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CONTENTS

Germination Behavior and Seedlings Growth Performance of *Tamarindus indica* L. in Nursery and Field Condition of Bangladesh

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Abstract

Germination percentage of *Tamarindus indica* L. seeds were observed with 4 pre-sowing treatments viz, i) soaked in cow urine for 24 hours, ii) soaked in cow dung slurry for 24 hours, ii) soaked in tap water for 24 hours, iv) soaked in hot water (100 ^{0} C) for 30 seconds and followed by one hour in tap water and v) control, in the nursery of Bangladesh Forest Research Institute, Chattogram. Growth performances of seedlings were also determined in nursery and field conditions. The germination test was conducted in nursery bed filled with soil and decomposed cow dung at a ratio of 3:1. The growth performance of seedlings were determined by transferring the young seedling after 30-45 days of germination having 5-6 leaves from germination bed to polybags (15 cm × 23 cm) filled with soil mixed with cow dung. Growth performance in the field was observed by out planting one year old seedling at 1.5 m × 1.5 m, 2.0 m × 2.0 m and 2.5 m × 2.5 m spacing. Germination percentage was significantly ($p<0.05$) influenced by pre-sowing treatments and highest germination percentage (86%) was obtained in cow urine treatment for 24 hours and lowest (44%) was found in hot water treatment. Growth performance of seedlings was also influenced by pre-sowing treatments in the nursery and highest vigor index was observed in cow urine treatment (3988) and lowest in hot water treatment (1629). Survival percentage of seedlings was highest 98% at 2.0 m × 2.0 m spacing in the field and average height was more than 68 cm after 12 months of out planting. Therefore, pre-sowing treatment of seed in cow-urine for 24 hours suggested for nursery raising and one old year seedlings may be planted at 2.0 m × 2.0 m spacing in the field for successful plantation of the species.

সারসংক্ষেপ

বাংলাদেশ বন গবেষণা ইনস্টিটিউট, চট্টগ্রামে নার্সারিতে তেঁতুল বীজের অংকুরোদগমের হারের উপর প্রি-ট্রিটমেন্টের প্রভাব নির্ণয়ের জন্য বীজ বপনের পূর্বে চার ধরনের প্রি-ট্রিটমেন্ট প্রয়োগ করা হয়। প্রি-ট্রিটমেন্টসমূহ হল: ১) বীজ ২৪ ঘন্টা গো-মূত্রে ভিজানো, ২) গরুর গোবর মিশ্রিত কাইতে (Cow dung slurry) ২৪ ঘন্টা ভিজানো, ৩) ট্যাপের পানিতে ২৪ ঘন্টা ভিজানো, ৪) গরম পানিতে ৩০ সেকেন্ড চুবানো এবং পরবর্তীতে এক ঘন্টা ট্যাপের পানিতে ভিজানো এবং ৫) কন্ট্রোল। নার্সারি ও মাঠ উভয় পর্যায়ে চারার বৃদ্ধির পরিমাপ করা হয়। বীজের অংকুরোদম পরীক্ষাটি নার্সারি বেডে সম্পন্ন করা হয়, যেখানে মাটি ও গোবর ৩:১ অনুপাতে মিশ্রিত ছিল। বীজ অংকুরোদগমের ৩০-৪৫ দিন পরে ৫-৬ টি পাতাযুক্ত চারা পলিব্যাগে (১৫×২৩ সে.মি.) স্থানান্তর এবং এক বছর পরে মাঠপর্যায়ে চারা রোপণ করা হয়। বীজের অংকুরোদগমের

উপর প্রি-ট্রিটমেন্টের তাৎপর্যপূর্ণ প্রভাব ($p<0.05$) পরিলক্ষিত হয়। গো-মূত্র দ্বারা (২৪ ঘণ্টা) ট্রিটমেন্টকৃত বীজের অংকুরোদগমের হার সবচেয়ে বেশী (৮৬%) এবং গরম পানি দ্বারা ট্রিটমেন্টকৃত বীজের অংকুরোদগমের হার সবচেয়ে কম (৪৪%) পাওয়া যায়। নার্সারিতে চারার বৃদ্ধির উপর প্রি-ট্রিটমেন্টের প্রভাব পরিলক্ষিত হয়, সবচাইতে বেশি ভিগর ইনডেকস পাওয়া যায় (৩৯৮৮) গো-মূত্র দ্বারা ট্রিটমেন্টকৃত বীজে এবং সবচাইতে কম ভিগর ইনডেকস পাওয়া যায় (১৬২৯) গরম পানি দ্বারা ট্রিটমেন্টকৃত বীজের ক্ষেত্রে। মাঠ পর্যায়ে ২ মি.×২ মি. দূরত্বে চারা লাগানোর এক বছর পর চারার বেঁচে থাকার হার ৯৮% পাওয়া যায় এবং চারার গড় উচ্চতা ছিল ৬৮ সে.মি.। সুতরাং নার্সারি উত্তোলনের জন্য বীজ গো-মূত্র দ্বারা ২৪ ঘন্টা প্রি-ট্রিটমেন্ট করে বপন এবং সফল বনায়নের জন্য ২ মি.×২ মি. দূরত্বে এক বছর বয়সী চারা রোপণ উত্তম বলে প্রতীয়মান হয়।

Keywords: *Tamarindus indica*, Pre-sowing treatment, Dormancy breaking, Germination rate, growth performance.

Introduction

Tamarindus indica L. is a large evergreen tree species belongs to the family Caesalpinaceae. The plant attains up to 20 m height with 2 m diameter (Verheij and Coronel 1991). Leaves even–pinnate, leaflets 10-20 pairs, linear-oblong, slightly notched at the apex, glabrescent. Flowers small, pale yellow in terminal lax racemes. Fruit pod indehiscent, curved and flattened at two sides with very acidic pulp when ripen. Seeds rectangular, dark brown, smooth with hard testa.

T. indica is an indigenous plant to the drier Savannas of tropical Africa. Besides, the tree is growing wild in Sudan, Arabia, Oman (Rahim *et al*. 2011). However, it is cultivated in Cameroon, Nigeria and Tanzania etc. There is a long history for introduction of the *T. indica* into India at an early date and subsequently spread into other tropical Asian regions (Troup and Joshi 1983). Day by day this species was widely distributed throughout the tropical regions from Africa and South East Asia, Taiwan and as far as China (Rahim *et al*. 2011). *T. indica* is well adapted to semi-arid, arid and tropical climatic regions where maximum temperature is 33 to 37^0C and minimum is 9.5 to 20^0C (Rahim *et al*. 2011). The species is sensitive to frost. A mean rainfall of 500-1500 mm is required for its better growth. *T. indica* is grown on a wide range of soils from gravelly to deep alluvial and thrives in loamy, deep, alluvial soils which favor the development of a long taproot (Troup and Joshi 1983). It tolerates slightly alkaline or saline soils (Hocking 1993).

The species is valued mainly for its fruit pulp. Its acidic pulp is a favorite ingredient in culinary preparations such as curries, chutney, sauces, tamarind ball, sweetmeat, mixed with sugar and dessert (Purseglove 1987). Seeds are used in the jam, jelly and confectionary industries for making condiments. Seed are also eaten after removal of the testa by roasting and boiling. The leaves are eaten by cattle and goats.

T. indica is used for many medicinal purposes. Phytochemical studies have revealed the presence of tannins, saponins, sesquiterpenes, alkaloids which are active against both gram positive and gram negative bacteria at 4-30^0C temperature (Doughari 2006). Phytochemical has anti-diabetic, anti-microbial, anti-venomic, anti-malarial, anti-asthmatic, and anti-thyperlipidemic properties (Bhadoriya *et al*. 2011). It is used as an essential amino acid and aromatic acid (Adeola 2013). The ripe fruit is used as a refrigerant, digestive, carminative and laxative. Seeds cotyledons contain albuminoids, fat and carbohydrates. Leaves contain glycosides and bark contains tannins and resin

(Ghani 2003). Hordenine is isolated from leaves, barks and flowers (Rastogi & Mehrotra 1993). Wood contains charcoal which is valued for producing gunpowder (NAS 1979). Wood is hard to very hard and heavy, medium fine textured (Das and Mohiuddin 2001). The whole parts of *T. indica* is used in many ways. Because of its multipurpose uses it became an important economic crop and medicinal plants in the Indian subcontinent including Bangladesh. However, there is very little information about its propagation, cultivation in the country. Therefore, an attempt has been made to investigate the effects of pre-sowing treatment on seed germination and seedling growth performance of *T. indica* in the nursery and field levels.

Materials and Methods

The study area

The study was carried out in the nursery of Bangladesh Forest Research Institute (BFRI), Sholoshahar, Chattogram and Hinguli Research Station, Mirsari, Chattogram, Bangladesh over a period of two years from June 2017 to July 2019. Geographic position of the study area is situated between 22^0 22′ 27″and $22^0 29'^0$ North latitude and $91^0 46'30''$ and $91^0 46'30''$ East longitudes. 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 28.31 to 31.9 ^{0}C and from 15.2 to 25.2 ^{0}C respectively (Hossain and Arefin 2012). Mean annual rainfall is around 3000 mm mainly occurred from June to September.

Seed collection and growing media

The seeds were collected in the middle of March 2017 from 20-25 years old matured healthy trees from Kaptai National Park of Rangamati Hill district, Bangladesh. Then the seeds were dried in the sunlight for 2-3 days and stored in air tight polybag. Shrinked, discolored and damaged seeds were separated from collected seeds and only healthy seeds were used for the experiment. The number of seed per kilogram was 220 to 240. The germination trail was carried out by sowing seeds in bed filled with soil and decomposed cow dung at the proportion of 3:1 by volume. Seeds were sown in the seed bed at the depth of 0.5-1.0 cm.

Experimental design and different treatments

Experiments were conducted in Completely Randomized Design (CRD) with five replications. Four treatment were applied to determine their effect on seed germination and seedling growth attributes. The treatments were i) soaking in cow urine for 24 hours, ii) soaking in cow-dung slurry for 24 hours, iii) soaking in hot water (100^{0}C) for 30 second followed by soaking in tap water for one hour, iv) soaking in tape water for 24 hours and v) control. In each replication 50 seeds were sown and in total 1250 seeds were used for germination trial in the seedbed of the nursery. Watering was carried out manually when necessary.

Assessment of seed germination and seedlings growth performance in seed bed

The effect of different treatments on seed germination and seedlings growth was explored periodically through counting the germinated seeds and measuring initial growth performance of seedlings. Germination data was collected at two days intervals starting from sowing and continued till ending of germination. For assessing the growth performance, above ground height all seedlings were measured and number of leaves were counted when the seedlings were one month old. Besides these ten seedlings from each replicate (50 from each treatment) were randomly uprooted and measured their total length (root length and shoot length separately). Vigor index (VI) was calculated according to Baki & Anderson (1973).

Assessment of seedling growth performance in the nursery (polybag) and in the field

When the seedlings were about 30-45 days old (with 5-6 leaves), they were transferred to the polybags (23 cm × 15 cm in size) filled with soil mixed with cow dung (3:1). The polybags were kept under full shade for one week and then placed under direct sunlight and allowed them to grow there. Data on shoot length, root length and leaf number of seedlings were also recorded at three months, six months, and twelve months after transferring them into polybags. When the seedlings were one year old, 225 seedlings were out planted in the field at the beginning of the monsoon (June- July). Equal number of seedlings (225), were allowed to grow in the nursery for one and half year more. Seedlings in the field were planted at 1.5 m × 1.5 m, 2.0 m × 2.0 m and 2.5 m × 2.5 m spacing at Hinguli Research Station, Chattogram, Bangladesh. The soil was sandy-loam with a pH 5.70-6.00. Average rainfall of the area was about 3200 mm and average maximum and minimum temperature was 34.7^0C and 20.7^0C respectively. Weeding was done every month in the nursery and water was added after planting. Data on the heights of each plant were recorded at six months and twelve months after planting. Survival percentage of the seedlings in the field was determined one year after planting the seedlings.

Data Analysis

All data were analyzed with computer software IBM SPSS var. 21 to conduct Analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) in order to determine the significant ($p \leq 0.05$) variations among the treatments.

Results

Seed germination and initial growth performance of seedlings in seed bed

Pre-sowing treatments influenced the germination period and germination percentage of *T. indica* seeds. Germination for all the treatments started 7 days after sowing (DAS) and continues up to 23 days with little variation among the treatments. The seeds soaked in cow urine for 24 h, showed highest germination (86%) and occurred within 7-19 DAS. Seeds soaked for 24 h in cow dung slurry showed 84% germination within7-21 DAS. Seeds soaking in tap water for 24 h showed 80% germination within7-23 DAS. Seeds soaked in hot water for 30 seconds showed 44% germination and 66% germination was recorded for control within 7-23 DAS (Fig. 1).

