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Review of the Challenges of Ecological Restoration of the Indian Sundarbans: Causes, Planning and Management Strategies

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Abstract:

Ecosystem exists at all scales. Ecosystem ranges from a grain of soil to the entire planet and include forests, rivers, wetlands, grasslands, estuaries and coral reefs. The global economy has seen incredible growth over recent decades; growth that has been fuelled by the erosion of the planet's natural assets. Ecosystem degradation is an environmental problem that diminishes the capacity of species to survive. Ecological restoration has a growing role in policy aimed at reversing the widespread effects of environmental degradation that includes activities to assist the recovery of ecosystem structure and function; and the associated provision of goods and services. On 1st March, 2019, the United Nations (UN) General Assembly (New York, USA) declared the decade of 2021–2030 the "*UN Decade on Ecosystem Restoration*". The purpose has been to recognize the need massively accelerate global restoration of degraded ecosystems, and to fight the climate heating crisis and protect biodiversity on the planet. The Sundarbans is the largest mangrove forest in the world; and it is known for its' rich biodiversity. Due to the increasein salinity, natural disasters, sea-level rise, illegal felling of trees and over-exploitation of scanty available natural resources, the Sundarbans is losing its rich biodiversity. Thus, this review aims in highlighting the restoration initiatives taken to reverse and conserve the Indian Sundarbans ecosystem. Nurturing this vision, there are three main goals of the UN Decade's strategy: prevention of degradation, increasing multiple benefits and implementing the idea of ecosystem restoration in education system. There could be a strong corporation between Indian and Bangladesh Governments for long term, sustainable and holistic management of the entire Sundarbans region.

সারসংক্ষেপ

বাস্তুতন্ত্রে সমস্ত রকম পর্যায় উপস্থিত। বাস্তুতন্ত্র একটি মাটির শস্য থেকে সমগ্র পৃথিবী জুড়েই বিস্তৃত এবং এর মধ্যে রয়েছে বন, নদী, জলাভূমি, তৃণভূমি, মোহনা এবং প্রবাল প্রাচীর। সাম্প্রতিক দশকগুলোতে বিশ্ব অর্থনীতি অবিশ্বাস্যভাবে বৃদ্ধি পেয়েছে, যা পৃথিবীর প্রাকৃতিক সম্পদকে ক্ষয়ের হাত থেকে রক্ষা করেছে। বাস্তুতন্ত্রের অবক্ষয় একটি পরিবেশগত সমস্যা যা প্রজাতির বেঁচে থাকার ক্ষমতা হ্রাস করে। বাস্তুসংস্থান পুনরুদ্ধারের নীতিতে একটি ক্রমবর্ধমান ভূমিকা রয়েছে যার লক্ষ্য পরিবেশগত অবনতির ব্যাপক প্রভাবগুলিকে বিপরীত করা। এর মধ্যে বাস্তুতন্ত্রের কাঠামো এবং কার্যকারিতা পুনরুদ্ধারে সহায়তা করার কার্যক্রম অন্তর্ভুক্ত রয়েছে; এবং পণ্য ও পরিবেশনের সহযোগী উপায় হয়ে উঠেছে। ১ মার্চ, ২০১৯-এ জাতিসংঘ (UN) সাধারণ পরিষদ (নিউ ইয়র্ক, মার্কিন যুক্তরাষ্ট্র) ২০২১-২০৩০ দশককে "বাস্তুতন্ত্র পুনরুদ্ধারে জাতিসংঘের দশক" ঘোষণা করেছে। এর উদ্দেশ্য হল অবক্ষয়িত বাস্তুতন্ত্রের বিশ্বব্যাপী পুনরুদ্ধারকে ব্যাপকভাবে ত্বরান্বিত করা এবং জলবায়ু উষ্ণ করার সংকটের সাথে লড়াই করা এবং পৃথিবীর জীববৈচিত্র্য রক্ষা করা। সুন্দরবন পৃথিবীর বৃহত্তম ম্যানগ্রোভ বন; এবং এটি এর সমৃদ্ধ জীববৈচিত্র্যের জন্য পরিচিত। লবণাক্ততা বৃদ্ধি, প্রাকৃতিক দুর্যোগ, সমুদ্রপৃষ্ঠের উচ্চতা বৃদ্ধি, অবৈধভাবে গাছ কাটা এবং স্বল্পলভ্য প্রাকৃতিক সম্পদের অত্যধিক শোষণের কারণে সুন্দরবন তার সমৃদ্ধ জীববৈচিত্র্য হারাচ্ছে। সুতরাং, এই পর্যালোচনার লক্ষ্য ভারতীয় সুন্দরবন বাস্তুতন্ত্রের বিপরীত ও সংরক্ষণের জন্য গৃহীত পুনরুদ্ধার উদ্যোগগুলিকে তুলে ধরা। এই দৃষ্টিভঙ্গির আলোকে জাতিসংঘের দশকের কৌশলের তিনটি প্রধান লক্ষ্য হল: অবক্ষয় রোধ, একাধিক সুবিধা বৃদ্ধি এবং শিক্ষা ব্যবস্থায় বাস্তুতন্ত্র পুনরুদ্ধারের ধারণা বাস্তবায়ন করা। সমগ্র সুন্দরবন অঞ্চলের দীর্ঘমেয়াদি, স্থিতিশীল এবং সামগ্রিক ব্যবস্থাপনার জন্য ভারত ও বাংলাদেশ সরকারের মধ্যে একটি শক্তিশালী সহযোগিতার প্রয়োজন।

Key words: Biodiversity loss, Climate change, Degradation, Ecosystem, Ecological restoration, Mangrove forests, Sundarbans, United Nations.

Introduction

Definition of Ecosystem – "*Ecosystem* as a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit" (United Nations Conv Biological diversity 1992). An ecosystem comprises all the living organisms and the interactions among them and with their surroundings in a given place. They exist at all scales, from a grain of soil to the entire planet, and include forests, rivers, wetlands, grasslands, estuaries and coral reefs. Cities and farmlands contain important human-modified ecosystems. Ecosystems provide invaluable benefits to human beings; that include a stable climate and breathable air; supplies of potable water, food and natural resources of all kinds; and offer protection from both natural disasters and diseases (Gray *et al.* 2003).

Natural ecosystems are important for human physical health, mental health, and for their identity. They are home to precious wildlife. For many, they are a source of wonder and spirituality. But the loss of nature, climate change, ecological degradation, various types of pollution etc. many type of environmental problems destroying millions of species, which are responsible for making the Earth more beautiful (Gray *et al.* 2003). All over the world, ecosystems face massive threats. Forests are being cleared; rivers and lakes polluted, wetlands and peat lands drained, coastal areas and oceans degraded and overfished, mountain soils eroded; and farmlands and grasslands overexploited (United Nations Environment Programme 2021). Human beings are both directly and indirectly involved in this process of degradation.

These communities can be damaged, degraded, or destroyed by **human activities**

- Damage refers to an acute and obvious harmful impact upon an ecosystem such as selective logging, road building, poaching or invasions of exotic species.
- Degradation refers to chronic human impacts resulting in the loss of biodiversity and the disruption of the structure, composition, and function of the natural ecosystem. Examples include: long-term grazing impacts, long-term over fishing or hunting pressure, and persistent invasions by non-native species.
- Destruction is the most severe level of impact. When degradation or damage removes all macroscopic life and commonly ruins the physical environment. Ecosystems are destroyed by such activities as land clearing, urbanization, coastal erosion, and mining.

Humans seem to have forgotten for long that they are also a part of this same planet. Human beings are capable and knowledgeable enough to put an end to this destruction and work for the restoration of the planet (Basu and Cetzal-Ix 2018b). If they take necessary steps, they can possibly bring the change. Unless they change their ways and work towards protecting and restoring the ecosystems, they will unfortunately destroy the desired landscapes, erode the foundations of their own well-being, and leave a highly degraded and hostile world to our future generations. We have been overexploiting and degrading the global ecosystems, and wild species, causing the erosion of the very basic natural services we depend upon (UNEP 2021). Now with Global Warming and Climate Change, anthropogenic pollution and introduction of exotic species we are further deteriorating our ecosystems (IPBES 2019; Benton *et al.* 2021).

Ecosystem Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. In order to embark on a more sustainable pathway, we need both to conserve and restore our natural ecosystems. This report makes the case why restoration, in particular, is so important and

outlines how the UN Decade can catalyze a movement to restore the global ecosystems. On 1st March 2019, the United Nations (UN) General Assembly (New York, USA) declared 2021–2030 as the "UN Decade on Ecosystem Restoration" (Waltham *et al.* 2020). More than 70 countries supported the task of restoring the global ecosystems. It aims to prevent, halt and reverse the degradation of all ecosystems and restore them to achieve the Sustainable Development Goals (SDGs) (Fig. 1).

Only with healthy ecosystems can we enhance the quality of lives and livelihoods of affected communities, counteract Global Warming Climate Change and prevent the erosion of biodiversity. The decade 2021-2030 gives us enough time to raise and develop global restoration movements for a better future. The United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) will take the initiative to develop building a strong, broad-based global movement to ramp up restoration and put the world on track for a sustainable future. That will also involve building a comprehensive political momentum for ecological restoration at the ground level (UNEP and FAO 2020).

The "*UN Decade on Ecosystem Restoration*" is commencing from 5th June, 2021 with Pakistan, being the leader of one of the world's most ambitious forest landscape restoration efforts. Pakistan hosted the World Environmental Day 2021, celebrating this year's theme of ecosystem restoration and the launch of the "*UN Decade on Ecosystem Restoration*". This flagship programme will be contributing towards the country's target to conserve and restore its fragile ecosystems and safeguard the livelihoods of communities. In 2020, the government initiatives brought together several dedicated non-governmental organizations, local fishermen and women to reinstate land using over 250,000 indigenous nursery plants and 461,000 cuttings (FAO 2021).

To guide and accelerate the global restoration movement, as of 2020, the UN Decade has established **a) Practices**-to focus on the dissemination of restoration knowledge over the next ten years; **b) Finance :** 1) to provide guidance to reorient subsidies towards

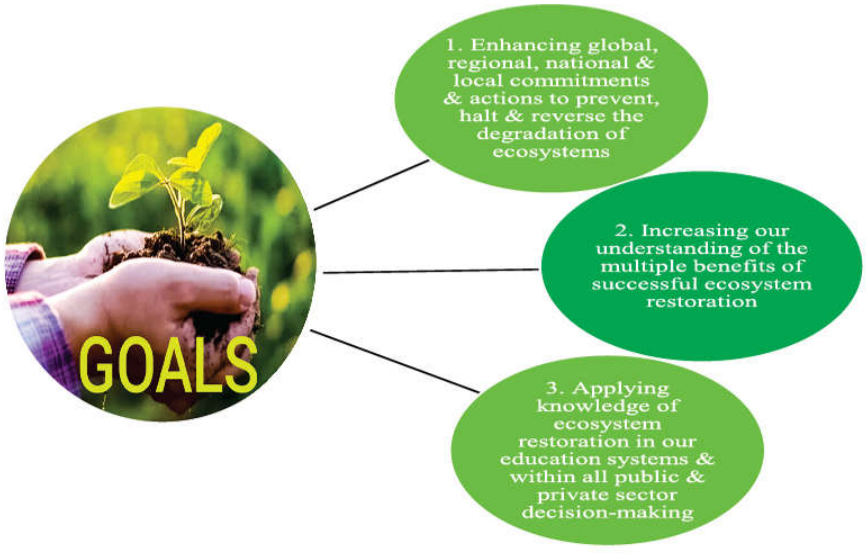

Figure 1. Goals of the UN Decade ecosystem restoration. [Source: United Nations 2020]

ecosystem restoration in an appropriate manner; 2) to counter economic forces and vested interests that result in ecosystem degradation; and 3) to incentivize public and corporate investors to co-invest in ecosystem restoration; **c) Monitoring**-which will help in employing and building the data reporting systems within relevant international commitments, conventions and plans to avoid extra reporting burdens for the global progress of UN Decade; **d) Science**-which will help in conveying concise information and concepts of terrestrial, freshwater and marine ecosystem restoration based on rigorous evidence. The involvement of Youth in the UN Decade is critically important, not only for the sustainability of restoration initiatives beyond 2030 but also for promoting intergenerational equity (Fig. 2).

The UN Decade is focused on eight broad categories of ecosystems, based upon the International Union for Conservation of Nature (IUCN 2020). It gives an idea of each ecosystem, it's benefits and how it gets degraded. The following selected ecosystems such as; farm lands, forests, freshwater, grass lands, shrub lands and savannahs, mountains,

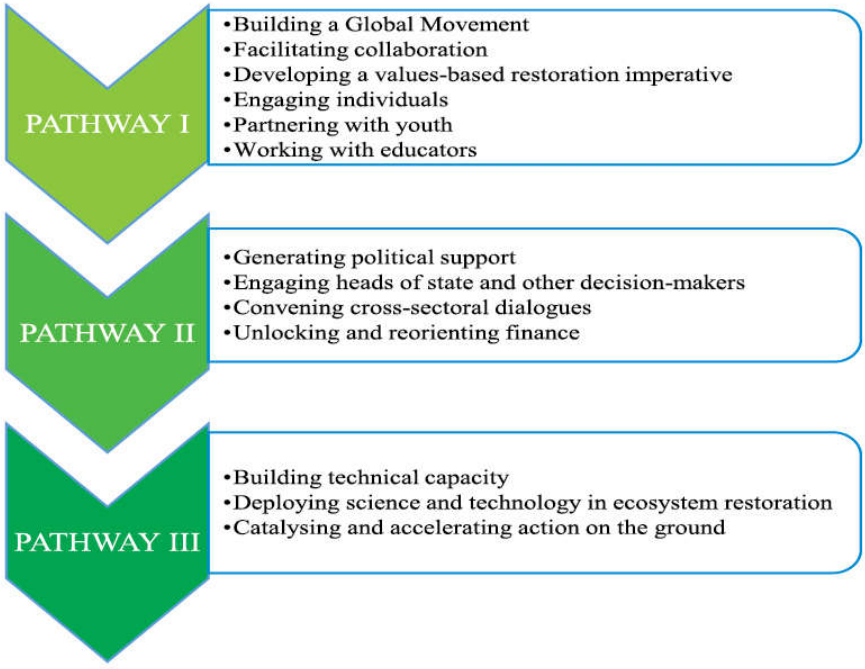

Figure 2. Pathways in carrying out goals. [Source: United Nations 2020]

oceans and coasts, peat lands and urban areas are degrading at an accelerating rate.

Among these eight categories of natural ecosystems, forests captures huge amount of climate-heating carbon and are home to most of our global biodiversity. Providing habitat to more than half of the world's land-based species, forests are important to humans for supply of natural resources (in the form of major and minor forest resources) as the source of food, fodder, fuel, and fertilizer for aesthetic purses as well as eco-tourism to promote the protection of forests in a sustainable manner (FAO 2018; FAO 2019).

Mangroves are one of the important parts of the forests as it gives protection to the coastline and minimizes disasters by behaving as shock absorbers. They perform important ecological functions like nutrient-cycling, hydrological regime and coastal soil protection (Ghosh 2014). The Sundarbans Mangrove Forest is rich in biodiversity in the world. If is famous for various types of unique species found in this region like, the abundance of Sundari trees, the only costal habitat of the famous Royal Bengal Tiger and estuarine crocodiles, etc.

The Sunderbans mangrove ecosystem supports about 334 plant species (Table 1 and Table 2), 120 fishes, 35 reptiles, 270 birds and 42 mammals (Huq *et al.* 2004). List of some important plant species are given in table 1 and table 2. Recent studies have shown that mangroves store more CO_2 than the other forests (Nyanga 2020). The coastal zone makes the Sundarbans more vulnerable to cyclones, sea level rise and high salinity (Begam *et al.* 2017) considerable progress has been achieved through the restoration of highly degraded mudflats by the extensive utilization of four native grass species plantings, *Porteresia coarctata, Myriostachya wightiana, Paspalum vaginatum* and *Sporobolus virginicus*. These grasses proved to exhibit the highest survival percentage (80–90). They are also threatened by increased over dependency of the local human population, unabated poaching,

Table 1. List of important plants of the Indian Sundarbans mangrove forest ecosystem. [Source: https://naturewildlife.org/fauna-of-sundarbans/]

Sl. No.	Scientific name	Common Bengali name	Family
1.	*Heritiera fomes*	Sundari	Malvaceae
2.	*Excoecaria agallocha*	Gewa	Euphorbiaceae
3.	*Ceriops decandra*	Goran	Rhizophoraceae
4.	*Sonneratia apetala*	Keora	Lythraceae
5.	*Xylocarpus granatum*	Dhundul	Meliaceae
6.	*Phoenix paludosa*	Hental	Arecaceae
7.	*Nypa fruticans*	Golpata	Arecaceae
8.	*Bruguiera gymnorhiza*	Kankra	Rhizophoraceae
9.	*Bruguiera cylindrica*	Son Champa	Rhizophoraceae
10.	*Bruguiera parviflora*	Bakul Kankra	Rhizophoraceae
11.	*Avicennia marina*	Peara Baine	Acanthaceae
12.	*Avicennia alba*	Kalo Baine	Acanthaceae
13.	*Avicennia officinails*	Jat Baine	Acanthaceae
14.	*Acanthus ilicifolius*	Hargoja	Acanthaceae
15.	*Aegiceras corniculatum*	Khalsi	Primulaceae
16.	*Aegialitis rotundifolia*	Tora	Plumbaginaceae
17.	*Xylocarpus mekongensis*	Pashur	Meliaceae
18.	*Rhizophora apiculata*	Garjan	Rhizophoraceae

conversion of forest land for agriculture, illegal cutting of trees, over exploitation of forest resources, coastal fishery and shrimp farming (Nishat *et al.* 2019; Das and Datta 2016). Gradually the Sundarbans is losing its rich biodiversity of indigenous flora and fauna at an alarming rate (Basu and Cetzal-Ix 2018 a, b; Jahan 2018). Thus, this review aims in highlighting the restoration of the Sundarbans mangrove forest ecosystem.

Sundarbans Mangrove Forest

The Sundarbans (Fig. 3) is the largest mangrove forest in the world, lies on the biggest delta region of the Ganga-Brahmaputra and Meghna rivers on the Bay of Bengal, spread across India and Bangladesh (Pani *et al.* 2013). It is also the world's largest coastal wetland (Fig. 4). The Sundarbans mangrove forest approximately occupy 10,000 km² of which 4,260 km² area in West Bengal, India

Table 2. List of medicinal plants from the of the Indian Sundarbans mangrove forest ecosystem. [**Source**: Simanek and Holden 2004]

Sl. No.	Scientific name	Family	Uses
1.	*Azanza lampas*	Malvaceae	Fruits for syphilis
2.	*Derris indica*	Fabaceae	Seed powder in bronchitis
3.	*Acanthus ilicifolius*	Acanthaceae	Asthma, Snake bite
4.	*Casuarina equisetifolia*	Casuarinaceae	Bark in diarrhea
5.	*Derris trifoliata*	Fabaceae	Antispasmodic and stimulant
6.	*Ceriops tagal*	Rhizophoraceae	Root as substitute of quinine
7.	*Rhizophora apiculata*	Rhizophoraceae	Root for blood pressure
8.	*Tamarix dioica*	Tamaricaceae	Tonic, Skin disease
9.	*Tamarix gallica*	Tamaricaceae	Astringent in dysentery

(across South and North 24 Parganas districts) and 6,017 km² area in Bangladesh [https://whc.unesco.org/en/list/798/]. In 2019, Sundarbans accepted formal designation as Ramsar Convention site (Begam *et al.* 2020). In 1997, it was reported by UNESCO as a World Heritage site (Sarker 2017).

Figure 3. Map of Sundarbans Mangrove Forest [Source: https://en.wikipedia.org/wiki/Sundarbans]

Figure 4. The Sundarbans mangrove forest ecosystem.

Figure 5. Nipa palm

The Sundarbans is rich in biodiversity with unique species in terms of flora and fauna. The major attraction of the Sundarbans is Sundari or Sundari (*Heritiera fomes*) and is believed that it was named after the Sundri or Sundari trees. Gewa (*Excoecaria agallocha*), Nipa palms (*Nypa fruticans*) (Fig. 5) and other salt-tolerant species like Holy mangrove (*Acanthus illicifolius*) (Fig. 6) are also found in this forest [https://www.britannica.com/place/Sundarbans]. This forest has a significant tiger population and is the only mangrove habitat where Bengal tiger (*Panthera tigris*) are found with unique aquatic hunting skills. It is also the home to many endangered species like the estuarine crocodile (*Crocodilus porosus*) (Fig. 7), fishing cat (*Felis viverrina*), common otter (*Lutra lutra*), water monitor lizard (*Varanus salvator*) (Fig. 8), irrawaddy dolphins (*Orcaella brevirostris*) and critically endangered species like northern river terrapins (*Batagur baska*), fishing cats (*Prionailurus viverrinus*), Ganges river dolphins (*Platanista gangetica*), spotted deer (*Cervus axis*) and wild boar (*Sus scrofa*) etc. [https://rsis.ramsar.org/ris/2370] (Basu and Cetzal-Ix 2018 a, b).

Figure 6. Holy mangrove

The Sundarbans has more than 250 bird species, both seasonal migrants and permanent residents, including hornbills, storks and other waders; 12 species of kingfishers and two of the world's four horseshoe crab species, marine turtles, crocodiles and many types of snakes like Indian pythons, common krait (*Bungarus caeruleus*) (Fig. 9) and Indian spectacled cobra (*Naja naja*) (Fig. 10) [https://whc.unesco.org/en/list/798/]. These mangrove forests protect different small riverine area, constantly transformed by the erosion forces of the sea wind along coast and also diverted upstream salty water. The Sundarbans mangrove forests act as a protective biological shield for the Sundarbans and its adjacent areas against the natural phenomenon like cyclones, storms, tsunamis, seepage and tidal surges (Barbier

2006). The dense mangrove forest saves the coastal community from destruction, reduces loss of lives and damages to properties. Most of the surface area in the Sundarbans is inundated with saline water. The landscape has been transformed by both by natural forces and anthropogenic activities (Ghosh *et al.* 2015; Nishat 2019).

Figure 7. Estuarine crocodile

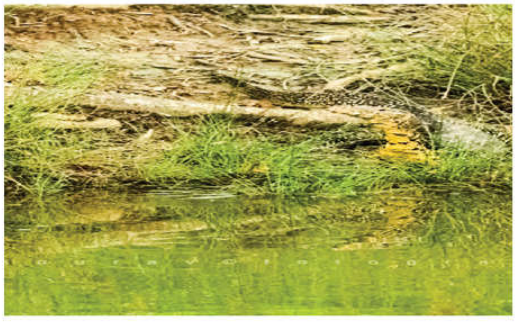

Figure 8. Water monitor lizard

Figure 9. Common krait

Figure 10. Indian spectacled cobra

Factors that contribute to the environmental issues in Sundarbans

The rapid destruction of the mangroves of Indian Sundarbans are due to over-exploitation, pollution, deforestation and pressured by many threats such as shrimp farming, human encroachment (including land reclamation), natural disasters e.g. storms, floods, cyclones, coastal erosion and natural changes in hydrology, sea level rise and inadequate regeneration (Ghosh *et al.* 2015) It is affected by climate change for increasing salinity of tropical cyclones. Agricultural practices and industrial development, over-logging in coastal areas causes severe damage to the ecosystem (Barbier 2006; Basu and Cetzal-Ix 2018 a, b). Over the past few decades, the anthropogenic impact on mangroves has rapidly increased (Carugati *et al.* 2018). The study seeks to identify the root causes of deterioration of the Sundarbans mangrove forest. The application of sustainable management strategies covers the needs for an advanced improvement of scientific research as well as conservation measures.

a. Natural Causes

- **Soil erosion** - Over the past three decades, 24.55% of Mangroves has been lost in India and Bangladesh due to erosion (Ghosh 2020). If the system is undisturbed, Sundarbans periodical erosion and accretion of sediments

in coastal mangroves are internal dynamics and it can be balanced by the ecosystem. Another key factor of high erosion activity over area is the impact of climate change such as changes of coastal current, changes in wind speed (Spalding 2014)

- **Climate change and Global warming** - Mangroves can withstand the damage caused by the natural calamities such as cyclones. But substantial damage caused by the increasing frequency and intensity of extreme events, such as floods, sea level rise, cyclones like Amphan, Yaas, etc (Fig. 11) weakens their potential tenacity. Climate change is set to damage biodiversity of the Sundarbans, increasing the immersed areas and salinity of water in coastal areas (Spalding 2014). Low-lying areas of the mangrove forest are flooded by tidal waters every year because of sea level rise along with massive silt deposition and shrinking of deltas (Basu *et al.* 2021). They are therefore extremely sensitive to current rising sea levels caused by global warming and climate change. Global warming is expected to cause changes such as higher temperatures, sea level rise and changing rainfall patterns, as well as more abrupt effects (Ghimire and Mayank 2012).

