্ষণ করা হয়। পর্যবেক্ষণে

দেখা যায় যে, নিয়ন্ত্রিত নমুনার তুলনায় তাপ প্রয়োগকৃত নমুনার যান্ত্রিক গুণাগুণ বেশী ছিল। প্রাপ্ত ফলাফলের উপর ভিত্তি করে দেখা যায়, তাপ প্রয়োগের মাধ্যমে নমুনা কাঠের স্থিতিশীল মাত্রা উন্নত হয়েছে। ক্রমবর্ধমান তাপমাত্রা এবং সময় বুজির সাথে সাথে কাঠের গুণাগুণ বৃদ্ধি পেয়েছে।

Keywords: *Albizia procera*, *Gmelina arborea*, Heat treatment, *Mangifera indica*, Mechanical properties, Physical properties, Temperature.

Introduction

Wood is the fifth most important product of the world trade (Christophe and Gregoire 2001). Due to its poor dimensional stability and low durability under variable atmosphere circumstance, researches on stabilization treatment are carried out to limit the moisture absorption by destroying or, combining the hydroxyl groups of the wood (Yan-jun *et al.* 2002). When wood is heated, its chemical and physical properties undergo permanent changes and its structure is reformed. Heat

treatment is one of the most environmentally friendly alternative processes to modify and improve some properties of wood. Mainly, the industrial process involves wood modification using high temperatures at different levels and with various time intervals- Heat treatment schedule (Boonstra, 2008; Korkut *et al.* 2008; Esteves and Pereira 2009; Baysal *et al.* 2014; Elaieb *et al.* 2015). Several studies have reported on enhanced properties of thermally modified wood such as resistance to fungal attack, equilibrium moisture content, shrinking and swelling. In addition, the color of heat-treated wood adds aesthetic value (Korkut and Hiziroglu 2009; Salca and Hiziroglu 2014). Solid wood is a versatile and renewable material that is widely used in different applications. However, due to the hygroscopic nature of wood it has some undesirable properties such as poor resistance against biological attack of fungi and insects, and swelling and shrinkage caused by water absorption and desorption. These limit the outdoor applications of wood (Kocaefe *et al.* 2007). The most commonly used method of wood preservation is chemical treatment which involves the impregnation of chemical substances such as traditional oil (creosote, pentachloro-phenol) and chromated copper arsenate into the wood. Different preservation methods are sought in order to avoid the toxic effects of these chemicals. Wood treatment at high temperature is a very promising alternative to the chemical treatment (Poncsák *et al.* 2006).

Heat treatment is an effective method to improve the dimensional stability of wood and resistance against bio-degradation. However, there is a noticeable reduction of mechanical properties after heat treatment, mainly due to the high temperatures involved (Esteves and Pereira 2009; Bekhta and Niemz

2003; Korkut 2008). Different methods for thermal modification of wood have been developed in France, Finland, Netherlands and Germany since the middle of the last century. In general, the effects of heat depend on the conditions of the heating process, and temperature is the most important factor to be taken into consideration. The main targets for industrial heat treatment are improved dimensional stability, increased biological durability, enhanced weather resistance and decreased shrinking of changes in the physical and mechanical properties of Iranian Hornbeam wood (*Carpinus betulus*) with heat treatment (Ghalehno and Nazerian 2011). This reduction results in increased dimensional stability (Krause *et al.* 2004), smaller moisture-induced movement in service (Militz and Tjeerdsma 2001) and improved resistance to fungal decay for above ground applications (Farahani *et al.* 2001; Heger *et al.* 2004). It is also held that the environmental credentials of thermally-modified wood (TMW) in terms of ecotoxicity are superior to that of untreated wood and may surpass those of several man-made materials (Van Eetvelde *et al.* 1998). Exposing wood to high temperatures however decreases its strength under various forms of stress (Gonzalez-Pena and Hale 2007). Previously determination of effect of heat treatment on physical and mechanical properties of five tree species. The best way of utilizing heat-treated timber is to make use of these improved properties. Indeed, it is possible to use low cost species for a higher end market. The aim of this study was determination of physical and mechanical properties of Gamar (*G. arborea*), Mango (*M. indica*) and Sil koroï (*A. procera*) through heat treatment.

Materials and Methods

Nine representative trees of Gamar (*G. arborea*), Mango (*M. indica*) and Sil koroi (*A. procera*) species were collected from Dhalupara in Bandarban district (Fig. 1).

Measurement of properties

Small clear specimens were tested, in both green and air-dry states, for the following physical and mechanical properties using the procedure given in ASTM (Anon 1971).

Each treatments group was heated at a given temperature for a given period in a convection oven. The heating period was 110°C, 130°C and 150°C for 3, 6 and 9 hrs respectively. Following heat treatment, all specimens including untreated controls were stacked indoors until the moisture content was about 12-15%. Physical properties like moisture content, specific gravity and volumetric shrinkage, Mechanical properties including modulus of rupture, modulus of elasticity, maximum crushing strength,

$$\text{Moisture content (\%)} = \frac{\text{Original weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

$$\text{Specific gravity} = \frac{\text{Oven dry weight}}{\text{Volume at green or air dry or oven dry condition}}$$

$$\text{Volumetric shrinkage (\%)} = \frac{\text{Green dimension} - \text{Air dry dimension or Oven dry dimension}}{\text{Green dimension}} \times 100$$

1. Physical properties

Three samples per bole were selected randomly from each of the trees consecutive 2.50m bolts above the stump height of each tree. One disk was taken from each bolt for determination of moisture content (MC), specific gravity and shrinkage. The sample size for MC and Specific gravity was 2.54cm × 2.54cm × 5.08cm and for shrinkage was 5.08cm × 5.08cm × 15.24cm.

2. Mechanical properties

For determination of mechanical properties, the bolts were marked into 6.35cm² according to the standard sawing diagram and were sawn to 6.35cm × 6.35cm × 2.50m sticks. The sticks for air-dry test were stacked using suitable stickers inside a drying shed and allowed to attain the equilibrium moisture

compressive strength, hardness and shearing strength of heat treated, samples were determined as per specification of American Society for Testing Materials (ASTM).

(A) Static bending

The size of specimens was 5.08cm × 5.08cm × 76cm is tested on a 71.12cm span with center loading. It furnishes data on bending strength and stiffness for use as beams, joists etc. The parameters of static bending are as follows:

i) Modulus of rupture (MOR)

The modulus of rupture, MOR (eqn. 1) can be found by substituting the maximum load, P1 for the load at the proportional limit.

$$MOR = \frac{3P1l}{2bh^2} \dots\dots\dots (1)$$



Figure 1. Different steps of the determination for physical and mechanical properties of Silkoro wood (A-I).

ii) Modulus of elasticity (MOE)

The modulus of elasticity, MOE (eqn. 2) can be determined and substitution

$$MOE = \frac{Pl^3}{4ybh^3} \dots\dots\dots (2)$$

Where,

- P = Load at the proportional limit
- l = Span of the test specimen
- b = Breadth of the test specimen
- h = Depth of the test specimen
- Pl = Total load and
- y = Deflection at the proportional limit

B) Compression parallel to grain

The size of specimens was 5.08cm × 5.08cm × 20cm. It furnishes data on strength and resistance to deformation when loaded in compression parallel to grain in a short post.

Maximum crushing strength C,

$$C = \frac{P}{A}$$

Where,

- P = The greatest load
- A = Area of cross section of the column

C) Compression perpendicular to grain

The size of specimens was 5.08cm × 5.08cm

× 15cm. It furnishes data necessary in computing the bearing area required at the ends of beams, joists or loads applied over limited area.

Compressive strength,

$$\delta PL = \frac{P}{A}$$

Where,

P = Proportional limit load

A = Area under the bearing plate

D) Hardness

The size of specimens was 5.08cm × 5.08cm × 15cm. It furnishes measure of resistance to indentation and wears which is useful in selecting species for flooring, trim, etc.

Statistical analysis

The average values of various strength properties including standard deviation in control, 110°C, 130°C and 150°C and 3, 6 and 9 hrs conditions were analyzed. For all

parameters, all multiple comparisons were first subjected to an analysis of variance (ANOVA) and significant differences between mean values of control and treated samples.

Results

Physical properties

The average values of physical properties such as moisture content, specific gravity and volumetric shrinkage of Gamar (*G. arborea*), Mango (*M. indica*) and Sil koroi (*A. procera*) wood were evaluated and presented in Table 1. The average values of physical properties including standard deviation in both control, during heat treatment at 3 different temperatures (110°C, 130°C and 150°C) and durations (3, 6 and 9 hrs) were observed. According to the average values of maximum parameters increased with increasing temperature. In some cases, these values were decreased with increasing temperature in treated samples than in control samples.

Table 1. Specific gravity and volumetric shrinkage of Gamar, Mango and Silkoroi (14% M.C).

Species	Temp. (°C)**	Time (hrs)*	Specific gravity	Volumetric shrinkage (%)	
Gamar	Control	0	0.53****± 0.026*****	5.62***±0.49*****	
		110°C	3	0.55 ± 0.017	4.56± 0.23
			6	0.53 ± 0.017	5.43± 0.46
	9		0.52± 0.043	4.75± 0.29	
	130°C	3	0.54± 0.015	4.06± 0.20	
		6	0.52± 0.012	4.03± 0.19	
		9	0.53± 0.011	4.63± 0.27	
	150°C	3	0.56± 0.024	4.83± 0.32	
		6	0.54 ± 0.027	4.31± 0.22	
		9	0.53± 0.038	4.03± 0.19	
	Mango	Control	0	0.59± 0.025	8.22± 0.97
			110°C	3	0.59± 0.015
6				0.57± 0.038	8.61± 1.03
9		0.56± 0.025		9.03± 1.05	
130°C		3	0.59± 0.016	7.63± 0.82	
		6	0.60± 0.036	7.03± 0.79	
		9	0.60± 0.056	8.37± 1.03	
150°C		3	0.57± 0.042	7.21± 0.76	
		6	0.57± 0.038	8.19± 0.93	
		9	0.55± 0.028	8.02± 0.92	

Species	Temp. (°C)**	Time (hrs)*	Specific gravity	Volumetric shrinkage (%)	
Silkoro	Control	0	0.66± 0.017	4.00± 0.23	
		110°C	3	0.66± 0.013	4.46± 0.25
			6	0.67± 0.022	5.06± 0.39
	9		0.66± 0.019	5.01± 0.27	
	130°C	3	0.69± 0.016	6.5± 0.35	
		6	0.68± 0.013	4.85± 0.32	
		9	0.67± 0.035	5.12± 0.31	
	150°C	3	0.68± 0.012	4.97± 0.29	
		6	0.64± 0.027	4.17± 0.22	
		9	0.61± 0.025	6.13± 0.34	

Note: *hrs=hours. ** Temp = Temperature. *** Avg = Average, ****± SD (Standard deviation). The mean difference is significant at the 0.05 level.

Mechanical properties

The average values of mechanical properties such as static bending in MOR and MOE, compression parallel to grain in maximum crushing strength, compression perpendicular to grain in compressive strength, hardness values of surface Side and End and shearing strength of radial and tangential values of Gamar, Mango and Sil koro wood were evaluated and displayed in Table 2 & Table 3.

The average values of strength properties including standard deviation in both controls, during heat treatment at three different temperatures (110°C, 130°C and 150°C) and durations (3, 6 and 9 hrs) were supplemented. According to the average values of maximum parameters increased with increasing temperature. In some cases, the results showed that these values were decreased with increasing temperature in treated samples than in control samples.

Table 2. Static bending, Crushing strength and Compressive strength of Gamar, Mango and Silkoro.