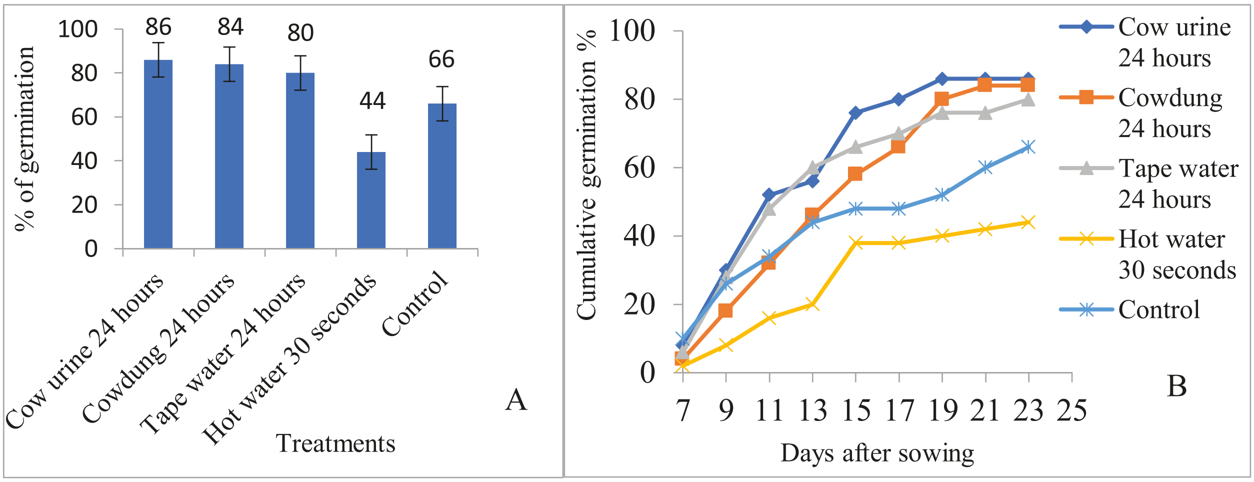

Figure 1. Germination percentage (A) and cumulative germination (B) of *T. indica* with different pre-sowing treatment

The initial growth performance of *T. indica* seedlings were influenced by pre-sowing treatment (Table 1). The highest root length (16.70 cm) and shoot length (29.67 cm) was recorded in seedlings from cow urine treated seeds. The second highest root length was recorded 15.67 cm whereas shoot length was 28.00 cm in the seeds soaked in cow dung slurry, followed by seeds soaked in tap water for 24 h and control. The lowest length (9.70 cm) of root was recorded in seeds treated with hot water. Average number of leaves varied from 8-10 among the treatments. Maximum number of leaf was recorded with seeds soaked in cow urine and lowest with the treatment soaked in hot water.

The vigor index of the seedlings was increased from 1629 in the treatment of seeds soaked in hot water to 3988 in the treatment of seeds soaked in cow urine for 24 hours (Table 1). The vigor index usually depends on the germination percentage and the seedling length. The study reveals that the seedling length was marginally different among the treatments. However, germination percentage in the treatment of seeds soaked in cow urine for 24 hours was almost doubled than that in the treatment of seeds soaked in hot water which led the vigor index substantially higher, seeds soaked in cow urine than of the other treatments.

Table 1. Initial growth performance of the seedlings germinated from various treatments one month after germination.

Treatments	**Growth parameters**			
	Ave. root length (cm)	**Ave. shoot length (cm)**	**Ave. Leaf number (Nos.)**	**Vigor Index**
Soaked in cow urine for 24 hours.	16.70±3.75	29.67±4.33	10.00±1.42	3988
Soaked in cow dung slurry for 24 hours	15.67±3.67	28.00±4.22	8.70±1.37	3668
Soaked in tap water for 24 hours	10.33±2.95	28.00±3.77	9.33±1.10	3066
Soaked in hot water (100^0 C) for 30 seconds and followed by 1 hour in tap water	9.70±2.87	27.33±3.74	8.33±1.20	1629
Control	9.60±2.95	27.00±3.89	8.67±1.45	2416

Seedlings growth performance in nursery polybag

The study, revealed that similar to that of germination percentage the initial growth performance of *T. indica* seedlings from cow urine treatment was higher than that of other treatments (Table 1). Therefore, we sowed only the seeds treated in cow urine for 24 hours in seed beds for assessing the seedlings growth performances in the nursery and field. Seven hundred fifty (750) seeds were sown in five blocks considering as replication of the nursery bed for the purpose. One and half months old seedlings were transferred in the 15 cm × 23 cm sized polybags filled with soils mixed with cow dung (3:1) and allowed them to grow there. After 12 months of transferring the seedlings in the polybag, 225 seedlings were outplanted in the field. Rests of the seedlings were grown in the nursery for another year more. The seedlings mortality in the nursery was found very negligible (1-2%). Growth variation of seedlings was observed in the nursery in relation to age and the results are presented in the Table 2.

Table 2. Seedlings growth performance of *T. indica* at different ages in the nursery.

Age of seedlings (months)	Ave. length of root (cm)	Ave. length of shoot (cm)	Ave. number of leaves /seedlings
3	18.55±0.65	31.10±0.44	13 .44 ±0.25
6	22.45±0.49	35.25±0.60	19.60 ±0.45
12	25.40±0.72	45.50±0.68	26.80 ±0.76
24	30.25±0.55	62.40±0.65	39. 10 ± 0.89

The seedlings attained 31.10 cm height with average root length 18.55 cm and 13 leaves at three months age. The seedlings became hard and attained a height of 35.25 cm with 22.45 cm root and 19 leaves at six months. The average height 45.50 cm with 25.40 cm root and 26 leaves was recorded at 12 months. The seedlings reached 62.40 cm height with 30.25 cm root and 39 leaves at 24 months.

Survival and growth performance of seedlings in the field

One-year old seedlings of *T. indica* raised in polybags were out planted in the field with different spacing at Hinguli Research Station. Survival Percentage was recorded at 12 months and seedlings growth performance were recorded at 6 and 12 months after planting in the field as shown in Table 3. Survival percentage varied from 96-98% with an average of 97% among the treatments at 12 months after planting. The seedlings height varied from 49.76 cm to 57.20 cm at six months and 59.50 cm to 68.10 cm at one year in the field.

Table 3. Growth performance of *T. indica* seedlings at different spacing in Hinguli Research Station.

Age of seedling Spacing	Survival % at 12 months	Average Height (cm)	
		6 months (cm)	12 months (cm)
1.50 m x 1.50 m	96	52.4 ± 0.59^{b}	65.95 ± 1.11^{b}
2.00 m x 2.00 m	98	57.20 ± 0.78^{a}	68.10 ± 1.21^{a}
2.50 m x 2.50 m	97	49.76 ± 0.54^{c}	59.50 ± 1.32^{c}

Discussion

Pre-sowing treatments overwhelmingly affected the germination period and germination percentage of *T. indica* seeds. The germination percentage in the seeds treated by cow urine for 24 hours is significantly ($p<0.05$) higher (86%) than control (66%) and seeds treated in hot water (100^0C) for the 30 seconds followed by one hour soaking in tap water is the lowest (44%). However, there was no significant variation between seeds treated cow dung slurry for 24 hours (84%) and treated in tap water for 24 hours (80%). Hartman *et al*. (2007) showed that soaking the seeds in tap water at room temperature helps in softening the seed coats, removal of inhibitors and reduces the time required for germination and increases germination percentage. (Ajiboye (2010) also showed that imbibition of water by seed helps to enlarge the embryo which leads to increase the seed germination. The above result was supported by some experiments i.e. Muhammad and Amusa (2003), Abubakar and Muhammad (2013). Haider *et al*. (2014b) showed that better germination (80%) by soaking the seeds in tap water for 24 hours against control (62%) in *Acacia catechu*. Naidu (2001) reported that better germination (79-81%) was observed when seeds were soaked in water or placed in running water against control (17%) in *Pterocarpus santalinus* seeds. Gupta (2003) mentioned that overnight soaking of *Rauwolfia serpentina* seeds in cold water gave better germination (86%) against control (40%). The findings of the present study is similar to the findings of the above mentioned study.

Growth performance of the seedlings was influenced by pre-sowing treatments of seeds. However, there was no significant variation in growth performance among the treatments at $p \leq 0.05$. Similar results were reported by several authors. It was also mentioned that seedling growth including root length, shoot length, total length and vigor index in *Terminalia chebula* was increased by pre-sowing treatment in tap water (Hossain *et al*. 2013). In another experiment, (Hossain *et al*. 2005b) showed maximum growth including shoot length, root length, total length and vigor index in *Terminalia belerica* seedlings when fruits were depulped and soaked in cold water. However, similar to the present study, there was no remarkable difference in average number of leaves per seedlings of *T. belerica* seedlings (Hossain *et al*. 2005a).

The height growth of the seedlings was higher (68.10 cm) in 2.0 m × 2.0 m spacing at twelve months from plantation and lowest (59.50 cm) in 2.5 m × 2.5 m spacing (Table 3). The variation of the growth in the seedling may be due to the microclimatic condition between the spacing. The survival percentage of the seedlings in the field was satisfactory (98%) in 2.0 m × 2.0 m spacing. Considering the above-mentioned facts and comparatively less land requirement, 2.0 m × 2.0 m spacing may be considered for planting of one-year old seedlings in the field. Abubakar and Muhammad (2013) also reported that one-year old seedlings of *T. indica* may be out planted in the field.

Conclusion

Pre-sowing treatment of *Tamarindus indica* seed plays vibrant role to enhance the seed germination under nursery conditions. Among the pre-sowing treatments, the best germination percentage and growth performance of *T. indica* was found in cow urine treatment. Pricking of seedlings at the age of 30-45 days after sowing of seeds from nursery bed to polybags ensures least mortality of seedlings. Therefore, pre-sowing treatments of *T. indica* seeds in cow urine for 24 hours is suitable for seedlings raising in the nursery and one year old seedlings may be planted at 2.0 m × 2.0 m spacing in the plantation program.

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In vitro Mass Propagation of *Dendrocalamus giganteus* Munro, the Giant Bamboo of Bangladesh

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Abstract

Dendrocalamus giganteus is one of the biggest and largest bamboo of Bangladesh which is locally known as bhudum bansh. The conventional propagation methods of bamboos are not economically viable for large scale production due to their scarcity of seeds, low multiplication rate, labor intensive and high cost. *In vitro* propagation is becoming a promising tool for conserving and mass propagation of different bamboo species. In this study establishment of a reliable and reproducible protocol for the micro propagation of *D. giganteus* from axenic culture of *in vitro* germinated seedlings has been reported. Highest 83.33% seeds were germinated on MS (Murashige and Skooge 1962) medium supplemented with 1.0 mg/L BAP (6-benzyl -amino-purine) after 7 days of culture. MS supplemented with different concentrations (0.0, 1.0, 2.0, 3.0 and 4.0 mg/L) of BAP and Kn (6-furfuralaminopurine) at evaluated either singly or in combinations for multiple shoot production. Maximum 16.33 numbers of young shoots per culture were recorded in medium supplemented with MS + 3.0 mg/L BAP + 1.0 mg/L Kn + 4% sugar + 2.75 g/L after 28 days of culture. Rooting ability of the shoots was assessed in half strength MS media supplemented with different concentrations (0.0, 1.0, 2.0, 3.0, and 4.0 mg/L) of IBA (Indole-3-butyric acid). The highest rooting percentage (66.67%) was achieved from the half strength MS medium supplemented with 1.0 mg/L IBA 2 after weeks of culture. The rooted plantlets were successfully hardened in soil under greenhouse and nursery of Silviculture Genetics Division, Bangladesh Forest Research Institute. The survival percentage of tissue culture plantlets in nursery was found to be 90-95% after 60 days of acclimatization. The protocol developed through this study enable to produce large number of *D. giganteus* bamboo seedlings for mass propagation in a short period of time.