Figure 11. Embankments damaged in West Bengal's coastal areas due to cyclone Yaas.

b. Anthropogenic Causes

- **Over-exploitation** - To meet the requirement of the growing people, over-exploitation of forests is one of the main problems of the Sundarbans. The illegitimate removal of timber is due to the wide gap between the demand and supply and almost permanent unemployment in rural areas (Patel and Rajagopalan 2009). The increased population has been recognized as extra stress on the Sundarbans mangrove forest environment, and it accelerates the degradation of forest resources and their production. The Sundarbans have been exploited for timber, fuel wood, bark tannin, animal fodder, native medicines and food for centuries. Population pressure has greatly increased the rate of exploitation, leading to serious destruction of the mangrove forest (Ghimire *et al.* 2012; Rahman *et al.* 2010).

- **Pollution** - The mangrove forest ecosystem of Indian Sundarbans has also become vulnerable to pollution such as oil spillage, heavy metals, agrochemicals–especially pesticides and nutrient enrichment. Oil pollution, especially crude oil and its derivatives, are one of the most harmful pollutants that enter the mangrove forest (Rahman *et al.* 2010).

- **Agriculture** - Agriculture and aquaculture lead to direct land clearing and conversion, deplete wild fish and crustacean populations, alter water quality through various inputs such as feed and medicines, and extract water which influences soil and water salinity. Agriculture and aquaculture near the river basins, has led to the production of huge amounts of garbage, waste water, pollutants and other effluents being discharged to the mangrove wetland (Mistri and Das 2015).

- **Biological resource use** - The local human population relies on the mangrove ecosystem for a range of resources, such as food fish and crustaceans, honey cultivation, hunting and poaching of tigers, spotted deer and boar, as well as tree harvesting for building materials,

firewood and paper production (Basu and Cetzal-Ix 2018 a, b; Gopal and Chauhan 2006).

- **Natural system modification and residential and commercial development** - Modifications to the ecosystem largely center around the construction of barrages, dams and embankments. Most prominent, the Farakka Barrage in 1975 substantially limited freshwater and sediment supply to the Sundarbans mangrove ecosystem as well as resulting in changes in salinity regime. Forest clearing and land conversion for human developments began at least as early as the 1700s. Mangroves continue to be cleared for the construction of jetties and harbours, commercial shipping traffic is increasing, and the tourism industry is growing quickly (Sievers *et al.* 2020).

- **Mass tourism and coastal development** – Tourism is a booming industry and major source of income in developing nation. It causes disturbances which damages mangroves and surrounding ecosystem. Tourism can be sustainable when groups are small and people leave the habitat the way they found it. Coastal development takes many forms, from ports and docks to hotels, marinas. Worst still, pollutants that accompany development can damage individual trees or whole tracts of mangroves (Gopal and Chauhan 2006; Sarker 2017)

Impact of the environmental issues in Sundarbans Mangrove Forest

Biodiversity loss of Sundarban Mangrove Forest

Sundarbans, the biggest chunk of swamp mangrove forest, was underneath the ocean around 4,000 years ago (Ali 1994). Pedologically, the forest's soil is young, inadequately depleted with uncured deposits having no distinct horizon. More than 120 species were noted to be caught by fishermen (Rahman *et al.* 2010). The Sundarbans has an extraordinarily rich diversity of aquatic and terrestrial flora and fauna, however the quantity is reducing continuously (Jahan 2018). The change of normal courses of waterways, development of banks, dams, extensions in the upstream, diminished buoy of freshwater in the streams brought about the expansion in the degree of saltiness at numerous spots causing subsequent negative changes to the mangrove biological community. Both natural and anthropogenic factors are responsible for the biodiversity loss of the Sundarbans (Das and Datta 2016; Rahman 2014)

Economical loss

Economically, the Sundarbans produces raw materials for privates (fuel wood, furniture, house construction, charcoal, match sticks, and newsprints) and public goods (air, natural beauty, fisheries, and navigation). The full value of the public goods supplied by the Sundarbans mangrove ecosystem is not recognized, as many of these items and offerings are now not traded in open markets (Basu and Cetzal-Ix 2018 a, b). The Sundarbans is a standout amongst the most various thriving ecosystem communities on the planet as a protective obstruction amid the catastrophic time frame for the coastal communities and serve as various monetary, social and natural advantages. This forest also provides occupation for nearby people through fishing, nectar and wax collection, tourism, wood, and non-wood items (Khan *et al.* 2021).

Shrimp farming

Increase in shrimp farming enterprise possesses their impact on deteriorating the mangrove forests. The entire vicinity under brackish water shrimp farming was increased from 51,812 - 2,17,000 ha in 1984-2008 in the coastal areas of the Sundarbans. During shrimp cultivation, individually utilized urea, which mixed with salty water, resulted in the degradation of the aquaculture lakes (Das and Datta 2016; Roy *et al.* 2016). Mangrove forests are responsible for the destruction of

wild fry by catch and salinization of soil and water. Recently, mangroves have been used for fish, shrimp and especially giant tiger prawn *Penaeus monodon* farming. Sundarbans has been completely destroyed in recent years because of shrimp farming. Shrimp fry fishing in particular is considered to be very destructive (Das and datta 2016).

Sea level rise

Climate change induces higher evapotranspiration and low drift in winter would increase salinity. As a result, an increase in fresh water-loving species would be impaired. The variation of temperature and precipitation of 34 stations of Bangladesh over the 33 years' time frame (1976-2008). It is observed that the average maximum temperature has been growing at a change of 0.018 °C/year. This mangrove forest is the passing route of cyclones formed over the sea or down from the Himalayas (Pramanik *et al.* 2015). The impacts would be ocean level ascent, force of the cyclonic tempest, unpredictable precipitation, increases salinity. If the sea level rises above 100 cm, around 15% of the forest will go underwater and will be fully destroyed (Banerjee *et al.* 2017). Due to the impact of climate change, species like *Heriteria fomes* (Sundari) would be replaced by less valuable species like *Ceriops* spp (Rahman *et al.* 2021; Rahman 2011).

Plant diseases

A dominant disease of *Heritiera fomes* is one of the major causes of the deterioration of the forest. More than 5-6% of the entire *Heritiera fomes* are now suffering from top dying and half of them have already been affected due to salinity intrusion. About 70% of *Heritiera fomes* stems were severely affected by diseases (Khan *et al.* 2021).

Environmental instability and more vulnerability

The environmental condition of the Sundarbans mangrove forest is getting unstable caused by several elements. Shrimp farming, increased salinity, accidents like oil spill and fire, pollution, global warming and climate change, and many others were the foremost reasons (Banerjee *et al.* 2017). It has been determined that, at high salinity, the predominant cause of the decrease in growth is the reduction in the expansion rate of leaf. Salinity impacts the normal development and efficiency of mangroves. The degradation of the forest and erosion of biodiversity is accountable for the change in climatic status, and global warming and climate change is triggering natural calamities (Ullah *et al.* 2021) The Sundarbans ecosystem works as a barrier for various natural disasters (*i.e.* cyclone, coastal flooding) that first strike on the coastal sector. As the safety barrier is damaging day by day, the damages are increasing all over the country (Basu and Cetzal-Ix 2018 a, b).

Some of the restoration programmes in the Sundarbans Mangrove Forest

1. The local resilience of mangrove forests in the Indian Sundarbans, the continuous mangrove habitat stretched between India and Bangladesh, is being destroyed due to anthropogenic coastal activities and climate change aggravates degradation of small coastal patches (Banerjee *et al.* 2017). Declination of forest coverage from ~ 98 to ~ 11% is caused due to nutrient limitation, rise in salinity, increases toxicity. An obvious change in species distribution is forecasted while salt-sensitive *Heritiera fomes, Xylocarpus spp*., and *Phoenix paludosa* failed to get along with increased salinity, perceptible by their absence from many forests. *Excoecaria agallocha* and *Avicennia spp.* Degraded forests across the Sundarbans have acclimated well and expanded freely. As primary mechanism for mangrove degradation, this study resolutely establishes encroachment on salinity.

Primarily due to different coastal development, more than 35% of the mangrove area has been lost. In the spatial distribution of vegetation, soil nutrient availability is an important factor that is essential for the understanding of mangrove growth patterns. Key factors controlling the density and development of mangrove forests depends upon the concentrations of organic carbon, ammonia–nitrogen, phosphorus and the activity of microbial enzymes for decomposition and nutrient cycling in sediments (Begam *et al.* 2020).

Reduction in the observed nutrient and salinity increase, sulfide and sand percentage, the major negative controlling factors influencing mangrove forest cover, were resolutely correlated with declining of forest. Mangroves' natural adaptations to high salinity and low nutrients can be defended against the observed consequences of habitat degradation (Basu and Cetzal-Ix 2018a; Gopal and Chauhan 2006). Unlike healthy forests, degraded forests exhibited visible degradation in terms of forest clearing, poor stunted growth of vegetation, and dominance of salt-tolerant species caused by human-related and natural causes. A strong statistical relationship would have been lacking, and the mangroves would have developed flexibility to face these natural limitations (Basu and Cetzal-Ix 2018b). These systems move from healthy to more degraded forests which increases salinity on both sides, riverward as well as landward side (Ghosh *et al.* 2018) .

In healthy forests, salinity-sensitive species have been seen growing towards landward side, while high salinity tolerant species are growing towards the river's edge. In contrast to the healthy forests, more degraded forests have salinity restricted zonation of mangroves which is observed to be disrupted. Some species which are intolerant or not salinity-sensitive, are absent from many forests. At present, *Heritiera fomes* which has a restricted distribution in India, is declared endangered, and *Phoenix paludosa* is considered near threatened by the International Union for Conservation of Nature (IUCN 2003).

2. The restoration technology, developed by Krishna Ray (WBSU) and Sandip Kumar Basak (Sarat Centenary College, Dhaniakhali) involves plantation of native salt-tolerant grasses (four native grass species) a diverse set of carefully identified mangrove species in different zones of degraded mangrove patches. It also involves the use of growth-promoting bacteria with the correction of nutrition of soil to prevent coastal erosion due to high tide and low tide, wave, floods (Begam *et al.* 2017)

Major restoration initiatives suggested for the Sundarbans ecosystem

i. Restoration and afforestation programmes

The Sundarbans Biosphere Reserve (SBR) has come out with strategy for conserving and restoring mangroves in the Indian Sundarbans: a) prevention to ensure that degradation is minimized; and b) better management to restore degraded mangroves and bring newly accreted mudflats under mangrove. An independent monitoring mechanism has also been established to assess the success of the afforestation programmes and also monitors changes in mudflats and erosion. Since the declaration of the SBR in 1989, a total of 17,000 ha of mangrove plantations have been established on mudflats, in degraded mangrove forests, and on river embankments. The planting technique involves cutting trenches at 4-m intervals along the river line and digging pits (30 cm x 30 cm x 30 cm) between the trenches in August–September. Dibbling of 2,500 seeds is done at a spacing of 4 m x 1 m, and afterwards 2,500 propagules are planted at a spacing of 4 m x 1 m. The species planted are mainly *Xylocarpus granatum* (dhundul),

Sonneratia apetala (keora) and *Heritiera fomes* (sundari) as potted seedlings. Reforestation is an urgent need as only mangroves can protect the inland from natural calamities to save both forest and livelihoods of local people, by building a functioning ecosystem (Samanta *et al.* 2021).

ii. The role of government and external development assistance

Government extension workers should be responsible for enforcing forestry and fisheries laws. There is a need to rationalize government policies and reconcile conflicting laws on mangrove conservation and management. For example, local governments should stop the widespread practice of accepting payments of real estate taxes on mangroves (as a means of raising much-needed revenues) which clearly violates the protection bestowed on mangroves by national laws (Pramanik 2014). Moreover, organized communities and committed leadership can only achieve limited success unless tenure rights are granted to resource users to other marine interventions and to improve sustainability of mangrove restoration. There is a need for international development banks, bilateral funding sources and other external assistance agencies to invest in the restoration of mangrove habitats (and agricultural lands) damaged by shrimp and aquaculture, natural disasters (Das and Datta 2016). In the longer term, developing alternative livelihoods through enhancing the skills of local people and improving their incomes and quality of life, should work to further reduce human-animal conflicts (Basu and Cetzal-Ix 2018 a, b).

iii. Restriction of people into the buffer and core areas

Local people's struggle in earning in subsistence living in the villages are located on the edge of the buffer area of SBR (Fig. 12).

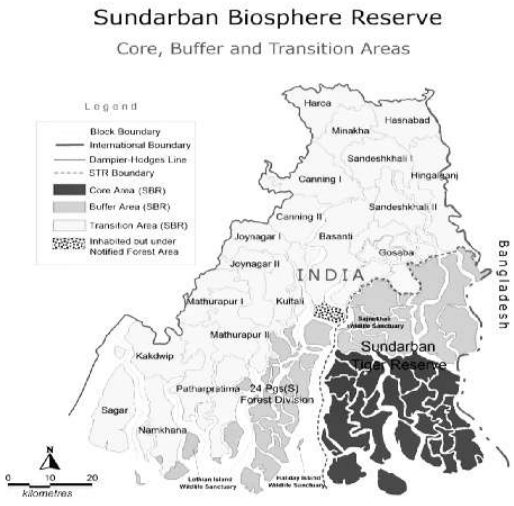

Figure 12. Area division of Sundarbans Mangrove Forest by SBR

People uses large amount of agricultural land and including their homestead. A large population of people living in scattered, often remotely located, islands, with poor access to basic facilities such as health, education, roads, sanitation, potable water and electricity (Gopal and Chauhan 2006). For a stable livelihood, they are solely dependent on the forest and rivers, and illegally get into the core area of the forest for fishing and honey cultivation which may hamper the species' environment. Core areas includes protected areas where Forest Department does not allow any anthropogenic activities (except research) to preserve the major habitats of diverse flora and fauna of the Sundarbans and buffer areas are those which are conserved alongside compatible human uses of the land or water for honey collection and fishing. The transition area is occupied by fishermen, farmer and others people (Ghosh 2015).

iv. Fishing regulations

The Sundarbans is an important breeding ground of fish and a habitat for tigers.

Livelihood options are limited and its concerns are highlighted by the fishing communities in the area, as it is one of the most important sources of livelihood. There is a need to re-assess the status of fisheries resources within the Sundarbans (Ghosh 2015). Provisions should also be made to assess the number of active fishers without Boat Licence Certificate (BLCs), and to reissue the inactive BLCs to them (Fig. 13).

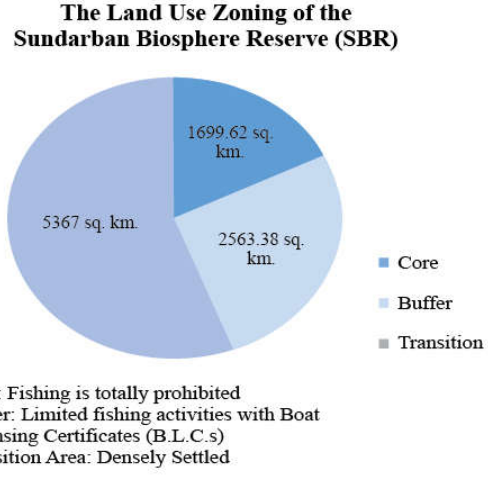

Figure 13. Graphical representation of land uses in Sundarbans Mangrove Forest.

The process of renewal of BLCs/permits should be made easier, as well as efficient, accountable and transparent, and fines should (Mistri and Das 2015). In the longer term, developing alternative livelihoods through enhancing the skills of local people and improving their incomes and quality of life, should work to further reduce human-animal conflicts not be charged for non-renewal of licenses (Patel and Rajagopalan 2009).

v. Forest regulation

- **Fines:** The Forest Department should develop transparent guidelines in a consultative and participatory manner, detailing the fine amounts to be paid (as 'compensation') for offences compounded. In improving compliance and implementation, the fine charts should be developed with information on the type of offence and the corresponding fine amount. To enable fishers to understand the offence, efforts needs to be made to note violations in the local languages. This should also be effectively implemented (Patel and Rajagopalan 2009).
- **Patrolling:** To ensure effective compliance and to reduce human animal-conflict, fishing communities should be involved in patrolling the PAs, along with the Forest Department (Patel and Rajagopalan 2009).

vi. Eco-tourism

A proper management is required to ensure the participation of the local people and retain the majority of revenue, resulting in reduction of their dependence on the forest to a great extent and aiding the conservation process (Ghimire and Mayank 2012). Policy guidelines ensuring equitable cost-benefit sharing mechanisms for tourism (Fig. 14) needs to be developed, keeping in mind that the worst affected community members get a larger share of the benefits. Employment options such as working as tour guides can be considered for at least some fisheries (Mistri and Das 2015).

Figure 14. The Sundarbans Eco-tourism.

Conclusion

Healthy, stable and biodiverse ecosystems are the foundation of our well-being. The loss of biodiversity, global warming and climate change, ecological degradation, anthropogenic pollution are all important threats to the Sundarbans ecosystem. In order to embark on a more sustainable pathway, we need to conserve and restore ecosystem. The UN Decade aims to catalyze a movement to restore the world's ecosystems as well as the development of new ambitions. Today, the frequency, intensity and the timing of the natural climatic events like cyclones, hurricanes, droughts and tidal surges are shifting as a result of anthropogenic activities. Global Warming and Climate Change are making the forest ecosystems even more susceptible to irreversible damages. The Sundarbans mangrove forests having rich global biodiversity is threatened by numerous factors such as floods, cyclones, sea-level rise, poaching, illegal felling of trees, over over-exploitation of scanty available forest resources etc., biodiversity loss, more vulnerability, environmental instability and economic loss lays a major impact on the Sundarbans ecosystem. Major restoration initiatives suggested for the Sundarbans ecosystem are regular and continuous afforestation programmes, the role of government and external development assistance, restrictions on fishing and use of forest resources. It is expected that if India and Bangladesh take joint initiative and collaborate with each other in the restoration programme, the Sundarbans can easily be restored and conserved on a sustainable manner. Similarly, to carry out the restoration programmes in each part of the ecosystems all over the world, there should be specific goals and pathways strategy to initiate the recovery of an ecosystem after disturbances. Since the forest stretches between two independent and sovereign countries, it is important to point that both nations need to explore opportunities for better cooperation, collaboration, coordination and communication (4Cs) in multiple domains for effective conservation. Exchange of census data of different key wildlife species inhabiting the sensitive ecological zone, their population dynamics, extensive vegetation survey using modern gadgets and technology, preparing detailed forest resources maps can play a very important role in better understanding standing the dynamics of the Sundarbans mangrove forest. Such a 4Cs approach can not only prevent poaching and trafficking of both dead and live wild animals and vulnerable forest products; but also help in establishing law of the land comprehensively across the entire region. The porous border has always been a serious security threat across the vast forested areas between the two countries. Hence, joint monitoring and surveillance by border security forces and forest guards of both countries can effectively help in reducing the dangers of poaching and human as well as wildlife trafficking in the densely forested areas.

It is important to realize that the Sundarbans mangrove ecosystem needs serious and dedicated efforts from all the stakeholders for its long term sustainable existence. The stakeholders in the process being the national and regional governments, non-government agencies, political parties, fisheries association, fishermen, farmers, crop producers, loggers, honey collectors, members of forest departments, wildlife and mangrove experts and border patrolling agencies of both India and Bangladesh. The rapid degradation of this unique ecosystem particularly due to the anthropogenic causes need to be addressed with serious attention, and also with strong determination and political will of both India and Bangladesh.

Hence, it is important that the local governments in both India and Bangladesh take a serious look in minimizing the severe dependency of local inhabitants on the scanty forest resources available. Alternative livelihoods as well as various programs for year-round economic employment are essential to reduce the continuous stress on the sensitive ecosystem. Afforestation with site suitable species needs to be followed year round with the help of modern and highly specialized mangrove nurseries to provide seedlings of various indigenous plant species. A comprehensive Joint Conservation Initiative (JCI) between India and Bangladesh will be important for restoration of this extremely vulnerable mangrove ecosystem. Both countries therefore need to follow cooperation, coordination, collaboration and communication at the ground level for a successful execution of conservation and sustainable ecosystem restoration strategies. In short, such unique ecosystem can be considered as filtration kidneys for our planet to survive and help in reducing the impacts of climate change. If do not take the initiative now; it may be too late to save one of the most unique global ecosystems of the planet.

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Dormancy Breaking by Pre-sowing Treatment and Growth Performance of Kusum (*Schleichera oleosa* Merr.) Seedlings in Nursery and Field Condition in Chattogram

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Abstract

Seed germination percentage of Kusum (*Schleichera oleosa* Merr.) was examined with 5 pre-sowing treatments in the nursery of Bangladesh Forest Research Institute and growth performances of seedlings were determined in the nursery and field condition. The main aims of the study were to determine the effect of different pre-sowing treatments on seed germination and seedlings growth performance in nursery and field condition. The pre-sowing treatments were: i) soaking of seeds in tap water for 12 hours, ii) soaking of seeds in tap water for 24 hours, iii) soaking of seeds in tap water for 36 hours, iv) soaking of seeds in tap water for 48 hours and v) control (0 hour). The seeds after soaking were sown in the seed bed directly in the nursery. Seed germination percentage were significantly ($p \leq 0.05$) influenced by pre-sowing treatments and the highest germination (72%) was obtained when soaked for 36 hours. and the lowest (48%) was in control. With treatment (T_3), the maximum shoot length (12.8 cm), root length (11.6 cm), and vigor index (1171.2) were noted. The young seedlings were transferred after 30 days of germination having 3-4 leaves from seed bed to polybags (15×23 cm size) filled with soil and cow dung at 3:1 ratio by volume. Survival percentage of seedlings was maximum (96%) at 2.00 m × 2.00 m spacing in the field and maximum height 105.54 cm 12 months after out-planting. The results of the study suggest the pre-sowing treatment of seeds in tap water for 36 hours was most effective treatment for higher germination percentage and out-planting of one year old seedlings at 2.00 m × 2.00 m spacing in the field for better growth performance of *S. oleosa* seedlings.