Species	Temp. (°C) **	Time (hrs) *	Static bending (kg/cm ²)		Max.crushing strength (kg/cm ²)	Compressive strength (kg/cm ²)	
			MOR	MOE			
Gamar	Control	0	***658± ****21	***76± **** 5.68	***229± **** 30	***81± **** 5.74	
		110°C	3	577± 28	79 ± 5.50	247 ± 8.50	64± 3.00
			6	582± 23	74 ± 4.34	265 ± 43.2	86 ± 8.54
	9		705± 19.5	82 ± 7.21	287 ± 19.6	82 ± 16.17	
	130°C	3	623 ± 56	83± 2.36	256± 17.2	74 ± 22.5	
		6	560 ± 97	71± 11.3	276 ± 31	80± 15.0	
		9	704 ± 63	82 ± 3.06	305± 52	97± 24.3	
	150°C	3	667 ± 76	87 ± 4.00	262± 42	96± 22.5	
		6	711± 41.7	82± 2.30	279 ± 40	84 ± 21.0	
		9	793 ± 56	92± 12.4	307± 49.4	110± 14.4	
	Mango	Control	0	632 ± 31	79 ± 8.18	325± 7.35	87± 12
			3	671 ± 46	68± 7.6	323± 18.0	127±6.35
110°C		6	591 ± 117	79± 8.38	279± 24.0	107± 12	
		9	621 ± 91	75± 16.0	290 ± 21.6	93± 9.07	

Species	Temp. (°C) **	Time (hrs) *	Static bending (kg/cm ²)		Max.crushing strength (kg/cm ²)	Compressive strength (kg/cm ²)
			MOR	MOE		
	130°C	3	769 ± 56	80± 10.0	345 ± 35.3	113 ± 17
		6	757± 49	68± 8.0	280 ±33	103± 24
		9	817± 53	73± 9.7	341± 53.7	116 ±6.00
	150°C	3	486 ± 139	68± 14.0	354 ± 47	114 ±11.3
		6	726 ± 91	74 ± 4.16	390± 51.4	124±19.5
		9	703 ± 77	68 ± 3.05	427± 50	110 ±7.37
Silkoroi	Control	0	689± 98	96± 19	413±24	133 ±11.0
	110°C	3	714± 40	120±28.5	433± 25.4	183± 16
		6	898 ± 52	129± 13	470± 96.7	172± 42
		9	941± 66	132±22.5	431± 38	168±32
	130°C	3	831 ± 20	109±3.51	405 ±17.5	152± 21
		6	732± 45	85±29	495 ±98.6	204 ± 33.4
		9	972± 79	105± 31	428 ±10.4	139± 26
	150°C	3	800± 86	134 ±9.0	493± 31.5	160 ± 28.5
		6	861± 119	117± 23	501± 40.26	188± 31
		9	1052± 151	123 ± 15	593 ±108	148±21

Note: *=hours. ** = Temperature. ***= Average ****=SD.

Table 3. Shearing strength and Hardness of Gamar, Mango and Sil koroi wood.

Species	Temp. (°C) **	Time (hrs) *	Shearing strength (kg/cm ²)		Hardness (Kg)	
			Radial	Tangential	Side	End
Gamar	Control	0	***85±	*** 100±	***271±	*** 307±
			**** 5.49	**** 12.3	**** 23	****27.5
		3	85±5.51	87 ±10.4	230±22.9	262±7.63
	110°C	6	84±9.45	92 ± 11.0	288±10.9	313±18.0
		9	73± 6.83	65 ± 6.24	287±17.7	295±16.6
		3	103± 8.72	114 ±21.5	275±26.8	340±28.3
	130°C	6	93 ±15.0	115±23	239±15.6	267±18.3
		9	113± 1.73	125 ±7.0	200±13.6	292±24.3
		3	87 ± 11.1	100± 14.0	265±24.7	287±7.07
	150°C	6	69± 6.36	89± 7.93	323±21.9	371±23.6
		9	82± 4.58	94 ± 4.16	284±9.89	314±24.4
		Control	0	110±3.54	118±10.27	286±6.37
Mango	110°C	3	129± 4.24	134 ± 10.6	298±22.8	363±35.3
		6	127±7.78	108± 9.19	309±12.7	370±13.6
		9	134 ±16.3	114± 7.80	312±6.35	388±18.4
	130°C	3	113 ±2.83	120± 3.54	311±13.8	370±17.8
		6	155 ±3.54	137± 11.3	370±21.0	337±20.5
		9	159±14	143±7.81	373±23.8	400±7.57
	150°C	3	113±11.5	125 ± 14.7	323±11.3	429±19.0
		6	134± 2.52	118±13.27	367±14.4	440±10.4
		9	139±18.7	132± 13.1	370±5.6	422±7.35

Species	Temp. (°C) **	Time (hrs) *	Shearing strength (kg/cm ²)		Hardness (Kg)		
			Radial	Tangential	Side	End	
Sil koroi	Control	0	131± 7.43	124± 6.23	465±28.6	563±56	
		110°C	3	159±4.24	123 ±10.6	346±48	426±41
			6	185±7.78	165±9.19	433±5.64	491±7.78
	130°C	9	175±16.3	169± 7.80	397±33	450±12.3	
		3	153± 2.83	149± 3.54	363±36	477±34.3	
		6	152± 10.4	125± 15.8	529±17.42	623±11.7	
	150°C	9	192± 10.4	210±6.65	480±13.4	565±18.5	
		3	158± 13.5	149 ±10.5	418±16.27	433±17.0	
		6	160± 11.3	163± 12.3	439±22.4	558±18.3	
		9	163± 11.9	174±22.4	644±7.78	729±9.34	

Note: *=hours. ** = Temperature. ***= Average ****=SD.

Gamar (*Gmelina arborea*)

In the case of Gamar, the results showed that the specific gravity of Gamar at 110°C, 130°C and 150°C temperatures was higher at 3 hrs than 6 and 9 hrs. The highest decreases were 0.52 at 110°C for 9 hrs and increases were 0.56 at 150°C for 3 hrs. According to the results obtained, the lowest and highest decrease in volumetric shrinkage occurred for treatments at 130°C and 150°C for 3 hrs. The volumetric shrinkage values were decreased with increasing temperature and heat treatment time (Table 1). The results showed that the mechanical properties of the specimens exposed to heat treatment (Table 2). The average values of modulus of rupture at 150°C temperature was higher for 9 hrs than 3 and 6 hrs than both at 110°C and 130°C temperature. The modulus of rupture at 150°C the bending strength at maximum heat treatment temperature is in wood treated at 150°C for 9 hrs is 793 kg/cm². The modulus of elasticity at 150°C temperature was higher than both 110°C and 130°C temperatures. The highest value of modulus of elasticity 92 kg/cm² at temperature 150°C for 9 hrs whereas the lowest value of 71 kg/cm² at temperature 130°C for 6 hrs. The higher value of compressive strength 110 kg/cm² at

temperature 150°C for 9 hrs whereas the lower value of compressive strength 64 kg/cm² at temperature 110°C for 3 hrs. The lower value of maximum crushing strength was 229 kg/cm² in control whereas the higher value was 307 kg/cm² at temperature 150°C for 9 hrs. The higher value of shearing strength (radial) 113 kg/cm² were exhibited at temperature 130°C for 9 hrs whereas the lower value of shearing strength (radial) 69 kg/cm² were showed at temperature 150°C for 6 hrs. The higher value of shearing strength (tangential) 125 kg/cm² at temperature 130°C for 9 hrs whereas the lower value of shearing strength (tangential) 65 kg/cm² at temperature 110°C for 9 hrs. The higher value of hardness (Side) was 323 kg; End 371 kg at temperature 150°C for 6 hrs whereas the lower value of hardness (Side) 200 kg; End 262 kg at temperature 130°C for 9 hrs and 110°C for 3 hrs (Table 3).

Mango (*Mangifera indica*)

The results of this study showed that the average specific gravity and volumetric shrinkage values of control samples were determined to be 0.59 and 8.22(%). The smallest decrease was observed in the treatments at 130°C for 6 hrs. The highest

decreases were 0.55 at 150°C for 9 hrs and increases were 0.60 at 130°C for 9 hrs (Table 1). The average values of MOR at temperature 130°C for 9 hrs was higher than both temperatures 110°C and 150°C. The highest value of MOR 817 kg/cm², 769 kg/cm² at temperature 130°C for 3 hrs whereas the lowest value of 591 kg/cm² were found at temperature 110°C for 6 hrs. Data also indicated that the MOE value was higher at temperature 130°C than both 150°C and 110°C. The highest value of MOE 80 kg/cm² were observed at temperature 130°C for 3 hrs whereas the lowest value of 68 kg/cm² at temperature 150°C for 9 hrs. The higher value of maximum crushing strength was 427 kg/cm² at temperature 150°C for 9 hrs whereas the lower value was 279 kg/cm² at temperature 110°C for 6 hrs. The higher value of compressive strength 124 kg/cm² at temperature 150°C for 6 hrs whereas the lower value of compressive strength 87 kg/cm² in control (Table 2). The data indicated that the higher value of shearing strength (radial) 159 kg/cm² was at temperature 130°C for 9 hrs whereas the lower value of shearing strength 110 kg/cm² in control. On the other side, the higher value of shearing strength (tangential) 143 kg/cm² were showed at temperature 130°C for 9 hrs whereas the lower value of shearing strength (tangential) 108 kg/cm² at temperature 110°C for 6 hrs at temperature 110°C for 6 hrs whereas the higher value of shearing strength (radial) 166 kg/cm² at temperature 130°C for 6 hrs. The higher value of hardness (Side) 373 kg was displayed at temperature 130°C for 9 hrs and hardness (End) 440 kg was at temperature 150°C for 6 hrs whereas the lower value of hardness (Side) 286 kg was in control and hardness (End) was 337 kg at temperature 130°C for 6 hrs (Table 3).

Silkoroi (*Albizia procera*)

The test results revealed that the average specific gravity of Silkoroi wood at 110°C, 130°C and 150°C temperature was higher for 3 hrs than 6 and 9 hrs. The lowest decrease was observed in the treatments at 130°C for 3 hrs. The highest decreases were 0.61 at 150°C for 9 hrs and increases were 0.69 at 130°C for 3 hrs. According to the results obtained, the lowest and highest increased in volumetric shrinkage occurred for treatments at 130°C and 110°C for 3 hrs. The volumetric shrinkage values were decreased with increasing temperature and heat treatment time (Table 1). The average values of MOR at 150°C and 130°C temperature was higher 9 hrs than both 3 and 6 hrs at 110°C temperature. The highest values of MOR 1052 kg/cm², 972 kg/cm² at temperature 150°C and 130°C for 9 hrs than 6 and 3 hrs whereas the lowest value of 689 kg/cm² in control. The MOE value at 150°C temperature was higher than both 130°C and 110°C temperature. The highest value of MOE 134 kg/cm² at temperature 150°C for 3 hrs whereas the lowest value of 85 kg/cm² at temperature 130°C for 6 hrs. The higher value of maximum crushing 593 kg/cm² was found at temperature 150°C for 9 hrs whereas the lower value was 405 kg/cm² at temperature 130°C for 3 hrs. The higher value of compressive strength 204 kg/cm² was revealed at temperature 130°C for 6 hrs whereas the lower value of compressive strength 133 kg/cm² in control (Table 2). The lower value of shearing strength (radial) 131 kg/cm² were displayed in control at temperature 130°C for 6 hrs whereas the higher value of shearing strength (radial) 192 kg/cm² at temperature 130°C for 9 hrs. The higher value of hardness (Side) 644 kg; End 729 kg were found at temperature 150°C for 9 hrs whereas the lower value of hardness

(Side) 346 kg; End 426 kg at temperature 110°C for 3 hrs. The maximum strength values were increased with increasing in temperature and heat treatment time except shearing strength (Table 3).