সারসংক্ষেপ

Dendrocalamus giganteus স্থানীয়ভাবে ভুদুম বাঁশ নামে পরিচিত। এটি বাংলাদেশের সবচেয়ে বড় আকৃতির বাঁশ। বাঁশের বীজের দুষ্প্রাপ্যতা, স্বল্পমাত্রায় সংখ্যা বৃদ্ধির হার, শ্রম ও উচ্চ ব্যয় স্বাপেক্ষ হওয়ায়

প্রচলিত বংশ বিস্তার পদ্ধতিগুলি অর্থনৈতিকভাবে সাশ্রয়ী নয়। বিভিন্ন প্রজাতি বাঁশের ব্যাপক বংশ বিস্তার ও সংরক্ষণে *In vitro* পদ্ধতি এখন ফলপ্রদ। বর্তমান গবেষণায় *In vitro* পদ্ধতিতে ভুদুম বাঁশের বীজের অংকুরোদগম এবং দ্রুত shoot উৎপাদনের মাধ্যমে micro propagation কৌশল উদ্ভাবন করা হয়েছে। Semi-solid MS খাদ্য মিডিয়ামে ৭ দিনে সর্বোচ্চ ৮৩.৩৩% বীজের অংকুরোদগম ১.০ মিলি গ্রাম/লিটার BAP প্রয়োগে পাওয়া যায়। Multiple shoot উৎপাদনে MS মিডিয়ামে বিভিন্ন ঘনত্বে BAP ও Kn (০.০,১.০,২.০,৩.০ ও ৪.০ মিলিগ্রাম/লিটার) একক ও যৌথভাবে প্রয়োগ করা হয়। ফলাফল থেকে দেখা যায় কালচার প্রতি সর্বোচ্চ ১৬.৩৩ টি নতুন shoot ৩.০ মি.গ্রা./লি. BAP এবং ১.০ মি.গ্রা./লি. Kn এর যৌথ প্রয়োগে উৎপন্ন হয়। উৎপাদিত shoot গুলি বিভিন্ন ঘনমাত্রার IBA যুক্ত অর্ধশক্তির MS মিডিয়ামে স্বাভাবিক মূল উৎপাদন করে। সর্বোচ্চ ৬৬.৬৭% কালচার ১.০ মি.গ্রাম/লিটার IBA যুক্ত মিডিয়ামে মূল উৎপাদন করে। এভাবে উৎপাদিত অনুচারাগুলিকে মাটি ভর্তি পলিব্যাগে স্থানান্তর করে গ্রীণ হাউসে এবং নার্সারীতে হার্ডেনিং করা হয়। ফলে প্রাকৃতিক পরিবেশে ৯০-৯৫% চারা বেঁচে থাকে। উদ্ভাবিত প্রযুক্তির মাধ্যমে ব্যাপক বাঁশ চাষের জন্য ভুদুম বাঁশের অধিক সংখ্যক চারা কম সময়ে উৎপাদন করা সম্ভব।

Keywords: *In vitro* propagation, Seed germination, *Dendrocalamus giganteus,* Giant bamboo

Introduction

Bamboo is one of the fastest growing, annually renewable and harvestable plants with highest productivity and short harvesting cycle in the world. It has been highly honored for its multifarious uses from time immemorial. This versatile plant has a great potential in poverty alleviation, industrial and sustainable development in rural areas in Bangladesh. It has been considered as poor man's timber for its diversified uses. The high utility of this woody grass has made it vulnerable to the rural communities for making houses and paper manufacturing units where it is consumed as a basic raw material. Currently, bamboo is also being used in furniture manufacturing as an alternative of timber. As a result, the demand of bamboos are increasing day by day which is vastly exceeds the supply. Therefore, the gap between the supply and demand is to be narrowed by large-scale production of bamboos. The greatest problem in the cultivation of this renewable resource is the difficulty in raising propagules every year because of long and often unpredictable flowering cycle (25-80 years).

Conventionally, bamboos are propagated through seeds, clump division, rhizome, offset and culm cuttings (Banik 1994; 1995). However, gregarious flowering at long intervals followed by the death of clumps (Austin and Marchesini 2012) short viability of seeds (Bereket 2008) presence of diseases and some pests (Singh *et al*. 2013) are limiting factors to use seeds as dependable source of propagation. Vegetative propagation methods have limitation for mass propagation *i.e*. propagules are difficult to extract, bulky to transport and planting materials are insufficient in number for large- scale plantation (Kassahun 2003; Mudoi *et al*. 2013). Seasonal dependence, low survival rate and limited rooting of the propagules are other limitations (Singh *et al*. 2013). In fact, vegetative propagation by rhizome or offset cuttings is an age-old practice but the method is unsuitable for large scale plantations due to limited availability of rhizomes and offsets along with the bulkiness, difficulties in extraction and transportation. The plantlets have also been found to grow slowly (Hassan 1980; Rao *et al*. 1985) in plantations. Besides, the survival potential of rhizome cutting is not always satisfactory and clumps lose their regenerative potential if more rhizomes (3-4) are excavated from a single clump. Considering problems encountered in both sexual and asexual propagation of bhudum bamboo (*D. giganteus*) as well as the growing interest of country's economy and ecological benefit, a method for rapid large scale production of bamboos is highly desirable.

So the present research has therefore been designed to develop an efficient and reproducible regeneration protocol for the commercially important thick bamboo species *D. giganteus* using shoot explants collected from the axenically developed seedlings.

Materials and Methods

Plant materials

In 2016, seeds of *D. giganteus* were collected from Mehergona Forest Range office campus, under Cox's Bazar North Division of Bangladesh Forest Department and stored at Silviculture Genetics Division (SGD) of Bangladesh Forest Research Institute (BFRI) (Fig. 1). To maintain the seed viability it was stored in plastic bag in refrigerator at 4°C temperature until use. Healthy seeds were selected carefully and used for raising axenic culture through *in vitro* germination. The experiments were carried out at the tissue culture laboratory and the nursery of Silviculture Genetics Division BFRI, Chattogram, Bangladesh.

Figure1. Seeds of *D. giganteus*

Sterilization and in vitro seed germination

Collected seeds were surface sterilized to get rid of all microorganisms before inoculation. Accordingly seeds were rinsed under running tap water for 40-60 minutes to remove debris and dehusked. The dehusked seeds were rinsed in distilled water and soaked for 2 hours. Then the imbibed seeds were washed by double distilled water (DDW) with 2-3 drops of Tween-20 for 12 minutes with agitation to physically remove most microorganisms and to remove some debris. The seeds were then treated with 70% ethanol for 1 minute under laminar air flow cabinet. After pretreatment with ethanol, the seeds were rinsed with autoclaved distilled water three times, to lower the toxic effect of ethanol followed by treatment with 0.1% Mercuric Chloride ($HgCl_2$) for 10 minutes with gentle shaking. Finally the seeds were washed with DDW thrice to remove the traces of $HgCl_2$.

Culture media and culture condition

The shoot tips collected from the axenic culture were inoculated onto MS medium comprising 3% sucrose as carbon source and 2.8 gm/L gelrite as solidifying agent for initial growth. Various plant growth regulators such as; cytokinins (BAP and Kn) and auxins (IBA and NAA) were used to prepare MS medium for the *in vitro* seed germination, regeneration of multiple shoots and development of roots from the base of excised shoots. The pH of the medium was adjusted to 5.8

before addition of gelrite and sterilization. The medium was autoclaved at 1.08 kg/cm^2 pressure and 121^{0}C for 20 minutes. The cultures were incubated at 25±2°C under cool white and fluorescent light of 2000-2500 lux, maintaining about 60-80% relative humidity and 16/8 hours light and dark period in the growth chamber, respectively. These culture conditions were used in all the experiments mentioned below unless otherwise stated. Observations were made at regular intervals and tabulated.

In vitro seed germination and multiple shoots production

MS medium supplemented with or without different concentrations of (0.0, 0.5, 1.0 and 1.5 mg/L) BAP was employed to find out suitable seed germination medium. Germinated shoots were multiplied in MS medium supplemented with different concentrations (0, 1.0, 2.0, 3.0 and 4.0 mg/L) and combinations of BAP and Kn. Number of shoots per explants and their morphology were observed periodically. To optimize the shoot production, effect of sub culturing and the strength of sucrose level in culture medium were evaluated. Rate of multiplication of shoots and their growth were recorded up to 4-8 weeks of culture.

Development of roots at the base of the shoot, hardening and acclimatization of plantlets

In vitro elongated shoots (6-7 cm.) with at least 3-4 nodes were taken out from the culture vessel and transferred to half strength MS medium with different concentrations (0, 1.0, 2.0, 3.0 and 4.0 mg/L) of IBA for root induction. When the plantlets developed few leaves and roots on the rooting medium, they were brought to the green house and kept 2-3 days losing the cap of culture bottles. The plantlets were taken out from the culture vessels, washed thoroughly under running tap water to remove the debris of gelling agent with care and transferred to a pot (10 cm x 9 cm) filled with 2:1 garden soil and compost. The potted plantlets were kept inside the green house for adaptation and maintain the humidity and temperature though misting. Within 10 - 15 days the potted plants began to form new leaves and resumed new growth. The tissue culture plants were brought out from the greenhouse successively and kept under full sunlight in the nursery for further growth up to the plantation season.

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

In vitro seed germination and culture initiation

In vitro seed germination and culture initiation of *D. giganteus* was carried out on full strength MS medium supplemented with or without different concentrations of BAP and seed germination was observed to be started within 1 week of culture. Seeds were also germinated on MS without growth regulator taking comparatively longer time than BAP supplemented medium. The highest 83.33 % seeds were germinated with shoot initiation in 1.0 mg/L BAP supplemented MS medium and the lowest 33.33% in the medium devoid of any growth regulators (Table 1). The growing shoots of about 2.0 cm in length were used for the development of multiple shoots. (Figure 3A).

Table 1. Effect of BAP fortified MS media* on *D. giganteus* seed germination and shoot initiation.

Treatment MS+ BAP (mg/L)	% of Seed germination and shoot initiation	Mean No. of Shoots	Mean Length of shoots	Days till initiation
0.0	33.33 ± 5.77	1.00 ± 0.00	6.91 ± 0.32	7.60 ± 1.67
0.5	66.67 ± 5.77	3.73 ± 1.00	4.48 ± 0.21	5.20 ± 1.30
1.0	**83.33 ± 11.55**	**5.60 ± 1.00**	**3.19 ± 0.23**	**4.60 ± 0.89**
1.5	50.00 ± 10.00	1.93 ± 1.02	5.33 ± 0.40	6.60 ± 1.14

Medium: MS+ additives, mean ± SE, n= 3 replicates

Shoot induction and multiplication

The effect of plant growth regulators on multiple shoot formation from the axenically raised shoot explant were tested on MS medium supplemented with different concentrations (0, 1.0, 2.0, 3.0, and 4.0 mg/L) of BAP and Kn. The result showed that both the cytokinins significantly influenced multiple shoot production as well as enhanced the shoot formation rate. The culture medium devoid of plant growth regulators produced a little number of slow growing shoots. Between the two cytokinins, BAP was found more potential than Kn for new shoot induction of multiple shoot formation from the inoculated explant. The maximum number of shoots produced per culture was observed in MS medium supplemented with 3.0 mg/L BAP, followed by 3.0 mg/L Kn with 4% sucrose. The mean number of shoots per culture was recorded as 12.33 and 8.66 respectively in the same medium after 4 weeks (Fig. 2). The initiation of regeneration and multiple shoot formation from the shoot explant has been presented in Fig. 3A and 3B. Shoots after their initial proliferation on medium containing 3.0 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+ 3.0 mg/L BAP + Vit.B_5 + 4% sucrose), the shoot numbers were increased significantly for the next four repeated transfers and reduced thereafter.

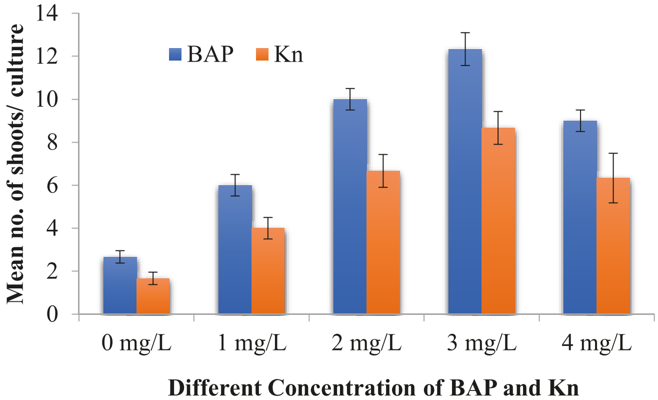

Figure 2. Effect of different concentrations of BAP and Kn supplemented with MS medium on multiple shoot production of *D. giganteus*. The vertical bar represents the standard error.

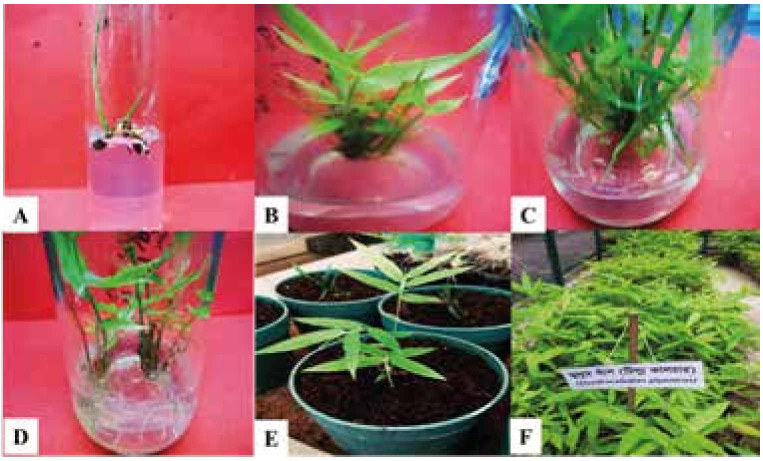

Figure 3. Micro-propagation of *D. giganteus*. A. Seed germination and culture initiation on MS + 1.0 mg/L BAP+ 3% sugar. B. Multiple shoot formation on MS + 3.0 mg/L BAP +4% sucrose after 28 days of culture. C. Combined effect of BAP and Kn on multiple shoot formation. MS + 3.0 mg/L BAP + 1.0 mg/L Kn + 4% sucrose after 28 days of culture. D. Root induction on the *in vitro* grown shoot. ½ MS + 1.0 mg/L IBA+ 2% sucrose after 28 days of culture. E. Transplanted rooted plantlets in the soil hardened in green house. Two months old tissue culture seedlings of *D. giganteus* at nursery.

Though, both the cytokinins BAP and Kn alone enhanced the shoot proliferation but the regenerated shoots remain stunted in their growth. To enhance the shoot elongation the combined effect of BAP and Kn was evaluated. The best concentration of BAP (3.0 mg/L) was supplemented with different concentrations of Kn (0.0, 1.0, 2.0, 3.0 and 4.0 mg/L) in MS medium. A positive effect was observed in both the shoot proliferation and shoot growth by this experiment. It enhanced the shoot proliferation as well as the shoot growth. The average highest shoot number per culture 16.33 and average shoot length was recorded as 6.28 cm on MS medium containing 3.0 mg/L BAP + 1.0 mg/L Kn and 4% sucrose after 28 days of culture (Table 2, Fig. 3C).