সারসংক্ষেপ

বাংলাদেশ বন গবেষণা ইনস্টিটিউটের নার্সারিতে ৫টি প্রি-ট্রিটমেন্ট-এর মাধ্যমে কুসুম-এর বীজের অঙ্কুরোদগম হার পরীক্ষা করা হয় এবং নার্সারি ও মাঠ পর্যায়ে চারার বৃদ্ধি পর্যবেক্ষণ করা হয়। গবেষণার প্রধান লক্ষ্য ছিল বীজের অঙ্কুরোদগম এর উপর বিভিন্ন প্রি-ট্রিটমেন্ট-এর প্রভাব এবং চারার বৃদ্ধি ও বেঁচে থাকার হার অনুসন্ধান করা। গবেষণায় কুসুম-এর বীজগুলোকে ১২ ঘণ্টা, ২৪ ঘণ্টা, ৩৬ ঘণ্টা, ৪৮ ঘণ্টা ও ০ ঘণ্টা (কন্ট্রোল) ট্যাপের পানিতে ভিজিয়ে ট্রিটমেন্ট করা হয়। উক্ত ট্রিটমেন্টগুলোর মাধ্যমে বীজগুলো সরাসরি বীজতলায় বপন করা হয়। বীজের অঙ্কুরোদগম হার উল্লেখযোগ্যভাবে ($p \leq ০.০৫$) প্রি-ট্রিটমেন্ট দ্বারা প্রভাবিত হয়েছে এবং ৩৬ ঘণ্টা ট্যাপের পানিতে ভিজিয়ে বীজ বপন করলে সর্বোচ্চ ৭২% ও কন্ট্রোলে সর্বনিম্ন ৪৮% অঙ্কুরোদগম পাওয়া যায়। T_3 ট্রিটমেন্টের ক্ষেত্রে সর্বাধিক কাণ্ডের দৈর্ঘ্য (১২.৮ সে.মি.), মূলের দৈর্ঘ্য (১১.৬ সে.মি.), এবং ভিগর ইনডেক্স (১১৭১.২) লক্ষ্য করা গেছে। অঙ্কুরোদগমের ৩০ দিন পরে ৩-৪টি পাতাসমৃদ্ধ চারা বীজতলা থেকে মাটি এবং গোবর (৩ ঃ ১) ভর্তি পলিব্যাগে (১৫×২৩ সে.মি. আকারের) স্থানান্তরিত করা হয়। মাঠ পর্যায়ে ২.০ মি. × ২.০ মি. দূরত্বে চারাগুলির বেঁচে থাকার হার সর্বাধিক (৯৬%) এবং ১২ মাস পরে সর্বোচ্চ উচ্চতা হয় ১০৫.৫৪ সে.মি.। কুসুম বীজের ক্ষেত্রে ৩৬ ঘণ্টা ট্যাপের পানিতে ভিজিয়ে বপন করা সর্বোত্তম কৌশল এবং মাঠ পর্যায়ে ২.০ মি. × ২.০ মি. দূরত্বে এক বছর বয়সি চারা রোপণ করা উপযুক্ত বলে প্রতীয়মান হয়।

Key words: Growth performances, *Schleichera oleosa,* Spacing, Survival capacity, Treatments.

Introduction

Schleichera oleosa Merr. is a medium sized to large deciduous tree species and belongs to the family Sapindaceae. The plant attains up to 35-40 meter height with 2-2.50 m diameter (Ahmed *et al*. 2009). *Schleichera oleosa* is locally known as kusum tree in Indian subcontinent, but is also known as Ceylon oak in Sri Lanka. This tree is noted for its growth of new leaves that are bright red and appears in March to May. The leaves are pinnate, with each leaf having 2-4 leaflets. Flowers are pale yellow or pale green. Sepals are ovate to deltoid, 1.5 mm long. Fruits are broadly ovoid to sub-globular, 15 × 13 mm long. Flowering and Fruiting occurs during March-November (Hossain and Kamaluddin 2005). About 60-64% kernel is found from the seeds (Baul *et al*. 2010). This tree grows naturally from the foothills of the Himalayas and the western Deccan Plateau, SriLanka, China and Southeast Asia. It grows in Bihar, Central and Southern parts of India. The tree occurs sporadically, seldom gregariously in dry, mixed deciduous forests. It is frost and drought tolerant species and it has good cropping power. It also grows in rocky, gravelly, or loamy, slightly acidic soil that is well drained. It is occasionally found in swampy locations, but it usually grows on rather dry soil, at low altitudes, but can be found at 900–1200 meters above mean sea level. The requirement of normal rain fall is 750–2800 mm and ambient temperature of 35-47.50°C (Ara *et al.* 2013).

In Bangladesh, the plant occasionally occurs in some gardens and forests under cultivated condition. Over exploitation is the main threat to this species. The wood is very hard and reddish brown, durable and used for the roller of oil and sugar mills, rice ponders, agricultural implements. Wood is used for making charcoal. Ripe fruit is eaten raw. Leaves and twigs are lopped for cattle fodder. Oil is also used to cure skin diseases. But the species is disappearing in an alarming rate due to forest fragmentation and deforestation (Ara *et al.* 2013; Hossain and Kamaluddin 2005). *Ex-situ* conservation measures have been proposed for this species (Ara *et al.* 2013). Seeds contain oil which is traditionally used for the cure of itch, acne, burns, other skin troubles, rheumatism (external massage), hair dressing and promoting hair growth. Powdered seeds of *Schleichera* are used for ulcers and wounds of cattle to remove maggots and bark is used for skin inflammations and ulcers. It has also been reported that oil is used as antimicrobial, antioxidant, anticancer activity, and can be used for the production of biodiesel (Meshram *et al.* 2015). The plant contains low tannin levels therefore it can be used as fodder for livestock. This species contains important phytochemicals such as terpenoids, betulin, betulinic acid etc. The literature reveals that this medicinal plant can be used as an alternative to synthetic compounds for use in preventing and treating several diseases. Considering this fact, therefore an attempt has been made to study the effect of pre-sowing treatments on seed germination in order to recommended suitable pre-sowing treatments for *S. oleosa.*

Materials and Methods

The study area

The study was carried out in the nursery of Bangladesh Forest Research Institute (BFRI), Chattogram, Bangladesh over a period of two years from August 2018 to July 2020. 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″ East longitudes (Fig. 1). The climate of the study area is tropical in nature and characterized by hot humid summer and cool dry winter. The maximum and minimum temperature in the area varies from 28.30-15.20°C (Hossain *et al.* 2005). Mean annual rainfall is around 3000 mm mainly occurred from June to September.

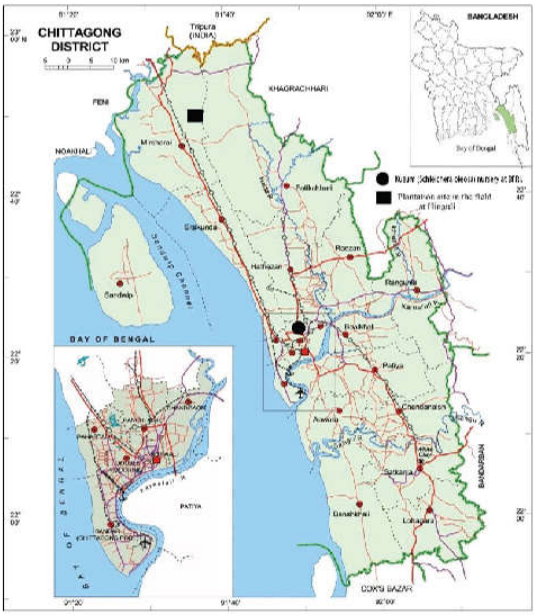

Figure 1. *Schleichera oleosa* nursery at BFRI campus and experimental plantation site at Hinguli Research Station in Chattogram district map of Bangladesh.

Seeds collection and preparation of germination experiments

Seeds were collected from 20-25 years old mother trees from Bangladesh Agricultural University Botanical Garden, Mymensingh, Bangladesh in last week of July 2018. Collected seeds were dried in room temperature for 2-3 days. Then sound and desirable seeds were separated from discolored and damaged seeds. The number of seeds varied from 1400-1700 in one kg and selected seeds were used for the experiments.

Experimental design and pre-sowing treatments

Experiment was conducted on Completely Randomized Design with five replications. To determine the effect of pre-sowing treatments on seeds germination and seedlings growth attributes, five treatments were applied. The pre-sowing seed treatments were: i) soaking in tap water for 12 hours (T_1), ii) soaking in tap water for 24 hours (T_2), iii) soaking in tap water for 36 hours (T_3), iv) soaking in tap water for 48 hours (T_4), and V) control 0 hour (T_0) (seeds without any treatment). There were five treatments, five replications, and 50 seeds were sown in each seed bed at 1.50 to 2.50 cm depths of soil in the first week of August. Thus a total of 1250 seeds were used for the germination experiments. Regularly watering was carried out manually.

Assessment of seed germination

The number of seeds germinated in each treatment was recorded regularly. The starting and closing dates of germination and other parameters were measured with carefully. Germination percentage estimates the viability of a population of seed. The number of seeds germinated at each day in each replication of treatments was counted to calculate the germination percentage (Kumar 1999; Almodares *et al.* 2007). Cumulative germination was recorded in every alternate day of sowing and continued till ending the germination (20 days after sowing the seeds).

Seedling growth performance in the nursery

To determine the seedlings growth performance in the nursery and field, one month old seedlings (developed from T_3) were transferred in polybags (15× 23 cm) filled with soils mixed with cowdung (3:1) and allowed them to grow there. At initial stages, the polybags were kept under nursery shade for one week and then exposed to partial sunlight. Regular watering was carried out manually.

For assessing the growth performance, all seedlings were measured for above ground height (from base to leaf tip) and number of leaves was counted when the seedlings were one month old. 10 seedlings were selected from each replication. Thus 50 seedlings were randomly uprooted and measured the total

length (root length and shoot length separately) for the assessment of growth performances in the nursery levels. These data were recorded at 3, 6, 12 and 24 months in the nursery levels. Seedlings vigor index (VI) were calculated according to Baki and Anderson (1973) as the germination percent multiplied by total length of seedling (*i.e.* sum of shoot and root length). Data on shoot length, root length and leaf number of these seedlings were also recorded at 3, 6, 12 and 24 months after transferring them in the polybags.

Assessment of seedlings growth performance in the field levels

When the seedlings were about one-year-old, 270 seedlings were out-planted in the field at the beginning of the monsoon (June-July). Equal numbers of seedlings were allowed to grow in the nursery for one year. Seedlings were planted in the field at 2.00 m × 2.00 m, 2.50 m × 2.50 m and 3.00 m × 3.00 m spacing at Hinguli Research Station, BFRI, Chattogram. For each treatment total 90 seedlings were planted in 3 replications, thus in 3 replications total 270 seedlings were planted for treatments. 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 34.70°C and 20.70°C respectively. Weeding was done at every four months in the field level of the first year. Survival percentages were determined and heights of the planted seedlings were also recorded at 6 and 12 months after planting.

Statistical analysis

Statistical analysis of data was done using the computer software package Statistical Package for the Social Sciences (SPSS) version 21. The analysis of variance (ANOVA) was studied by applying Duncan's Multiple Range Test (DMRT).

Results

Seeds germination and their percentage

The present study revealed that germination period and germination percentage of *S. oleosa* Merr. were influenced by pre-sowing treatments. The seed soaking in tap water for 36 hours showed the highest germination (72%) and occurred between 8-15 days after sowing DAS. Seeds soaked in tap water for 12 hours showed 56% germination between the periods of 8-18 DAS. Seeds soaked in tap water for 24 hours showed 64% germination between the periods of 8-18 DAS (Fig. 2A & 2B).

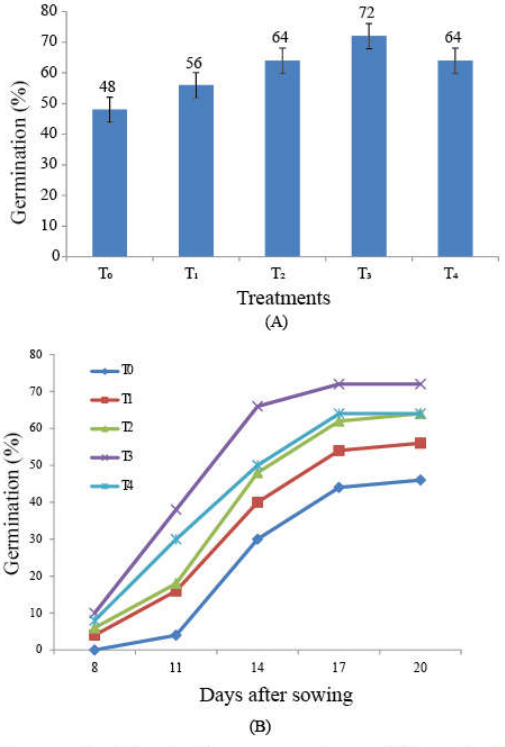

Figure 2. Germination percentage (A) and the germination pattern (B) of *S. oleosa* seeds under various treatments.

Seeds soaked in tap water for 48 hours showed 64% germination between the periods of 8-17 DAS. The lowest germination was found 46% in control and the periods of 11-20 DAS. The

germination percentage in the seeds treated with tap water for 36 hours was significantly (p<0.05) the highest than the other treatments. The germination periods were statistically similar in different treatments, but germination percentages were greatly varied in tap water treatments 12 hours, 24 hours, 48 hours and control.

Seedlings growth performance in nursery condition

The shoot length, root length and vigor index are shown in the following table (Table 1). The highest shoot length (12.80 cm), root length (11.60 cm) and vigor index (1171.20) were marked with treated in tap water for 36 hours (Table 1).

Table 1. Initial growth performance of *S. oleosa* seedlings germinated from different treatments one month after germination.

Treatments	Shoot length (cm)	Root length (cm)	Vigor index (VI)
T_0	8.60±0.67^{c}	7.80±0.87^{c}	787.20^{c}
T_1	10.80±0.37^{b}	9.40±0.51^{bc}	969.60^{b}
T_2	12.00±0.55^{ab}	10.40±0.40^{ab}	1075.20^{ab}
T_3	12.80±0.37^{a}	11.60±0.26^{a}	1171.20^{a}
T_4	10.80±0.58^{b}	9.20±0.37^{bc}	960.00^{b}

Note: Treatment values associated with same letters indicates no significance difference among the treatments at $p \leq 0.05$; ± indicates standard error of mean. T_0=Control. T_1=Seeds soaked in tap water for 12 hours, T_2=Seeds soaked in tap water for 24 hours, T_3=Seeds soaked in tap water for 36 hours, T_4=Seeds soaked in tap water for 48 hours.

The lowest length of shoot (8.60 cm), root length (7.80 cm) and vigor index (787.20) were observed in seed with control. There were significant differences observed in growth performance among the treatments at $p \leq 0.05$. 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 vigor index mainly depends on germination percentage and seedlings length. The study reveals that there was marginal variation of seedlings length among the treatment but the germination percentage with seeds soaked in tap water for 36 hours was much higher than the other treatment which leads the vigor index considerably higher in the seeds soaked in tap water for 36 hours than other treatments.

In the experiment, only the seedlings developed from the seeds treated in tap water for 36 hours were used for assessing the seedlings growth performances in the nursery and the field (Fig. 3). One month old seedlings having 3-4 leaves were transferred in the polybags (15 × 23 cm) which was filled with soil and cow dung (3:1) and allow them to grow there. The seedlings mortality in the nursery bed, during and after transferring to the polybags was about 3-4% which is very insignificant.

The seedlings achieved a height of 21.13 cm with 20.14 cm root and 17 numbers of leaves were recorded at 3 months. The average height 30.27 cm with 27.73 cm root and 21 numbers of leaves were recorded at 6 months. The seedlings touched 44 cm height with 34.97 cm root and 38 numbers of leaves were recorded at 12 months. Finally, the seedlings attained 102.10 cm height with 69.50 cm root and 67 numbers of leaves were recorded at 24 months and their survival percentages were 96% in the nursery level (Table 2).

Seedlings survival and growth performance in the field

One year old seedlings of *S. oleosa* raised in the polybags were out planted in the field. Survival

(A) (B) (C)

Figure 3. Seeds and seedlings of Kusum (*S. oleosa*) at nursery. (A) *S. oleosa* seeds (B) Germination stage (C) 12 months seedlings after germination.

Table 2. Seedlings growth performance of *Schleichera oleosa* at different ages up to 24 months in the nursery condition.

Age of seedlings (month)	Survival (%)	Average length of shoots (cm)	Average length of roots (cm)	Average number of leaves per seedling (cm)
3	98	21.13±2.89	20.14±1.45	17.00±1.24
6	96	30.27±2.69	27.73±1.21	21.00±1.68
12	96	44.98±2.58	34.97±1.39	38.00±1.33
24	96	102.10±2.82	69.50±2.21	67.00±1.15

was recorded at 12 months and seedlings growth performances were determined at 6 and 12 months after planting in the field and shown in Table 3. Survival percentage varied from 92-96 with an average of 94 % in the field level. The seedlings height varied from 74.79 – 83.12 cm at six months and 93.23 – 105.54 cm in one year old seedlings in the field level. (Table 3).

Table 3. Survival percentage and seedlings growth performance of *S. oleosa* in different spacing at Hinguli Research Station after one year planting in field condition.

Spacing used	Survival (%)	Average height (cm)	
		6 months	12 months
1.50 m×1.50 m	92^{c}	74.79±1.11^{c}	93.23±1.10^{c}
2.00 m×2.00 m	96^{a}	83.12 ±1.13^{a}	105.54.10±1.13^{a}
2.50 m×2.50 m	94^{b}	78.30±1.01^{b}	96.20±1.16^{b}

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

The heights of seedlings were significantly affected by distances in the field level. (Table 3). The variation of the height growth in the seedlings may be due to the microclimatic condition between the spacing. The survival percentage and height growth of the seedlings in the field were satisfactory at 2.00 m × 2.00 m spacing. The average survivals of seedlings were 94% in the field level. Considering the above mentioned facts and comparatively less land requirement, 2.00 m × 2.00 m spacing may be considered for planting of one year old seedlings in the field.

Discussion

Several scientists suggested that seed germination was influenced by environmental factors (Mukarati *et al*. 2013; Soleymani and Sharajabian 2018). Soaking of the seeds in water helps in softening the seeds coat, removal of inhibitors and reduces required time for germination and enhances germination percentage (Hartman *et al*. 2007). The present study also revealed that soaking the seeds in water helps to increase the germination rate and reduces require time for germination. Gupta (2003) observed that overnight soaking of *Rauwolfia serpentina* seeds in cold water offered increased germination (86%) against control (48%). *Acacia catechu* seeds showed better germination (80%) against control (62%) when the seeds are soaked in cold water for 24 hours (Haider *et al*. 2014). The finding of the present study is similar to the previous findings.

Azad *et al*. (2012) mentioned that germination percentage and seedling growth including shoot, root and total length of *Acacia auriculiformis* increased significantly with pre-sowing treatment especially by hot water treatment. The vigor index of the seedling in the study was increased remarkably from 787.20 in control to 1171.20 in the treated seeds soaked in tap water for 36 hours.

Similarly report was made by Haider *et al*. (2014) and mentioned that *Acacia catechu* seedlings showed satisfactory growth performance when they were planted at 2.00 m× 2.00 m spacing at the age of 6 months, in the field. On the other hand, seedlings height was low in the nursery level (102.10 cm) in comparison to the field level (105.54 cm) at 2 years age. The present study indicated that seedlings growth influenced by silvicultural practices such as weeding, watering and edaphic characteristics. The study revealed that the survival capacity was higher in the nursery level than the field level.

Conclusion

Pre-sowing treatments of seeds influence the germination percentage under nursery condition. Seeds start germination after 8 days of sowing and complete within 20 days. Maximum germination and highest initial growth performance was perceived in seeds treated with tap water for 36 hours which was much higher than other treatments. Pricking of the seedlings at 30 days after germination from nursery seed bed to polybag ensure minimum mortality. Survival of the seedlings (96%) and growth performance of the seedlings in the field was satisfactory after out planting one year old seedlings planting at 2.00 m × 2.00 m spacing. Therefore, pre-sowing treatment of seeds with tap water for 36 hours is suitable for seedling raising in the nursery and one year old seedlings planting at 2.00 m × 2.00 m spacing may be suggested for plantation program.

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In Vitro Propagation of Aloe vera (*Aloe indica* Royle) through Apical Shoot Tip Culture

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Abstract

An efficient *in vitro* protocol was established for large production of Aloe vera (*Aloe indica* Royle). The shoot tip explants, collected from the axenic cultures were used for the optimization of rapid shoot production on MS medium supplemented with different concentrations (0.5, 1.0, 2.0 and 3.0 mg/L) of BAP and Kn. The maximum shoot number were recorded as 14.33 per culture on medium added with MS + 1.0 mg/L BAP + 4% sucrose + 2.8 g/L gelrite after 30 days of culture. The shoots were rooted under *in vitro* and *in vivo* condition. About 90% shoots produced root on medium, ½ MS + 0.5 mg/L IBA+ 2% sugar after 30 days of culture. Simultaneously *in vitro* grown shoots were inoculated in the sand made propagation bed for *ex vitro* rooting under mist house condition. In the propagation bed 100% of the micro shoots survived and well rooted while taking a longer time (8 weeks) than that of *in vitro* rooting. The rooted seedlings were transferred in polybag containing garden soil, compost and sand with the proportion of 1:1:1 respectively. After hardening 99% seedlings survived in polybag and showed excellent growth.

সারসংক্ষেপ

এ্যালোভেরা উদ্ভিদের কাণ্ডের শীর্ষাগ্র (Apical shoot tip) থেকে অধিক সংখ্যক চারা উৎপাদনের একটি কার্যকরী *In vitro* কৌশল উদ্ভাবন করা হয়েছে। জীবাণুমুক্ত কালচার এ নতুন জন্মানো ক্ষুদ্র বিটপগুলি থেকে explant নিয়ে দ্রুত বিটপ উৎপাদনের মাত্রা নিরূপণে MS মিডিয়ামে বিভিন্ন ঘনত্বে (০.৫, ১.০, ২.০ ও ৩.০ মিলিগ্রাম/লিটার) BAP ও Kn যোগ করা হয়। চার সপ্তাহ পরে ১.০ মিলিগ্রাম/লিটার ঘনত্বে BAP গ্রোথ হরমোন ও ৪% চিনিযুক্ত যুক্ত খাদ্য মিডিয়ামে কালচার প্রতি সর্বোচ্চ গড়ে ১৪.৩৩টি বিটপ পাওয়া যায়। উৎপাদিত বিটপগুলিকে নিয়ন্ত্রিত ও অনিয়ন্ত্রিত উভয় পরিবেশে শিকড় জন্মানো হয়। নিয়ন্ত্রিত পরিবেশে ৩০ দিনের মধ্যে অর্ধ শক্তির MS মিডিয়াম এর সাথে ০.৫ মিলিগ্রাম/লিটার IBA এবং শতকরা ২ ভাগ চিনিযুক্ত খাদ্য মিডিয়ামে শতকরা ৯০% বিটপ এ শিকড় গজায়। একইভাবে নিয়ন্ত্রিত পরিবেশে জন্মানো বিটপগুলিকে মিস্ট হাউজে বালুর বেডে লাগিয়ে শিকড় জন্মানো হয়। বালুর বেডে বিটপগুলির শতকরা ১০০ ভাগ বেঁচে থাকে এবং শিকড় গজায়। এ ক্ষেত্রে বিটপে শিকড় গজাতে কিছুটা সময় বেশি লাগে। বেডে লাগানোর ৮ সপ্তাহ পর শিকড় গজাতে শুরু করে। এভাবে উৎপাদিত অনু চারাগুলিকে পলিব্যাগে স্থানান্তর করা হয় এবং ৯৯% চারা বাইরের পরিবেশে দ্রুত বেড়ে উঠে।

Key words: *Aloe indica*, *In vitro* propagation, Optimization, Shoot tip culture.