Discussion

Ghalehno and Nazerian (2011) reported that the bending strength for *Carpinus betulus* wood was 933 kg/cm² at temperature 130°C for 9 hrs is higher than Gamar and 150°C for 9 hrs is lower than Silkoroi. After heat modification, the hornbeam wood acquires a color that simulate some tropical species the main targets for industrial heat treatment are improved dimensional stability, increased biological durability, enhanced weather resistance and decreased shrinking. Kaygin *et al.* (2009) reported that physical properties of *Paulownia elongata* wood improved with increasing treatment temperatures and durations, the specific gravity of lowest values obtained was 0.278 at the treatment of 200°C for 7 hrs whereas the highest values was also obtained 0.32 for samples treated at 160°C for 3 hrs. Gündüz *et al.* (2008) reported that, when wood has been treated at high temperatures and long durations, it is recommended that such wood not be used structurally for load-bearing purposes. Farahani *et al.* (2001) reported that heat treatment is improved resistance to fungal decay for above ground applications. Poncsák *et al.* (2006) reported that heat treated birch and showed a reduction of bending strength (MOR) with increasing heat treatment temperature especially above 200°C. Moreover, modified wood is much cheaper and does not require additional surface finishing and impregnation with protective substances and can be used for floor covering, garden furniture and decor, the arrangement

of terraces, playground etc. Rokeya *et al.* (2021) reported that, physical properties of Acacia hybrid wood improved with increasing treatment temperatures and durations, the specific gravity of lowest values obtained was 0.57 at the treatment of 110°C for 9 hrs whereas highest values was also obtained 0.62 for samples treated at 150°C for 6 hrs. The average values of MOR at 150°C temperature was higher 6 and 9 hrs than both at 110°C and 130°C temperature. The highest value of MOR 1128 kg/cm², 1120 kg/cm² was exhibited at temperature 150°C for 6 and 9 hrs whereas the lowest value of 742 kg/cm² in control.

Conclusion

Treated wood has its own properties which are not comparable to that one of untreated wood. In this research, strength values of the samples of Gamar, Mango and Sil koroi wood increased with increasing time and temperature treatments. The smallest decrease was observed at the thermal treatment of 110°C for 3 hrs. The maximum increase of all properties was observed when samples were treated with a temperature of 150°C for 9 hrs, the increase in strength values when evaluating the effectiveness of using this treatment. In some cases, it is shown that the strength properties decrease with increasing temperature and time duration.

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Effects of Storage Time and Shade on Seed Germination and Early Seedling Growth of Agar (*Aquilaria malaccensis* Lamk.)

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Abstract

Nursery trials were conducted to examine the effects of storage time (days) and shade on agar (*Aquilaria malaccensis* Lamk.) seed germination and seedling growth. Three levels of shade were applied, e.g. full shade, partial shade, and no shade. Seed sowing was followed by a 35-days monitoring period to observe the germination process, culminating in the final germination stage. Maximum germination (92%) was obtained with fresh seeds followed by 39.6% at 5 days and 4% after 10 days of stored seeds. There is no germination of seeds after 15 days stored seeds. The shade tolerance capacity of agar seeds was assessed during germination by partial shade and full shade as compared to control treatments (No shade). Maximum germination (78%) was obtained under full shade (Double layer mesh cloth) in comparison to single layer mesh cloth shade and control (75% and 63.8% respectively). The significant correlation ($p < 0.05$) was observed between seed moisture content and seeds germination percentage. The growth parameters like plumule; radical length; plant height and leaf area were also higher under full shade. Direct light as well as storage of seeds even for few days reduce seed germination and seedling growth considerably stressing factors for regeneration of agar in the field. These findings may be useful for raising seedlings at large scale for *Aquilaria* plantation programmes.

সারসংক্ষেপ

আগর বীজের অঙ্কুরোদগম এবং চারার বৃদ্ধিতে স্টোরেজ পিরিয়ড এবং ছায়ার প্রভাব পরীক্ষা করার জন্য নার্সারি ট্রায়ালগুলো পরিচালিত হয়েছিল। এতে ছায়ার তিনটি স্তর প্রয়োগ করা হয়েছিল যথা পূর্ণমাত্রার ছায়া, আংশিক ছায়া এবং ছায়াহীন স্তর। বীজ বপনের পরে অঙ্কুরোদগম প্রক্রিয়া পর্যবেক্ষণের জন্য ৩৫ দিনের পর্যবেক্ষণ সময়কাল ছিল, যা দুডাত অঙ্কুরোদগমের পর্যায়ে শেষ হয়। ত্রৈশ বীজ বপন করে সর্বাধিক অঙ্কুরোদগম ৯২% এবং ৫ দিন সংরক্ষিত বীজ বপন করে ৩৯.৬% ও ১০ দিনে ৪% বীজের অঙ্কুরোদগম পাওয়া গিয়েছিল। ১৫ দিন সংরক্ষিত বীজ বপন করে কোন অঙ্কুরোদগম পাওয়া যায়নি। অপরদিকে আগর বীজের ছায়া সহনশীল ক্ষমতা পরীক্ষা করার জন্য কম্বইলের (ছায়াহীন) সাথে আংশিক ছায়া এবং পূর্ণমাত্রার ছায়া ছাড়া অঙ্কুরোদগমের সময় মূল্যায়ন করা হয়েছিল। আংশিক ছায়া এবং ছায়াহীন ট্রেটমেন্টের (যথাক্রমে ৭৫% এবং ৬৩.৮%) তুলনায় পূর্ণমাত্রার ছায়ায় (ডাবল লেয়ার জাল কাপড়) সর্বোচ্চ অঙ্কুরোদগম ৭৮% পাওয়া গিয়েছিল। বীজের আর্দ্রতা এবং বীজের অঙ্কুরোদগমের পড়াংশের মধ্যে উল্লেখযোগ্য পারস্পরিক সম্পর্ক ($p < 0.05$) পরিলক্ষিত হয়েছে। তাছাড়া পূর্ণমাত্রার ছায়ার ছাড়া উৎপন্ন চারার প্রমিউল, ভগ্নমূলের দৈর্ঘ্য, চারার উচ্চতা এবং পাতার আয়তনও অধিক পাওয়া গিয়েছিল। প্রত্যেক আলোর পাশাপাশি কয়েক দিনের জন্য বীজ সংরক্ষণ করলে বীজের অঙ্কুরোদগম এবং চারা গজানোর ক্ষেত্রে উল্লেখযোগ্য ভাবে চাপ সৃষ্টি করে। এই ফলাফলগুলো আগর প্লান্টেশন প্রোগ্রামের জন্য বৃহৎ পরিসরে চারা উত্তোলনের নিমিত্তে ব্যবহার করা যেতে পারে।

Keywords: Agar, Germination, Recalcitrant seeds, Shade tolerance, Storage period.

Introduction

Aquilaria malaccensis Lamk (Agar) is a large evergreen tree, up to 30m tall with clear bole and maximum 60cm in dbh (Hossain 2015). It is reported as a shade tolerant tree found growing underneath tall trees in the tropical and sub-tropical evergreen forest in nature (Swaine *et al.* 1997). Natural populations occur mostly in South and South-East Asia. In the past, agar naturally grown in the forests of greater Sylhet, Chattogram and CHT of Bangladesh (Baksha *et al.* 2009). The high value of the wood has resulted in indiscriminate felling of natural populations, and the species is listed in CITES. Agar is a mid-canopy tree and propagates readily through seeds. *Aquilaria* seeds are produced during the monsoon season, i.e. June to August. Seeds are recalcitrant with short viability. Studies on seed biology and physiological ecology help to understand the processes such as germination, establishment, succession, and regeneration that occur in plant communities. The changes in light quality and temperature fluctuations are the main factors that influence seed germination (Souza and Valio 2001). Generally, late successional, shade tolerant species have larger seeds with high water content, short or no dormancy with short life period (Swaine and Whitmore 1988); however, some shade tolerant species may have smaller seeds (Kelly and Purvis 1993) than light demanders. Germination in some small-seeded species, although not possible in the dark, but can occur under conditions of low red/far-red ratios (R/FR) as in the forest understory trees (Drake 1993). Tolerance is a term that foresters and ecologists use to indicate a tree's capacity to develop and grow in the shade of, and in competition with, other trees. It is the

degree to which a species can share resources on a site and still be successful, most often reflects as shade tolerance. Shade tolerance is the relative capacity of tree species to compete for survival under shaded conditions. This functional adaptation varies between species to species and becomes evident in forest succession. The natural regeneration rate of Agar is reported to be high (Soehartono and Newton 2001a). However, the seed production and seedling dispersion in the forest is limited. Under nursery conditions, it has been documented that fresh seeds exhibit a high germination percentage, whereas stored seeds show a lower germination rate (IUCN 2012). Comprehensive research on these aspects may be helpful since germination capacity is also influenced by abiotic and other factors like light availability, soil type and seedling density (He *et al.* 2005).

Agar is an economically important but critically endangered tree species (Oldfield *et al.* 1998). It has been listed in the 'Word List of Threatened Trees since late 2000s (Chakrabarty *et al.* 1994). The people's understanding about valuable and precious agar wood has led to its heavy extraction from natural forest in recent years. In addition to utilization pressure, agar tree faces limitations from important ecological factors namely, light availability, seed viability period and insect attack both under nursery and field conditions. Being a tremendously important tree species, information is required on the growth and survival of the species in response to different environmental factors to manage it sustainably. Few studies on regeneration of Agar species using different technologies have been undertaken (He *et al.* 2005; Ahmad and Gogoi 2000) as most seeds become incompatible within very short periods (Gupta

2004). Keeping in view the degradation of natural population and biological conservation of Agar in Bangladesh, investigations were carried out with the main objective to understand the response of agar seed biology and effect of shades on germination and establishment of seedlings in the nursery.

Materials and Methods

The study area

The study was carried out in the nursery of Seed Orchard Division, Bangladesh Forest Research Institute (BFRI), Chattogram, over a period of 1 year from June 2019 to July 2020. The climate of the study area is tropical in nature and characterized by humid summers and cool dry winter. The maximum and minimum temperature in the area varies from 28.31°C to 31.9°C. Mean annual rainfall is around 3000mm mainly occurred from June to September (Hossain and Arefin 2012)

Seed collection and growing media

The seeds were collected in the middle of June 2019 from 15 - 20 years old matured healthy plus trees from Dulahazara, Cox's Bazar, Bangladesh. Healthy and fresh seeds were used for the experiment. The number of seeds per kilogram was 1,500. The germination trial involved sowing these seeds in a sand-filled seed bed at a depth of 0.5–1.0cm.

Effect of storage periods on seed germination

Germination tests of agar seeds were conducted with four treatments (0, 5, 10 and 15 day's stored seeds) in the nursery of Seed Orchard Division, BFRI during June to August 2019 (Fig. 1). Fresh and healthy seeds of uniform size were separated into four lots with three replications of fifty seeds each. From each lot, the seeds were sown in the nursery bed after measuring their fresh weight. The number of seedlings was counted to 35 days after sowing. The percentage of germination was calculated using the following formula (Kumar 1999):

$$\text{Germination (\%)} = \frac{\text{No. of germinated seeds} \times 100}{\text{Total number of seeds sown}}$$

Effect of shades on seed germination

The effect of shades on seed germination were tested with three treatments, i.e. full shade, partial shade and no shades by partitioning the nursery in three compartments. The shade was made of mesh cloth. The experimental design was a completely randomized design (CRD) with three replicates of fifty seeds each. The emergence of seedlings was counted to 35 days after sowing and germinations percentage was calculated using the above formula. The plumule and radical were measured after 5 days of germination whereas, the plant height and leaf area were measured after 35 days of germination.