Table 2. Combined effect of BAP and Kn on shoot multiplication of *D. giganteus*

Hormonal conc. (mg/L)	**Mean no. of Shoot/culture**	**Average shoot length (cm)**
3.0 BAP + 0.0 Kn	12.00 ± 0.00	1.30 ± 0.08
3.0 BAP + 1.0 Kn	**16.33 ± 2.00**	**6.28 ± 0.38**
3.0 BAP + 2.0 Kn	13.00 ± 3.00	5.45 ± 0.28
3.0 BAP + 3.0 Kn	10.00 ± 2.50	4.49 ± 0.26
3.0 BAP + 4.0 Kn	9.00 ± 1.80	2.95 ± 0.21

Medium: MS+ additives, mean ± SE, n= 3 replicates

Rooting of regenerated shoots

The full or half strength of MS medium without any hormonal supplement was failed to induce rooting of regenerated shoots. However, shoots were capable to induce root when cultured on medium containing different auxins. Two auxins namely IBA and NAA in different concentrations singly or in combination were evaluated for rooting potential of regenerated shoots. It was found that both the auxins were capable of inducing root at the base of the in vitro grown shoots where IBA performed better than NAA. Among the various concentrations of IBA investigated, ½ MS media supplemented with 1.0 mg/L showed highest percentage of root induction (66.67%), followed by 2.0 mg/L IBA (60.00 %) (Table 3). However, the best rooting response was observed on medium containing 1.0 mg/L IBA supplemented with 2% sucrose and 2.8 g/L gelrite. The cultures were initiated rooting after 7 days of inoculation and maximum (66.67%) culture induced root within 28 days. With regard to average number of roots developed per culture in ½ strength MS media with 1.0 IBA proved its superiority over the other treatments by producing 4.00 roots per culture followed by 3.00 and 2.60 with 2.0 mg/L IBA and 3.0 mg/L IBA respectively (Table 3, Fig. 3D). The highest number of roots per bunch which were not significantly different from each other was obtained from ½ strength MS medium fortified 1.0 mg/L IBA. In most of the treatments, root induction was started after 7 days of inoculation but media supplemented with higher IBA concentration delayed up to 14 days.

Table 3. Rooting ability of *D. giganteus* shoots in half strength MS media supplemented with various concentrations of IBA after 4 weeks of culture.

Treatment	**% of culture induced root**	**Mean no. roots per culture**	**Days till root induction**
½ MS + IBA (mg/L)			
0.0	0.0	0.0	0.0
1.0	66.67 ± 10.55	4.00 ± 1.58	7.25 ± 2.06
2.0	60.00 ± 0.00	3.00 ± 0.71	7.75 ± 3.10
3.0	46.67 ± 6.56	2.60 ± 0.55	9.50 ± 4.43
4.0	46.50 ± 6.56	2.40 ± 0.55	9.25 ± 2.06

Medium: ½ MS+ additives, mean ± SE, n= 3 replicates

Acclimatization of plantlets

Acclimatization is essential for the survival and successful establishment of plantlets. Plants grown *in vitro* were gradually acclimated to the external environmental condition in the greenhouse and the nursery of Silviculture Genetics Division. *In vitro* rooted plantlets with culture bottles were brought to the green house for initial hardening. All caps of the culture tubes and bottles were made loosen and kept for the next 2-3 days. The plantlets were then removed from the culture tubes and washed under tap water for complete removal of the medium attached with roots. The rooted plantlets were planted in small plastic pot or poly bag containing forest soil and compost (3:1) and kept in the greenhouse followed by transfer to net house after another 2–3 weeks of hardening. Finally the acclimatized and hardened plants (1–2 feet height) were transferred to the open sun in the nursery under natural conditions. After 10 day of hardening 2-3 new leaves were developed from each shoots. Gradually the plantlets started growing and the leaf number increased as the plant height increases. Progressively, as the acclimatization process continue, color of the leaves turned to deep green and size of the leave get increased with the size of the plant. Furthermore, proliferation of new tillers was observed after 30 days of hardening. The survival rate was found 90 - 95% after 60 days of hardening of the tissue culture produced *D. giganteus* seedlings in the nursery.

Discussion

Mature seeds of *D. giganteus* were cultured on full strength MS supplemented with various concentrations of BAP as well as without plant growth regulator for *in vitro* germination and shoot initiation. The germination competence of the seed explants seems to be markedly influenced by different growth regulators in nutrient media (Padual and Pant 2012). MS with or without growth regulators was found to be effective for the germination of immature seeds (Pant and Swar 2011). BAP concentration significantly affected the seed germination and shoot initiation i.e., days required for germination, number of shoot and shoot length. The result was supported by Arya *et al*. (1999; 2012) who mentioned that the shoot initiation percentage was greatly influenced by the type and concentrations of BAP in *Dendrocalamus asper* and *Dendrocalamus hamiltonii* respectively. Herath and Colleagues (2004) also observed that kenaf explants pre- cultured on BAP medium started shoot growth at an earlier stage compare to pre-cultured explants on plant growth regulator free medium. The requirement of exogenous plant growth regulators for *in vitro* regeneration depended on the endogenous level of the plant tissue, which varied with organs, plant genotype and the phase of plant growth (Chand and Singh 2004; Rahman *et al*. 2018). The regeneration efficiency depended on plant growth regulator concentrations and combinations (Nodong *et al*. 2006; Popelka *et al*. 2006). The effect of BAP in inducing multiple shoots has already been reported in bamboo species like *Arundinaria callosa* (Devi and Sharma 2009), *Dendrocalamus. hamiltonii* (Sood *et al*. 2002) and *Bambusa oldhamii* (Thiruvengadam *et al*. 2011). The superiority of BAP in shoot induction may due to its ability to induce production of natural hormones such as zeatin within the tissues than other synthetic cytokinins (Zaerr and Mapes 1982). Accordingly, the ability of plant tissues to metabolize the natural hormones is faster than artificial growth regulators.

Mekbib and Meresa (2015) reported that the effect of BAP was better than Kn in shoot proliferation percentage and multiple shoot induction. The present result is in agreement with the findings of other researchers who have noted the effectiveness of BAP for the induction of multiple shoot from seeds in different bamboo species (Nadgir *et al*. 1984; Tuan *et al*. 2012). The finding was in line with Arya *et al*. (1999) and Singh *et al*. (2012) who reported reduction in shoot length in different bamboo species with increasing cytokinins concentration. According to Woeste *et al*. (1999) the reduction in shoot length at higher concentration of BAP might be due to the toxic effects of ethylene produced at higher cytokinin concentration. Moreover, the results are supported by the previous studies of Arya *et al*. (2006) in *D. giganteus* and Bisht *et al*. (2010) in *Gigantochloa atroviolaceae*. Rapid shoot multiplication and mass production of *D. giganteus* was initiated through *in vitro* seed germinated shoot. MS medium supplemented with different concentrations of BAP (0.0, 1.0, 2.0, 3.0 and 4.0 mg/L) and Kn (0.0, 1.0, 2.0 3.0 and 4.0 mg/L) were evaluated for the multiple shoot production from single shoot. In the present study, it was observed that the shoot proliferation was positively influenced by the addition of cytokinins in the culture medium than the medium devoid of plant growth regulators. Rahman *et al*. (2018) stated that the concentrations of cytokinin had a crucial effect on multiple shoot formation of *Phyllanthus emblica*. It was also observed that BAP and Kn at higher concentrations significantly reduced the number of shoots per explant. This result might be due to explants cultured on those medium produced less number of shoots (1-2 shoots), thus the nutritional competition was not very strong or due to the toxic effects of ethylene which can be produced at higher cytokinin concentration (Lorteau 2001). The result was consistent with the report of Arya *et al*. (1999) on decreasing of shoot length developed from the explants as cytokinin concentration was increased. These findings also were consonance with the findings in *Opuntia ficusindica* (Garcia – Saucedo *et al*. 2005), *Zingiber petiolatum* (Prathanturarug *et al*. 2004) and *P. emblica* (Rahman *et.al* 2018). The micro shoots produced in lower levels of BAP and Kn were green, taller having bigger leaves than those produced at higher concentration of cytokinins. In MS medium containing BAP the plantlet formed were slightly taller than those produced in MS medium supplemented with Kn. Cytokinin types had a strong effect on the quality of the shoots produced (Neves *et al*. 2001). Kalinina and Brown (2007) found that treatments of *Prunus sp*. with elevated BAP concentrations promoted the shoot numbers per explants but decreased the shoot length and negatively affected shoot development.

The single shoots were cultured on MS medium fortified with the best BAP concentration (3.0 mg/L) and different concentrations of Kn (0.0, 1.0, 2.0 3.0 and 4.0 mg/L) to evaluate the combined effect of cytokinins on multiple shoot production. In all of the formulations of BAP with Kn, explants regenerated and produced shoots. The highest mean number of shoots per culture was 16.0 after 4 weeks of culture in media having 3.0 mg/L BAP with 1.0 mg/L Kn. The highest shoot length was recorded as in the same media composition. BAP was the most widely used cytokinin for multiple shoot formation (Herath *et al*. 2004). The superiority of BAP over Kn and other cytokinins for multiple shoot formation was also demonstrated *Salix pseudolasiogyne* (Park *et al*. 2008). The results showed that the lower concentration of BAP and Kn in the medium enhanced the shoot regenerative ability of *D. giganteus* however, the number of multiple shoot reduced at higher concentration of BAP and Kn. *In vitro* rooting of shoots was tested in half strength MS with different concentrations of IBA and NAA viz. 0.0, 1.0, 2.0, 3.0, and 4.0 mg/L. All media responded positively for root formation on the excised shoots but no rooting was observed in the hormone free medium. However, in the present study, IBA was found to be more effective than NAA for *in vitro* rooting of *D. giganteus.* In woody trees, usually low level of salt concentration is sufficient for rooting of shoots. Similar observation was made by Rai *et al*. (2010). Superiority of IBA over NAA for *in vitro* root induction was reported by Parthiban *et al*. (2013) on *Bambusa balcooa*.

In vitro developed plantlets have morphological and physiological abnormalities due to the *in vitro* culture conditions (Pospišilova *et al*. 1999). Direct transfer of *in vitro* plantlets to *ex vitro* environment may result in rapid wilt and death (Lesar *et al*. 2012). Therefore acclimatization is essential for the survival and successful establishment of plantlets (Deb and Imchen 2010). Plants grown *in vitro* were gradually acclimated to the external environmental condition in the greenhouse and the nursery of Silviculture Genetics Division of BFRI. Addition of compost to the soil increases the porosity resulting in better aeration of roots and thus better growth of the plantlets. Season was found to influence the survival rate and growth of the plantlets in the field. High humidity in the environment during the rains provides optimum conditions for the survival of delicate tissue culture raised plants in the field.

Conclusion

The current research work was undertaken to develop a comprehensive method for *in vitro* regeneration of *D. giganteus* for mass clonal propagation from shoot explant of axenically raised seedling. The establishment of axinic culture from disinfected seeds was carried out in MS media with or without growth regulators. Shoots were excised from *in vitro* germinated seedlings and cultured in the MS media augmented with different concentration (0.0, 1.0, 2.0, 3.0 and 4.0 mg/L) of BAP and Kn alone or in combination with gelrite as solidifying agent for shoot multiplication. The highest shoot multiplication with maximum number of shoot and shoot length per culture was recorded 16.33 and 6.28 cm respectively from the medium having 3.0mg/LBAP + 1.0 mg/L Kn + 4% sucrose after 4 weeks of culture. Plantlets with well-developed shoots and roots were transplanted on a small pots containing mixture of forest soil: compost in 3:1 ratio for acclimatization in greenhouse and nursery successively. After the gradual exposure in sunlight and assessment after 60 days confirmed the survival rate of 90-95% under nursery condition.