Introduction

Aloe indica is one of the important species which has valuable medicinal properties and used commercially in pharmaceutical, cosmetic and food industries. It is an important xerophytic medicinal plant that belongs to the family Asphodelaceae (Liliaceae). Although Aloe vera originated in the warm, dry climates of Africa, the plant is readily adaptable and grows even in rainfall condition worldwide (Steenkamp and Stewart 2007). The plant prefers sunny weather, requires well-drained soil and can grow in nutritionally poor soil. Mexico, followed by the rest of Latin America, China, Thailand and the USA were described as main producing countries for Aloe (Rodríguez *et al.* 2010). Pharmaceutical and cosmetic industry has great demand for Aloe vera. Its therapeutic use was reported earlier by several scientists (Cera *et al.* 1980; Afzal *et al.* 1991; Davis *et al*. 1998). *Aloes* have been used for a variety of purposes in ancestral and modern societies. They are used for preparing food, feed and beverages, formulating ethnomedicinal and ethnoveterinary remedies and preparing traditional and modern cosmetic products. They are also grown for ornamental purposes. *Aloe* gels and latexes are used in treating bacterial, fungal, and viral diseases, healing wounds and skin burns, treating protozoan and helminthic infections and normalizing noninfectious physiological ailments. *Aloe* based cosmetic and healthcare products such as shampoos, moisturizers and skin conditioners are good sources of revenues in many countries (Dwivedi *et al.* 2014; Habtemariam and Medhanie 2017; Yemane and Medhanie 2016; Beyene 2015; Abdi *et al.* 2013; Elsheikh *et al.* 2013; Abadi and Kaviani 2010). Moreover, many *Aloe* species are extensively used in the preparation of cosmetic and toiletry industries. *Aloes* grow nearly in all parts of the world (Dwivedi *et al.* 2014; Smith *et al.* 2008; Newton 2004; IASC 2002). Different accounts put the number of *Aloe* species between 450 and 600. The demands for *Aloes* in the medicinal and cosmetic industries is increasing at an alarming rate, but large-scale production schemes to meet the demand are limited (Dwivedi *et al.* 2014; Haque and Ghosh 2013). There is a lack of production of *Aloe* leaf to meet the industry demand and so it is necessary to undertake large scale cultivation of *Aloe* (Aggarwal and Barna 2004).

Propagation of Aloe vera by conventional methods or by means of offshoots has many drawbacks. Poor natural propagation by means of axillary shoots and the presence of male sterility are the two major barriers in rapid propagation of Aloe vera (Natali 1990; Demissew and Nordal 2010). To overcome this problem, plant tissue culture based clonal propagation system can of great help (Murashige 1974; 1978). The technique is particularly useful for plants where the rate of multiplication is very slow. Hence, there have been many attempts to multiply the crop *in vitro* by many workers. Several studies have reported rapid *in vitro* propagation of Aloe vera (Meyer and Staden 1991; Aggarwal and Barna 2004; Ahmed 2007; Gantait 2010; Mukesh Kumar 2011; Baksha *et al.* 2005). Shoot tips have been used as the explant source in most of the *in vitro* micro propagation protocols (Baksha *et al.* 2005; Singh and Sood 2009; Hosseini and Parsa 2007; Hashemabadi and Kaviani 2008; Kalimuthu *et al.* 2010). Scientists had obtained different results applying formulation of plant growth regulators with MS media. This study was conducted to develop a reproducible protocol of *in vitro* micro propagation of *Aloe indca* using the most common plant growth regulators to produce quality planting materials for large production.

Materials and Methods

Explants collection, preparation and sterilization for axenic culture

Two weeks old Aloe vera seedlings were collected from outdoor source. The seedlings were maintained under greenhouse condition up to 6 weeks to obtain enough amount of planting materials to start the experiment. A total of ten shoot tip explants were collected from the offshoot-derived from the mother plant. The explants were thoroughly washed in running tap water about 30 minutes. After that it trimmed to 3-4 cm and treated with Tween 20 for 5-10 minutes. Finally washed thoroughly with sterile distilled water for 2 to 3 times. Prior to inoculation, the explants were subsequently surface sterilized with 70% ethanol for 2-3 minutes, 20% sodium hypochlorite solution for 10 minutes and washed 3 to 4 times with sterile distilled water under laminar air flow.

Preparation of culture media

Culture media were prepared as per the standard protocol of Murashige and Skoog (MS) (1962) media supplemented with various concentrations of different PGRs, namely, BAP, Kn IBA, and NAA. Full-strength (for initiation and shooting) and half-strength (for rooting) MS media were prepared by adding appropriate stock solutions of micronutrients, macronutrients, and additives and by enriching them with 30-40 gm sucrose and 2.8 gm/L gelrite as a solidifying agent. pH of the medium was adjusted to about 5.8 by adding drops of 1N HCl and 1N NaOH as appropriate. The media were autoclaved at 121°C and 15 psi (pounds per square inch) for 20 minutes and allowed to cool at room temperature to about 60°C.

Culture conditions

The cultures were incubated at 25±2°C under cool white and fluorescent light of 2000-2500 lux, relative humidity about 60-80% and 16/8 hours photo and dark period were maintained in growth chamber respectively. Data on seed germination, multiple shoot induction, elongation and rooting were taken and statistically analyzed. Observations were recorded periodically. These culture conditions were used in all the experiments mentioned below unless otherwise stated.

Culture initiation for multiple shoot production

The initial cultures were established in full-strength MS medium supplemented with 1.0 mg/L BAP adding 3% sucrose. Cultures were also started with devoid of growth regulators as control treatment. Single explant was inoculated into each culture bottle. They were incubated for 4 weeks in a growth room adjusted to 25±2°C under fluorescent tube light with 16 hours photoperiod and 2000–2500 lux light intensity.

Induction of multiple shoots and optimization

The shoot tips collected from axenic cultures were cultured on MS medium supplemented with 0.0, 0.5, 1.0, 2.0, 3.0 mg/L of BAP and Kn alone and/or in combination along with 3-4 % sucrose. Physiological conditions and number of shoots per explant were observed periodically. Rate of multiplication of shoots was recorded up to 3-4 weeks of post inoculation. *In vitro* elongation was also attained on the same medium.

In vitro rooting of the shoot

In vitro elongated shoots (6-7 cm) were taken out from the culture vessel and transferred to half strength MS medium with different concentration (0.0, 0.5, 1.0, 1.5, 2.0 mg/L) of IBA for root induction and one control without PGRs. All treatments were replicated three times.

Ex vitro rooting of the shoots

The *in vitro* grown elongated shoots were rooted in sand made propagation bed inside the mist house. The culture bottles with shoots were brought out from the growth room and kept under green house for 2-3 days losing the cap. Then the shoots were removed from the culture bottle and washed under tap running tap water until the medium is cleaned up. The cleaned shoots were then inoculated in the sand made propagation bed for rooting.

Hardening and acclimatization of plantlets

Cleaned rooted plantlets were transferred to sterile soil mix prepared by mixing garden soil, compost and sand in a 1:1:1 ratio and subjected to photoautotrophic culture system for 20 days prior to the greenhouse transfer. After transferring to the temperature and humidity controlled greenhouse, plants were hardened for a month time. Subsequently, well established plants were shifted to nursery beds.

Statistical analysis

All experiments were performed as Completely Randomized Design (CRD). Data were analyzed using statistical analysis system (SAS v9.3) and means were statistically compared using LSD test. The significance level was set up at $p < 0.05$. Three replications were considered for each treatment and repeated thrice.

Results

Culture initiation for multiple shoot production

Sometimes it seems to be difficult for establishing contamination free culture of Aloe vera. So, axenic culture of Aloe vera was established on MS medium from axillary shoot tip explants derived from greenhouse grown seedlings. Culture initiated from the axillary shoot tip of young seedling in MS medium supplemented with different concentrations of BAP (0.0, 0.5, 1.0, 1.5 mg/L). Under given conditions and over a culture period of 30 days explants from all the treatments produced multiple shoots simultaneously. The best media combination for culture establishment and multiple shoot initiation was found MS + 1.0 mg/L BAP + 4% sucrose. In this media combination, cultures were started to respond for new shoot initiation within 7 days and 100% of the cultures were established by the next 30 days.

Shoot induction and multiplication

The shoot multiplication rate was significantly different according to the various concentration of cytokinins supplemented in the media. To establish shoot regenerative potential and multiple shoot production, the single shoot was cultured on MS medium supplemented with different concentrations of cytokinins alone or in combination. Cytokinin level produced a significant response upon the number of shoots and leaves produced per plant. Treatment with BAP 1.0 mg/L induced comparable number of shoots (Fig.1). MS basal medium devoid of plant growth regulators (PGR) did not support the induction of multiple shoots. Among the different cytokinins, BAP at its 1.0 mg/L concentration evoked best response than the other concentrations. Shoots after their initial proliferation on medium containing 1.0 mg/L BAP were sub-cultured on same fresh medium after every 15 days. After excision of the multiple shoots, when the mother explants was cultured on the fresh shoot multiplication medium (MS+ 1.0 mg/L BAP) then the shoot numbers were increased significantly for the next four repeated transfers and reduced thereafter. Incorporation of Kn into MS medium supported shoot multiplication.

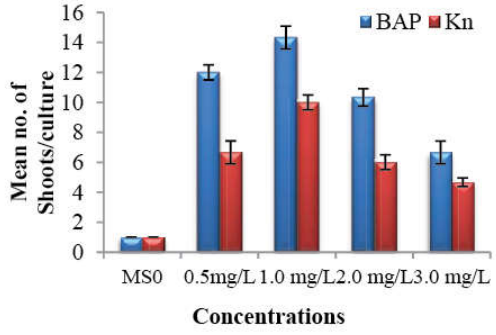

Figure 1. Effect of different concentrations of cytokinin on shoot multiplication of Aloe vera after 30 days of culture. Each value is the mean of three replications. Vertical bars indicated standard errors.

However, BAP proved to be a better choice than Kn because the maximum number of shoots per culture was obtained 14.33 on 1.0 mg/L BAP (Fig.1, Fig. 2B & 2C) and 10.0 for 1.0 mg/L Kn (Fig.1, Fig. 2D, 2E & 2F) after 30 days of culture respectively.

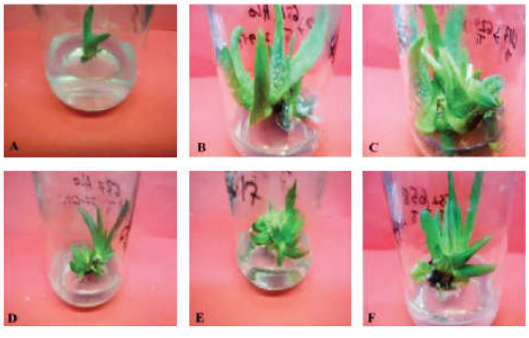

Figure 2. Effect of different concentrations of BAP and Kn in MS medium on multiple shoot production of Aloe vera. A. Control. B. MS + 1.0 mg/L BAP + 4% sugar after 15 days & C. after 30 days of culture. D & E. MS + 1.0 mg/L Kn + 4% sugar after 15 days and F. after 30 days.

In vitro rooting of regenerated shoots

The regenerated shoots were well rooted in ½ MS +0.5 IBA+ 2% sucrose medium. Roots were induced within one week of culture at the base of the shoots. The half strength of MS medium without any PGR was failed to induce rooting of regenerated shoots. However, shoots were capable to induce root when cultured on medium containing auxins. Auxins in different concentrations induced roots when incorporated in the medium containing ½ strength of MS salts. The best rooting response, about 99% of the cultures was observed on medium containing 0.5 mg/L IBA supplemented with 2% sugar and 2.8 g/L gelrite after 28 days. The maximum mean number of roots per culture was recorded 13 with a length of 10 cm after 28 days of culture (Fig. 3, Fig. 4A, 4B, 4C & 4D).

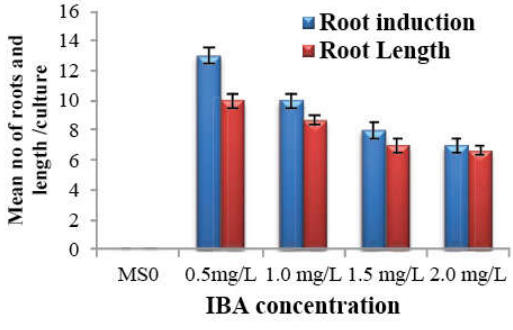

Figure 3. Effect of different concentrations of IBA on root induction of Aloe vera from *in vitro* regenerated shoots after 4 weeks of culture. Each value is the mean of three replications. Vertical bars indicated standard error.

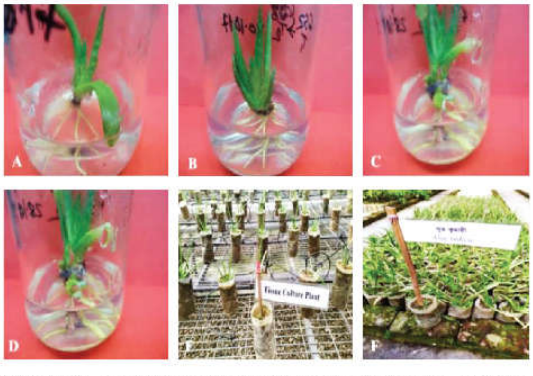

Figure 4. *In vitro* rooting and plant production of Aloe vera. A, B, C & D. shoots with roots in culture bottles. E. Plantlets transferred in poly bag for hardening under green house. F. Tissue cultured plants in the nursery bed.

Ex vitro rooting of regenerated shoots

The regenerated shoots were also rooted under *ex vitro* condition in the mist house. Four weeks old *in vitro* grown shoots were brought out from the growth room and kept inside the green house for 3 to 4 days losing the cap of culture bottle. Later the shoots were washed under running tap water and cleaned the base from medium. The cleaned shoots were inoculated in the sand made propagation bed for rooting. The results showed that 100% shoots were survived and started for rooting at the base within one month after transferred in propagation bed. The shoots also produced axillary shoots at a various level during rooting period. The highest mean number of root per plant was recorded as 14 with a length of 4.0 cm after 8 weeks (Table 1, Fig. 5).

Table 1. Root initiation and plant production of *in vitro* grown shoots of *Aloe vera* in propagation bed.

Days	Morphogenic response			
	% of shoot induced root	Mean no. of root /plant	Mean length of root /plant	Mean no. of new shoots/ plant
2 weeks	0	0 ± 0.0	0 ± 0.0	1 ± 0.0
4 weeks	50	8 ± 0.57	2 ± 0.28	2 ± 0.57
6 weeks	70	11 ± 0.76	3 ± 0.0	3 ± 0.50
8 weeks	100	14 ± 0.57	4 ± 0.50	3 ± 0.28

The rooted plants were transferred in polybag containing sterile soil: cow dung: sand (1:1:1) for hardening. The plantlets were hardened and grown well in polybag at nursery bed for further developing new shoots.

Figure 5. *Ex vitro* rooting of *in vitro* grown shoots of Aloe vera in propagation bed and plant production. A) Shoots are inserted in propagation bed from culture bottle. B) Shoots at the propagation bed after 8 weeks. C) Rooted shoots, & D) Plantlets in polybags for hardening.

Acclimatization of plantlets

The culture bottles with rooted shoots were brought out from the growth room and kept under green house for 2-3 days losing the cap. Then the shoots were removed from the culture bottle and washed under tap water until the medium is cleaned up from the roots. Cleaned rooted plantlets were transferred to sterile soil mix prepared by mixing sand and cow dung in a 1:1:1 ratio. After transferring to the temperature and humidity controlled greenhouse, plants were hardened for a month. Subsequently, well-established plants were shifted to nursery beds. Similarly, the well rooted shoots in the propagation bed under mist house were transferred to soil in polybag and hardened for further growth and development (Fig. 4E & 4F, Fig. 5D).

Discussion

In vitro optimization of shoot production for mass propagation of Aloe vera was established in MS medium supplemented with different cytokinins. It was observed that shoot proliferation was faster with the addition of

cytokinins in the culture media than the media devoid of plant growth regulators. The results revealed that the supplementation of plant growth regulators were positively influenced the shoot proliferation of Aloe vera. Rahman *et al.* (2018) stated that the apical shoot tip of *Phylanthus emblica* was able to produce multiple shoots in MS medium supplemented with different concentrations of cytokinins BAP and Kn. The shoot tip culture of *Gynura procumbens* proliferated faster with the addition of cytokinins than the medium devoid of plant growth regulators (Rahman *et al.* 2019). However, growth regulators, mainly cytokinins are the most important factors affecting the shoot proliferation. Different concentrations of cytokinin i.e. BAP, kinetin and 2-ip have been used in micropropagation research work (Bhojwani and Razdan 1992). BAP is the most reliable and useful cytokinin which is demonstrated by a wider survey of existing literature. In the present study, shoot proliferation also occurred in presence of cytokinin. Signs of shoot proliferation were showed after 7 days of culturing. Multiplication of shoot was best on MS medium with 1.0 mg/L BAP. The percentage of shoot proliferation and number of shoots were 90 and 15, respectively. BAP variations affecting shoot proliferation were also reported by Bhandari *et al*. (2010), Gantait *et al.* (2010) and Mangal *et al.* (2009). Abrie and Staden (2001) and Chaudhuri and Mukundan (2001) had also reported the use of BAP in shoot proliferation of *Aloe polyphylla* and *Aloe vera,* respectively. It was also reported that the highest shoot proliferation in *Aloe vera* was found in MS medium containing BAP and IBA (Aggarwal and Barna 2004; Mukesh *et al.* 2011 and Meyer and Staden 1991). This is in contrast to earlier reports in *Aloe vera* by Natali *et al.* (1990) where better proliferation occurred on medium containing kinetin instead of BAP. Baksha *et al.* (2005) also reported that the enhancement of shoots was observed by using BA and NAA. Rooting response of micro shoots was also reported with the use of growth regulators such as NAA and IBA in medium (Bhojwani and Razdan 1992). In the present study, healthy rooting was observed in IBA (0.5 mg/L) medium. Healthy roots were obtained in medium with IBA 0.5 mg/L in 30 days of time. The highest root response in *Aloe vera* was reported in hormone free medium (Bhandari *et al.* 2010; Aggarwal and Barna 2004). The highest shoot proliferation was also reported in MS medium containing BAP 1.0 mg/L and IBA 0.2 mg/L (Mukesh *et al.* 2011) while highest percentage of root induction (80%) was observed in MS medium supplemented with IBA 0.5 mg/L. Similar result was reported by Abrie and Staden (2001) in *Aloe vera*. Based on hardening, explants were transferred to plastic cups containing sterilized sand and every day moistened with 10 times diluted MS broth. After two weeks they were transferred to earthen pots containing soil and sand under greenhouse conditions for 3-4 weeks for acclimatization. The survival rate was 99% and the plants established well in 4-6 weeks of growth at nursery bed.

Conclusion

Like many species of *Aloe vera*, *Aloe indica* can be a good source of phytochemicals with medicinal, nutritional, and pharmaceutical potential. Exploring into the *in vitro* micropropagation of the plant is one effort in a large-scale project aiming at elucidating its regeneration, physicochemical, and agronomic characteristics. As the present study shows, the plant can easily and successfully be propagated *in vitro* with the help of the commonly used PGRs, namely, BAP, Kn and IBA. The results of the study will serve as important foundation for future research using many different media formulations and combinations to develop an optimized protocol of large-scale *in vitro* micropropagation. The developed protocols

enable to produce large number of healthy tissue culture plants of aloe vera within a short period of time for future demand.

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Treatability and Natural Durability of Pitali (*Trewia nudiflora* L.) Wood

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Abstract

The experiment was undertaken to investigate the retention of chromated-copper-boron (CCB) preservatives in Pitali (*Trewia nudiflora* L.) wood applying soaking as well as diffusion method. The assessments were applied for 5, 7, 9 and 11 days for both the method. The retention of the preservatives were recorded 12.29 kg/m^3, 14.97 kg/m^3, 15.11 kg/m^3 and 15.72 kg/m^3 in Pitali wood where soaking method applied. Moreover, retention was found 11.43 kg/m^3, 23.49 kg/m^3, 24.14 kg/m^3 and 25.38 kg/m^3 in Pitali when diffusion method applied. In case of both the method, highest retention was recorded 15.72 kg/m^3 and 25.38 kg/m^3 in pitali wood after 11 days. Considering the Standard of Bangladesh Standards and Testing Institution (BSTI), i.e., 15.72 kg/m^3 and 25.38 kg/m^3 in Pitali can meet the suitability of the study. According to BDS code, the required retention of CCB is 8–16 kg/m^3.

সারসংক্ষেপ

পিটালী কাঠের ধারণ মূল্যায়নের জন্য চুবানো এবং ডিফিউশন পদ্ধতিতে ১০% সিসিবি দ্রবণ দ্বারা পরীক্ষাটি করা হয়েছিল। উভয় পদ্ধতিতে ৫, ৭, ৯ এবং ১১ দিনের জন্য এ পরীক্ষাটি প্রয়োগ করা হয়েছিল। উক্ত সময়ে চুবানো পদ্ধতি প্রয়োগ করে ১২.২৯, ১৪.৯৭, ১৫.১১ এবং ১৫.৭২ কেজি/ঘনমিটার ধারণ রেকর্ড করা হয়েছে। অধিকন্তু, ডিফিউশন পদ্ধতি প্রয়োগ করে ৫, ৭, ৯ এবং ১১ দিনের জন্য যথাক্রমে ১১.৪৩, ২৩.৪৯, ২৪.১৪ এবং ২৫.৩৮ কেজি/ঘনমিটার ধারণ রেকর্ড করা হয়েছে। উভয় পদ্ধতিতে ১১ দিন প্রয়োগ করে পিটালী কাঠের সর্বোচ্চ ধারণ ১৫.৭২ এবং ২৫.৩৮ কেজি/ঘনমিটার রেকর্ড করা হয়েছে যা (পিটালী কাঠের ধারণ ১৫.৭২ এবং ২৫.৩৮ কেজি/ঘনমিটার পাওয়া গেছে) বাংলাদেশ স্ট্যান্ডার্ডস অ্যান্ড টেস্টিং ইনস্টিটিউশন (বিএসটিআই)-এর মান বিবেচনা করে উপযুক্ত বলে প্রতীয়মান হয়। বিডিএস কোড অনুসারে, সিসিবি-এর প্রয়োজনীয় ধারণ ৮–১৬ কেজি/ঘনমিটার।

Key words: Diffusion method, Penetration, Retention, Soaking method, *Trewia nudiflora* L.

Introduction

Bangladesh is a tropical monsoon country of South Asia. The country covers an area of 147,570 km² with about 12.8% under total forest cover (BFD 2015) and only land area is considered, forest cover is 14.1% (BFD 2015). However, the Bangladesh Forest Department (BFD) puts the total forest cover at 17.62% of the surface area of the country. The BFD manages and establishes plantation, harvests and sells the forest products, develops parks and gardens. Bangladesh Forest Research Institute (BFRI), and the Bangladesh Forest Industries Development Corporation (BFIDC) for conducting research and processing timber and forest products respectively. There are many kinds of indigenous and exotic species in Bangladesh. Day by day, indigenous species decreases from our forest all over Bangladesh. In 1871, Teak (*Tectona grandis*) was introduced from Myanmar. Since then, natural forests have been replaced successively with many exotic species and monoculture was started. Among the exotics, *Acacia auriculiformis* and *Acacia mangium*, *Eucalyptus camaldulensis*, and *Leucaena leucocephala* are important (Jasimuddin and Inoue 2012). Village forests are very important suppliers of forest products in Bangladesh. Douglas, 1981 indicate that these forests contribute about 80 to 82% of forest products.

Pitali is a common indigenous species in Bangladesh. *T. nudiflora* occurs in the forests of Chattogram, Cox's Bazar, Chattogram Hill Tracts and Sylhet. It is usually growing on moist ground by the side of streams and rivers. It is also found in villages by the side of ditches, tangs or canals and by river banks on sandy tracts, throughout the country (Das *et al.* 2001). The plant is found almost everywhere in Bangladesh. May be that's why the plant has many local names: pitthalu, pitalu, medda, meragota, lattu, latim, laddu. It has also vernacular names: *Pitali* (Trade and Beng.), *lattoo, sital* (Beng.), *mera, merua, gotagamar* (Sylhet), *pitagola* (Chittagong Hill Tracts), *bol-diktak, bolno-khap* (Garo), *hruprukban* (Magh.) (Das *et al.* 2001). During the rainy season, the village children play with the fruit in the water. More than that, the tree can survive after being submerged for long period. *Trewia nudiflora* is a deciduous tree with spreading branches. Leaves opposite, broadly ovate, long pointed, Chordate or rounded base, young leaves are hairy beneath, acuminate, glabrous later and 2–7 cm long stalks. Male and female flowers on separate trees, males flowers yellow in long lax drooping inflorescences, female flowers on long peduncles, green solitary or 3–4 together in the leaf axis. Fruits are fleshy and globose berry, 3 cm by 3.5 cm. Fruits are a capsule 2–3 cm across, greenish brown, woody, broadly cognate to rounded, pericarp of fruit is very thick; the seeds are globe and ovoid (Ghai *et al.* 2019).