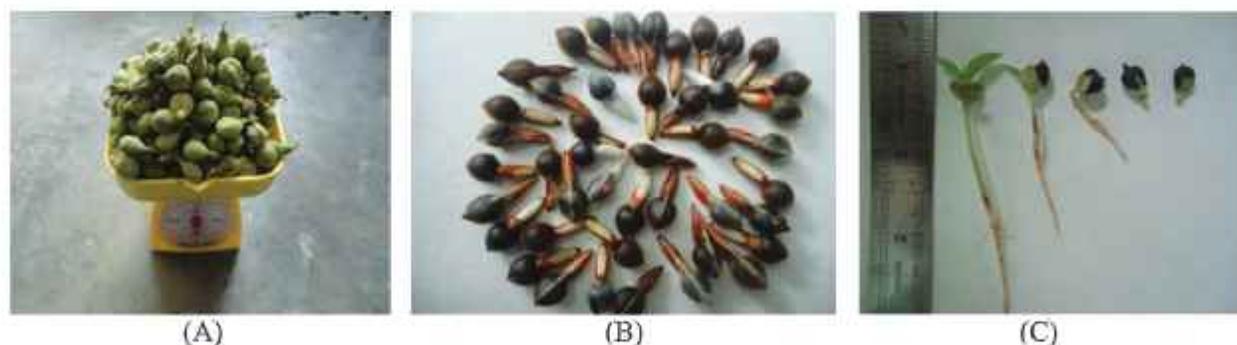


Figure 1. Fruits, mature seeds, and germinated seedlings of agar (A) (B) and (C).

Statistical analysis

The germination and growth parameters of agar seedlings were analyzed using Microsoft Excel Spreadsheet and SPSS version-22 software.

Results

Effect of storage periods on seed germination

Germination percentage of seeds was found directly proportional to seed's storage period. The germination started on 13th day and continued up to 35th day after sowing. The results showed that the highest germination percentage (92%) was recorded with fresh seeds sown immediately after harvest which reduced drastically by 5 days (39.6%) and 10 days (4%) stored seeds (Table 1 & Fig. 2). The 15 days old seeds showed no germination at all. The seeds stored for 15 days became hard, shrunken and turned black in color. The highest average fresh weight of seeds was recorded as 39.10g/50 seeds which reduced to 35.4g after 5 days, 32.8g after 10 days and 30.0g after 15 days (Table 1). Seeds lost turgidity very fast and their original appearance after 15 days. The survival percentage of seedlings was calculated after 35 days and recorded highest (80%) for fresh seeds followed by 5 days (33.2%) and 10 days (2.8%) for stored seeds respectively. The

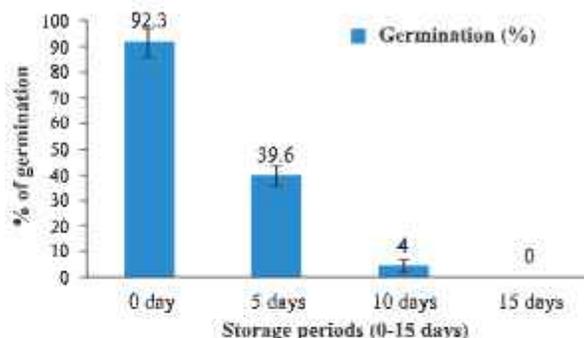


Figure 2. Germination % of agar seeds at different storage periods.

moisture content of seeds was found significantly correlated ($p < 0.05$) with the germination of seeds.

Effect of shades on seed germination

Agar is a large evergreen tree, up to 30m tall rows naturally underneath canopy of dominant trees in the forest. The experiments were conducted to assess the shade tolerance capacity of agar seeds in relation to germination percentage by creating three artificial shadings, i.e. full shade, partial shade, and no shading as control (Fig. 3). The seeds sown without shade showed the least germination percentage (62.6%) and poor performance in growth parameters in comparison to seeds sown under partial shade (75%) and full shade with maximum germination percentage (94%) (Table 2). The growth and development were also dynamic under full shade with longest plumule, and radical length measured as 12.10cm and 27.7cm

Table 1. Effect of storage periods on seed germination and survival of agar.

Storage Period (in Days)	Germination Characteristics		
	Average Seed Weight (mg./seeds)	Germination (%)	Survival (%) (after 25 days of germination)
0 days	39.1±2.31 ^a	92.0±3.82 ^b	80.0±1.76 ^a
5 days	35.4±3.11 ^b	39.6±2.76 ^b	33.2±8.18 ^b
10 days	32.8±3.33 ^c	4.0±0.11 ^c	2.8±6.00 ^c
15 days	30.0±2.41 ^d	0.0	0.0
Sig. diff	0.006*	0.00**	0.00**

Note: Values with different superscripts across each column are significant different at $P < 0.05$

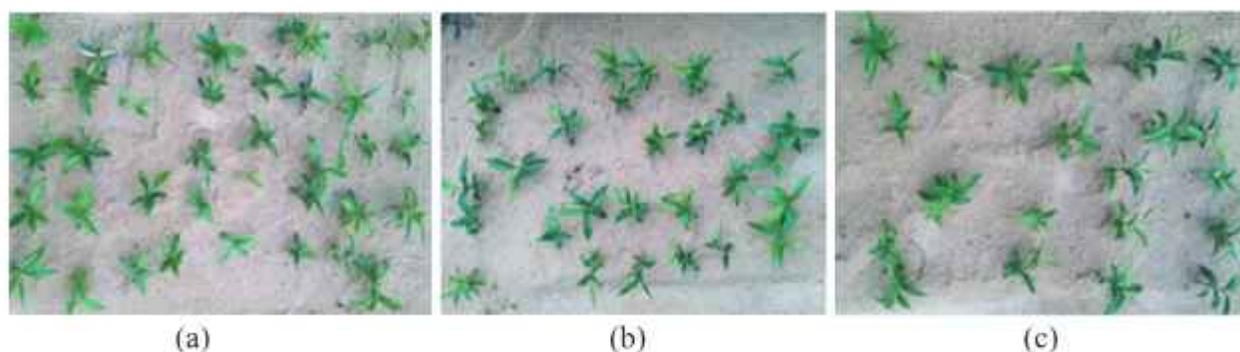


Figure 3: Agar seed germination and seedlings growth under full shade, partial shade and no shade (a, b & c).

Table 2. Effect of shades on seed germination and establishment of agar.

Shade level	Germination (%)	5 DAG*		35 DAG	
		Plumule length (cm)	Radical length (cm)	Plant height (cm)	Leaf area (cm ²)
Full shade	94.0±2.8 ^a	12.1±1.2 ^a	27.7±3.6 ^a	38.9±4.5 ^a	7.3±4.2 ^a
Partial shade	75.0±7.6 ^b	11.3±1.4 ^a	26.2±1.2 ^a	36.2±1.8 ^a	7.2±1.5 ^a
No shade	62.6±7.2 ^c	10.2±1.2 ^b	23.9±4.0 ^b	33.1±2.2 ^b	6.6±1.4 ^b

*DAG=Days after Germination, Significant at P<0.05

respectively followed by partial shade (11.3cm & 26.2cm) and control (10.2cm & 23.93cm). The height and leaf area of plants in full shade were measured as 38.9cm and 7.3cm², followed by partial shade (36.2cm & 7.2cm²) as compared to no shade (33.1cm & 6.6cm²). In one way ANOVA of seed germination values, seed moisture contents in relation to storage periods characteristics and effect of shade on seed germination and establishment of agar were recorded as significant at P<0.05.

Discussion

The germination trial on seeds using different shelf life and shades under nursery condition have shown high germination percentage (more than 90%) in case of fresh seeds sown immediately after harvesting which supported earlier findings (IUCN 2012). The percentage

of seed germination also declined drastically with an increase in storage period from 31% for seeds without storage to 25% for 5 days of storage and only 1% for 14 days shelf life (Gupta 2004). The recalcitrant seeds of agar regenerate freely under natural conditions in the forest probably due to availability of necessary moisture and light under the shaded canopy. The fleshy covering of agar fruits also provides moisture to the seeds for their survival. Saikia and Khan (2012) noticed germination of agar seeds up to 45 days with a decreased germination percentage by increase in storage period and 100% viability on Tetrazolium test of fresh seeds. The natural regeneration rate was found moderately higher (Soehartono and Newton 2001a) despite intensive extraction of agar wood for economic benefits, limited seed productions and dispersion in the forests (He *et al.* 2005).

The annual seed production period is also relatively shorter i.e. from mid-June to mid-August which might be a contributing factor for relatively low density of naturally regenerated plants putting tremendous pressures on this forest species. The moisture contents of seeds decreased considerably with the increase of storage period. The percentage of seed germination was inversely proportional to their storage period, as storage reduces moisture contents and in turn viability of seeds. Therefore, the probability of seed germination depends on seeds moisture content, physiological processes and in turn embryonic activities. The germination percentage was significantly correlated with seed weight and moisture contents supporting earlier findings (Nath *et al.* 1999; Kumar *et al.* 2007). Generally, seeds are associated with behavioral differences in morphological, physiological, anatomical structure and biochemical composition during storage periods (Mohammed *et al.* 2008). These factors might have caused storage of seeds difficult for commercial exploitation, cultivation and conservation of this species hence needs some biotechnological intervention for sustainable management. Shade house and lab experiments help in determining the relative importance of factors influencing seed germination processes (Wareing and Phillips 1978). The seeds sown under full shade have shown approximately absolute germination rate (94%) as compared to partial shade (75%) and control (62%) with healthier and taller plants in this study. This may be attributed to low soil moisture evaporation rate due to shades that minimize it and other supportive abiotic factors, which in turn aided in profuse seed germination. The

seeds sown under no shade showed the least germination percentage and poor performance in growth parameters such as seedling height, leaf area, plumule and radical length. Shading might be one of the factors that change the light requirements of photoblastic seeds. These have established the fact that agar is rather a shade demander tree than shade tolerant. However, a general trend has been considered for shade tolerates having large seeds and light demanders having small seeds (Souza and Valio 2001) usually not fitting for Agar bearing medium sized seeds but a shade tolerant species. In our trials, seed germination and emergence were observed 35 days post-sowing. Earlier workers reported germination of agar seeds from 37 to 45 days (Gupta 2004; Tran *et al.* 2003) from sowing day. Some seedlings died even after emergence which may be due to physiological disorder, fungal infection and insect attack which usually prevail during sowing season. Proper mycorrhizal symbiosis may also be an appropriate solution.

Conclusion

The artificial regeneration and plantation have been encouraged to promote conservation of agar at large. The present findings may be useful for raising large scale planting stock from fresh seeds.

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বাংলাদেশের পশ্চিম উপকূলীয় এলাকায় কেওড়া বাগান সুষ্ঠুভাবে ব্যবস্থাপনা করার জন্য একটি উপযুক্ত বন ব্যবস্থাপনা পদ্ধতি নির্বাচন করতে সহায়তা করবে।

Keywords: Coastal belt, Diameter, Growth, Height, *Sonneratia apetala*.