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Phenological Traits of Recalcitrant Seed-earing Trees in Bangladesh

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Abstract

Functioning and productivity of forest ecosystems vastly dependents on the phenological characteristics of the tree species. The study was carried out from June 2017 to December 2018 to explore the phenological traits of 74 recalcitrant seed bearing tree species of natural forests and plantations in Bangladesh. Data were collected from Chittagong University campus, Hathazari, Boalkhali, Hazarikhil, Dohazari, Rangamati, Kaptai, Ukhiya, Bandarban and Khagrachari through repeated field visits including review of published papers. The results showed that flowering, fruiting and seed maturity periods varied from species to species. The Seventy Four tree species belongs to 55 genera of 31 families. Maximum (39.19%) fruits were under the Berry category and minimum (1.35%) in Samara. The study revealed that flowering of maximum species occurred during March (54.05%) and fruiting in May (54.05%). The peak period for collecting viable recalcitrant seeds was found both in May and June (36.49% respectively). The study will be a ready reference with information on flowering, fruit initiation and seed collection time of 74 recalcitrant seed bearing trees of Bangladesh. The findings of the study may be useful to the nursery owners, foresters, and private plant growers for collection of seeds in right time and establishment of the plantations. This paper may also be a supportive document to the policymakers in taking decision on raising seedlings of recalcitrant seed bearing trees for mass plantations towards the greening program of the country.

mvims‡¶c

বন বাস্তুকারদের কাজ ও উৎপাদনশীলতা বৃক্ষপ্রজাতির ফেনোলজিক্যাল বৈশিষ্ট্যের উপর নির্ভরশীল। বাংলাদেশের প্রাকৃতিক বনাঞ্চল ও বাগানগুলির ৭৪ টি recalcitrant বীজ বৃক্ষ প্রজাতির ফেনোলজিক্যাল বৈশিষ্ট্য অন্বেষণ করার লক্ষ্যে জুন ২০১৭ থেকে ডিসেম্বর ২০১৮ পর্যন্ত এই গবেষণা করা হয়। গবেষণা পর্যালোচনাসহ বারবার মাঠ পরিদর্শনের মাধ্যমে চট্টগ্রাম ক্যাম্পাস, হাটহাজারী, বোয়ালখালী, হাজারিখিল, দোহাজারী, রাঙ্গামাটি, কাপ্তাই, উখিয়া, বান্দরবান ও খাগড়াছড়ি থেকে তথ্য সংগ্রহ করা হয়। ফলাফলে দেখা গেছে, ফুল ফোটা, ফুল ধারণ ও বীজের পরিপক্কতা সময় প্রজাতি থেকে প্রজাতি-তে বৈচিত্রময়। অধ্যয়নকৃত ৭৪ টি বৃক্ষ প্রজাতি ৩১ টি পরিবারের ৫৫ টি গোত্রের অধীনে পাওয়া যায়। সর্বোচ্চ ফল পাওয়া গেছে বেরি ক্যাটাগোরিতে (৩৯.১৯%) এবং সর্বনিম্ন সামারা-তে (১.৩৫%)। বর্তমান গবেষণায় প্রকাশ, সর্বাধিক প্রজাতির ফুল ফুটেছে মার্চ মাসে (৫৪.০৫%) এবং ফল ধারণ হয়েছে মে মাসে (৫৪.০৫%)। কার্যকরী recalcitrant বীজ সংগ্রহের জন্য সবচেয়ে উপযুক্ত সময়কাল পাওয়া গেছে মে ও জুন উভয় মাস (৩৬.৪৯% পর্যায়ক্রমে)। অতএব এই গবেষণায় বাংলাদেশের ৭৪ টি recalcitrant বীজ বৃক্ষ প্রজাতির ফুল ফোটা, ফল ধারণ, ও বীজ সংগ্রহ সংক্রান্ত প্রয়োজনীয় সকল তথ্য নিয়ে প্রস্তুত রেফারেন্স থাকবে। এই গবেষণার ফলাফল

বাগান স্থাপনের জন্য নার্সারী মালিক, বনরক্ষী, বেসরকারী বৃক্ষচাষীদের সহযোগী উপকরণ হবে। এই গবেষণাটি একটি সবুজ বাংলাদেশ গড়ার লক্ষ্য অর্জনে ব্যাপক অঙ্গণে বনায়ন করতে গাছের চারা উৎপাদনের ক্ষেত্রে নীতিনির্ধারকদের সহায়ক দলিল হবে।

Keywords: Flowering, Fruiting and seed maturity, Phenology, Recalcitrant seed, Forest and plantation tree species

Introduction

Phenology is the study of the timing of recurring biological events where it not only provides knowledge about plant growth but also supportive to the afforestation programs (Kumar *et al*. 2014, Nath 2012). In identifying the quality fruits and seeds, the knowledge of phenotypic or physical characteristics is an important factor (Cantín *et al*. 2010). Phenological traits can explain the evolution of plants including their flowering, fruiting, and seed maturity behavior influenced by the timing of biotic and abiotic events (Davies *et al*. 2013; Forrest and Miller-Rushing 2010, Khanduri 2014). Though it has a significant impact on individual species to whole ecosystems, it usually an overlooked aspect of plant ecology (Cleland *et al*. 2007, Omondi *et al*. 2016).

Seed is a fundamental element of plant life cycle, while intact as a storehouse of genetic traits, necessary for regeneration, disperse, establish, and develop to maintain the species heredity (Nambara and Nonogaki 2012). It is the most important reproductive part for introducing a plant in any area and in establishing a plantation. Production of seeds in sufficient quantities will go in vain if plant producers do not know the seed collection time of the desired species (Hasnat *et al*. 2016). Seed quality is, therefore, of critical importance in determining many options and outcomes in producing seedlings (Aras *et al*. 2007). However, the basic knowledge of phenology is essential for anyone involved in seed collection and supply, both in order to identify fruits or seeds and to design processing procedures (Vidyarthi and Tripathi 2002).

The term 'recalcitrance' refers to seeds that undergo no maturation drying (Berjak *et al*. 1989, Radwan *et al*. 2014), as the final phase of development tolerate very little post-shedding desiccation and are often chilling-sensitive. Such seeds are not storable by applying any of the methods used for drying orthodox seeds (Berjak *et al*. 1989, Walters *et al*. 2013). By nature, recalcitrant seeds are short-lived, most commonly found in moist regions with an invariant climate. The seeds either germinate or eaten by animals in the wild (Berjak and Pammenter 2007, Lee *et al*. 2012). In addition, recalcitrant seeds are mainly fleshy seeds produced by woody plants of both the temperate zone and the tropics and generally forest trees of the families Araucariaceae and Dipterocarpaceae (Kozlowski and Pallardy 1997). However, mangrove plants are a special example of recalcitrant seeds, but the phenomenon is much more widespread and is seen in plantation species as well (Srivastava 2002).

A good, healthy, successful plantation depends on seed quality and seed quality primarily depends on the physical quality of fruits and seeds (Barracosa *et al*. 2007). However, the study of phenotypic characteristics of fruits and seeds of natural and planted tree species in Bangladesh is only at the pioneer stage (Vozzo 2002). Some researchers reported the phenological behaviors such as flowering, fruiting and seed collection time of different species (Alvim and Alvim 1978, Anwar and Takewaka 2014, Borchert 2000, Hasnat *et al*. 2016, Jadeja and Nakar 2010, Kushwaha *et al*. 2011a;b, Motaleb and Hossain 2010, Nahar *et al*. 2010, Pezzini *et al*. 2014, Rahman and Islam 2015, Sheikh and Matin 2007), but studies on phenology of solely recalcitrant seeds has yet not been found. Therefore, the present study aimed to generate a physical feature and document with general information about the phenological characteristics of recalcitrant seeds of Bangladesh which will help the foresters and other stakeholders about the timing of flowering, fruiting, and seed maturity as well as information to collect desired fruits and seeds in time.

Materials and Methods

The study was carried out during June 2017 to December 2018 at Seed Research Laboratory of Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh. In the study, both primary and secondary data were collected. Natural, plantation and homestead forests of Hathazari, Boalkhali, Hazarikhil, Dohazari, Rangamati, Kaptai, Ukhiya, Bandarban, Khagrachari, and Chittagong University campus were visited repeatedly for primary data collection. Recalcitrant fruits and seeds of 74 tree species were collected from fields, and preserved in the Seed Research Laboratory after identification and verification. Flowering, fruiting and seed collection time were recorded for most of the species. However, few data on phenological behaviors were collected from field guides and existing research documents. The data were verified with the existing reports by different researchers (Ahmed *et al*. 2008;2009, Brandis 1906, Heinig 1925, Hasnat *et al*. 2014, Hasnat *et al*. 2018, Hasnat *et al*. 2019, Hossain *et al*. 2013, Hossain and Ahmed 2008, Hossain and Hossain 2014, Motaleb and Hossain 2010, Rahman *et al*. 2017, Uddin and Hassan 2010, Uddin and Hassan 2018) studied on natural, plantation and homestead forests.

Results

The study revealed that 74 tree species are belonging to 55 genera and 31 families. Maximum (12.16%) species were found in Anacardiaceae family followed by Myrtaceae (10.81%) and Dipterocarpaceae (8.11%) whereas 14 species found from 14 different families (Table 1).

Table 1. Flowering, fruiting and seed collection time of 74 recalcitrant seed-bearing tree species in Bangladesh

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
1	Annonaceae	*Annona reticulata*	Nona Ata	A	Oct-Nov	Jan-Feb	Mar-Apr
2		*Annona squamosa*	Sharifa	A	Mar-Apr	Oct-Nov	Jan-Feb
3	Anacardiaceae	*Bouea oppositifolia*	Miriam, Mailam	D	Nov-Jan	Jan-May	May-Jun
4		*Drimycarpus racemosus*	Kodi-barela	D	Sep-Nov	Mar-Apr	May-Jun
5		*Holigarna caustica*	Barela	D	Mar-May	May-Jul	Jun-Jul

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
6		*Lannea coromandelica*	Jial Bhadi	D	Mar-Apr	May-Jul	Jul-Aug
7		*Mangifera indica*	Aam	D	Jan-Feb	Apr-Jun	May-Jul
8		*Mangifera longipes*	Jangli Aam	D	Feb-Apr	Apr-Sep	Sep-Nov
9		*Mangifera sylvatica*	Uri Aam	D	Jan-Feb	Feb-Apr	May-Jun
10		*Semecarpus anacardium*	Beula, Bhela	D	May-Jun	Oct-Nov	Feb-Mar
11		*Swintonia floribunda*	Civit	D	Feb-Apr	Apr-May	May-Jun
12	Arecaceae	*Arenga pinnata*	Chini Tal	D	Mar-Apr	Jul-Aug	Dec-Jan
13	Apocynaceae	*Carissa carandas*	Karamcha	B	Mar-Jun	May-Oct	Sep-Nov
14		*Wrightia arborea*	Dud Kuruch	F	May-Jul	Jun-Nov	Sep-Jan
15	Araucariaceae	*Araucaria cunninghamii*	Araucaria	C	Jun-Jul	Sep-Oct	Dec-Jan
16	Boraginaceae	*Cordia dichotoma*	Bohal	D	Mar-Apr	Apr-Aug	Sep-Oct
17	Celastraceae	*Lophopetalum wightianum*	Raktan	C	Dec-Jan	May-Jun	Aug-Sep
18	Clusiaceae	*Garcinia acuminata*	Kuki	B	Sep-Oct	Mar-Apr	Jun-Jul
19		*Garcinia cowa*	Kau	B	Feb-Apr	Mar-Jul	May-Aug
20		*Garcinia xanthochymus*	Dephal	B	Mar-Apr	Apr-May	Apr-May
21		*Messua ferrea*	Nageshwar	C	Feb-May	Mar-Aug	Jun-Oct
22	Combretaceae	*Anogeissus acuminata*	Chakwa	P	Jan-Feb	Mar-Apr	May-Jun
23		*Terminalia bellerica*	Bohera	D	Mar-May	Jan-Feb	Jan-Feb
24	Datiscaceae	*Tetrameles nudiflora*	Chandul	C	Mar-Apr	May-Jun	Aug-Oct
25	Dilleniaceae	*Dillenia indica*	Chalta	D	May-Jul	Jul-Dec	Dec-Feb
26		*Dillenia pentagyna*	Hargaza	B	Feb-Apr	Apr-May	May-Jun
27	Dipterocarpaceae	*Anisoptera scapula*	Boilam	P	Dec-Jan	Mar-Apr	Apr-May
28		*Dipterocarpus alatus*	Dhullya Garjan	N	Dec-Jan	Jan-Apr	Apr-May
29		*Dipterocarpus costatus*	Baittya Garjan	N	Dec-Feb	Feb-Apr	Apr-May
30		*Dipterocarpus turbinatus*	Telia Garjan	N	Mar-Apr	Apr-Jun	May-Jun
31		*Hopea odorata*	Telsur	N	Mar-Apr	May-Jun	May-Jun
32		*Shorea robusta*	Sal	S	Mar-Apr	Apr-Jun	Jun-Jul
33	Euphorbiaceae	*Phyllanthus acidus*	Orboroi	D	Mar-May	May-Aug	Aug-Dec
34		*Phyllanthus emblica*	Amloki	D	Nov-Dec	Mar-Apr	Jan-Feb
35		*Trewia nudiflora*	Pitali	B	Mar-Apr	Apr-Jun	Jul-Aug
36	Fabaceae	*Gliricidia sepium*	Bashanta Manjuri	P	Jan-Mar	Mar-May	Apr-May
37		*Ormosia robusta*	Ormosia	P	Feb-Mar	May-Jun	May-Jun
38		*Pongamia pinnata*	Kerong	P	Apr-Jun	Feb-May	Apr-Jun