T. nudiflora is a light, weak and non-durable wood. It is mentionable that untreated pitali samples were affected by insects, fungus etc. within 7 to 8 months. Natural durability of *Trewia nudiflora* is 7 to 8 months in outdoor condition. It is suitable for packing cases, plywood, sports and athletic goods and matches (Sattar *et al.* 1999). Pitali wood normally use as a fuel wood in the villages also. This wood is soft, light and fine grained, and used for making packing boxes (Das *et al.* 2001). Some physical and mechanical properties of experimental sample are mention herewith. Specific gravity of *Trewia nudiflora* is 0.40, 0.42 and 0.44 in green, airdry and ovendry condition respectively (Sattar *et al.* 1999). Some mechanical properties of Pitali (*Trewia nudiflora*) wood like as static bending (Modulus of rupture and Modulus of elasticity), Compression parallel to grain, Compression perpendicular to grain, Cleavage and Toughness

are mention herewith. Modulus of rupture (MOR) of *Trewia nudiflora* is 466 kg/cm^2 and 557 kg/cm^2 in green and air dry condition respectively. Modulus of elasticity (MOE) of *T. nudiflora* is 79 kg/cm^2 and 93 kg/cm^2 in green and airdry condition respectively. Compression parallel to grain of *T. nudiflora* is 280 kg/cm^2 and 385 kg/cm^2 in green and air dry condition respectively. Compression perpendicular to grain of *T. nudiflora* is 40 kg/cm^2 and 44 kg/cm^2 in green and air dry condition respectively. (Sattar *et al.*1999). Cleavage (Radial) of *T. nudiflora* is 45 kg/cm and 49 kg/cm in green and air dry condition respectively. Cleavage (Tangential) of *T. nudiflora* is 49 kg/cm and 58 kg/cm in green and airdry condition respectively. Toughness (Radial) of *T. nudiflora* is 195 cm-kg/specimen and 235 cm-kg/specimen in green and air dry condition respectively. Toughness (Tangential) of *T. nudiflora* is 190 cm-kg/specimen and 230 cm-kg/specimen in green and air dry condition respectively. (Sattar *et al.* 1999).

Treatability and natural durability of *Trewia nudiflora* has been determined for transferred to the end users. Treatability and natural durability of some non- durable wood viz. Mango, Rubber, Rajkoroi etc. have been determined and technology on this information is being transferred to the end users. Penetration and retention of Rajkoroi (*Albizia richardiana*) wood were recorded 4.60 cm and 16.88 kg/m^3 at soaking method for 28 days (Salam *et al.* 2019). This study was undertaken to determine the treatability and durability of Pitali wood. It might be helpful in maximizing utilization of forest resources as well as improving national economy.

Materials and Methods

The Wood Preservation Division of Bangladesh Forest Research Institute carried out the treatability and natural durability of Pitali (*Trewia nudiflora*) wood species which were collected from Patiya Upazila, under Chattogram district. Patiya is located at latitude 22.3000° N and longitude 91.9833°E. The age of the *Trewia nudiflora* wood was 12 years. Then the logs were sawn and dried in shed of Bangladesh Forest Research Institute (BFRI) Laboratory to reduce the moisture content. Average moisture content was 81.5% when the wood was collected. Before treatment, all planks were sized into 50.8 cm × 5.08 cm × 2.54 cm. A total number of 48 wood samples were prepared for experiment (Fig. 1).

Figure 1. Untreated pitali wood samples

Then, all specimens were allowed to dry for reducing moisture content up to fiber saturation point (FSP) at 25–30% moisture content for treatment. Out of 48 samples, 24 samples were taken for soaking method and remaining 24 for diffusion method. 10% CCB aqueous solution was applied both the method. The percentage of preservative solution is less than 10%, then retention rate become lower than the standard level. The percentage is higher than 10%, and then retention rate become higher than the standard level but treatment cost become increase, which is not economically viable. Wood will be treated by 10% CCB aqueous solution for obtaining required retention and

reducing experimental period. Many studies have been published on the use of CCB solutions at 10% for having a better result. It will be cost-effective and entrepreneurs can apply the concentration of the solution. The physical and mechanical properties of wood increase after treatment using 10% CCB aqueous solution (Shanu *et al.* 2015). Sample will be shown the light blue color after treatment.

Firstly, for soaking method, every 6 samples were immersed into 10% CCB aqueous solution (2:2:1) for 5 days, 7 days, 9 days and 11 days separately. Twenty four samples were staked after treatment by soaking method using 10% CCB aqueous solution (Fig. 2).

Figure 2. Wood samples treated by soaking method

The absorption and retention of immersed samples were determined by weighing the samples. Again the samples were dried. Finally retention and penetration were measured. Slightly dry samples were crossed-section for determination of penetration. Then, Chrome-azuralS solution applied in opened wood samples which reaction with CCB preservatives and change color. The blue color indicates the penetration of treated samples. Depth and intensity of blue color indicates penetration range and treatability group of treated samples. Finally, average penetration and retention were measured.

Wood specimens maximum and minimum moisture content were 62.38% and 50.72% for diffusion method. Every 6 samples were immersed into 10% chromated-copper-boron (CCB) aqueous solution (2:2:1) for 5 days, 7 days, 9 days and 11 days separately. Twenty four samples were staked after treatment by diffusion method using 10% CCB aqueous solution (Fig. 3).

Figure 3. Wood samples treated by diffusion method

The treated samples withdraw from 10% CCB aqueous solution and kept 12 hours for dry. The absorption and retention of immersed samples were determined by weighing the samples before and after treatment. Treated samples were cross-section for determination of penetration. Then, Chrome-azurolS solution applied in opened wood samples which reaction with CCB preservatives and change color. The blue color indicates the penetration of treated samples. Depth and intensity of blue color indicates penetration range and group of treated samples. Finally, average penetration and retention were calculated of treated wood samples using diffusion method. Treated and untreated wood specimens were stake in BFRI stake-yard for service test (Fig. 4).

Figure 4. BFRI Stake yard

Results

Soaking method

24 samples were treated by soaking method using 10% CCB aqueous solution for different duration. Penetration and retention of treated samples were measured. The retention of preservatives in experimental sample was founded 12.29 kg/m^3 , 14.97 kg/m^3, 15.11 kg/m^3 and 15.72 kg/m^3 when soaked for 5, 7, 9 and 11 days respectively (Table 1). The highest retention was founded 15.72 kg/m^3 in Pitali wood samples with soaking method for 11 days and wood samples are moderately treatable. The lowest retention was found 12.29 kg/m^3 at 5 days in this species applying soaking method.

Table 1. Retention of preservatives in experimental sample (*T. nudiflora* L.) using soaking method.

Charge No.	Sample size (cm)	Treatment period (day)	Retention (kg/m^3)	F-ratio (ANOVA)
1	2.54×5.08×50.8 52.31	5	12.29±0.30	(p=1.11*)
2		7	14.97±0.30	
3		9	15.11±0.27	
4		11	15.72±0.27	
	F-ratio (ANOVA)	4.23		

Note: (*) indicates significant at 5% probability level.

Diffusion method

Twenty four samples were treated by diffusion method using 10% CCB aqueous solution for four different durations. Penetration and retention of treated samples were determined. Retention of preservatives of wood samples were recorded 11.43 kg/m^3, 23.49 kg/m^3, 24.14 kg/m^3 and 25.38 kg/m^3 when diffused for 5, 7, 9 and 11 days respectively (Table 2). The highest retention was recorded 25.38 kg/m^3 in wood samples with diffusion method for 11 days and wood samples are treatable. The lowest retention was found 11.43 kg/m^3 at 5 days in the species of Pitali applying diffusion method.

Table 2. Retention of preservatives wood sample (Size: 2.54×5.08×50.8 cm) using diffusion method.

Charge No.	Av. moisture content (%)	Treatment period (day)	Retention (kg/m³) ± Standard error	F-ratio (ANOVA)
1	62.38±0.17	5	11.43±0.23	19.0 (p=0.00018*)
2	51.22±0.06	7	23.49±0.53	
3	50.72±0.17	9	24.14±0.49	
4	54.19±0.53	11	25.38±0.37	
F-ratio (ANOVA)		19.05		

Note: (*) Indicates significant at 5% probability level.

Discussion

The highest retention is 15.72 kg/m³ in Pitali wood using soaking method for 11 days which can be supported with BSTI Standard (Anon 1975). The rate of retention increased rapidly at soaking period of 5 to 7 days. On the other hand, the rate of retention increased slowly at soaking period of 7 to 11 days. If treatment period was continued for more than 11 days in soaking method, retention would probably motionless.

The highest retention of Pitali wood is 25.38 kg/m³ using diffusion method at 54.19% moisture content, which supports with BSTI Standard. According to BDS code, the required retention of CCB is 8–16 kg/m³ (Anon 1975). Different retention was observed in pitali wood due to applying different moisture content and time period. The rate of retention increased rapidly at treatment period of 5 to 7 days. On the other hand, the rate of retention increased slowly at treatment period of 7 to 11 days. If treatment period was continued for more than 11 days in diffusion method, retention would probably slightly increase.

According to Bangladesh Standard 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 CCA preservative chemical is 8–16 kg/m³ (Anon 1975). In this study, the retention results of treated samples at 11 days are acceptable for both the methods.

Chandra and Gupta (1972) stated that, 16 kg/m³ of dry salt was necessary for the effective preservation of the poles in contact with ground. In the experiment, the highest retention was found 15.72 kg/m³ and 25.38 kg/m³ for the species which is near up to standard and matched with Chandra and Gupta (1972). Research report of Commonwealth Scientific and Industrial Research (CSIR) (Du Toit 1988) indicated that average sapwood retention levels are required for adequate protection of poles against wood rot and termite attack. Findings of the present study prove that penetration and retention level can be maximized into Pitali wood by applying soaking and diffusion. Accordingly, this wood can be free from wood rot and termite attack resulting in escalating the durability.

Conclusion

Pitali wood can be treated with 10% CCB aqueous solution. It is mentionable that

untreated samples were affected by insects, fungus etc. within 7 to 8 months. Till now, the treated *Trewia nudiflora* samples are in good condition in the BFRI stake yard. Longevity of Pitali wood was made enhanced in association with soaking and diffusion method. Prescribed to use the wood with the narrated treatment for short time use at outdoor and for life time use at indoor condition.

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Determination of Physical and Mechanical Properties of Thai Bansh (*Thyrsostachys siamensis* Kurz, Gamble)

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Abstract

Physical and mechanical properties of Thai bansh (*Thyrsostachys siamensis* has been studied at three different height positions along the culm. These properties were found to vary significantly along the culm height. The moisture content, shrinkage and the bending strength decreased as the height increased, but the specific gravity, compressive strength and modulus of elasticity increased with the height. Variations of these properties were also found significant among the species.

সারসংক্ষেপ

তিনটি বিভিন্ন উচ্চতায় থাই বাঁশের ভৌত এবং শক্তি সম্বন্ধীয় গুণাবলি পরীক্ষা করা হয়েছে। দেখা গেছে যে, উচ্চতা ভেদে এ ধর্মগুলির পরিবর্তন বিশেষ তাৎপর্যপূর্ণ। বাঁশের জলীয় অংশ, সংকোচন এবং বক্রতার শক্তি উচ্চতা বৃদ্ধির সাথে সাথে হ্রাস পায়, কিন্তু আপেক্ষিক গুরুত্ব, আঁশ বরাবর চাপ শক্তি ও দৃঢ়তার গুনাংক উচ্চতার সাথে সাথে বৃদ্ধি পেয়েছে। প্রজাতির মধ্যে এই বৈশিষ্ট্যগুলোর বৈচিত্র্যগুলোও উল্লেখযোগ্য পাওয়া গেছে।

Key words: Bamboo, Modulus of elasticity, Shrinkage, Strength properties

Introduction

Bamboo is used for a great variety of purposes, such as, construction, bridge, reinforcing material, household article, walking stick, umbrella handle, musical instrument and a host of other uses. Bamboo is considered as good as other building materials like steel, concrete and timber (Janssen 1985). It, thus, plays an important role in everyday life in rural and urban areas alike. It grows very fast within a few months and subsequently becomes strong.

Knowledge of the physical and mechanical properties of bamboo is needed to ensure its proper and manifold uses. An extensive research has been carried out on physical and mechanical properties of bamboo in different parts of the world. In India, Shekhar and Bhartari (1960), Kishan *et al*. (1958), Rehman and Ishaq (1947), Limaye (1952) and Wakchaure and Kute (2012) studied the properties of different bamboos. In Malaysia Daud *et al.* (2018), Zakikhani *et al.* (2017) and Hamdan *et al.* (2005) determine Physical and Mechanical Properties of different Bamboo species. In Netherlands, Janssen (1980, 1981, 1985) studied thoroughly the various aspects of mechanical properties of *Bambusa blumeana* species. Liese (1987) correlated its anatomical properties with the physical properties. In Philippines, Espiloy (1979, 1983) determined the physical and mechanical properties of *Bambusa blumeana* and

Gigantochloa levis. Glenn (1950) made a comprehensive report on bamboo reinforcement of cement concrete. In Bangladesh, the physical and mechanical properties of muli (*Melocanna baccifera*) and borak (*Bambusa balcooa*) bamboos were studied (Sattar *et al.* 1990; Talukdar and Sattar 1980). No information regarding physical and mechanical properties on other species is available in our country. For this reason, a new species named Thai bansh (*Thyrsostachys siamensis*) has been studied, this particular bamboo species is new for our country. Borak bansh (*Bambusa balcooa*) and Baijja bansh (*Bambusa vulgaris*) species studied earlier has also been included to compare at the same condition.

Materials and Methods

Preparation of Materials

Thai bansh (*Thyrsostachys siamensis)* were collected from the bambusetum of Bangladesh Forest Research Institute, Chattogram. Three bamboo culms of thai bansh of three years old were studied because the culms attain maturity at this age (Espiloy 1991; Sattar *et al.* 1990). Three height positions, the bottom, the middle and the top were considered for each test. The size of the specimens for the determination of moisture content and specific gravity were of 2.5 cm rings from each height position. The specific gravity was determined on the basis of green and ovendry volumes. The specimens for shrinkage in wall thickness was also of 2.5 cm rings and for diameter shrinkage the specimen consisted the internodes of the culms bounded by nodes at the extremity. Three rings and three internodal culms were cut from each of the height position.

Physical and Mechanical Properties

Procedures and method used for the determination of physical and mechanical properties of bamboo were referringto International Standard ISO 22157-1 and ISO 22157-2.

Determination of Moisture Content

Samples of 25 mm x 25 mm x wall thickness for green bamboo were taken near to the failure place for the determination of moisture content and density. The bamboo were cut from the each section of culm (bottom, middle, top). Initial weight before drying was weighed. Then, the samples were dried in an oven at a temperature of 103 ± 2°C. After 24 hours, the mass was recorded. For each test piece, the moisture content MC were calculated by using the Equation (1).

$$MC(\%) = \frac{m-m_o}{m-m_o} \times 100 \quad \ldots (1)$$

Where,

m = mass before drying (gm) and m_0: mass after oven drying (gm)

Determination of Specific Gravity (SG)

The samples used in the determination of moisture content were the same used for density determination. The oven-dry density of each sample were calculated using Equation (2)

$$SG = \frac{Oven\ dry\ weight}{Volume} \quad \ldots (2)$$

Compressive Strength

The bamboo was cut into three sections of each culm from the bottom, middle and top part. The compressive strength parallel to grain was determined from the internode of the culm on full diameter and the length was ten times of the average wall thickness of the culms.

Compression strength were tested by using universal testing machine. The maximum compressive stress then were calculated by using the Equation (3).

$$\delta_{ult} = \frac{F_{ult}}{A} \quad \ldots (3)$$

Where,

δ_{ult} = Compressive stress ($kgcm^{-2}$), F_{ult}: maximum load (lb) and A: bamboo wall cross-sectional area (cm^2).

Static Bending Test

The bending capacity of the bamboo culms were tested using a four-point bending test until failure. The length of the specimens for the static bending test was 75 cm. These was bounded by two nodes. The paired specimens were prepared for both compressive and static bending test from each portion, one for test in the green condition and the other for test in the airdry condition. All the tests were tested by using the Universal Testing Machine. Deflections were measured at mid-span with every 50 lb load increment. The modulus of rupture (MOR) were calculated by using Equation (4). Then, the modulus of elasticity was calculated by using the Equation (5).

$$MOR = F \times \frac{L}{6} \times \frac{\frac{D}{2}}{1B} \quad \ldots (4)$$

Where,

F = Maximum load (lb), L: free span (cm), D: outer diameter (mm) and IB: second moment of area (cm^2).

$$MOE = \frac{23 \times F \times L^3}{1000 \times \delta \times 1B} \quad \ldots (5)$$

Where,

δ = deflection mid-span (cm).

Mechanical properties, viz., compressive and static bending were carried out according to the Indian method (Anon 2008). The size of the specimens for the static bending test was of 75 cm length bounded by two nodes. Paired specimens were prepared for each of the height position, one for the test in green condition and other for the test airdry condition. The modulus of elasticity and the modulus of rupture were evaluated from this test. The compressive stress parallel to grain was determined from the specimens on full diameter and the length was ten times of the average wall thickness of the culms. Paired specimens were also prepared from each of height position for testing in green and airdry conditions (Fig. 1). All the tests were conducted with bamboos of three years old because it was found in previous studies that bamboos like muli, borak and also other species mature at the age of three years (Limaye 1952; Sattar *et al.* 1990)

Figure 1. Different steps of The determination for physical and mechanical properties of Thai bansh (A-H).

Results

The results of length and weight of culms, no. of nodes, internodes and weight of branches of Thai bansh are presented in Table 1 and the length of internodes, circumferences of internodes, circumferences of the nodes are in Table 2. The results of physical properties viz., moisture content, the specific based on green and oven-dry volumes, shrinkage in wall thickness, shrinkage in diameter at different height positions are shown in Fig 1, 2, 3 & 4. In these figures the moisture content of bottom portion is higher (75%) than the top portion (52%), the specific gravity of top portion is higher (1.20) than the bottom position (0.85), the shrinkage of wall thickness and diameter is higher (13% & 4.45%) in bottom portion than the other two portions. The results of the mechanical properties viz., compression parallel to grain, modulus of elasticity and modulus of rupture in green and air-dry condition are given in Fig 5, 6, & 7. In these figures the compression parallel to grain of top position is higher (53.93 Mpa) than the other two portion middle (45 Mpa) and bottom (37.37 Mpa), the modulus of rupture of middle portion is higher (81.88 Mpa) than the bottom (73.54 Mpa.) and top (70.60 Mpa) portion, the modulus of elasticity of top position is higher (1677 Mpa.) than the other two portions (bottom 1422 Mpa and middle 1592 Mpa).

Table 1. Physical characteristics of the three culms of Thai bansh.

Sl. No.	Ave. length of culm (cm)	Ave. weight of culm (kg) (in green condition)	Ave. no. of nodes	Ave. no. of internodes	Ave. weight of branches and leaves (kg)
1.	1097 ± 0.50	28± 0.68	26 ± 0.32	25 ± 0.25	9 ± 0.41
2.	1036± 0.49	27 ± 0.71	27 ± 0.29	27± 0.23	8 ± 0.39
3	1067± 0.53	26 ± 0.70	26 ± 0.31	25± 0.24	7 ± 0.40

Table 2. Length of internodes, Circumferences of internodes and Circumferences of nodes of different height position Thai bansh.

Sl. No.	Ave. length of internodes			Ave. circumferences of internodes			Ave. circumferences of nodes		
	Bottom (cm)	Middle (cm)	Top (cm)	Bottom (cm)	Middle (cm)	Top (cm)	Bottom (cm)	Middle (cm)	Top (cm)
1.	21.64 ± 0.02	20.32 ± 0.03	21.08 ± 0.05	26.67 ± 0.06	25.40 ± 0. 54	26.03 ± 0.42	26.67 ± 0.85	25.4 ± 0.38	26.03 ± 0.48
2.	24.13 ± 0.01	25.40 ± 0.04	23.49 ± 0.04	24.13 ± 0.05	22.86 ± 0.53	23.49 ± 0.41	25.40 ± 0.81	25.40 ± 0.32	26.03 ± 0.49
3.	22.86 ± 0.01	24.13 ± 0.03	23.49 ± 0.03	25.40 ± 0.04	26.03 ± 0.53	26.67 ± 0.39	27.30 ± 0.82	26.03 ± 0.36	27.30 ± 0.43

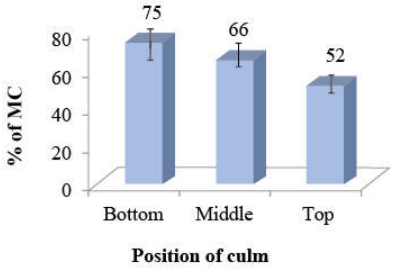

Figure 1. Moisture content (%) of different height position of thai bansh.

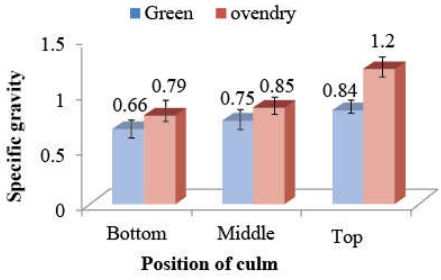

Figure 2. Specific gravity of different height position of thai bansh.

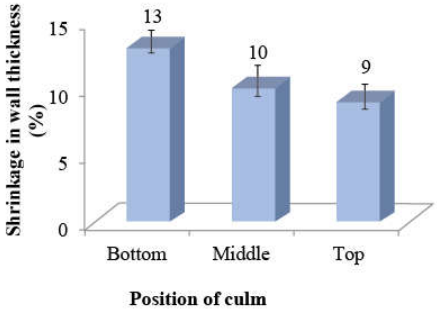

Figure 3. Shrinkage (%) in wall thickness (Green to ovendry) of different height position of thai bansh.

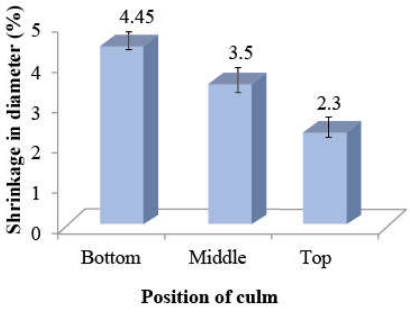

Figure 4. Shrinkage (%) in diameter (Green to airdry) of different height position of thai bansh.

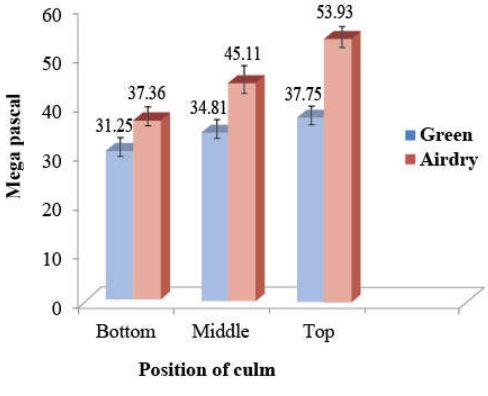

Figure 5. Compression parallel to grain (Mpa) of different height position of thai bansh.