Introduction

The coast has been defined as the area where terrestrial and marine habitats interact and vice versa (Carter 1991). The coastal ecosystem is one of the most dynamic ecosystems on the planet (Serajuddoula *et al.* 1995). Bangladesh's coastline extends over 710 km along the Bay of Bengal (Das and Siddiqi 1985; Siddiqi 2001), and the coastal zone encompasses 47,201 square kilometers between latitudes 21° and 23° north and longitudes 89° and 93° east (Islam and Rahman 2015). Because mangrove roots and pneumatophores efficiently impede water velocity and operate as efficient sediment trappers, fast accretion occurs along the shoreline (Woodroffe 1992). Plantation is a frequent approach for recovering mangrove forests (Chen *et al.* 2009), and Bangladesh is one of the leading countries in the world for coastal afforestation with several mangrove species (Islam *et al.* 2016). In the coastal regions, approximately 1,90,000 hectares (ha.) of accreted land were afforested with mangrove species until 2010 (Islam *et al.* 2013) and 1,92,000 ha. till 2013 (Hasan 2013). The most successful planted species is *Sonneratia apetala* (Keora), while *Avicennia officinalis* (Baen) is the second most successful species in coastal mangrove plantations (Siddiqi 2001). Because *S. apetala* has the best survival and growth performance in newly accreted areas throughout the coastal belt, it is the most common species planted in coastal afforestation programs (Islam *et al.* 2016). Currently, *S. apetala* alone accounts for 94.4% of all established mangrove

plantations, whereas *A. officinalis* accounts for only 4.8% (Siddiqi and Khan 2004).

Sonneratia apetala is an ecologically significant tree species in Indo-Malayan mangroves (Tomlinson 1986) and is commonly used for mangrove restoration operations in a variety of locales (Lu *et al.* 2014). It is a light-demanding (Rashid and Rahman 2012; Lu *et al.* 2014; Hossain 2015), fast growing pioneer (Das and Siddiqi 1985; Chen *et al.* 2003; Lu *et al.* 2014; Hossain 2015), woody evergreen tree species (Ren *et al.* 2009; Hossain 2015). It can grow up to 20 m (Siddiqi 2001; Kairo *et al.* 2009; Ren *et al.* 2009; Hossain 2015) and DBH varies between 30-70cm (Hossain 2015). It improves soil fertility significantly and exhibits a number of desirable qualities as a pioneer restoration species (Chen *et al.* 2003; Ren *et al.* 2009). It accounts for around 4.5% of the Sundarbans' merchantable growing stock (Chaffey *et al.* 1985) and 95% of Bangladesh's coastal afforestation (Siddiqi and Shahjalal 1997). This tree was the most successful all along the coastal line and accounted for 94.4% of the total plantation in coastal areas of Bangladesh (Siddiqi and Khan 2004). Tree growth is frequently quantified using stem DBH and tree height (Sumida *et al.* 2013), and it continues for years as both diameter and height increase (Henry and Aarssen 1999). The diametric and hypsometric tree growth trends varied by tree species or forest stands (Sumida *et al.* 1997). Without a doubt, tree growth is influenced by their age (Lukaszkiwicz 2010), and the growth of all forests follows a predictable pattern with age (Binkley *et al.* 2002). While radial growth continues throughout the tree's life, the tree's height may only reach a maximum, which is

unique to each tree species (Woolhouse 1972; Koch *et al.* 2004; Niklas 2007). Forest development is significant both economically and ecologically (Binkley *et al.* 2002), and knowing tree growth can help with CO₂ reductions in the atmosphere, air quality advantages, storm water runoff, and tree maintenance costs (Lukaszkiwicz 2010). To improve biodiversity and ecosystem services, as well as to ensure long-term sustainable forest resources, forest growth studies have been needed on site quality, tree competitive status, stand density management, and silvicultural management (Briseño-Reyes *et al.* 2020). Because of the importance of *S. apetala* plantations in Bangladesh, a better understanding of their growth in relation to their stand age is needed at the regional, national, and worldwide levels. The objective of this study is to find out the variation or changes in the growth (height and DBH) of *S. apetala* in relation to stand age or increasing stand age. With the knowledge of the growth rate of this species, policymakers and decision-makers will be able to make decisions about *S. apetala* species for future coastal plantation, restoration, and management programs.

Materials and Methods

Study area

The research was conducted at Char Kukri-Mukri research station in Bhola district and Rangabali research station in Patuakhali district. The Char Kukri-Mukri area is located between the latitudes of 21°54' and 22°52' north, and the longitudes of 90°34' and 91°01' east (Dey *et al.* 2021a). On the other hand, the Rangabali area is located between the latitude of 21°59' and 21°59' north, and the longitudes

of 90°28' and 90°28' east (Moula and Miah 2020). The site conditions in these two areas are almost similar (Islam *et al.* 2015). Annual rainfall ranges from 2500 to 3000mm, with mean minimum and maximum temperatures ranging from 18 to 32°C (Siddiqi 2002). The delta of the extended Himalayan drainage ecosystem, which makes up the lowest landmass, includes this region. The combined actions of the rivers Brahmaputra, Meghna, and Ganges have created low-lying terrain, estuaries, and inlands along the seacoast. Water salinity varies between 3-27 ppt during the monsoon season and 10-33 ppt during the dry season (Siddiqi and Khan 1990). The soil type in the research region is silt-clay-loam, with salinity varying from 0.3-4.2 ds/m in December to 9 ds/m in April-May (Hasan 1987). The soil pH ranges from 7.5 to 8.0, and it is slightly alkaline (Siddiqi and Khan 2000).

Sampling design

At each station, different available stand ages were considered for establishing permanent sample plots (PSP). The PSP size was 10m x 10m. Thirty-two PSPs (four PSPs for each age class) were established in the Char Kukri-Mukri area under eight age classes (11, 15, 20, 30, 35, 40, 42, and 45 years), covering a total area of 3200 square meters. On the other hand, in the Rangabali area, 28 PSPs (four PSPs for each age class) were established under seven age classes (30, 35, 42, 44, 45, 48, and 50 years), covering a 2800 sq. m. area. The PSPs were selected following the stratified random sampling method. All PSPs were demarcated by bamboo or wooden sticks, and all trees in the study plots were numbered sequentially.

Data collection

Data from the permanent sample plots were collected during December for three subsequent years: 2018, 2019, and 2020. Diameter tape was used to measure the DBH at 1.3m. above the tree from the ground. On the other hand, Haga altimeter was used to measure tree height.

Statistical analysis

The variations in height and DBH increment over time in relation to stand age were analyzed using a one-way ANOVA (analysis of variance). When a significant difference was identified, pairwise comparisons were performed using post hoc testing (Tukey's HSD). To the findings of all statistical analysis, a significance value of $p < 0.05$ was used. The normality and homogeneity of variance assumptions were met prior to the ANOVA test. The data was computed and analyzed using a Microsoft Excel spreadsheet, SPSS (Version 23.0) and the Statistix 10 statistical program.

Results

In Char Kukri-Mukri area, the highest mean height was found at the age of 42, followed by 35, 40, 30, 45, 20, 15 and 11 years of *S. apetala* plantation (Fig. 1). On the other hand, in the same area, the highest mean DBH was found at the age of 42, followed by 45, 35, 40, 30, 15, 20 and 11 years (Fig. 2). A significant difference was found for the mean height growth rate after 1 year (2019) and 2 years (2020). The highest mean height growth rate was found for the age of 11 years (0.357m), followed by 15 (0.255m), 20 (0.197m), 30 (0.160m), 40 (0.118m), 35 (0.100m), 45 (0.095m) and 42 (0.075m) years after one year of measurement in 2019 (Table 1). On the other hand, in the same plantation, the highest mean height growth rate was found at the age of 11 years (0.662m), followed by 15 (0.525m), 20 (0.412m), 30 (0.375m), 40 (0.186m), 35 (0.180m), 42 (0.150m) and 45 (0.147m) years after 2 years of measurement in 2020 (Table 1). In the same area, a significant difference was

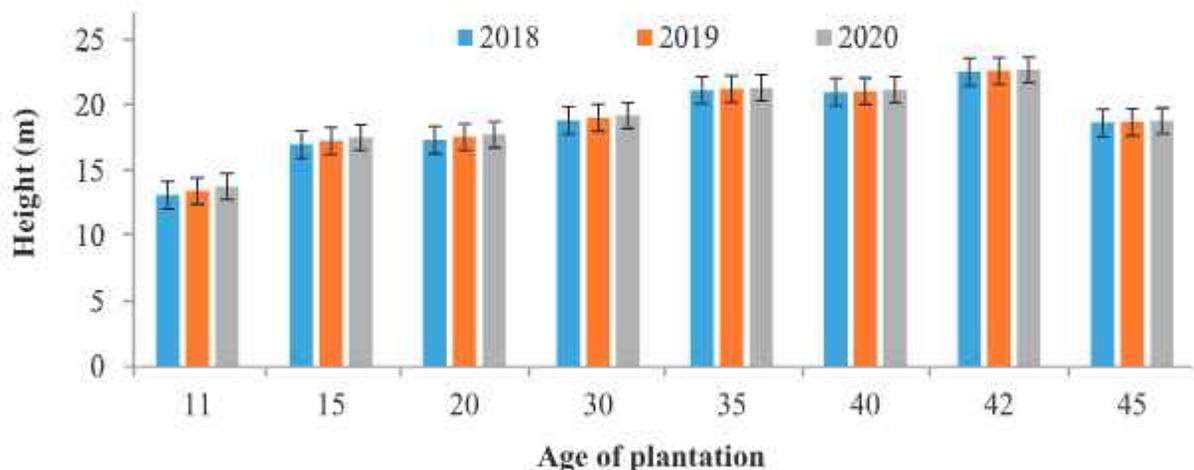


Figure 1. Height of Keora at Char Kukri-Mukri area in three subsequent years.

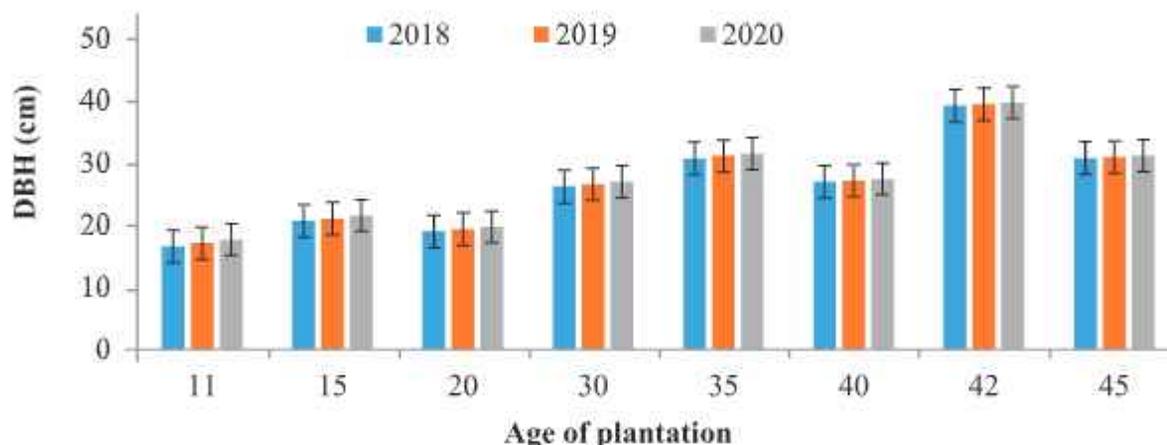


Figure 2. DBH of Keora at Char Kukri-Mukri area in three subsequent years.

found for the mean DBH growth rate after 1 year (2019) and 2 years (2020). The highest mean DBH growth rate was found at the age of 11 years (0.570cm), followed by 15 (0.482cm), 30 (0.415cm), 35 (0.407cm), 20 (0.340cm), 40 (0.282cm), 42 (0.280cm) and 45 (0.207cm) years plantation after 1 year measurement in 2019 (Table 1). On the other hand, in the same plantation, the highest mean DBH growth rate was found at the age of 11 years (1.085cm), followed by 15 (0.857cm), 35 (0.797cm), 30 (0.782cm), 20 (0.700cm), 42 (0.492cm), 40 (0.487cm) and 45 (0.360

cm) years after 2 years of measurement in 2020 (Table 1).