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
39		*Pterocarpus indicus*	Paduk	P	Mar -Apr	Apr-May	May-Jun
40	Flacourtiaceae	*Flacourtia jangomas*	Painnagula	B	Mar-May	Apr-Jun	Jul-Oct
41		*Hydnocarpus laurifolius*	Hiddigach	B	Jul-Sep	Aug-Dec	Dec-Feb
42	Lauraceae	*Cinnamomum verum*	Dalchini	B	Jan-Feb	Feb-Mar	Feb-Mar
43	Lecythidaceae	*Careya arborea*	Kumbi	C	Apr-May	May-Jun	Jun –Jul
44	Magnoliaceae	*Michelia champaca*	Champa	C	Mar-May	Apr-Jun	Jun-Jul
45	Meliaceae	*Azadirachta indica*	Neem	C	Mar-Apr	Apr-May	Jun-Jul
46	Moraceae	*Artocarpus chama*	Chapalish	D	Dec-Mar	Feb-Apr	May-Jun
47		*Artocarpus lachucha*	Barta /Dewa	D	Mar-Apr	Apr-Jun	May-Jun
48	Moringaceae	*Moringa oleifera*	Sajna	P	Oct-Dec	Dec-Feb	Dec-Feb
49	Myrsinaceae	*Aegiceras corniculata*	Kholshi	C	Mar-May	May-Aug	Jul-Aug
50	Myrtaceae	*Melaleuca leucadendrone*	Melaleuca	C	Mar-May	Apr-Jun	Jun –Jul
51		*Syzygium balsamea*	Buti-jam	B	Oct-Nov	Dec-Feb	Feb-Mar
52		*Syzygium cumini*	Kala Jam	B	Feb-Mar	Mar-Apr	Apr-May
53		*Syzygium firmum*	Dhaki Jam	B	Feb-Mar	Mar-Apr	Apr-May
54		*Syzygium formosum*	Paniya Jam	B	Dec-Jan	Jun-Jul	Sep-Oct
55		*Syzygium fruiticosum*	Puti Jam	B	Mar-Apr	Apr-Jun	Apr-Jun
56		*Syzygium jambos*	Gulab Jam	B	Mar-Apr	Apr-Jun	Apr-Jun
57		*Syzygium malaccense*	Jamrul	B	Feb-Mar	May-Jun	Aug-Sep
58	Oxalidaceae	*Averrhoa bilimbi*	Belamboo	B	Oct-Dec	Nov-Feb	Feb-Apr
59		*Averrhoa carambola*	Kamranga	B	Sep-Oct	Oct-Mar	Feb-Apr
60	Rhizophoraceae	*Bruguira gymnorrhiza*	Kankra	D	Dec-Feb	Feb-Mar	Mar-Apr
61		*Bruguira parviflora*	Rohinia	B	Jan-Feb	Apr-May	Jun-Jul
62		*Ceriops decandra*	Goran	B	Jan-Mar	Mar-Jun	May-Jun
63		*Rhizophora apiculata*	Bhora, garjan	B	Oct-Nov	Feb-Mar	Apr-May
64	Rubiaceae	*Haldina cordifolia*	Haldu	B	Apr-Jul	Jun-Dec	Dec-Feb
65		*Mitragyna diversifolia*	Phul Kadam	C	Aug-Sep	Oct-Nov	Jan-Feb
66		*Mitragyna parvifolia*	Puti Kadam	F	Nov-Dec	Dec-Jan	Jan-Feb
67	Rutaceae	*Aegle marmelos*	Bel	B	Apr-Jul	Jun-Dec	Sep-Dec
68		*Limonia acidissima*	Kotbel	B	Feb-Apr	Mar-Oct	Oct-Dec
69	Sapindaceae	*Schleichera oleosa*	Kusum	B	Mar-May	May-Oct	Oct-Nov
70	Sapotaceae	*Madhuca longifolia*	Mahua	B	Mar-May	Apr-Aug	Jul-Aug
71		*Palaquim polyanthum*	Tali	B	Mar-Apr	May-Jun	Jul-Aug

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
72	Sterculiaceae	*Firmiana colorata*	Udal	B	Mar-Apr	Apr-May	Apr-May
73		*Pterospermum semisagittatum*	Lana Assar	B	Apr-Jun	Jun-Aug	Jul-Aug
74	Thymelaeaceae	*Aquilaria malaccensis*	Agar	C	May-Jul	Jul-Sep	Aug-Oct

[Here, *A: Achene, B: Berry, C: Capsule, D: Drupe, F: Follicle, N: Nut, P: Pod, S: Samara]

The fruit types of the studied species were categorized into Achene, Berry, Capsule, Drupe, Follicle, Nut, Pod, and Samara. Maximum (39.19%) fruits were recorded under the Berry category followed by Drupe (24.32%) and Capsule (14.86%), whereas only 1.35% was recorded from Samara (Fig. 1).

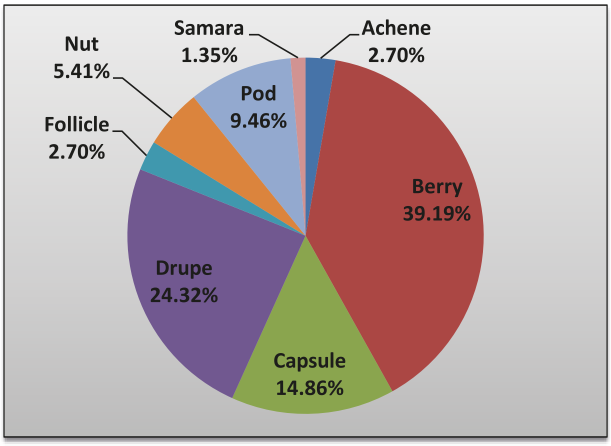

Figure 1. Fruits belonging to different categories

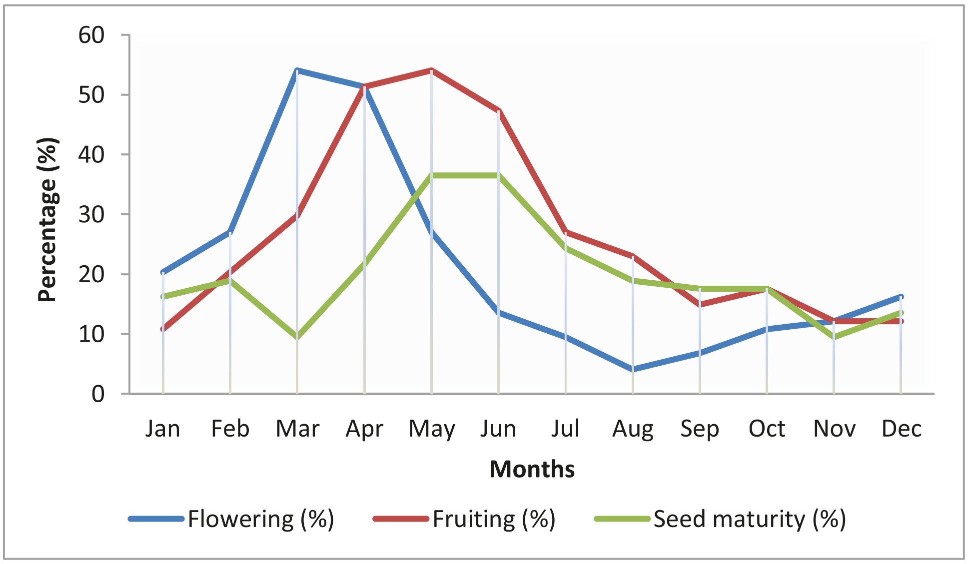

Figure 2. Time of flowering, fruiting and seed maturity of 74 recalcitrant seed-bearing tree species in Bangladesh

The graphical presentation of field observation revealed that flowering, fruiting and seed maturity occurred round the year. Visible flowering time was between January and May. Maximum trees (54.05%) bloomed in March and minimum (4.05%) flower blooming occurred in August. Results revealed that noticeable fruiting was found in April to June, fruiting of maximum species (54.05%) occurred in May, whereas minimum (10.81%) in January. The prominent seed collection time varied from April to July, maximum seeds (36.49%) were available for collection during May and June respectively, whereas minimum (9.46%) in March and November respectively (Fig. 2).

Discussion

Phenological behaviors, such as flowering, fruiting and seed maturity time of trees are very important as they are the indisputable factors of seed biology and regeneration process as well as forest dynamics (Dey 2006, Hasnat *et al*. 2016). The present study is in agreement with the findings of Hossain and Ahmed (2008), Kaur et al. (2013), Rahman *et al*. (2018), Schmidt and Jøker (2000), Singh and Kushwaha (2005), Upadhyay and Mishra (2010), Vashistha *et al*. (2009) where they studied different species from different regions of the world and revealed that phenological characteristics varied with time and species. In Bangladesh, Hasnat *et al*. (2016) recorded flowering, fruiting and seed maturity time of common 65 plantation tree species where they found the best time for collecting viable recalcitrant seeds was May and June that also supports the present findings. The same results found by Hasan (1971) that seeds of most of the tree species may be collected from May to June.

The present study also supported by the findings of Motaleb and Hossain (2010) where they reported that most of the fruits and seeds become available for collection from May to September. Seed collection time of some tropical and subtropical species represented by Schmidt (2000), which supports this study too. Findings from different researches (Bajpai *et al*. 2012, Bhat 1992, Kumar *et al*. 2014, Kushwaha *et al*. 2011a, Mishra *et al*. 2006, Singh and Kushwaha 2006) revealed that flowering and fruiting of most species occurred just before the rains that also supports the findings of the present study.

Conclusion

Knowledge on phenological behaviors of trees, e.g. flowering, fruiting, and seed collection time is fundamental for any forestry programs. Recalcitrant seeds have short viability ranging from few days to weeks. Lack of proper information about the flowering, fruiting, and seed maturity traits of recalcitrant seed trees may delayed afforestation or reforestation programs and may lead to a failure of plantation establishment. The study elucidated the information on flowering, fruiting and seed collection time of 74 recalcitrant seed tree species from natural and plantation forests of Bangladesh. The information may be useful to government and non-government organizations, policymakers, extension officers, foresters, general nurserymen, and local plantation growers.

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Mathematical Models and Tables for Estimating Total Volume of *Lagerstroemia speciosa* (L.) Pers. Grown in Bangladesh

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Abstract

Jarul (*Lagerstroemia speciosa* L. Pers., Family- Lythraceae) is a semi-deciduous medium to large-sized tree with fluted bole, small buttress and slightly flaky bark tropical flowering tree species. It is a common ornamental tree planted along roadsides, gardens and parks in Bangladesh. The main aim of this study is to develop mathematical models for total volume estimation of jarul. To meet the quest we have tested 21 models for volume equation by regression technique. The best-fitted model for studied species have been selected by highest value of R^2 (coefficients of determination), the lowest value of Akaike Information Criterion (AIC) and Root Mean Square Error (RMSE). The selected models also validated by Chi-square test of goodness of fit, Paired t-test, Percent Absolute Deviation (*%AD*) and 45 degree line test. The study appearance that, for one way analyses the model $\ln(V) = a+b\ln(D)$ and for two way analyses $\ln(V)= a+b\ln(D)+c\ln(H)$ appeared to the best model for estimating the standing tree volume of jarul. Conversion factors equation has been determined to estimate under bark volume and under bark volume of different top end girth of 30, 35, 40 and 45 centimeters from these models. The best-fit volume model showed the highest efficiency in volume estimation compared to previous developed volume model of this species in terms of Model Prediction Error (MPE), Model Efficiency (ME) and Root Mean Square Error (RMSE).

mvims‡¶c

জারুল একটি পাতা-ঝরা ছোট থেকে মাঝারি আকারের গাছ যা খাঁজকাটা গুঁড়ি, ছোট ঠেকনা এবং কিছুটা স্তরপূর্ণ ছালযুক্ত গ্রীষ্মমন্ডলীয় ফুল প্রাজাতির গাছ। এটি বাংলাদেশের রাস্তাঘাট, উদ্যান এবং পার্কের পাশে লাগানো একটি সাধারণ শোভাময় বৃক্ষ। এই গবেষণার মূল লক্ষ্য হচ্ছে জারুল গাছের মোট আয়তন নির্ণয়ের গাণিতিক মডেল উন্নয়ন করা। এই গবেষণা কার্য্যটি পরিচালনার জন্য আমরা রিগ্রেশন কৌশল দ্বারা আয়তন নির্ণয়ের ২১ টি মডেল পরীক্ষা করেছি। রিগ্রেশন কৌশলে প্রাপ্ত সর্বোচ্চ R2 (coefficients of determination) মান, সর্বনিম্ন AIC (Akaike Information Criterion) এবং RMSE (Root Mean Square Error) দ্বারা সেরা-যথাযথ মডেল নির্বাচন করা হয়েছে। নির্বাাচিত মডেল গুলি কাই-বর্গ, জোড়া টি-টেস্ট, Percent Absolute Deviation (%AD) এবং ৪৫ ডিগ্রি লাইন পরীক্ষা দ্বারা বৈধতা পরীক্ষা করা হয়েছে। উক্ত গবেষণায় দাঁড়ানো জারুল গাছের একমূখী আয়তন নির্ণয়ে $\ln(V) = a+b\ln(D)$ এবং দ্বিমূখী আয়তন নির্ণয়ে $\ln(V)= a+b\ln(D)+c\ln(H)$ মডেলদ্বয় সেরা মডেল নির্বাচিত হয়েছে। জারুল গাছের বাকলসহ মোট আয়তন হতে বাকল ছাড়া গাছের আয়তন, গাছের ৩০, ৩৫, ৪০ এবং ৪৫ সে.মি. শীর্ষ প্রান্ত পর্যন্ত আয়তন নির্ণয়ের রুপান্তর গুণক নির্ণয়ের সমীকরণও নির্ণয় করা হয়েছে। সেরা ফিট আয়তন নির্ণয়ের মডেলটি মডেল পূর্বাভাস ক্রুটি (MPE), মডেল দক্ষতা