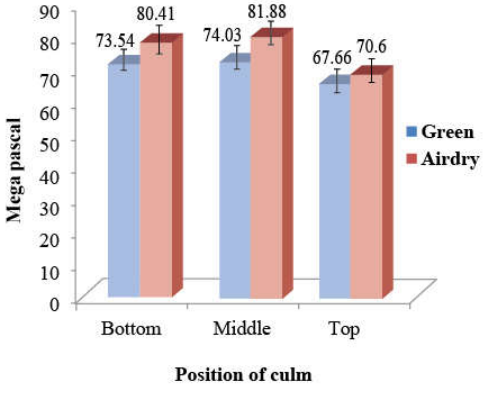

Figure 6. Modulus of rupture (MoR) of different height position of thai bansh.

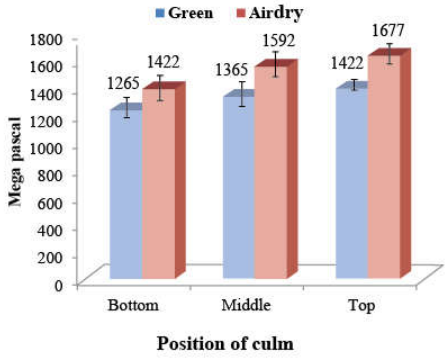

Figure 7. Modulus of elasticity (MoE) of different height position of thai bansh.

Discussion

It was observed that moisture content decreased from the bottom to top, whereas specific gravity increased with the increasing height. Shrinkage in wall thickness decreased from the bottom to top where as Shrinkage in diameter increased with the increasing height. The ovendried bamboos were denser than green ones. Thai bansh has been compared with the results of borak (*B. balcooa*) and baijja bansh (*B. vulgaris*) tested earlier. Moisture contents of thai bansh is lower parameter and the specific gravity is higher were found to vary significantly among the species. Thai bamboo exhibited the highest specific gravity and baijja bamboo showed the lowest value among the three species but the baijja bamboo shows the highest value of shrinkage in wall thickness and shrinkage in diameter.

The effects of height on shrinkage in wall thickness and in diameter were found significant, but the variation of these properties among the species were insignificant. Shrinkage in wall thickness were found to decrease from the bottom to the top for all the species. Diameter shrinkage was less than shrinkage in wall thickness.

The effect of height on compressive strength was found significant. The compressive strength increased as the height increased. The increased proportion of compressive strength may be associated with specific gravity which was found to increased due to the increasing percentage of sclerenchyma fibres from bottom to top (Janssen1981). This property varied significantly among the species. Thai bansh (*T. siamensis*) was the strongest inrespect of compressive strength where as baijja showed the lowest value and borak bansh was showed middle values. The moisture content affected the strength properties significantly. This is why the air dried bamboo became stronger than the green ones.

The modulus of rupture and the modulus of elasticity changed significantly along the culm height and variation of these properties among the species were also found significantly. As the diameter of bamboo increased the modulus of elasticity decreased. This agrees well with the findings of Abdullah *et al*. (2017), Bhonde *et al*. (2014), Gutu (2013) and Sanyal *et al*. (1988). Borak was found to be the strongest in bending strength where as baijja showed the lowest value and thai bamboo is in the middle. The bottom was found superior in modulus of rupture to the middle and the top positions. Most of the scientist of the world showed that the higher the wall thickness, the higher is the modulus of rupture. This may not hold true if the strength properties are expressed per unit by wall thickness, which is done in the investigation.

Conclusion

Specific gravity, compressive strength and modulus of elasticity increased and moisture content, shrinkages and modulus of rupture decreased along the culm height of bamboo. Except the shrinkage, the physical and

mechanical properties varied significantly among the species.Thai bamboo showed the highest specific gravity and modulus of rupture where as borak bansh, Thai bansh (*T. siamensis*) and Baijja bansh (*B. vulgaris*) exhibited the lowest value among the species.

Acknowledgement

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Avian Species Diversity of Dhanmondi Lake Area, Dhaka, Bangladesh: Role of an Urban Ecosystem in Supporting Bird's Conservation

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Abstract

The Dhanmondi Lake Area (DLA), Dhaka possesses an overview performance for being an ideal site for bird's habitat because of its landscape, planted vegetation coverage, old trees and wetland. A study on the avian species diversity, richness and abundance, status, and seasonal variation was conducted from July 2019 to June 2021 in the green space of Dhanmondi Lake Area, Dhaka, Bangladesh. A total 57 species of avian fauna belonging to 12 orders, 27 families and 43 genera were recorded during the study period. Among the bird species passerines constituted the highest 30 species (56% of the total species) belonging to 15 families and 23 genera and non-passerine represented 27 species (44% of the total species) belonging to 13 families and 20 genera. Among the total species recorded during the study period 47 (82.46%) were resident bird species and 10 (17.54%) were migratory species. Identified birds' abundances, richness and threats to them were also discussed in this article.

সারসংক্ষেপ

ঢাকার ধানমণ্ডি লেক এলাকার জলাভূমি, এর তীরভূমিতে রোপণ করা গাছপালা ও পুরানো বৃক্ষ মিলে যে সবুজায়ন গড়ে উঠেছে তাকে আপাতদৃষ্টিতে পাখি প্রজাতির উপযোগী আবাসস্থল বলে প্রতীয়মান হয়। এখানে পাখির প্রজাতি বৈচিত্র্য, প্রাচুর্য, বর্তমান অবস্থা ও ঋতুগত বৈচিত্র্যের উপর জুলাই, ২০১৯ হতে জুন, ২০২১ পর্যন্ত একটি গবেষণা কার্যক্রম পরিচালনা করা হয়। এ সময়ে সর্বমোট ৫৭ প্রজাতির পাখি রেকর্ড করা হয়, যারা ১২টি বর্গের ২৭টি গোত্রভুক্ত এবং ৪৩ গণের অন্তর্ভুক্ত। রেকর্ড করা পাখিদের মধ্যে সর্বোচ্চ ৩০টি (৫৬%) প্রজাতি ছিল গায়ক (passerines) এরা ১৫টি গোত্রভুক্ত এবং ২৩ গণের অন্তর্ভুক্ত এবং ২৭টি (৪৪%) প্রজাতি ছিল অগায়ক (non-passerines) যারা ১৫টি গোত্রভুক্ত এবং ২৩ গণের অন্তর্ভুক্ত ছিল। এসব পাখি প্রজাতির মধ্যে ৪৭টি (৮২.৪৬%) প্রজাতি স্থায়ী ও ১০টি (১৭.৫৪%) প্রজাতি ছিল পরিযায়ী। ধানমণ্ডি লেক এলাকা হতে শনাক্তকৃত পাখি প্রজাতিগুলির প্রাচুর্য, সমৃদ্ধি এবং এখানে তাদের প্রতি হুমকিসমূহও এ নিবন্ধে আলোচনা করা হয়েছে।

Key words: Birds' abundances, Dhanmondi lake, Green space, Habitat, Status.

Introduction

Geographical location, landscape, climate and ecosystem of Bangladesh support rich avian species diversity and population. About 10,500 species of birds inhabit in the world of which a total of 718 species is expected to home in Bangladesh (IUCN 2015). Entire Bangladesh was an ideal habitat for birds at one time. But, in course of time, with the increase of population and their needs bird's natural habitat has been faced damaged, alteration and ongoing thinning for housing, food producing and building infrastructure facilities for the over grown citizens. Similar to the other region of the world, urban areas are expanding in size and number in Bangladesh. Cities are typically located near large river bank, water bodies, estuaries or long coast lines that traditionally support rich vertebrate community especially avifauna. As a result, large parks and reserves in urban areas may support high species diversity because these sheltered areas are the fragmented habitat of highly diverse, productive ecosystems. Several species of the existing wildlife of Bangladesh can be present in some small areas at a very low population (Rahman 2009). In recent times, conservation biologists of non-government organization and universities are collecting data on wildlife of protected areas and reserve forest areas and focused predominantly on the protection of natural ecosystem but have given little importance on urban biodiversity (Jules 1997; Rahman 2013; Rahman 2014). But, it is very vital to understand the diversity and abundance of avian species as a tool to value ecological significance and biodiversity conservation of a landscape in high human pressure (Chettri 2001; Payra 2017). Plants and wildlife of the green open areas in highly modified city areas impact urban environment. And thus, bird species distribution and diversity is associated to the existing habitat feature and the extent of urbanization (Fontana *et al.* 2011; Pickett *et al.* 2011). Bird population and species could spread and use various habitats from plain land, forest, desert, ocean, mountain, ice zone to man habitation. So, any detrimental change of an ecosystem reflects on bird's varieties and numbers, thus it roles as an ideal barometer of a healthy ecosystem (Khan *et al.* 2011). Capital Dhaka has past historic jubilee of 400 years. In the past it was a small city within rivers, swamps and jungles. Wildlife was very rich in numbers and diversity from the present record. As regards of birds, waterfowls, pheasants, partridges, bustards, cranes, storks, eagle, hawks, falcons, owls, herons and egrets etc. were existing in Dhaka except present city birds (Simpson 1882; Tytler 1854).

Capital Dhaka is an over-populated city with more than 21.7 million citizens in 2021 within an area of 306 square km. There is no wildlife habitat that has not been damaged, alternated and polluted. A few existing and restored green spaces provide home to birds. Dhanmondi Lake, established in the heart of Dhaka city, and tree cover along the lake side land is considered as safe haven for birds. No scientific and systematic monitoring of bird has been done yet at DLA, Dhaka, endowed with planted and regenerated trees, other plants and a vast water body. For better understanding of the possible changes and greater sustainability of urban ecosystem of Dhaka city, it is very important to study and assess avian species diversity of the DLA for taking further sophisticated initiatives of future sustainable conservation of the biodiversity and eradicate adverse effects on their existence in this area. So this study has been taken to find out the basic data on avian fauna with its status at the DLA. The study findings will eventually be helpful for implementing the conservation measures to protect the birds of the area.

Materials and Methods

Study area

The Dhanmondi Lake Area is amassing of unique green space and wetland within Dhaka metropolitan area. It is situated between 23°44′12′′ and 23°45′22′′ north latitudes and between 90°22′ and 90°23′ east longitudes (Fig. 1). The Dhanmondi Lake Area is amassing of unique green space and wetland within Dhaka metropolitan area. It is situated in the middle of Dhaka City at 23°43' North latitude and 90°26' East longitude (Fig. 1). It lies within the vicinity of Dhanmondi residential area. Originally Dhanmondi Lake was an abandoned channel of the 'Karwan Bazar Nadi' whose alignment was possibly along Begunbari Khal-Green Road-Kalabagan-Dhanmondi Lake to the Turag River. Expansion of urbanization in this area during Pakistan period has changed the natural water system in this place. Dhanmondi residential area was developed in 1956 with 240.74 ha of land including the lake. The lake is about 16% of the total area of Dhanmondi. Beginning from Jigatola (Dhanmondi Road - 2) the lake extends up to Road - 27 (new l6A), and bounded by the Mohammadpur-Lalmatia area in the north, Satmasjid Road in the west, BGB Gate (Dhanmondi Road -2) in the south and in the east by Kalabagan residential area. It is 3 km in length, 35-100 m in width, with a maximum depth of 4.77 m and the total area of the water body is 37.37 ha. There is one box culvert in the lake near Sukrabad area, which is the only outlet of the lake (Wikipedia 2021).

The lake is under the management of several authorities looking after its various aspects. At present, part of the lake used for sport fishing and the Fisheries Department looks after fishery development and aquaculture; the Dhaka South is the principal civic body, exercises some responsibility in its improvement. The Department of Environment (DoE) looks after the aspects of proper environment and protection of aquatic resources of the lake. In and around Dhanmondi Lake some renovation works and tree plantation were carried out from 1998 to 2001 with a view to making the lake a pollution free, green and recreation zone (Hossain 2014; Banglapedia 2021).

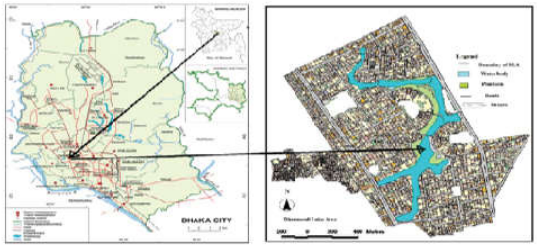

Figure 1. Map of Dhanmondi Lake Area, Dhaka, Bangladesh

Data collection and analysis

The study was carried out from July, 2020 to June, 2021. Study period covered three seasons i.e., monsoon (July-October), winter (November-February) and summer (March-May). A periodical survey, of 5 days per month was conducted in the field during the study.

The observations started early in the morning and continued to 11:00 am, and in the afternoon session from 3:00 m to late the evening. Data were collected through direct field observation along the selected line transects about 1 km long and 10 m wide on both sides of wake ways in the lake areas. A pair of binocular and a digital camera (PowerShot Sx70HS) has been used for watching the avian species, and taking photo of birds for identification. If failed to identify any species in the field, pictures were used to identify by checking field guides. The local status of species was determined on the basis of relative presence as stated by Khan (1982): (1) **very common** – species observed 80-100% of the field visits and good number

(2) **common**- species seen 50-79% of the field visits (3) **uncommon**- species detected 20-49% during the field visits and (4) **rare**- species witnessed less than 19% of the field visits and in very small number. Shannon-Weaver Index (1964), Simpson's index (1949) of diversity, evenness (quantifies how numerically equal the community is) of species and effective numbers of species (Jost 2006) in the study area were also calculated using the following formulas (Suryakant 2017) (Table 1). The collected data were computed using MS Excel programme.

Table 1. The list of formulae used for calculating bird species diversity indices of the DLA.

Equation No.	Biodiversity indices	Formula	References
1.	Shannon-Weaver's diversity index (H′)	$H' = \sum_{i=1}^{s} -PilnPi$	Shannon and Weaver (1964)
2.	Simpson's diversity index (D)	$D = \frac{\Sigma n(n-1)}{N(N-1)}$	Simpson (1949)
3.	Species evenness index (E)	$E = \frac{H'}{\log(S)}$	Shannon and Weaver (1964)
4.	Effective number of species (Ens)	Ens= EXP(H′)	Jost (2006)

(Where, Pi = , n = $\frac{\text{(Number of individuals of one species (N))}}{\text{(Total number of all individuals (S))}}$ number of individuals of each species, H′ = Shannon Weaver diversity index)

Results

The Dhanmondi Lake Area (DLA), located in the heart of the capital and enriched with cover of native and exotic tree species, planted on both sides of the lake and a big water body supported a good number of bird species. A total 57 species of avian fauna belonging to 12 orders, 27 families and 43 genera were recorded during the study (Table 2).

Table 2. Bird species observed at Dhanmondi Lake Area, Dhaka from July, 2020 to June, 2021.

Sl. No.	Order	Family	Scientific Name	Common English Name	Resident Status	Observed Status
01.	Anseriformes	Antidae	*Dendrocygna javanica*	Lesser whistling Duck	r	R
02.	Columbiformes	Columbidae	*Columba livia*	Rock Pigeon	r	Vc
03.	Columbiformes	Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	r	C
04.	Columbiformes	Columbidae	*Streptopelia chinensis*	Eastern Spotted Dove	r	Vc
05.	Cuculiformes	Cuculidae	*Eudynamys scolopacea*	Asian Koel	r	Vc

Sl. No.	Order	Family	Scientific Name	Common English Name	Resident Status	Observed Status
06.	Cuculiformes	Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo	r	R
07.	Pelecaniformes	Ardidae	*Butorides striata*	Striated Heron	r	R
08.	Pelecaniformes	Ardidae	*Ardeola grayii*	Indian Pond Heron	r	C
09.	Pelecaniformes	Ardidae	*Nycticorax nycticorax*	Black-crowned Night Heron	r	R
10.	Suliformes	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	r	Vc
11.	Caprimulgiformes	Apodidea	*Cypsiurus balasiensis*	Asian Palm Swift	r	Uc
12.	Caprimulgiformes	Apodidea	*Apus nipalensis*	House Swift	r	Vc
13.	Psittaciformes	Psittacidae	*Psittacula krameri*	Rose Ringed Parakeet	r	Vc
14.	Psittaciformes	Psittacidae	*Psittacula alexanderi*	Red-breasted Parakeet	r	R
15.	Psittaciformes	Psittacidae	*Psittacula eupatria*	Alexander Parakeet	r	Vc
16.	Accipitriformes	Accipitridae	*Milvus migrans*	Black Kite	r	Vc
17.	Strigiformes	Srtigidae	*Athene brama*	Spotted Owlet	r	R
18.	Strigiformes	Srtigidae	*Tyto alba*	Common Barn Owl	r	R
19.	Strigiformes	Srtigidae	*Ninox scutulata*	Brown Boobook	r	R
20.	Coraciformes	Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	r	Vc
21.	Coraciformes	Alcedinidae	*Halcyon atthis*	Common Kingfisher	r	Vc
22.	Coraciformes	Alcedinidae	*Halcyon capensis*	Stork-billed Kingfisher	r	Uc
23.	Coraciformes	Meropidae	*Merops orientalis*	Asian Green Bee-eater	r	Uc
24.	Piciformes	Picidae	*Dinopium macei*	Fulvous-breasted Woodpecker	r	C
25.	Piciformes	Picidae	*Dinopium benghalense*	Black - rumped Woodpecker	r	Vc
26.	Piciformes	Picidae	*Micropternus brachyurus*	Roufous Woodpecker	r	R
27.	Piciformes	Megalaimidae	*Megalaima haemacephala*	Coppersmith Barbet	r	Vc
28.	Passeriformes	Lanidae	*Lanius cristatus*	Brown Shrike	Wm	Uc
29.	Passeriformes	Lanidae	*Lanius schach*	Long-tailed Shrike	r	R
30.	Passeriformes	Lanidae	*Lanius tephronotus*	Grey backed Shrike	Wm	R
31.	Passeriformes	Oriolidae	*Oriolus xanthornus*	Black-hooded Oriole	r	Vc

Sl. No.	Order	Family	Scientific Name	Common English Name	Resident Status	Observed Status
32.	Passeriformes	Dicruridiae	*Dicrurus macrocercus*	Black Drongo	r	C
33.	Passeriformes	Dicruridiae	*Dicrurus leucophaeus*	Ashy Drongo	Wm	R
34.	Passeriformes	Corvidae	*Corvus splendens*	House Crow	r	Vc
35.	Passeriformes	Corvidae	*Corvus macrorhynchos*	Jungle Crow	r	C
36.	Passeriformes	Corvidae	*Dendrocitta vagabunda*	Tree Pie	r	Vc
37.	Passeriformes	Paridae	*Parus major*	Great Tit	r	Vc
38.	Passeriformes	Sylvidae	*Orthotomus sutorius*	Common Tailorbird	r	Vc
39.	Passeriformes	Sylvidae	*Phylloscopus fuscatus*	Dusky Warbler	m	Vc
40.	Passeriformes	Sylvidae	*Phylloscopus trochiloides*	Greenish Warbler	m	R
41.	Passeriformes	Sylvidae	*Acrocephalus dumetorum*	Blyth's Reed warbler	m	Uc
42.	Passeriformes	Sylvidae	*Phylloscopus inornatus*	Yellow-browed Warbler	m	C
43.	Passeriformes	Sturnidae	*Acridotheres tristis*	Common Myna	r	Vc
44.	Passeriformes	Sturnidae	*Acridotheres fuscus*	Jungle Myna	r	Vc
45.	Passeriformes	Sturnidae	*Sturnus contra*	Pied Starling	r	Vc
46.	Passeriformes	Sturnidae	*Sturnus malabaricus*	Chestnut-tailed Starling	r	Vc
47.	Passeriformes	Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	m	R
48.	Passeriformes	Muscicapidae	*Ficedula albicilla*	Taiga Flycatcher	m	Vc
49.	Passeriformes	Muscicapidae	*Eumyias thalassina*	Verditer Flycatcher	m	R
50.	Passeriformes	Muscicapidae	*Copsychus saularis*	Oriental Magpie-robin	r	Vc
51.	Passeriformes	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	r	Vc
52.	Passeriformes	Nectarinidae	*Nectarinia asiatica*	Purple Sunbird	r	Vc
53.	Passeriformes	Nectarinidae Sunbird	*Nectarinia zeylonica*	Purple rumped	r	C
54.	Passeriformes	Passeridae	*Passer domesticus*	House Sparrow	r	Vc
55.	Passeriformes	Estrilidae	*Lonchura punctulata*	Scaly breasted Munia	r	R
56.	Passeriformes	Motacilidae	*Motacilla madaraspatensis*	White browed Wagtail	r	R
57.	Passeriformes	Turdidae	*Zoothera citrina*	Orange headed	r	R

Code used: Vc = Very common, C = Common, Uc = Uncommon and R= Rare; r = resident and m = migratory

Among the presently recorded bird species Passeriformes constituted the largest order (in terms of number of species) in the Lake areas and it includes 30 species (56% of the total species) belonging to 15 families and 23 genera and non-passerine represented 27 species (44% of the total species) included 13 families and 20 genera. There were 47 (82.46%) resident bird species and 10 (17.54%) migratory bird species recorded during study in the area. The resident bird species were more than about five times higher than those of migratory ones.

Status and relative abundance of avifauna

Over all relative abundance showed that 44% birds were very common, 7% common, 19 % uncommon 30% rare (Fig. 2).

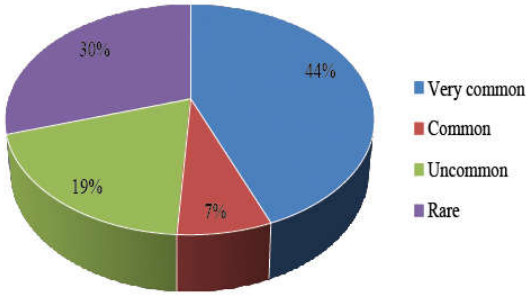

Figure 2. Status of different bird species in the study area from July, 2020 to June, 2021.

The highest number of individuals were found in the month of January (1327 individuals) followed by February (1123 individuals), December (1018 individuals), and lowest number were in the month of July (645 individuals) followed by August (720 individuals) and June (732 individuals) (Fig. 3).

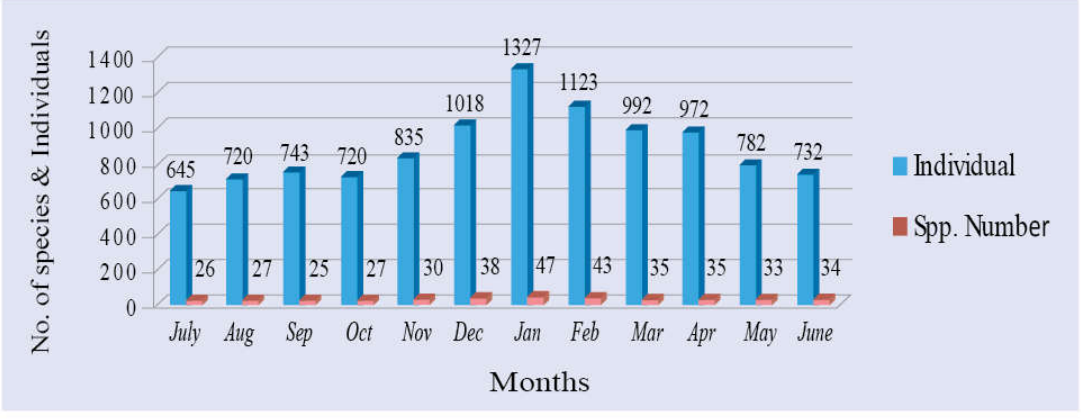

Figure 3. Monthly variation of bird species and individuals observed from July, 2020 to June, 2021.

Corvus splendens was the dominating species followed by *Passer domesticus*, *Sturnus contra* and *Milvus migrans* among the observed avifauna during the study at the DLA.

Variation was observed in the effective number of Species at DLA among the three seasons. In winter, the highest numbers of species (30 spp.) were active in the area followed by summer (25 spp.) and monsoon (18 spp.) (Fig. 4).