In the Rangabali area, the highest mean height was found at the age of 45, followed by the ages of 35, 50, 48, 44, 42, and 30 years of *S. apetala* plantation (Fig. 3). On the other hand, in the same area, the highest mean DBH was found at the age of 45, followed by 35, 30, 48, 42, 50, and 44 years (Fig. 4). A significant difference was found for the mean height growth rate after 1 year (2019) and 2

Table 1. Height and DBH growth of *S. apetala* at Char Kukri-Mukri area.

Age of the plantation (years)	Height growth (m)		DBH growth (cm)	
	After 1 year (2019)	After 2 years (2020)	After 1 year (2019)	After 2 years (2020)
11	0.357 ± 0.04 ^a	0.662 ± 0.09 ^a	0.570 ± 0.02 ^a	1.085 ± 0.02 ^a
15	0.255 ± 0.03 ^{ab}	0.525 ± 0.03 ^{ab}	0.482 ± 0.01 ^{ab}	0.857 ± 0.01 ^{ab}
20	0.197 ± 0.02 ^{bc}	0.412 ± 0.05 ^b	0.340 ± 0.02 ^{bcd}	0.700 ± 0.03 ^{bc}
30	0.160 ± 0.01 ^{bcd}	0.375 ± 0.02 ^{bc}	0.415 ± 0.01 ^{bc}	0.782 ± 0.06 ^b
35	0.100 ± 0.01 ^{cd}	0.180 ± 0.03 ^{cd}	0.407 ± 0.03 ^{bc}	0.797 ± 0.07 ^b
40	0.118 ± 0.02 ^{cd}	0.186 ± 0.03 ^{cd}	0.282 ± 0.03 ^{cd}	0.487 ± 0.03 ^{cd}
42	0.075 ± 0.01 ^d	0.150 ± 0.02 ^d	0.280 ± 0.01 ^{cd}	0.492 ± 0.01 ^{cd}
45	0.095 ± 0.01 ^{cd}	0.147 ± 0.01 ^d	0.207 ± 0.05 ^d	0.360 ± 0.09 ^d

Note: Treatment values followed by different letters (like a, b, c, etc.) significantly differ at the 5% significance level.

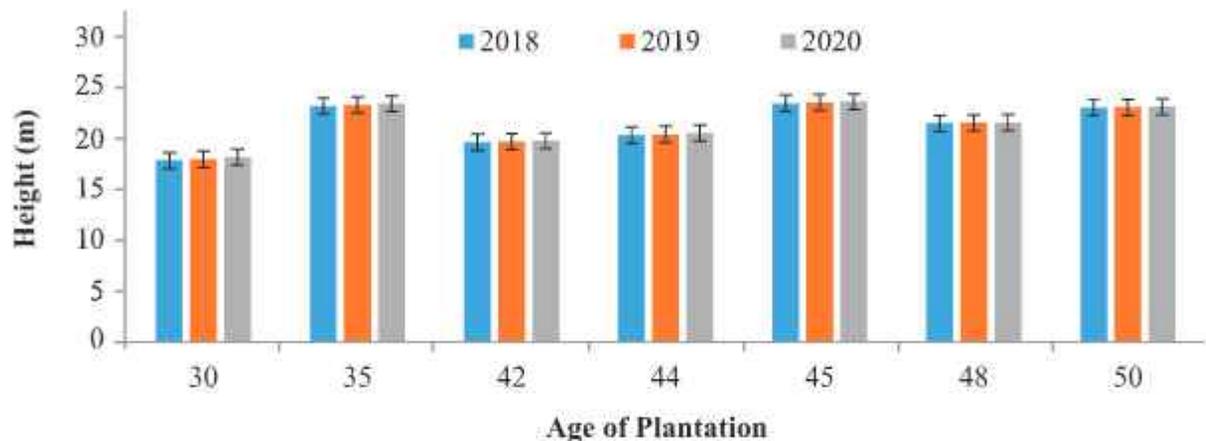


Figure 3. Height of Keora at Rangabali area in three subsequent years.

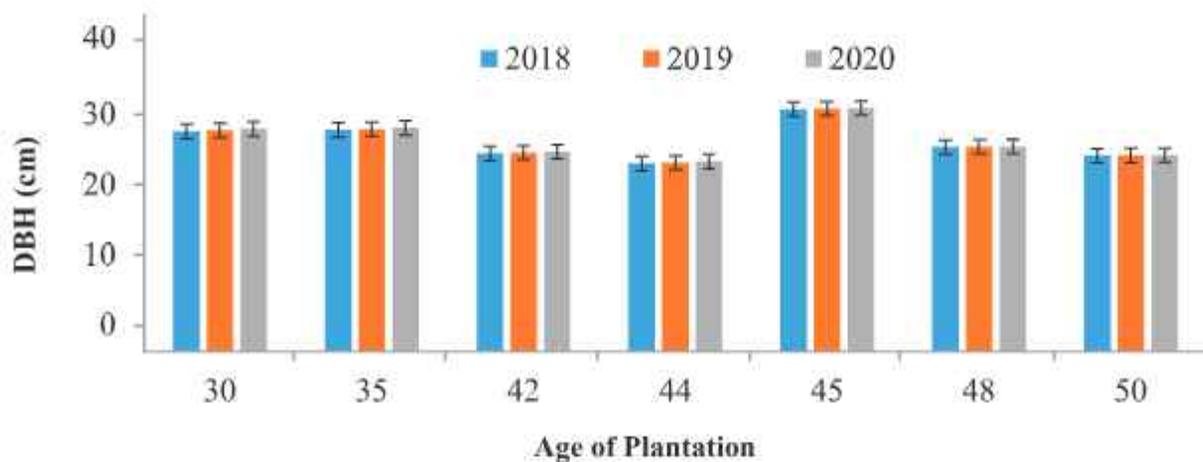


Figure 4. DBH of Keora at Rangabali area in three subsequent years.

years (2020). The highest mean height growth rate was found at the age of 30 years (0.216m), followed by 35 (0.150m), 44 (0.136m), 42 (0.090m), 45 (0.086m), 50 (0.063m), and 48 (0.036m) years after 1 year in 2019 (Table 2). On the other hand, in the same plantation, the highest height growth rate was found at the age of 30 years (0.353 m), followed by 35 (0.243m), 44 (0.223m), 45 (0.173m), 42 (0.150m), 48 (0.103m), and 50 (0.093m) years after 2 years in 2020 (Table 2). In the same area, a significant difference was found for the mean DBH growth rate after 1

year (2019) and 2 years (2020). The highest mean DBH growth rate was found at the age of 30 years (0.246cm), followed by 44 (0.206cm), 35 (0.203cm), 42 (0.126cm), 45 (0.060 cm), 48 (0.036 cm) and 50 (0.023cm) years after 1 year in 2019 (Table 2). On the other hand, in the same plantation, the highest DBH growth rate was found at the age of 30 years (0.390cm), followed by 44 (0.300cm), 35 (0.283cm), 42 (0.240cm), 45 (0.123cm), 48 (0.083cm) and 50 (0.036cm) years after 2 years in 2020 (Table 2). Besides in the objectives,

Table 2. Height and DBH growth of *S. apetala* at Rangabali research station.

Age of the plantation (years)	Height growth (m)		DBH growth (cm)	
	After 1 year (2019)	After 2 years (2020)	After 1 year (2019)	After 2 years (2020)
11	0.357 ± 0.04 ^a	0.662 ± 0.09 ^a	0.570 ± 0.02 ^a	1.085 ± 0.02 ^a
15	0.255 ± 0.03 ^{ab}	0.525 ± 0.03 ^{ab}	0.482 ± 0.01 ^{ab}	0.857 ± 0.01 ^{ab}
20	0.197 ± 0.02 ^{bc}	0.412 ± 0.05 ^b	0.340 ± 0.02 ^{bcd}	0.700 ± 0.03 ^{bc}
30	0.160 ± 0.01 ^{bcd}	0.375 ± 0.02 ^{bc}	0.415 ± 0.01 ^{bc}	0.782 ± 0.06 ^b
35	0.100 ± 0.01 ^{cd}	0.180 ± 0.03 ^{cd}	0.407 ± 0.03 ^{bc}	0.797 ± 0.07 ^b
40	0.118 ± 0.02 ^{cd}	0.186 ± 0.03 ^{cd}	0.282 ± 0.03 ^{cd}	0.487 ± 0.03 ^{cd}
42	0.075 ± 0.01 ^d	0.150 ± 0.02 ^d	0.280 ± 0.01 ^{cd}	0.492 ± 0.01 ^{cd}
45	0.095 ± 0.01 ^{cd}	0.147 ± 0.01 ^d	0.207 ± 0.05 ^d	0.360 ± 0.09 ^d

Note: Treatment values followed by different letters significantly differ at the 5% significance level.

there was found a positive and strong relationship between height and DBH growth (for both 1 and 2 years) in both the Char Kukri-Mukri and Rangabali areas (Fig. 5 & Fig. 6). In the Char Kukri-Mukri area, a positive, strong relationship was found between height and DBH growth rate

after 1 year ($r = 0.850$) and 2 years ($r = 0.859$) (Fig. 5A & Fig.5B). On the other hand, in the Rangabali area, a positive and very strong relationship was found between height and DBH growth after 1 year ($r = 0.931$) and 2 years ($r = 0.913$) (Fig. 6A & Fig.6B).

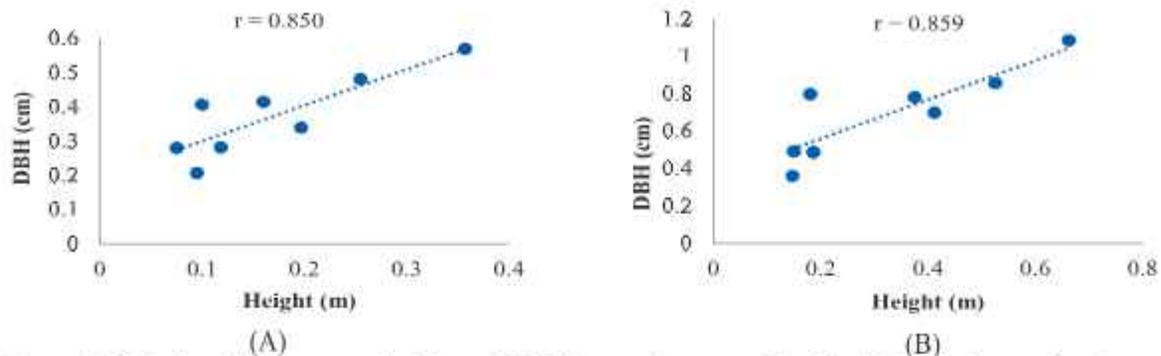


Figure 5. Relationship between height and DBH growth rate at Char Kukri-Mukri area after 1 year (A) and 2 years (B).

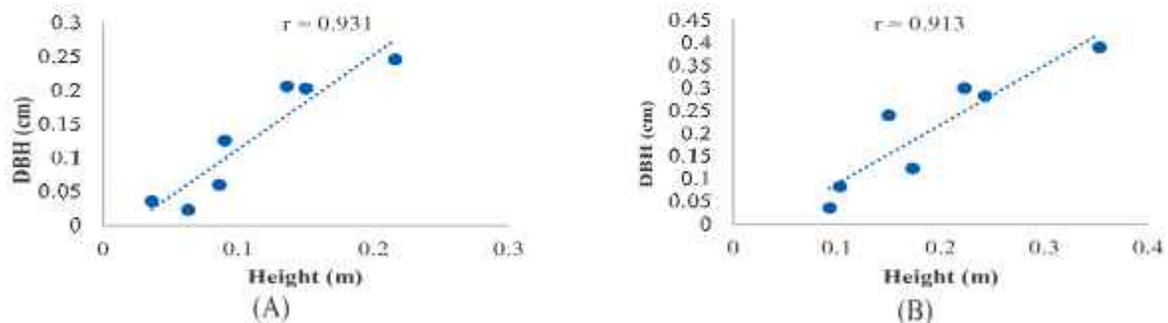


Figure 6. Relationship between height (m) and DBH (cm) growth rate at Rangabali area after 1 year (A) and 2 years (B).