(ME) এবং রুট মিন স্কয়ার ত্রুটি (RMSE) বিবেচনায় পূর্ববর্তী উন্নয়নকৃত মডেলের তুলনায় আয়তন অনুমানের সর্বোচ্চ দক্ষতা দেখিয়েছে।

Keywords: *Lagerstroemia speciosa*, Total Volume, Volume Model, Volume table

Introduction

Jarul is a semi-deciduous medium to large-sized tree with fluted bole, small buttress and slightly flaky bark tropical flowering tree species found in the *Lagerstroemia* species of the Lythraceae family. This tropical flowering tree is one of the most outstanding summer bloomers, which reflect its attractive and colourful flowers. It is called Queen Crape Myrtle because it is the Queen of the Crape Myrtles dominating with larger crinkled flowers. It is also known as Pyinma (Burmese), Pride of India, Banaba (Filipino), Sebokok (Malay), Murutu (Sinhala), Pumarathu (Tamil), Bang-lang nuoc (Vietnamese) (Rahman *et al*. 2011). It is a medium sized to large deciduous tree with a rounded crown distributed throughout Bangladesh (Ghani 1998). *Lagerstroemia speciosa* (L.) Pers is a fast-growing much branched semi deciduous tree generally used boat building, making doors, windows, house posts and different parts for medicine. It is also recognized as an important species for fuel wood, shade tree, ornamental road side avenue tree and in gardens, parks, throughout the country. It is distributed to India, Srilanka, Myanmar, Philippines, Malaysia, China, Vietnam and tropical Australia (Kirtikar 1987). Drigo *et al*. (1988) developed a local two way volume model for *L. speciosa* during inventory of forest resources of southern Sylhet forest division. They developed only two-way volume model by using a total of 74 standing sample trees of *L. speciosa* locally. They were recommended further volume model develop with covered the wide area and wide diameter range. However, volume models for *L. speciosa* are lacking in existing literature while this species is well distributed in Bangladesh (Das and Alam 2001) and neighboring countries (Kirtikar 1987). Considering its economic importance, proper management of this species is necessary. Volume equations play a crucial role in forest management. The importance of volume equations is indicated by the existence of numerous such equations and the constant search for their improvement. For more than a century, researchers have been trying to estimate the volume of different trees over the time. Now days quite a number of volume equations have been used to estimate tree and stand volume, and have played a significant role in forest inventories and management. Studies of tree volume began in the early nineteenth century. A multitude of equations have been published in forest literature (Spurr 1952, Clutter *et al*. 1983, Avery and Burkhart 2002, Abel 2014, Latif and Islam 2014). Because of inherent morphological differences among tree species, it is generally necessary to develop separate standard volume equations for each species or closely related species group (Burkhart and Gregoire 1994). These are simple methods and tools that can be used to obtain individual tree volume and the volumes of entire stands. Such information is vital for forest management. Sustainable forest management requires among others knowledge on the total volume of the growing forest stock. Usually volume is estimated as total volume per unit area, whereby models predicting total tree volume of individual trees are used. The objective of any volume equation is to provide accurate estimates with acceptable levels of local bias over the entire diameter range in the data. Equations that provide accurate predictions of volume without local bias over the entire range of diameter are one of the basic building blocks of a forest growth and yield simulation system (Bi and Hamilton 1998).

Development of sound management practice is one of the major priorities of the forestry sector. The biomass of a tree can be determined by multiplying the volume of the tree by the biomass conversion factor. Hence volume equation provide to the tree biomass and carbon estimation in non-destructive way.

Tree volumes were calculated using formulae such as Huber's, Newton's and Smallian's. The resulting functions mostly predicted volume from a single parameter such as total tree height or diameter/girth at breast height (DBH/GBH), or from a combination of both variables. Normally, a form factor was also included in the equations to account for the variability in tree form (Hush *et al*. 1982; Laasasenaho 1982).

Volume equations have been developed more than forty two different important tree species in Bangladesh (Latif and Islam 2014; Islam *et al*. 2014; Hossain *et al*. 2016). A considerable amount of work on volume has been done by researcher of Bangladesh Forest Research Institute (BFRI). Volume equations and tables of jarul are needed to estimate the quantity of harvest which is necessary for sustainable forest management system, carbon assessment and economic analysis. However, accurate volume equations of this species are not available. This study, therefore, aims to derive volume prediction equations and tables for *L. speciosa* for yield estimation. The results of the study could serve as input information that is necessary in the operation of subsequent forest regulations such as economic rotation, cut allocation and scheduling, and forest development schedules. Generally, such information could facilitate the effective and sound management in the business projection for *L. speciosa* (Islam *et al*. 2014; Hossain *et al*. 2016).

Materials and Methods

Description of the Study area

The study has been conducted in the remnant the natural forest and existence plantation Moulavi Bazar and Kaptai range under Sylhet South and Rangamati South Forest Division, Bangladesh. The study area contains tropical evergreen and semi-evergreen tree species with natural and plantation stands. The study area Lawachara in Moulavi Bazar range geographically, lies between 24°30'–24°32' N and 91°37'–91°47' E. The soil texture of this area is yellowish brown to reddish brown in colour, loam to clay loam and sandy clay loam of Pliocene origin (Hossain *et al*. 2019). Soil is acidic, organic matter and fertility levels are generally low. The moist tropical climate of this study area is generally warm and humid, turning cool in the winter. Moderately cool and lovely, and dry conditions exist from mid-November to the end of February while June to September is the time of the highest precipitation. Average maximum and minimum temperatures are 35 °C and 15 °C, respectively (Khatun *et al.* 2016). The average annual rainfall is 3800 mm, and humidity ranges from 70% to 85% in most parts of the year (Khatun *et al.* 2016). The study area Kaptai range under Rangamati South Forest Division approximately at the intersection 92°13' E and 22°32' N. The soil of this area is mainly yellowish-brown to reddish-brown loams which grade into broken shale or sandstone at a variable depth. The valley soil is mainly acid loams and clays subject to seasonal flooding (Hossain *et al*. 2014). Soil is acidic and organic matter content of the topsoil varies from 0.15 to 3.32%. While, total nitrogen concentration varies from 0.03 to 0.24% (Hossain *et al*. 2014). The average temperature of the study area ranges from 19.9 °C to 28.3 °C, while the average annual rain fall is about 2900 mm and average annual relative humidity is about 78 %. The climate of this region is characterized by mainly three distinct seasons: a hot, humid summer from March to June; a cool, rainy monsoon season from June to October, and a cool, dry winter from October to March (Khatun *et al*. 2016).

Sampling of trees

A sufficient numbers of sample tree were selected on the basis of girth at breast height (GBH) classes and height classes at random. All sample trees were selected to avoid specimens with broken top, hollow trunk, damage caused by natural calamities or animals, and evidence of suppression or disease. We collected 316 individuals (Table 1) in different GBH class to derive the mathematical volume models and tables of jarul. Sample trees were selected purposively and covered existence wide GBH range and height range. Another 30 sample trees at all girth classes were recollected for model validation.

Measurement of trees

Standing sampled jarul trees in representing different girth classes were selected at random for preparation of mathematical volume functions and tables. Trees girth at breast height in cm and total height in meter were measured with diameter tape and Haga-altimeter respectively and the nondestructive method was used to estimate the volume. The girth and bark thickness at one meter intervals in the stem and branches girth were measured by climbing the trees with a ladder. The bark thicknesses of the samples were measured with a bark gauge. To calculate branch volume for bigger branches whose mid-girth ≥30 cm in particular length also taken and smaller branches not taken. The collected fitting data set were categorized on the basis of GBH and height of the trees. The GBH -height class distribution of the sample trees are given in Table 1.

Table 1: Stand table of collected volume table data of *L. speciosa*

Girth class (cm)	**No. of sample trees under different Height Class (m)**						
	<9	9.1 -14	14.1 -18	18.1 -22	22.1 -26	>26	Total
<35	8	1					9
35.1 -45	8	4					12
45.1 -55	4	14	1				19
55.1 -65	2	19	3				24
65.1 -75	2	15	18				35
75.1 -85		5	26	5			36
85.1 -95		6	29	8			43
95.1 -105		1	22	12	6		41
105.1 -115		1	13	8	9		31
115.1 -125			5	18	6		29
125.1 -135		1	3	6	6		16
>135			2	7	10	2	21
Total	24	67	122	64	37	2	316

Compilation of data

Volumes of all sections except top and bottom section were determined by using the mean cross-sectional areas of the two ends of each section following Smalian's formula cubic volume = [(*B*+*b*)/2]L, where *B*= the cross-sectional area at the large end of the log, *b*= the cross-sectional area at the small end of the log, and *L*= log length. In determining the volume of bottom sections, the formulae used for calculating the volume of a cylinder was considered. Assuming the top section as cone the volume was computed to one third of the cylindrical volume of the portion. We considered the top end diameter measurement for each tree as the base diameter of the cone. In computing the under bark volume of the tree the volume of top section i.e. cone was ignored. The total volume of the tree is the sum of the volume of all sections and branches volume found in a tree. The individual tree total volumes (V), GBH (G) and total height (H) were variable in regression techniques using various functions and transformations as required in the models.

Computation of volume function

Multiple regression analysis techniques were used to select the best suited model equations. The following 21 models (Clutter *et al.* 1983; Bi Hamilton 1998; Latif and Islam 2014 and Islam *et al.* 2017) were tested to select the equation of best fit with different variables are given in Table 2.

Table 2: Frequently used volume models

Model No.	Models
1	$V = a + bG$
2	$V = a + bG + cG^2$
3	$V = a + bG^2$
4	$V = aG + bG^2$
5	$V = aG + bG^{-1}$
6	$V = aG + bG^{-2}$
7	$\log(V) = a + bG$
8	$V = a + b\log(G)$
9	$\log(V) = a + b\log(G)$
10	$V = a + bG^2H$
11	$V = a + bG + cH$
12	$V = a + bG + cG^2H$
13	$V = a + bG + cGH$
14	$V = a + bG + cH + dGH$
15	$V = a + bG + cH + dG^2H$
16	$V = a + bG^2 + cH + dGH$
17	$V = a + bG^2 + cH + dG^2H$
18	$V = a + bG^2 + cGH + dG^2H$
19	$V = a + b\log(G) + c\log(H)$
20	$\log(V) = a + b\log(G) + c\log(H)$
21	$V = a + bG^{-1} + cH^{-1}$

Where: V = total volume over bark in cubic meters, G = girth at breast height in centimeters, H = is total height in meters, a is the regression constant and b, c and d are regression coefficients. The logarithmic functions are to the base e.

Following original and transformed variables were used to select the best suited regression models: Dependent variables: *V, Log (V),*

Independent variables: *G, G2, G-1, G-2, H, H-1, GH, G2H, Log (G), Log(H)*

The dependent variables mentioned above were regressed with the independent variables.

The equations of the best fit based on the highest multiple coefficients of determination; F-ratio and lowest residual mean square and AIC value statistic were chosen. Models for estimation of the total volume over bark were selected and the conversion factors to estimate under bark volume and volume to top end girths of approximately 30, 35, 40 and 45 cm were also estimated.

Model validation

The best suited models were tested with a set of data recollected from 30 trees of different diameter class and compiled in the same procedure as earlier. The actual volumes of these trees were collectively compared with the corresponding volume predicted by the selected models. The independent tests for validation were chi-square test of goodness of fit, paired t-test and Percent absolute deviation (*%AD*). This was also compared with 45 degree line test by plotting the observed values and the predicated value in the graph.

Model comparison

Best-fit volume model was compared with the previous developed local volume model of *L.speciosa* by Drigo *et al*. (1988) (Equation 1) in terms of Model Prediction Error (MPE), Model Efficiency (ME), and Root Mean Square Error (RMSE) (Mayer and Butler, 1993). This comparison was conducted with data set which recollected for validation.

The volume model developed by Drigo *et al*. (1988) and comparison tools are given in the equations:

$$\ln(\mathrm{V}) = -9.6744 + 2.1065 \times \ln(\mathrm{D}) + 0.6675 \times \ln(\mathrm{H}) \quad (1)$$

$$\mathrm{MPE}(\%) = \frac{100}{\mathrm{n}} \times \sum \left[\frac{(\mathrm{Y_p} - \mathrm{Y_0}}{\mathrm{Y_0}} \right] \quad (2)$$

$$\mathrm{ME} = 1 - \left[\frac{\sum (Y_0 - Y_p)^2}{\sum (Y_0 - \bar{Y})^2} \right] \quad (3)$$

$$\mathrm{MSE}(\%) = 100 \times \sqrt{\frac{1}{\mathrm{n}} \sum (\mathrm{Y_p} - \mathrm{Y_0})^2} \quad (4)$$

Where V = Total volume over bark in cubic meter, D = Diameter at breast height in cm, H = Total height in meter, n = Number of trees, Yp = Predicted volume from the model, Yo = Observed volume in field measurement, and $\bar{Y}$ = Mean of the observed volume. Regression between predicted volume (Yp) (in the X-axis) and observed volume (Yo) (in the Y-axis) were also derived for the best-fit volume model, and developed model by Drigo *et al*. (1988) (Equation 1).