Species diversity indices

The value of Shannon-Weaver index was calculated the highest (H′= 3.3960) in the winter season (Nov-Feb), followed by (H′= 3.2133) summer (Mar-Jun) and the lowest (H′= 2.9054) was in the monsoon (Jul-Oct). Similarly, value of Simpson's index of diversity was found to be maximum (D=0. 0.9581) in the winter, followed by summer

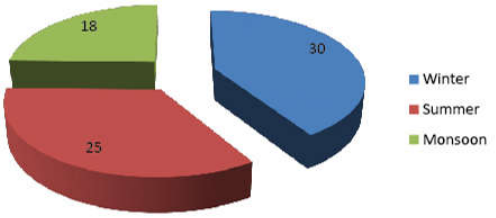

Figure 4. Seasonal variation of the bird Species at DLA from July, 2020 to June, 2021.

(D=0.9504) and monsoon (D=0.9231). The study also calculated species evenness which found that birds species were more evenly distributed (E=0.8710) in the summer season, then in winter (0.8680) and lowest in the monsoon (E=0.8460) (Table 3).

Table 3. Species diversity indices according to season at DLA from July, 2020 to June, 2021.

Prameter	Monsoon	Winter	Summer
Shannon-Weaver index (H')	2.9054	3.3960	3.2133
Simpson's index of diversity(D)	0.9504	0.9581	0.9231
Evenness (E)	0.8460	0.8680	0.8710
Observed species	31	50	40
Observed Individuals	2822	4639	3586

Threats to conservation

Dhanmondi Lake Area is a popular zone for visiting. On a hot summer, walking beside the lake can be very relaxing and delightful to pass the leisure times. Many trees around the lake take various look of colors and beauty such as red, orange, pink, yellow, white and purple with the changes of seasons. Presence of 57 species of birds has been confirmed from DLA at this study but they are facing vulnerability due to the following threats —

Over visitors' pressure

Visitors start coming at dawn for exercising, walking, and sports. With the rising sun their numbers and movements increase and peak at the evening for recreations, selling and buying goods. At the weak end their numbers raise and multiply on the events especially at the time of cultural functions and sport fishing at dry season. Consequently, bird's habitat of DLA is severely disturbed by over crowd of visitors.

Sound and light pollution

There are two streets around DLA, Mirpur road in the east, and Satmasid road in the west. A huge numbers of vehicles ply through the roads all days and nights. Numerous roads of residential area, and through the DLA always carry out hundreds of cars, motor bikes, auto rickshaws, rickshaws and vans. Thus the area is affected by serious sound pollution from noise of car engine and whistle, and din and bustle from mass people gathering and their activities. In the same way light pollution occurs from severe beam of vehicles, lighting and fireworks at the time of occasions in and around the lake area. Both terrify bird and damage suitability of its habitat.

Water pollution

Water body of DLA is subjected to the various anthropogenic and natural pollution like, discharge of residential garbage, waste water from nearby household, shops, commercial activities, rain water runoff with waste, dumping of plastics, polythene, chips packets, unused papers etc. Polluted lake water is directly or indirectly detrimental to lake ecosystems and associated bio-diversity.

Discussion

A total of 57 species of birds were recorded at Dhanmodi Lake Area, Dhaka. The recorded species of birds from DLA covered 10.07% of the country's total avifauna species 566 (IUCN 2015). There are some confirmations of bird's diversity recording within the capital. For instance, Akash *et al.* (2013) stated 50 species of birds consisting of 12 orders and 30 families at Curzon Hall premises of Dhaka University. Banu *et al.* (2016) identified 54 species were in

10 orders and 27 families from Dhaka university campus. Rajia *et al.* (2015) found 50 species of birds belonging to 11 orders and 28 families at Ramna Park area, Dhaka. As, the existing bird habitat of these areas are about similar and the same kind of disturbance prevail, therefore bird species recording is about nearer to the present study.

Islam *et al.* (2014) confirmed a total of 65 species of birds under 11 orders and 28 families from National Botanical Garden, the protected area, less disturbed and enriched habitat in Dhaka. It is the highest record of avian species diversity in the capital. The recent documentation of 57 species of birds by this study at DLA is the second highest diverse presence of birds within the capital Dhaka. Khan (1982) concluded that a bird watcher could record minimum 50 species of birds in a city of Bangladesh. Therefore, the study area demands conservation requirements as a potential habitat for birds.

Although there is a large water body (37.37 ha) in the DLA, it could not attract resident and migratory water fowl. This is because of high disturbance as a result of sound pollution and crowd existing there all the year round. So, only a few resident aquatic birds viz. little egret, black crown night heron, little cormorant, green backed heron and kingfishers were recorded there. Alexandar parakeet (*Psittacula eupatria*) is the most attractive and beautiful bird of DLA.

From December migratory birds join the resident's birds, and increased species diversity and population of the area that peaks in the January and continues till February. In the summer, beginning of breeding season for resident birds, though decrease species variety but their members found high in numbers. On the other hand, high temperature, low food availability, expanding of grazing habitat at the onset of rains that attracts and scatters species to nearby agriculture ecosystem may be the reason of low species diversity and population.

Conclusion

The existence of 57 species of bird and their population, seasonal variation at DLA has indicated significant baseline data on avian species diversity and present status. The study indicates that plantation along the lake side open space has made DLA area green and attractive to winged beauties. Water body of DLA is about twice comparing to lake side land area cover. Assemble of a unique green space and water body, DLA attracts bird species with availability of diversified habitat, food and cover. But birds' habitat is severely disturbed by existing threats to the DLA. The anthropogenic activities and human influence directly or indirectly affects the avian fauna. There is a requirement of conservation of green space and wetland of DLA for their further conservation of birds and associated other biodiversity. So, for recovering the soundness of the lake, strong regulation need to introduce; illegal encroachment and waste dumping have to stop through implementation of existing laws and regulations. Moreover driving of public awareness activities is necessary. Remedial and conservation initiatives need to undertake for restoration of the lake areas such as preventing or reducing of processes degrading or polluting lake water quality, preventing developments that are directly or indirectly detrimental to lake ecosystems, creating and maintaining existing buffer zones between the lake and other public amenities.

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Effect of Pre-sowing Treatments and Different Growing Media on Seed Germination and Seedling Growth of Jigni (*Trema orientalis* Linn. Blume)

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Abstract

Effect of pre-sowing treatments on seed germination of jigni (*Trema orientalis*) was conducted in different growing media to optimize cultural practices for raising seedlings at nursery level. The study was conducted during 2017-2020 at Headquarters Nursery, Silviculture Research Division, Bangladesh Forest Research Institute, Chattogram. The experiment for the nursery technique were laid out in a Completely Randomized Design (CRD). The seeds of *Trema orientalis* have been observed to exhibit physical dormancy due to presence of hard seed-coat. To overcome this problem, seeds were treated with six water soaking treatments except two (Coated seed without treatment, T_0 and un-coated seeds without soaking treatment, T_{00}) and were sown in germination media such as trays, polybags and seed beds. Six pre-sowing treatments were, Coated seeds immersed in normal water for 24 hours (T_1), 72 hours (T_2) and 120 hours (T_3) and un-coated seeds dipped in normal water for 24 hours (T_{01}), 72 hours (T_{02}) and 120 hours (T_{03}) respectively. Jigni seeds showed the highest germination (75.94%) in T_{03} sown in seed bed and lowest T_{00} (20.24%) which was significantly (P<0.05) different from other treatments. The result also showed that the highest mean height (88.5 cm) and collar diameter (3.77 mm) was recorded in T_{03}. These findings revealed that, seeds soaked in normal water for 120 hours and then sown in seedbed were found suitable for quick germination and maximum seedlings production for jigni.

সারসংক্ষেপ

নার্সারি পর্যায়ে পূর্ব-পরিশোধন প্রক্রিয়ায় জিগনির বীজ হতে চারা উত্তোলন পদ্ধতি উন্নতিকরণ ও বিভিন্ন উৎপাদন মাধ্যমে এর প্রভাব মূল্যায়নের জন্য গবেষণাটি পরিচালিত হয়। গবেষণাটি হেডকোয়ার্টার নার্সারি, সিলভিকালচার রিসার্চ বিভাগ, বাংলাদেশ বন গবেষণা ইনস্টিটিউট, চট্টগ্রামে ২০১৭-২০২০ সময়কালে পরিচালিত হয়। নার্সারি কৌশলের জন্য গবেষণাটি কমপ্লিটলি রান্ডমাইজড ডিজাইন (সিআরডি) এ স্থাপন করা হয়। জিগনির বীজ শক্ত কোট বিশিষ্ট, এ প্রতিবন্ধকতা দূর করার জন্য পানিতে ভিজানো ছয়টি পরীক্ষণে জিগনির বীজগুলি তিনটি উৎপাদন মাধ্যমে যেমন: ট্রে, পলিব্যাগ এবং বীজতলায় অঙ্কুরোদগম হার পর্যবেক্ষণের জন্য বপন করা হয়েছিল। পরীক্ষণ ছয়টি হল, বাকলসহ বীজ ২৪ ঘণ্টা (T_1), ৭২ ঘণ্টা (T_2) এবং ১২০ ঘণ্টা (T_3) এবং বাকলছাড়া বীজ ২৪ ঘণ্টা (T_{01}), ৭২ ঘণ্টা (T_{02}) এবং ১২০ ঘণ্টা (T_{03})। এছাড়াও বাকলসহ কোনো প্রকার পরিশোধন ছাড়া (T_0) এবং বাকল ও পানিতে ভিজানো পরিশোধন ছাড়া (T_{00}) উপরোল্লিখিত তিনটি উৎপাদন মাধ্যমে বীজ বপন করা হয়। জিগনি বীজ বীজতলায় T_{00} পরীক্ষণে সর্বনিম্ন অঙ্কুরোদগম হার (২০.২৪%) এবং T_{03} পরীক্ষণে সর্বাধিক (৭৫.৯৪%) অঙ্কুরোদগম হার, গড় উচ্চতা (৮৮.৫ সে.মি.) এবং চারার গোড়ার বেড় (৩.৭৭ মি.মি.) প্রদর্শন করে যা ৫% লেভেলে তাৎপর্যপূর্ণ পার্থক্য দেখা যায়। পরীক্ষা হতে প্রতীয়মান হয় যে, জিগনি বীজকে ১২০ ঘণ্টা সাধারণ পানিতে ভিজিয়ে বীজতলায় বপন করলে দ্রুত অঙ্কুরোদগম এবং সর্বাধিক চারা উৎপাদন করা যায়।

Key words: Growing media, Pre-sowing treatment, Seedlings growth and *Trema orientalis*.

Introduction

Jigni (*T. orientalis* L. Blume) is a multipurpose plant species showing better growth performance than *Acacia mangium* and *Eucalyptus camaldulensis* (Jahan and Mun 2005). It grows naturally throughout Bangladesh, especially central and northern parts of the country. Owing to its dense root system in the surface soil, it grows rapidly in stone and drought land (Chang *et al.* 2007). It is a nitrogen-fixing tree and an economically valuable species for local communities due to its use as fuel wood (Chang *et al.* 2007). It is used in paper production, manufacturing of poles and for medicinal purposes including the treatment of respiratory, inflammatory, and helminthic diseases (Adinortey *et al.* 2013).

It is one of the fastest-growing species in the tropical region. In Bangladesh, the pulp and paper industry are looking for new raw materials with high productivity per hectare. To overcome the scarcity of raw materials, jigni was chosen as an alternative source for pulp production (Jahan 2013). Although *T. orientalis* is a suitable candidate for reforestation and may be a suitable source of fiber supply for paper making in near future (Jahan and Mun 2004). But a low germination percentage and non-synchronous germination prevent the species from being effectively used for large-scale reforestation programs. (Rodrigues and Rodrigues 2014). Thus, investigating the enhancement of seed germination and seedling production of *T. orientalis* in the nursery is a major step for using this species in plantation for pulp and paper industries and in sustainable ecological restoration of degraded wastelands. The selection of appropriate pre-sowing treatment is essential for quick and maximum seed germination (Thapa and Gautam 2006). Hard coated seeds need more time to germinate and thus, direct sowing is not effective (Anon 1972). Proper pre-treatments of seeds can stimulate germination time and germination process (Azad *et al.* 2006a; Azad *et al.* 2011; Azad *et al.* 2012). The effect of pre-sowing treatments on seed germination of few tropical forest tree species has been informed by several authors (Ahamed *et al.* 1983; Khan *et al.* 2001; Alamgir and Hossain 2005; Azad *et al.* 2006b; Matin *et al.* 2006 and Haider *et al.* 2014). According to Wang *et al.* (2002) indicated that fresh ripe fruits of *T. orientalis* sown directly seldom germinate and soon decay, but that germination is higher in de-pulped seeds and was highest in seeds excreted by birds. Sometimes chemical treatment may get the germination higher but chemical use not safe and economical for the planters. To increase the ability of seed germination, potential media play a significant role (Gholami *et al.* 2009; Mia *et al.* 2010). Therefore, an endeavor has made to study the effect of pre-sowing treatments and seed growing media on seed germination to identify appropriate pre-sowing treatment and growing media for *T. orientalis*. The study was to evaluate the seed germination response of *T. orientalis* in different media under different treatments.

Materials and Methods

The study was conducted at Head Quarters nursery of Silviculture Research Division, Bangladesh Forest Research Institute, Chattogram for nursery technique improvement during 2017-2020. Normal water pre-sowing treatment for 120 hours (the water changed daily) was applied to reduce its dormancy period. Data were collected on germination percentage and survivability. Simultaneously seeds were stored and observed its germination percentage at different time scales. Seedlings were raised applying pre-sowing treatments. Completely Randomized Design (CRD) was used for the experiment with five replications. Data were collected on germination percentage

of seed, survival percentage, growth and collar diameter of seedlings.

Seed collection

T. orientalis fruits were collected from Charaljani Siliviculture Research Station, BFRI, Tangail, during October 2017-2020. Phenotypic characteristics of seeds were recorded. Ripen fruits were immersed in water overnight then extracted seeds, dried in the open sun for an hour (Fig. 1).

Figure 1. Jigni seed

Randomly selected seeds length and width are 3.18±0.05 mm and 0.0045±0.002 mm respectively. There were around 90,000 seeds found per kg.

Experimental design

T. orientalis has tiny and hard coated seed. It showed low germination percentages and non-synchronous seed germination. Considering the circumstances, an alternative use of chemical treatment, seeds were tested in germination tray, seed bed and poly bag (Fig. 2) by following different duration of water (normal) soaking treatment for the ease of planters. To carry out the experiment, each experimental plot was designed by a completely randomized design. Seeds were sown in three germination media viz: i) nursery bed, ii) polybags and iii) tray. For polybag, growing media used in the experiment was collected from the forest floor. After collection soil was screened well with <3 mm sized sieve and mixed with decomposed cow-dung in a ratio of 3:1. The three types of treatments with seed germination growing media were

i) Polybags of 15 cm × 10 cm (6" × 4") filled with the soil and cow-dung mixture (3:1) and put in open sun light,

ii) Tray with course sand media and controlled from rain and open sun with special plastic shade and

iii) Nursery seedbed prepared as an alternative of forest floor and set with sand and soil mixture (9:1).

The investigation is made up of eight pre-sowing treatments with 3 replications (1gm=90 seed per replication) in a randomized complete block design. The treatments are:

T_0- Coated seeds without treatment, Control.

T_1- Coated Seeds immersed in normal water for 24 hours.

T_2- Coated Seeds immersed in normal water for 72 hours.

T_3- Coated Seeds immersed in normal water for 120 hours.

T_{00}- Uncoated seeds without soaking treatment.

T_{01}- Uncoated Seeds immersed in normal water for 24 hours.

T_{02}- Uncoated Seeds immersed in normal water for 72 hours.

T_{03}- Uncoated Seeds immersed in normal water for 120 hours.

Ninety (90) healthy seeds were chosen randomly from each treatment. Daily germination was recorded as soon as germination starts. Seedlings which raised in selected media and showed four leaves were transferred to polybag (Fig. 2).

Seed bed | Tray | Polybag | Jigni seedlings

Figure 2. Jigni seedling raised in different germination medium

The transferred seedlings were kept in shade for 2 weeks and then the shade was removed. Proper care and maintenance were done regularly. Six seedlings from each treatment were selected randomly and shoot height and root lengths of the seedlings were recorded.

Germination performance

Germination performance is the percentage of seeds germinated in an experiment during the study period. Germination performances were classified as follows: a) 90-100%-very good, b) 70-90%-good, c) 50-70%-average, d) 30-50%-poor, e) 20-30%-very poor and f) (<) less than 10% extremely poor (Kumar 1999). The germination time was counted, from the commencement to the termination of germination out of 100 seeds. (Kumar 1999).

$$\text{Germination \% (GP)} = \frac{\text{No of seed germinated}}{\text{No. of seed sown}} \times 100$$

Statistical analysis

Data analysis was conducted using statistical software SPSS version 22. Analysis of variance (ANOVA) was done in order to determine the significance ($p<0.05$) of variations of the data recoded.

Results

Germination response

The germination performance of *T. orientalis* seeds was responsed by different pre-sowing treatments in different germination media of the study. Seed germination starts first in T_3 at 19th days after sowing (DAS) and T_0 required maximum time (at 35th DAS) to initiate germination.

In seed bed, maximum germination for coated seed was found in T_3 (60.71%) whereas in uncoated seed was found in T_{03} (75.94%). Minimum germination % for coated seed was found in T_0 (30.29%) compared to uncoated seed T_{00} (35.12%). The minimum germination period was found in T_{03} (20 days) than T_{02} (22 days) and the highest germination period was observed in T_0 (55 days). (Table 1).

Table 1. Germination response of *T. orientalis* in Seed bed.

Treatments	Seed bed (sand)			
	Germination Start (DAS)	Ger. Period (days)	Ger. (%)	Ger. capacity
T_0	35	55	30.29±1.30	Poor
T_1	22	29	40.07±0.31	Poor
T_2	22	24	50.10±0.44	Average
T_3	22	24	60.71±0.31	Average
T_{00}	35	45	35.12±0.31	Poor
T_{01}	22	28	35.12±0.31	Poor
T_{02}	22	22	65.18±0.83	Average
T_{03}	**19**	**20**	**75.94±1.30**	**Good**

In Tray, maximum germination for coated seed was found in T_2 (50.16%) and T_3 (50.15%)

whereas in uncoated seed was found in T_{03} (50.29%). Minimum germination for coated seed was found in T_0 (25.16%) compared to uncoated seed was T_{00} (29.10%). The minimum germination period was found in T_{03} (21 days) and highest germination period observed in T_0 (45 days) (Table 2).

Table 2. Germination response of *T. orientalis* in Tray.

Treatments	Tray (sand)			
	Ger. Start (DAS)	Ger. Period (days)	Ger. (%)	Ger. capacity
T_0	28	45	25.16±0.70	Very poor
T_1	24	28	30.14±0.54	Poor
T_2	22	25	50.16±0.70	Average
T_3	24	22	50.15±0.63	Average
T_{00}	30	40	29.10±0.44	Very poor
T_{01}	19	25	40.24±1.09	Poor
T_{02}	22	23	48.25±1.30	Poor
T_{03}	**20**	**21**	**50.29±1.14**	**Average**

In polybag, maximum germination for coated seed was found in T_3 (33.17%) and in uncoated seed was found in T_{03} (33.27 %). Minimum germination for coated seed was found in T_0 (20.29%) and for uncoated seed was in T_{00} (20.24%). The lowest germination period was found in T_3 (25 days) and T_{03} (25 days) whereas the highest germination period observed in T_0 (55 days) (Table 3).

Table 3. Germination response of *T. orientalis* in - Polybag (3:1 ration of soil and cow dung)

Treatments	Polybag (Soil : cowdung)			
	Ger. Start (DAS)	Ger. Period (days)	Ger. (%)	Ger. capacity
T_0	40	55	20.29±0.70	Very poor
T_1	23	30	22.29±0.79	Very poor
T_2	25	27	25.08±0.70	Very poor
T_3	25	25	33.17±1.30	Poor
T_{00}	40	50	20.24±0.70	Very poor
T_{01}	19	30	27.22±0.21	Very poor
T_{02}	22	27	30.10±1.00	Very poor
T_{03}	**19**	**25**	**33.27±1.30**	**Poor**

Table 4. Maximum germination response of *T. orientalis* among the three different seed germination bed.

Seed Germination bed	Treatments							
	T_0	T_1	T_2	T_3	T_{00}	T_{01}	T_{02}	T_{03}
	Germination %							
Seed bed	30.29±1.30	40.07±0.31	50.10±0.44	60.71±0.31	35.12±0.31	35.12±0.31	65.18±0.83	75.94±1.30
Tray	25.16±0.70	30.14±0.54	50.16±0.70	50.15±0.63	29.10±0.44	40.24±1.09	48.25±1.30	50.29±1.14
Polybag	20.29±0.70	22.29±0.79	25.08±0.70	33.17±1.30	20.24±0.70	27.22±0.21	30.10±1.00	33.27±1.30

From the above result it was found that maximum germination percentage (75.94%) was recorded in T_{03} (without coated seeds immersed in normal water for 120 hours) followed by 60% in T_3 (with seed coat immersed in normal water for 120 hours) (Table 4). Germination percentage was lowest (28%) in T_0 (coated seeds with no treatment, or

control) which has significantly ($p<0.05$) different from other treatments. (Table 4).

Growth performance

Different treatments affected the growth of *T. orientalis* seedlings in the nursery. After 3 months of seed germination in seed bed, the highest mean height (88.5 cm) and collar diameter (3.77 mm) was recorded in T_{03} and the lowest mean height (48.0 cm) and collar diameter (2.65 mm) was observed in T_{00}. The decreased order of maximum height for the treatment was $T_{03}>T_3>T_{02}>T_2>T_{01}>T_1>T_0>T_{00}$ (Fig. 3) and collar diameter. was $T_{03}>T_3>T_{02}>T_2>T_1>T_{01}>T_0>T_{00}$ (Table 5).

In Tray, the highest mean height (87.8 cm) was recorded in T_{03} and T_{02} and highest collar diameter (3.67 mm) was in T_3 whereas lowest mean height (55.5) and collar diameter (2.82 mm) was observed in T_0. In The decreased order of maximum height for the treatment was $T_{03}\geq T_{02}>T_3>T_2>T_1>T_{01}>T_{00}>T_0$ (Fig. 3) and collar diameter in $T_3>T_{03}>T_2>T_{02}>T_{01}\geq T_1>T_0\geq T_{00}$ (Table 5)

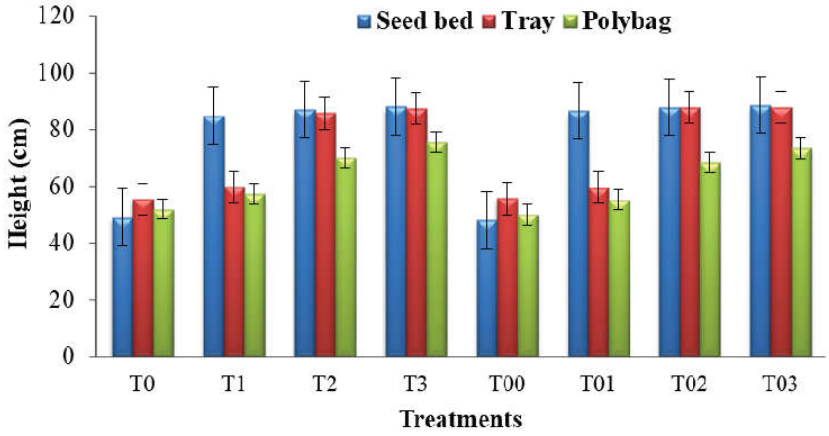

Figure 3. Growth of *Trema orientalis* seedlings in response to different treatments.

Table 5. Comparative morphological study of 3 months old *Trema orientalis* seedlings in different treatments in different growing media.