Discussion

In this research, a significant difference was found in the height growth rate among the different stand ages for 1 year (2019) and 2 years (2020) in both the Char Kukri-Mukri and Rangabali areas. However, the growth rate did not always follow the decreasing trend of the growth rate with increasing stand age in both Char Kukri-Mukri and Rangabali areas. In the Char Kukri-Mukri area, the annual height increment was found to decrease with increasing stand age, up to the age of 11 to 30 years. Then it broke the trend, and the annual height increment of 40 years of age was more (0.118m) than the 35 years growth (0.100m), and the growth of 45 years was more (0.095m) than the 42 years growth (0.075m). When the data were collected, after 2 years in the same plantation, the previous one followed without a height growth rate of 42, which was more (0.150m) than the 45 years growth rate (0.147m). On the other hand, in the Rangabali area, the annual (2019) height growth rate of 44 years was more (0.136m) than the 42 years growth rate (0.090m), and the 50 years growth rate was more (0.063m) than the 48 years growth rate (0.036m). In case of height growth, the growth rate of DBH was not following the decreasing trend with increasing stand age in both the Char Kukri-Mukri and Rangabali areas. In the Char Kukri-Mukri area, the annual (2019) DBH growth rate of 30 years and 35 years was higher (0.415 and 0.407cm) than the 20 years growth rate (0.340cm). On the other hand, in the Rangabali area, the DBH growth rate of 44 years was higher (0.300cm) than the 35 years and 42 years growth rate (0.283 and 0.240cm) after 2 years of data collection (2020). Siddiqi (2001) found the maximum mean annual diameter increment (MAI) of *S. apetala* up to 11 years was 1.23cm and the height increment

was 1.16m in the coastal area of Bangladesh. In addition, Siddiqi (1988) found that the annual DBH and height increment (MAI) were 1.33cm and 0.936cm, respectively, up to 10 years of *S. apetala* plantation in the Char Kukri-Mukri area of Bhola district. Moreover, *S. caseolaris*, a species near to *S. apetala*, showed the highest growth among all planted species, with an annual diameter increment (MAI) of 1.92cm and a height increment of 0.97m, which occurred in low saline areas (up to 16 ppt) (Siddiqi and Khan 1990). The height and DBH of different years stands showed variation, which means that in some cases, the lower year stand has more height and DBH than the older one. As well, variation happened between the locations at the same age. Like in the Char Kukri Mukri area, the height of 45 years was less than the heights of 30, 35, 40, and 42 years. On the other hand, in the Rangabali area, the DBH of a 45 years old plantation was higher than the 48 and 50 years old plantations. It was found that at 45 years old plantation (Kukri Mukri area), some big trees are dead, and it could be a possible case of reason to take the mean data (both height and DBH) of all the trees in the plots. Poor-quality seeds and planting stocks can be the reason for this low productivity, or grazing can happen after plantation that severely affects plantation establishment and affects the growth of the species (Shafi 1982; Kathirensan and Ravikumar 1993; Nandy *et al.* 2004). For the same age plantation, the height and DBH are greater in the Rangabali area than in the Char Kukri-Mukri area. *Sonneratia apetala* performs better on barren, muddy beaches, with higher survival and growth rates (Ren *et al.* 2009), which could be one reason for this. It grows best in thick and soft muddy soils from the middle to the low tidal zone with low salinity (0–15) (Huang

and Zhang 2002; Chen *et al.* 2003; Liao *et al.* 2004), that can be the reason for variation. Siddiqi (2001) stated that growth was higher in places with lower salinity and declined in places with higher salinity. The depth, duration, and frequency of flooding are all important factors in the survival of mangrove seedlings and mature trees (Mitsch *et al.* 2002; Lewis 2005). All of the above-mentioned factors can be a possible factor in the different growth rates of different age groups, along with the age factor in both the same and other locations. The height-diameter relationship varies greatly between forest types and regions (Feldpausch *et al.* 2011). Dey *et al.* (2021b) found a strong positive relationship ($r= 0.789$) between DBH and height for *Acacia auriculiformis* at the Char Kukri-Mukri area in the Bhola district of Bangladesh, which was one of the study areas in this research. In the savanna zone of Nigeria, Arzai and Aliyu (2010) found a very strong linear relationship between DBH and height in *Khaya senegalensis*, *Parkia biglobosa* and *Eucalyptus species*.

Conclusion

A significant difference was found for the growth (height and DBH) of *S. apetala* among the different ages of plantations in the western coastal belt of Bangladesh. However, there is not always a decline in growth rate (height and DBH) as age increases. The findings will be helpful for managing *S. apetala* plantations on a sustainable basis and determining appropriate forest management methods to mitigate the negative effects of climate change. This was only examined the growth rates of different age groups of *S. apetala* stands, but the other climatic factor was not included; that could be another research study.

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Suitability of Manufacturing Furniture from Toon (*Cedrela toona*) Wood in terms of Exhibiting Some Machining and Handtool Properties

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Abstract

Toon wood (*Cedrela toona*) is less known in Bangladesh as a commercial timber species, but it also has the prospects of being used for joinery, musical instruments, and some specific furniture manufacturing purposes depending on its physical and mechanical properties. This study was intended to identify the compatibility of Toon (*Cedrela toona*) wood for furniture manufacturing in terms of exhibiting some machining and handtool properties viz., planing, shaping, boring, mortising, and turning tests. The appraisal in both machining and handtool property tests were based on the frequency of the defect-free samples. The finishing property was also ascertained by using two types of polishing materials, viz., carpa and shellac. The defects of the samples were conjectured by visual and tactile observation. The percentage of defect-free samples was assessed for each property operation and classified based on five quality grades. The results of this study mainly emphasized good working properties, and toon wood may be suitable for furniture manufacturing.

সারসংক্ষেপ

এই গবেষণায় তুন কাঠের কিছু মেশিনিং এবং হ্যান্ডটুল গুণাগুণ, যেমন: প্লেনিং, শেপিং, বোরিং, মর্টিজিং এবং টার্নিং প্রভৃতির উপর ভিত্তি করে উক্ত কাঠ দিয়ে আসবাবপত্র তৈরীর উপযুক্ততা নিরূপণ করা হয়েছে। মেশিনিং এবং হ্যান্ডটুল উভয় পর্যবেক্ষণের ক্ষেত্রেই ক্রটিমুক্ত নমুনার প্রাপ্যতার ভিত্তিতে চূড়ান্ত ক্যাঙ্কপ নির্ধারণ করা হয়েছে। দুই ধরনের পলিশিং পদার্থ, যথা: কার্পা এবং শেলাক ব্যবহার করেই পলিশিং গুণাগুণ মূল্যায়ন করা হয়েছে। শক্তকরা হিসেবে প্রাপ্য ক্রটিমুক্ত নমুনার প্রতিটি গুণাগুণ চাক্ষুস এবং স্পর্শন দ্বারা নির্ধারণ করা হয়েছে এবং পাঁচ প্রকারের রেড অনুযায়ী শ্রেণিকরণ করা হয়েছে। এই গবেষণা কার্যক্রমটি মূলত সকল গুণাগুণের সন্তোষজনক ফলাফলের ভিত্তিতে তুন কাঠ দ্বারা টেকসই এবং মানসম্মত আসবাবপত্র তৈরীর বিষয়ে অনুপ্রাণিত করেছে।

Keywords: Boring, Carpa, Machining, Planing, Mortising, Shaping, Shellac, Turning.

Introduction

Cedrela toona Roxb., a medium- to large-sized deciduous tree with a brown to gray scaly bark, 18 to 21m tall and with a diameter of 0.57 to 0.95m. The crown is broad and rounded. The leaves are compound 30 to 55cm long. It has a

single stem or trunk and branches that support leaves. Beneath the ground, a tree has a root system that acts as an anchor and store the water and nutrients the plant needs to grow (Khan 2022). Seeds have wings on both ends and are elliptic-shaped, measuring 10–20mm long and 6–8mm in diameter (Shah and Patel 2021). Since the beginning of time, wood has served as a raw material for man, providing benefits that have helped him survive and build civilizations. It is also true that wood is the most typical foundational material for various things, despite being disregarded today due to the advent of synthetic substances. By using cutting-edge research techniques to examine this natural source of material's growth, structure, chemical composition, and exploitation, it's worth is preserved and increased. There are numerous cutting-edge uses for wood. The wood is processed into a veneer from the creation of buildings, furniture, pillars, and other everyday items, which is then glued to plywood, constructions (such as beams, arches, and helicopter propellers), etc., typically using waterproof adhesives (Namichev *et al.* 2019).

The analysis of the wood and all of its features, from physical, chemical, and mechanical to ergonomic, wear, surface coatings, and other factors, is the essence of how wood influences the technological processes involved in the furniture-making process. Each type of wood has specific characteristics and flaws, and by considering this in mind, it may be influenced technological advancements to boost yield and cut expenses while accomplishing more work in a shorter amount of time. Today's finest furniture is often manufactured from wood. Every home

is required to utilize wood because of its innate advantages, attractive appearance, and inherent characteristics (Namichev *et al.* 2019). Traditional wood, in its original aspect, will increase in value and esteem in the future. The production of elegant instruments and furniture, as well as the making of sculpture and carvings, will be bestowed even more respect on the cultural hierarchy (Namichev *et al.* 2019). Wood tends to be used less for products that retain their original structure, but there is a noticeable increase in products that involve mechanical or chemical modification of the wood. These wood-based items are anticipated to represent the majority of wood utilization in the future (Namichev *et al.* 2019). Toon wood is a fragile, unstable, and lightweight form of timber. Lightweight furniture, doors, panels, windows, tea boxes, boat equipment, toys, carving goods, musical instruments, etc. can all be manufactured out of it (Sarker *et al.* 2021). The demand for wood products is gradually increasing due to the rapid growth of the population in Bangladesh. The distinction that exists between a resource and a necessity is very significant. As a result, our forest resources are becoming less accessible with each passing day (Biswas *et al.* 2017). Evaluating the effects of wood machining characteristics (for planing, shaping, boring, mortising, and turning) on surface quality requires determining and enhancing wood machining properties as well as defining convenient usage areas for several unconventional wood species found in Bangladesh (Sofuoglu and Kurtoglu 2014). Therefore, the working and finishing characteristics of this wood are essential to explore as an alternative source to conventional timber species and enhance its economic value.

Materials and Methods

To conduct this study, toon wood were procured in the log form from the Lama upazila of Bandarban district for the test. The logs were converted to planks and sawing quality was determined. Samples, 25.4mm × 127mm × 1219.2mm in size were made out of wood species. Before conducting the tests, these samples were seasoned to 12-15% moisture content and were again converted into smaller pieces suitable for different tests. The samples were immediately examined visually to sort out the defect-free ones. After completing tests, samples were classified based on five quality grades (Table 1). The percentage of defect free samples based on total samples was determined. The percentage was considered as the measure of its property quality. The tests were carried out by ASTM Standards: D-1666-64 (Anon 2004). Similar property tests were conducted using carpenter's handtool, and it was accomplished at Bangladesh Forest Research Institute, Chattogram (during July 2020 to June 2022).

Planing and finishing test

The test samples for planing and finishing property was 25.4mm × 101.6mm × 914.4mm in size. The test was carried out in a Whitney No. 105 single surface planer with four

straight knives. The cutter head speed was 3000 rpm. The depth of cut was 1.59 mm for all runs. The feed rate was adjusted to 636 mm per minute so that the target number of knife marks was 40 per 25.4mm. The run was made with a sharpness angle of 30 degrees and cutting angle of 25 degrees. The exact number of samples was tested with the carpenter's hand planner, and a similar testing procedure was applied. The planning test samples were used for the test of finishing after completing all planning property tests. In the finishing test, two polish types, namely shellac and carpa were applied, and performance was recorded based on the surface finish and physical appearances.

Boring test

The size of the test for boring property was 25.4mm × 76.2mm × 304.8mm. The test was conducted in a 508mm single spindle hand feed drill press of Walker Turner Model No. 1113-41. A one-inch single twist solid center bred point type wood boring bit was used for the test. The drill machine was adjusted to maintain a spindle speed of 2850 rpm. In terms of handtool property test, boring was done by a carpenter's hand drill. A one-inch single twist solid center screwed point type

Table 1. Performance-wise quality grades of all property tests.

Defects	Performance	Quality Grade
No defect	Excellent	1
Few slight defects	Good	2
Lots of slight defects	Fair	3
Serious defects	Poor	4
Very serious defects	Very poor	5

wood boring auger bit was used for the test. A solid hardboard was used as backing underneath to avoid the tearing and splintering of samples at the bottom during boring both for machining and handtool test.

Shaping test

The test samples used for boring were also used for carrying out shaping tests of machining and handtool, respectively. The test was carried out in a hand-fed single spindle shaper of J.A.Fay and Egan Company, Model No. 252, with two knives having a spindle speed of 6500 rpm. Here the cutting angle was 25 degrees. The cutter used to obtain a quarter round pattern had a radius of curvature of 12.7mm. In case of handtool test, ripping of the sample was done by carpenter's handsaw to obtain the quarter round pattern. The shaping was carried out by carpenter's chisel of half-round type.

Mortising test

The samples used for boring and shaping tests were also used for the mortising test. Machining and handtool property tests were ascertained from the separate samples. It was used as hardboard backing when mortises were cut on each sample. Each mortise was cut with two sides parallel to the grain and perpendicular to the grain. The machining test was carried out in a foot feed vertical square hollow mortising chisel of Oliver Machinery Com., Model No. 91D. The spindle speed of the drill machine was 3600 rpm. A one fourth inch square chisel was applied in this property test.

Turning test

The size of the test samples used for turning property was 25.4mm × 25.4mm × 152.4mm. The test was carried out in a variable speed wood lathe of Oliver Machinery Com., Model No. 159A. The speed of the variable lathe was 2400 rpm. A set of high-speed steel cutter were used to give head and cove for having different turning features and the ability to cut at different angles with the grain.

Statistical analysis

The data were analyzed using Microsoft Excel Spreadsheet and SPSS version-22.

Results

In conformity with the variation of grain orientation and the load applied to the saw blade, toon wood required less pressure on the saw blade, which exhibited easy to saw (Table 2). The fiber and grain structure of wood determine the type of wood as well as the quality of sawing and finishing. According to specific gravity, this wood responded as light timber. A comparison of the defect-free samples as a percentage among three wood species, both in machining and handtool testing, has been presented (Fig. 1 & Fig. 2). The percentage of raised grain, fuzzy grain, tear-out, and broken corner defects taken from the total number of samples of toon wood in both machining and handtool tests is displayed (Fig. 3 & Fig. 4). The grade-wise performance of different machining and handtool property tests of toon wood based on the number of defect-free samples as a percentage has been displayed in Table 3. All kinds of finishing quality of toon wood showed promising results.

Table 2: Specific gravity, age, sawing and finishing quality of wood species

Sl. No.	Property/Parameter	Value/Quality	Remarks
1	Age of the tree	30 to 35 (Years)	According to annual growth rings
2	*Specific gravity (Green condition)	0.40	Light timber
3	*Specific gravity (Oven-dry condition)	0.48	
4	Finishing quality	Good	Two types of polishing
5	Sawing quality	Easy	According to load application

*Data source: Sattar *et al.* 1999

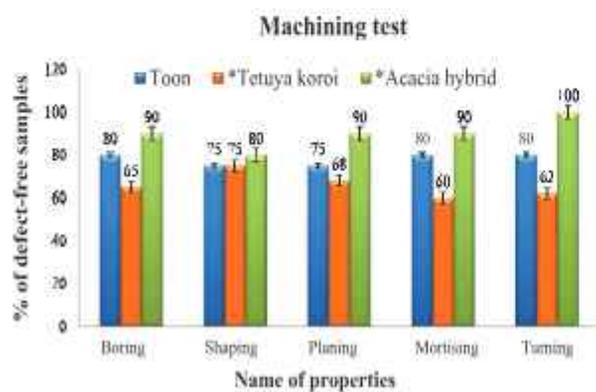


Figure 1. Comparison of the number of defect-free samples as a percentage among three wood species in machining test. [*Data source:(Sarker *et al.* 2021)]

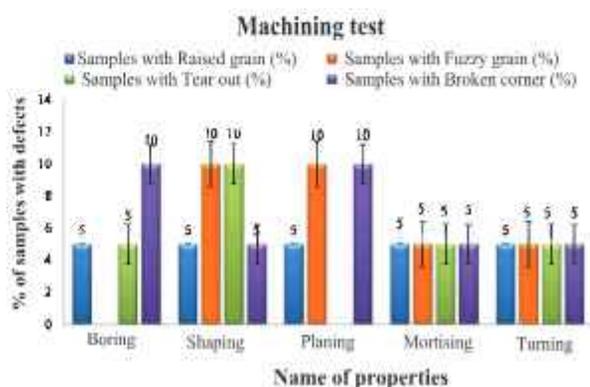


Figure 3. Percentage of raised grain, fuzzy grain, tear-out, and broken corner defects taken from the total number of samples of toon wood in machining test.

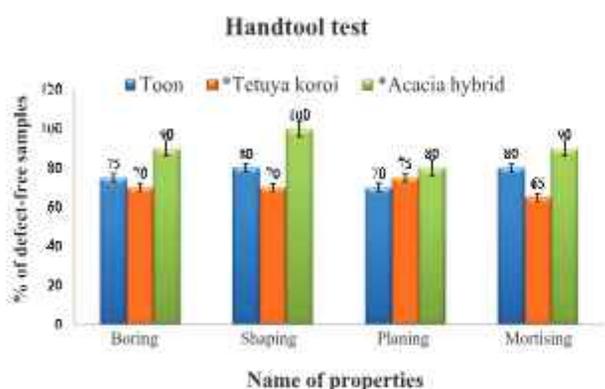


Figure 2. Comparison of the number of defect-free samples as a percentage among three wood species in handtool test. [*Data Source: (Sarker *et al.* 2021)]

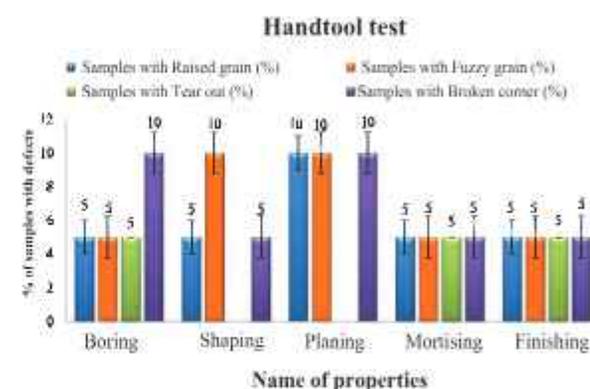


Figure 4. Percentage of raised grain, fuzzy grain, tear-out, and broken corner defects taken from the total number of samples of toon wood in handtool test.

Table 3. Grade-wise performance of different machining and handtool property tests of toon wood based on the number of defect-free samples as a percentage.

Property		Number of tested samples	Percentage of property tests leading to Grade 1 quality
Name	Type		
Planing	Machining	20	75
	Handtool	20	70
Shaping	Machining	20	75
	Handtool	20	80
Boring	Machining	20	80
	Handtool	20	75
Mortising	Machining	20	80
	Handtool	20	80
Turning	Machining	20	80

Discussion

Since Lambu (*Khaya anthotica*) wood was light, sawing was made less difficult since less force was needed on the edge of the blade. In addition, as Jhau (*Casuarina equisetifolia*) wood was heavy and hard, sawing it was tough (Sarker *et al.* 2015). During property evaluation of Mahogany (*Swietenia macrophylla*) wood, it displayed 100% qualified grade in all machining and handtool tests except for machining property of planning operation which rated 95% qualified grade (Sarker *et al.* 2019). But during the evaluation of all the properties of toon wood, both for machining and handtool tests, 70 to 80% of the tested samples exhibited grade 1 quality. Based on comparisons of the defect free samples for different property operations, Toon wood illustrated comparatively better quality in both machining and handtool test than Tetuya koroï (*Albizia odoratissima*) wood which also displayed good quality whereas Acacia hybrid

(*Acacia mangium* × *Acacia auriculiformis*) showed an excellent quality of property results in most cases (Sarker *et al.* 2021). The most common defects of planning tests both for Tetuya koroï (*Albizia odoratissima*) wood and Acacia hybrid (*Acacia mangium* × *Acacia auriculiformis*) were fuzzy grains (Sarker *et al.* 2021). On the other hand, in this study, the observable defects of toon wood both for machining and handtool tests were due to fuzzy grains and broken corners, whereas defects due to raised grains and tear-out were less significant. Sharpened cutters and robust, well-maintained machines are mandatory for the finest machining of the material. With several blades placed inside the blade head, all cutters should be used uniformly (Sofuoglu and Kurtoglu 2014). In general, unusual wood with gelatinous fibers those shrink and expand more than regular wood when the moisture content changes are linked to fuzzy grain. Low rake angles, sanding, dull blades, and other similar factors are frequently related to raise grain. The moisture content of various species

has numerous impacts on the previously mentioned wood machining defects. For instance, raised grain may appear through machining wood at high or low moisture content and then adjusting the moisture content due to the unequal shrinkage and swelling of the early wood and latewood. Fuzzy grains may appear as the moisture content increases. In general, machining defects can be reduced by variations in the moisture content. Minimizing machining defects can be achieved by machining wood at its optimum moisture content (8-12%) and then preserving it there while in use (Harold 1980). When considering wood as a structural element, the moisture percentage is a crucial factor. The future performance of wood within a structure is impacted by its moisture content (Malesza 2015). Visual inspection presented the basis on assessing machining imperfections. However, it proved incapable to precisely evaluate them. An in-depth investigation of the machining experiments could not be performed due to equipment deficits. Further investigation is still required for the best findings (Sarker *et al.* 2019). The wooden materials are supposed to have a smooth grain and be free of knurls or other structures that can cause grain deviations (Sofuoglu and Kurtoglu 2014). In this research, there was found got overall satisfactory results in both machining and handtool property tests of toon wood, which encouraged the people to use this wood species as an alternate to be used for domestic furniture making and other utilization purposes.

Conclusion

Wood-based household furniture is an intimate part of every family as a symbol of

necessity and aristocracy. But it may not always be possible for most of the people in our country to decorate their houses with furniture manufactured from so-called expensive traditional timber species. Hence, it would be a better substitute for manufacturing sustainable and remunerative furniture from toon wood, thereby reducing pressure on conventional timber species. Further investigation might be needed to get information regarding the load bearing capacity and durability of the manufactured furniture.

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Acknowledgements

People, who contributed to the work but are not authors, should be listed in the acknowledgements part, along with their contributions. Authors have to ensure that everyone whose name is included in the acknowledgements does not have any objection to include their name in the acknowledgement part of that particular manuscript.

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