Treatments	Growing Media					
	Sand : Soil (9:1) in seed bed		Sand in Tray		Soil : Cow dung (3:1) in Polybag	
	Collar dia. (mm)	Leaf no.	Collar dia. (mm)	Leaf no.	Collar dia. (mm)	Leaf no.
T_0	2.69±0.21	8.89±0.26	2.82±0.62	9.67±0.13	2.75±0.35	8.45±0.13
T_1	3.59±0.22	8.28±0.21	2.92±0.54	8.67±0.13	2.87±0.66	8.45±0.13
T_2	3.67±0.29	7.43±0.11	3.59±0.26	7.45±0.15	3.20±1.09	7.68±0.26
T_3	3.74±0.48	8.06±0.26	3.67±0.6	8,86±0.26	3.35±1.37	8.43±0.21

Treatments	Growing Media					
	Sand : Soil (9:1) in seed bed		Sand in Tray		Soil : Cow dung (3:1) in Polybag	
	Collar dia. (mm)	Leaf no.	Collar dia. (mm)	Leaf no.	Collar dia. (mm)	Leaf no.
T_{00}	2.65±0.23	9.69±0.15	2.82±0.21	8.34±0.21	2.70±0.45	9.78±0.31
T_{01}	3.58±0.36	9.37±0.19	2.92±0.43	9.56±0.19	2.83±0.24	9.34±0.19
T_{02}	3.69±0.2	9.38±0.30	3.56±0.15	9.56±0.19	3.19±0.17	9.75±0.21
T_{03}	3.77±0.11	10.45±0.29	3.60±0.23	10.48±0.29	3.30±0.21	9.47±0.15
Sig. dif	0.02	0.037	0.02	0.041	0.02	0.054

Note: According to one way Analysis of Variance (ANOVA), in column values are significantly different at $p \leq 0.05$.

In Polybag, the highest mean height (75.5 cm) and collar diameter (3.35 mm) was recorded in T_3 and lowest mean height (50.0) and collar diameter. (2.70 mm) was observed in T_{00}. The decreased order of maximum height and collar diameter for the treatment was $T_3 > T_{03} > T_2 > T_{02} > T_1 > T_{01} > T_0 > T_{00}$ (Fig. 3, Table 5). From the above result it was found that the maximum growth was recorded in T_{03} (height : 88.5; collar diameter 3.77) (Fig. 3, Table 5) and there was a significant ($p<0.05$) difference observed among the rest of the treatments. On the other hand, maximum collar diameter (3.77) was found in T_{03} but there was no significant difference among other treatments. The maximum and minimum leaf numbers were recorded in T_{03} (10.45) and T_2 (7.43) respectively (Fig. 3, Table 5).

Discussion

Hard coated seeds are impermeable to sufficient water and nutrients for vigorous seedlings production. These seeds require suitable pre-sowing treatments for producing vigorous seedlings for plantation in degraded forest land. Germination and seedling's growth performance of *T. orientalis* varied among different pre-sowing treatments. The seed of *T. orientalis* showed maximum germination (75.94%), when using dry seed without coat in five days normal water soaking treatment in seed bed. Seeds without treatments (control) showed the lowest germination (20.24%). Experiments conducted in different medium showed significant interactions at $p \leq 0.05$ level between the seed treatments and germination medium, indicating that seed bed help to make the treated seed germination quicker (35th DAS to 19th DAS). For the polybag media, the soil was collected from the forest floor and it provides sufficient nutrients to accelerate the seedlings' growth. On the contrary, fine sand media collected from Sylhet was devoid of nutrients. Dey and Hossain (2019) found that *Suregada multiflora* seedlings raised in seedbed containing sand and soil showed the highest germination and survival rate, but the growth rate was lowest as sand media failed to provide sufficient nutrients for growing plants. In this study it was found that the similar results for germination and survival rate for *T. orientalis*. Hasnat *et al*. (2016) stated that soaking in cold water for 24 hours was the more effective in germination and vigorous seedlings production of *Canarium resiniferum* in contrary same treatment for *T. orientalis* did not show satisfactory germination. According to Haider *et al*. (2014) seeds of *Acacia catechu* obtained the highest germination percentage (80-81%) when soaked in normal water for 24 hours but in our study, it took 120 hours to obtain the similar germination percentage due hard seed

coat of *T. orientalis*. Currie (1984) also reported that water, air and mineral nutrient availability of the growth medium is the most important physical factor affecting seedlings growth. In the experiment it was observed that, jigni seeds sown seed bed showed early germination than the rest of the media because sand enhances germination and root development which soothe the sapling transfer to polybags without much disturbing the root system. It is to be mentioned here that after germination, when germinated seeds are at four-leaf, should be transplanted to polybag as early as possible. In this case, when the seedlings were transplanted to polybag it grew faster (ht: 88.5; dia. 3.77) than the seedlings of other media (ht: 75.5; dia. 3.35). So, seedbed was used only for early germination of tiny hard-coated seeds of *T. orientalis* followed by extending the normal water treatment time 120 hours. This technique is suitable for normal nursery owners to raise seedling commercially.

Conclusion

Nursery technique for jigni seedling production was standardized to facilitate its plantation establishment. Jigni showed 75.94% germination in case of using dry seed without coat but dry seed with coat showed 60.71% germination. To enhance germination percentage appropriate soaking duration is five days after transplanting from seed bed, partial shade is required for its survival. Seedbed coupled with uncoated seed with a five-day soak time proved to be the most effective and safe for planters. So, this combination of treatment is recommended for increasing germination and producing quality seedlings of jigni for large scale plantation program.

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Development of Particleboard from Uprooted Tea (*Camellia sinensis*) Plants

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Abstract

This study was carried out to investigate the suitability of particleboards using uprooted tea plants (*Camellia sinensis*). Wastage and uprooted tea plants were collected from Neptune Tea Garden, Chattogram. The uprooted tea plants were cut into the clipper machine into small portions. Following that, they were processed into chips using a hammer mill machine, which was then dried in a batch oven to the suitable moisture content (5%). Single-layer particleboards were fabricated in a laboratory hot press machine with four different densities i.e. 650, 700, 750 and 800 kg/m^3 using liquid urea formaldehyde as an adhesive. Finally the physical and mechanical properties of particleboards made from uprooted tea plants were studied. Characteristics of particleboards such as modulus of rupture (MOR), internal bond strength (IB), water absorption (WA) and thickness swelling (TS) were measured as a part of the experiment. Results show that particleboards made from uprooted tea plants of 800 kg/m^3 density had good static bending MOR property (112.00 kg/cm^2) and excellent IB strength property (10.04 kg/cm^2). The mean MOR value of the 800 kg/m^3 density particleboards was above the Indian (IS 3087, 2005) and ANSI (A208.1-1999) standard specifications but lower than the British (BS 5669-2:1989) standard specification. Moreover IB strength value was above the Indian, ANSI and British standard specifications.

সারসংক্ষেপ

উপড়ে ফেলা চা গাছের (*Camellia sinensis*) কুঁচি ব্যবহার করে পার্টিকেল বোর্ড তৈরির উপযুক্ততা যাচাই করার উদ্দেশ্যে এই গবেষণাটি করা হয়। নেপচুন চা বাগান, চট্টগ্রাম থেকে উপড়ে ফেলা চা গাছগুলো সংগ্রহ করা হয়। উপড়ে ফেলা চা গাছগুলোকে প্রথমে ক্লিপার মেশিনের সাহায্যে টুকরা করা হয়। পরে হ্যামার মিল মেশিনের সাহায্যে টুকরাগুলো থেকে চিপস প্রস্তুত করে একটি ব্যাচ ওভেনে উপযুক্ত আর্দ্রতায় (৫%) শুকানো হয়। একটি ল্যাবরেটরি হটপ্রেস মেশিনের সাহায্যে এক স্তরবিশিষ্ট চারটি ভিন্ন ঘনমাত্রার (৬৫০, ৭০০, ৭৫০ এবং ৮০০ কেজি/মি.^{3}) পার্টিকেল বোর্ড তৈরি করা হয় যেখানে আঠা হিসেবে তরল ইউরিয়া ফরম্যালডিহাইড ব্যবহার করা হয়েছিল। পরিশেষে উপড়ে ফেলা চা গাছ থেকে তৈরিকৃত পার্টিকেল বোর্ডগুলোর ভৌত ও যান্ত্রিক শক্তির বৈশিষ্ট্য নির্ণয় করা হয়। উক্ত গবেষণার অংশ হিসেবে পার্টিকেল বোর্ডগুলোর মডুলাস অব রাপচার (MOR), অভ্যন্তরীণ বন্ধন শক্তি (IB), জল শোষণ ক্ষমতা (WA), পুরুত্বের স্ফিতি (TS) পরিমাপ করা হয়েছিল। ফলাফল বিশ্লেষণে দেখা যায় যে, উপড়ে ফেলা চা গাছ থেকে প্রস্তুতকৃত ৮০০ কেজি/মি.^{3} ঘনত্বের পার্টিকেল বোর্ডগুলোর MOR বৈশিষ্ট্য ভাল (১১২.০০ কেজি/সেমি.^{2}) এবং চমৎকার অভ্যন্তরীণ বন্ধন শক্তিবিশিষ্ট (১০.০৪ কেজি/সেমি.^{2})। ৮০০ কেজি/মি.^{3} ঘনত্বের পার্টিকেল বোর্ডগুলোর MOR শক্তির গড় মান ভারতীয় (IS 3087, 2005) এবং এএনএসআই (A208.1-1999) স্ট্যান্ডার্ড মানের উপরে কিন্তু ব্রিটিশ স্ট্যান্ডার্ড (BS 5669-2:1989) মানের চেয়ে নিচে। অন্যদিকে অভ্যন্তরীণ বন্ধন শক্তির (IB) মান ভারতীয়, এএনএসআই এবং ব্রিটিশ স্ট্যান্ডার্ড মানের উপরে।

Key words: Ammonium chloride (NH_4Cl), Particleboards, Uprooted tea plants, Urea formaldehyde (UF),

Introduction

The forest area has declined due to the increasing demand for agricultural land, timber, firewood and other forest produces (ADB 1992). The timber resources have become scarce day by day because of unplanned and irrational resource management including most of the long rotation wood species of which only one-tenth are in great demand for furniture and plywood industries. The vast majority of timber species are utilized. With an expanding local and worldwide demand for tropical timber, there is increased interest in the suitability for commercial purposes of lesser-used tropical timber species as an alternative raw material for forest based industries and to ensure sustainable management of the forest. Through maximum utilization (plywood/ particleboard making), increasing service life and improving the quality of wood, we can conserve more forest resources.

Bangladesh is an important tea-producing country. It is the 10th largest tea producer in the world. Its tea industry dates back to British rule, when the East India Company initiated the tea trade in the hills of the Sylhet region. In addition to that, tea cultivation was introduced to greater Chattogram in 1840. Now Bangladesh has 166 commercial tea estates, including many of the world's largest plantations. The tea industry of Bangladesh accounts for 3% of global tea production and employs more than 4 million people. The global production of tea is about 4,299 million kg produced in about 40 countries in the world (ITC 2013). The average yield of tea (*Camellia sinensis*) in Bangladesh is very low in comparison to other major tea producing countries e.g. India, Sri Lanka and Kenya. One of the main reasons for such yield difference is the length of the harvesting season. Being in the sub-tropics, tea is harvested about 8-9 months per year in Bangladesh, whereas in South India, Sri Lanka and Kenya it is harvested all the year round due to prevailing favorable climatic conditions e.g. day length, temperature and rainfall (De Costa *et al.* 2007). There is a greater tendency for tea shoots to become dormant when the photoperiod is less than 11.16 hours and during the winter it becomes 10.6 hours in Bangladesh (Alam 1999).

In terms of both economics and ecology, it is quite profitable to make particleboard with product residues (Ghalehno *et al.* 2013). Several research works have been carried out on particleboard production from a mixture of waste tea leaves and wood chips (Yalinkilic *et al.* 1998; Batiancela *et al.* 2014; Risnasari *et al.* 2019). The gluing characteristics of many introduced timber or non timber species of Bangladesh are not known. Adequate knowledge of the gluing characteristics is essential for optimum utilization of the resources by the respective industries. It is established a fact that gluability is a function of wood, its structure, presence of extraneous materials etc. No research papers were found related to tea plant particleboards. The study was undertaken in finding out the gluability of the tea plant in the manufacture of particleboards.

Materials and Methods

Raw material collection and processing

Wastage and uprooted tea plants were collected from Neptune Tea Garden, Vujpur, Fotikchori, Chattogram. At first plants were cut into small pieces with a clipper machine and then the small pieces were converted into chips in a hammer mill machine. After that, the chips were dried up to 5% moisture content in a batch oven.

Particleboard manufacturing

Five-single layer particleboards sizes of 500 mm × 500 mm × 12 mm having a target density of 650, 700, 750 and 800 kg/m^3 were made in a

laboratory hot press machine. The temperature of the platens of the hot press was maintained at 140°C. In the particleboard preparation liquid UF glue (50% solid content) was used as a binder in which NH_4Cl was mixed as a hardener. The amount of UF glue was 20% based on oven dry chips whereas 2% NH_4Cl was used based on UF glue. After mixing the glue with the chips the mat was formed by hand. Then the mats were pressed in a vertical moving up hydraulic laboratory press machine (160 Ton, Williams-White & Co., USA) primarily at 35.6 kg/cm^2 for 6 minutes which was then reduced step by step (Table 1). Finally, the boards were conditioned at 65±5% relative humidity and 20±2°C temperature before they were set to tests.

Table 1. Manufacturing process under experimental conditions.

Board thickness	Solid content of UF glue	Proportion of UF glue used	Hot press temperature	Specific Pressure	Pressure time
(mm)	(%)	(%)	(°C)	(kg/cm^2)	(min)
12	50	20	140	35.6	6
				10.5	4
				3.5	2

Test sample preparation

After conditioning, the particleboards were cut into various test specimens. The MOR and IB strength tests were carried out according to the specification of IS: 2380 (Anon 1977) in a computerized wood-based panel Universal Testing Machine (Tenson, MWW-10, China). For the determination of TS and WA, Three specimen sizes of 100 mm x 100 mm were taken from each board. The thickness of the specimens was measured with the platform type thickness gauze with an accuracy of 0.01 mm. The test specimens were immersed in 25 mm depth of cold water. Then the test specimens were withdrawn from the water, wiped with a damp cloth, reweighed and re-measured the thickness at two different times (2 hours and 24 hours) as before. After that, the percentage of WA and TS were calculated. The test results were then compared with the standard specifications given in Table 2.

Table 2. Standards specifications for physical and mechanical property of particleboards.

Standards	Board thickness (mm)	Density (kg/m^3)	MOR (kg/cm^2)	IB (kg/cm^2)	TS (%)		WA (%)	
					2hr	24hr	2hr	24hr
IS 3087 (Anon 2005)	6-20	500-900	110.00	8.00	10.00	NA	25.00	50.00
ANSI A208.1 (Anon 1999)			110.00	4.00	NA	8.00	NA	NA
BS 5669-2 (Anon 1989)			138.00	3.40	8.00 (for 1 hour)	NA	NA	NA

NA= not specified in test requirements

Statistical design and analysis

The experiments were carried out in a completely randomized design (CRD) with five replications. Analysis of variance (ANOVA) and least significant difference (LSD) test were carried out to evaluate the significance of differences among the different densities of boards.

Results

Analysis of variance (ANOVA) was used to assess any correlation between boards of different densities. The results showed that the different densities had significant effects as $p \leq 0.05$ on the MOR, IB, TS and WA properties. The mean value of MOR and IB are given in Table 3.

From Table 3, it was found that the MOR values of the particleboards were different for four different densities. Particleboards containing 800 kg/m^3 density had the highest MOR value compared to the other densities (Fig. 1). The value was 112.00 kg/cm^2 which satisfied both the Indian (110.00 kg/cm^2) and ANSI Standards (110.00 kg/cm^2) but not the British standard (138.00 kg/cm^2) specification (Table 2).

Measurements of IB strength properties are presented in Table 3. It was found that the IB values were different for different densities of particleboards. Particleboards containing a density of 800 kg/m^3 had the highest IB strength values among all other densities of particleboards (Fig. 2). The value was 10.04 kg/cm^2 which satisfied the Indian (IS 3087: 2005), ANSI (A208.1: 1999) and British Standard (BS: 5669-2: 1989) specifications.

Table 3. Mechanical properties of particleboards made from uprooted tea plants.

Board thickness	Density kg/m^3	Static bending strength (MOR) kg/cm^2	Internal bond strength (IB) kg/cm^2
12 mm	650	63.54 ± 2.75	8.06 ± 0.11
	700	68.60 ± 1.16	8.31 ± 0.12
	750	87.24 ± 0.60	8.71 ± 0.08
	800	112.00 ± 0.73	10.04 ± 0.14
F-value		1294.94	3006.33
Significant value		4.79E-21	5.02E-25

Note: Mean followed by standard error (± SE)

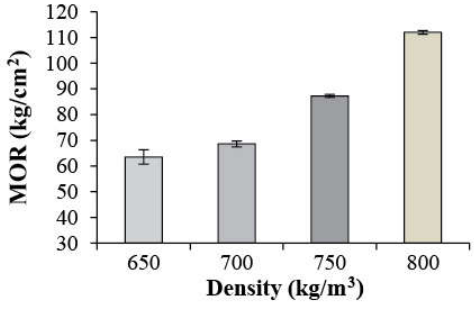

Figure 1. Density vs. MOR

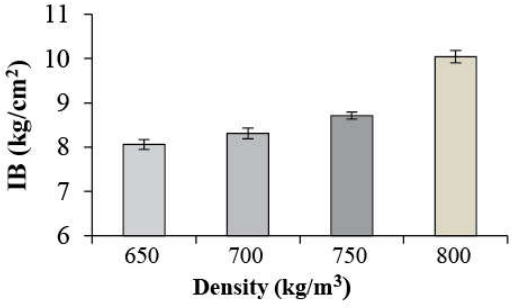

Figure 2. Density vs. IB strength

Table 4. Physical properties of particleboards made from uprooted tea plants.

Board Thickness	Density kg/m³	TS (%)		WA (%)	
		2 hr	24 hr	2 hr	24 hr
12 mm	650	19.34 ± 0.11	23.77 ± 0.22	44.45 ± 1.04	53.28 ± 1.08
	700	19.15 ± 0.12	23.62 ± 0.16	43.79 ± 0.62	51.89 ± 0.67
	750	18.22 ± 0.10	23.19 ± 0.22	42.19 ± 0.34	50.99 ± 0.27
	800	18.12 ± 0.14	21.25 ± 0.24	40.23 ± 0.30	48.04 ± 0.35
F-value		2924.20	2885.87	2712.55	2642.70
Significant value		6.79E-25	7.85E-25	1.54E-24	2.05E-24

Note: Mean followed by standard error (± SE). hr = Hour

The WA and TS properties had been evaluated for different densities of particleboards made from uprooted tea plant chips (Table 4). The test samples were soaked under water for 2 hours and 24 hours, weight and thickness differences were measured for the determination of WA and TS values (Fig. 3, 4, 5 and 6). The observed TS values of the different types of particleboards were 18.12-19.34% after 2 hours and 21.25- 23.77% after 24 hours of water soaking (Table 4).

The WA values of the different types of particleboards made from uprooted tea plants ranged from 40.23-44.45% after 2 hrs and 48.04-53.28% after 24 hrs (Table 4).

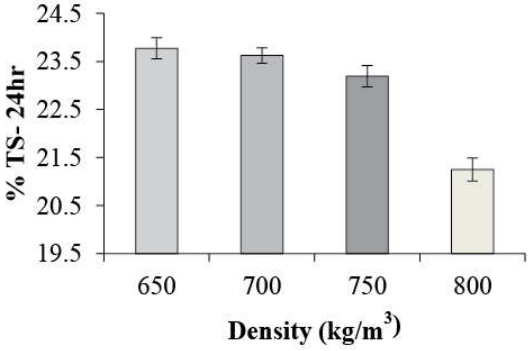

Figure 4. Density vs. thickness swelling for 24 hours

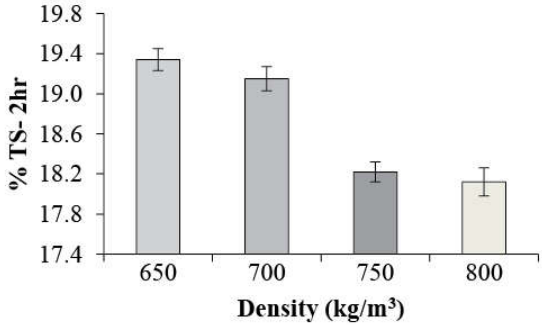

Figure 3. Density vs. thickness swelling for 2 hours

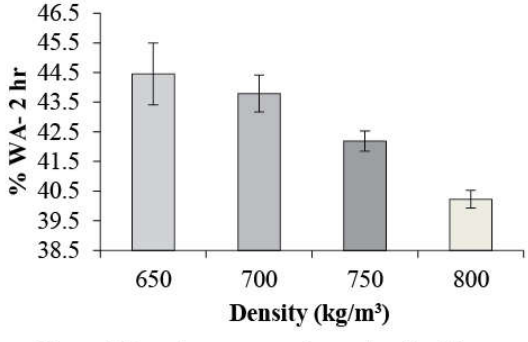

Figure 5. Density vs. water absorption for 2 hours

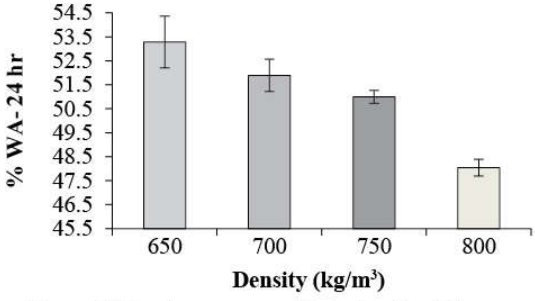

Figure 6. Density vs. water absorption for 24 hours

Discussion

After data analysis, we saw that the MOR value increased with increasing the board density. However, the extent of this growth was not proportional. Particleboards containing a density of 800 kg/m³ had the highest MOR values than the other densities of particleboards. The higher density particleboard makes it stronger and more resistant to breaking when under heavy loads. The density of the board is one of the factors that affect the low or high MOR value. As the MOR value decreases the bond between the boards weakens (Haygreen and Bowyer 1996). According to Kollmann *et al.* (1975), MOR is the most essential mechanical characteristic of particleboards in terms of their use as interior components.

The numerical values of IB strength properties were found different for different densities of particleboards. The result demonstrated that an increase in board density leads to an increase in IB strength. 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 particleboards, which ensures a fine adhesive property and dimensional stability of the particleboard structure. Risnasari (2019) found that the IB value made from 100% waste tea leaf particleboard was 1.12 kg/cm².

The TS or WA value of particleboards is one of the basic properties that determine whether the panel will be used in dry or humid situations. When particleboard is exposed to water contact, wood chips 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 particleboard are also reduced by both WA and TS properties. From Table 4, it had been observed that the TS and WA of the particleboards decreased with increasing the board density. These growth values were not linear. The TS of the panels is related to the amount of WA, so higher WA contributes to higher swelling in thickness. From the results, it was observed that the mean WA value of 800 kg/m³ particleboard after 24 hours of soaking was 5.78% lower than that of particleboards having 750 kg/m³ densities.

Particleboard is 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 two hours 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 particleboards. The physical and mechanical properties of the experimental particleboards made from 100% uprooted tea plants are better than the particleboards prepared from a mixture of weste tea leaves and wood chips as indicated by Yalinkilic *et al.* (1998); Batiancela *et al. (*2014); Risnasari *et al.* (2019).

Conclusion

The mechanical strength properties and the dimensional stability of 800 kg/m³ density particleboard made from uprooted tea plants are satisfactory and the board can be used as furniture components. The mechanical strength values indicate stronger bonding. If uprooted tea plants can be used as an alternative source of raw materials for manufacturing particleboards it is possible to protect forest resources through maximum utilization.

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Bangladesh Journal of Forest Science

A Half-yearly Peer Reviewed Journal of Bangladesh Forest Research Institute

EDITORIAL

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