Significance of slope (b = 1) and intercept (a = 1) were tested (Pin˜eiro *et al*. 2008) to understand the overestimation or underestimation of each predicted volume value from observed value by using 1:1 line (Sileshi 2014).

Data Analysis

Data collected were organized and screened (removing the outliers) for analysis. Descriptive statistical analysis was further carried out in order to summarize the data. All analysis carried out were conducted using MS Excel 2013, SPSS 17 Inc and EViews (Quantitative Micro Software, LLC) statistical package version 9.

Results

Dependent and independent variables

Total volume over bark have been calculated from total of 316 sample trees of jarul, in this study. Descriptive statistics of dependent and independent variables represent in Table 3.

Table 3: Descriptive statistics for sample trees for volume-girth and height relationships

Variables	No. of Sample	Mean	Minimum	Maximum	Standard Error	Standard Deviation	Confidence Level (95.0%)
GBH (cm)	316	90.3	30.0	178.0	1.7	29.6	3.3
Height (m)	316	16.4	6.5	27.0	0.3	4.5	0.5
Volume (m^3)	316	0.6	0.0	2.6	0.0	0.4	0.0

Volume equations

We have selected volume equations for estimation of total volume over-bark for *L.speciosa*. The regression models number 9 and 20 are best suited for one way and two way volume equations respectively to estimate total volume over bark. The selected volume equations are given in Table 4.

Table 4: Selected best suitable volume equations of *L. speciosa*

Selected models	Fit statistics			
	R^2	*RMSE*	*AIC*	*N*
$\ln(V_{ob}) = -12.0813 + 2.5114 \times \ln(G)$	0.96	0.19	-0.49	316
$\ln(V_{ob}) = -11.6519 + 1.87239 \times \ln(G) + 0.87445 \times \ln(H)$	0.98	0.14	-1.10	316

Where, G is girth at breast height in cm, H is total height in m, V_{ob} is total volume over bark in m^3, and ln is natural logarithm (logarithm on base e).

Most of the times end users and forest managers need the volume under-bark and the volume at different top end girth along the stem. So, this study is also developed mathematical models and tables for predicting conversion factors to estimate under-bark volume and volume at different proportion of stem from over-bark volume for *L. speciosa*. The conversion factors equations to estimate under-bark volume and volume to different top end girths of approximately 30, 35, 40 and 45 cm from stem volume over bark have been determined and selected conversion factor equations are given in Table 5.

Table 5: Selected best suitable conversion factor equations of *L. speciosa*

Selected models	Fit statistics			
	R^2	*RMSE*	*AIC*	*N*
$F_{ub} = G/(3.0086 + 0.99167 \times G + 0.0000932 \times G^2)$	0.78	0.01	-7.23	316
$F_{30} = G/(24.6933 + 0.69134 \times G + 0.00113 \times G^2)$	0.92	0.02	-4.89	316
$F_{35} = G/(64.2948 + 0.23157 \times G + 0.00282 \times G^2)$	0.97	0.22	-4.82	316
$F_{40} = G/(78.3896 + 0.13294 \times G + 0.003268 \times G^2)$	0.93	0.03	-3.98	312
$F_{45} = G/(113.5499 - 0.2076 \times G + 0.004779 \times G^2)$	0.89	0.04	-3.53	308

Where, F_{ub}, F_{30}, F_{35}, F_{40} and F_{45} are conversion factor to estimate total under bark volume, volumes upto 30 cm top end girth, 35 cm top end girth, 40 cm top end girth and 45 cm top end girth respectively from total volume over bark volume.

Model validation

The statistical requirement to best fitted models by considering those equations having the highest R^2 with lowest RMSE, Akaike Information Criterion (*AIC*) were tested. Results were presented in Table 4 and 5.

Independent test

The best suited volume equations for one way and two way were tested with a set of data recollected from 30 trees of different girth class and complied in the same procedure as earlier. The actual volumes of these trees were collectively compared with the corresponding volume predicted by the selected models. The independent tests for validation were the chi-square test, paired t-test, absolute deviation percent (%AD) and 45 degree line test (Islam *et al*. 1992 and Latif and Islam, 2001).

The computed chi-square, t-values, absolute deviation percent and slope (45-dergee line test) of studied tree species are given Table 6.

Table 6: Result of independent test for predicted volume equations of *L. speciosa*

Model Types	***Chi***	***t***	***%AD***	***Slope^o***
One way	0.35	1.02	3.0	44.1
Two way	0.14	1.71	3.4	44.0

Model comparison

The total volume best-fit model showed lowest (−1.603%) MPE and RMSE (6.42%) and highest ME (0.986 close to the reference value 1) compared to the local volume models of Drigo *et al*. (1988) (Table 7). The graphical presentation from 1:1 line indicated that the best-fit volume model was capable to estimate the total volume more accurately. While locally used Drigo *et al*. (1988) model underestimated the total volume for *L. speciosa* compared to the derived best-fit total volume model in this study (Fig. 1).

Table 7: Comparison of best-fit total volume model with the Drigo *et al*. (1988) model

Source	Type	MPE (%)	ME	MSE (%)
Best Fit Model	Nationally (This study)	-1.603	0.986	6.422
Drigo *et al.* (1988)	Locally in Southern Sylhet	1.602	0.979	7.773

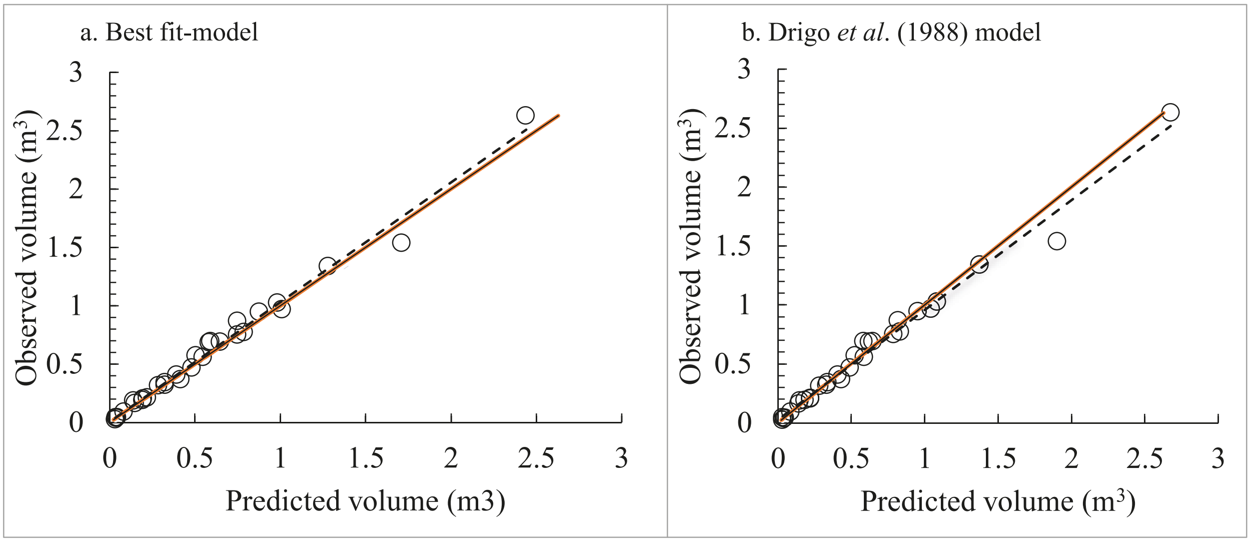

Figure 1: Comparison of best-fit total volume model with Drigo *et al*. (1988) volume model

We have estimated volumes and conversion factors for ready use and are presented in Table 8 and 9. The volume equations and tables are applicable for jarul growing in the different forest areas of Bangladesh.

Table 8: One and Two way volume table for *L. speciosa* grown in Bangladesh

GBH (cm)	One Way	Two-way											
		Height in meter											
		6	8	10	12	14	16	18	20	22	24	26	28
30	0.029	0.024	0.031	0.038	0.045	0.051	0.057	0.064	0.070	0.076	0.082	0.088	0.094
32	0.034	0.027	0.035	0.043	0.050	0.058	0.065	0.072	0.079	0.085	0.092	0.099	0.106
34	0.040	0.031	0.040	0.048	0.056	0.064	0.072	0.080	0.088	0.096	0.103	0.111	0.118
36	0.046	0.034	0.044	0.053	0.063	0.072	0.081	0.089	0.098	0.107	0.115	0.123	0.132
38	0.053	0.038	0.049	0.059	0.069	0.079	0.089	0.099	0.108	0.118	0.127	0.136	0.146
40	0.060	0.042	0.054	0.065	0.076	0.087	0.098	0.109	0.119	0.130	0.140	0.150	0.160
42	0.068	0.046	0.059	0.071	0.084	0.096	0.108	0.119	0.131	0.142	0.153	0.165	0.176
44	0.076	0.050	0.064	0.078	0.091	0.104	0.117	0.130	0.143	0.155	0.167	0.180	0.192
46	0.085	0.054	0.070	0.085	0.099	0.114	0.128	0.141	0.155	0.169	0.182	0.195	0.208
48	0.094	0.059	0.075	0.092	0.107	0.123	0.138	0.153	0.168	0.183	0.197	0.211	0.225

GBH (cm)	One Way	Two-way Height in meter											
		6	8	10	12	14	16	18	20	22	24	26	28
50	0.105	0.063	0.081	0.099	0.116	0.133	0.149	0.165	0.181	0.197	0.213	0.228	0.243
52	0.116	0.068	0.088	0.106	0.125	0.143	0.161	0.178	0.195	0.212	0.229	0.245	0.262
54	0.127	0.073	0.094	0.114	0.134	0.153	0.172	0.191	0.209	0.228	0.246	0.263	0.281
56	0.139	0.078	0.101	0.122	0.143	0.164	0.184	0.204	0.224	0.244	0.263	0.282	0.301
58	0.152	0.084	0.107	0.131	0.153	0.175	0.197	0.218	0.239	0.260	0.281	0.301	0.321
60	0.166	0.089	0.114	0.139	0.163	0.187	0.210	0.233	0.255	0.277	0.299	0.321	0.342
62	0.180	0.095	0.122	0.148	0.174	0.199	0.223	0.247	0.271	0.295	0.318	0.341	0.364
64	0.195	0.100	0.129	0.157	0.184	0.211	0.237	0.263	0.288	0.313	0.338	0.362	0.386
66	0.210	0.106	0.137	0.166	0.195	0.223	0.251	0.278	0.305	0.331	0.358	0.384	0.409
68	0.227	0.113	0.145	0.176	0.206	0.236	0.265	0.294	0.322	0.351	0.378	0.406	0.433
70	0.244	0.119	0.153	0.186	0.218	0.249	0.280	0.310	0.340	0.370	0.399	0.428	0.457
72	0.262	0.125	0.161	0.196	0.230	0.263	0.295	0.327	0.359	0.390	0.421	0.451	0.482
74	0.280	0.132	0.170	0.206	0.242	0.277	0.311	0.345	0.378	0.411	0.443	0.475	0.507
76	0.300	0.139	0.178	0.217	0.254	0.291	0.327	0.362	0.397	0.432	0.466	0.500	0.533
78	0.320	0.145	0.187	0.227	0.267	0.305	0.343	0.380	0.417	0.453	0.489	0.524	0.560
80	0.341	0.153	0.196	0.238	0.280	0.320	0.360	0.399	0.437	0.475	0.513	0.550	0.587
82	0.363	0.160	0.205	0.250	0.293	0.335	0.377	0.418	0.458	0.498	0.537	0.576	0.614
84	0.385	0.167	0.215	0.261	0.306	0.351	0.394	0.437	0.479	0.521	0.562	0.603	0.643
86	0.409	0.175	0.225	0.273	0.320	0.366	0.412	0.457	0.501	0.544	0.587	0.630	0.672
88	0.433	0.182	0.235	0.285	0.334	0.383	0.430	0.477	0.523	0.568	0.613	0.657	0.701
90	0.458	0.190	0.245	0.297	0.349	0.399	0.448	0.497	0.545	0.592	0.639	0.686	0.731
92	0.484	0.198	0.255	0.310	0.363	0.416	0.467	0.518	0.568	0.617	0.666	0.714	0.762
94	0.511	0.206	0.265	0.323	0.378	0.433	0.486	0.539	0.591	0.643	0.693	0.744	0.794
96	0.539	0.215	0.276	0.335	0.393	0.450	0.506	0.561	0.615	0.669	0.721	0.774	0.825
98	0.567	0.223	0.287	0.349	0.409	0.468	0.526	0.583	0.639	0.695	0.750	0.804	0.858
100	0.597	0.232	0.298	0.362	0.425	0.486	0.546	0.605	0.664	0.722	0.779	0.835	0.891
102	0.627	0.240	0.309	0.376	0.441	0.504	0.567	0.628	0.689	0.749	0.808	0.867	0.925
104	0.659	0.249	0.321	0.390	0.457	0.523	0.588	0.652	0.714	0.777	0.838	0.899	0.959
106	0.691	0.258	0.332	0.404	0.474	0.542	0.609	0.675	0.740	0.805	0.868	0.931	0.994
108	0.724	0.268	0.344	0.418	0.491	0.561	0.631	0.699	0.767	0.833	0.899	0.965	1.029
110	0.758	0.277	0.356	0.433	0.508	0.581	0.653	0.724	0.794	0.863	0.931	0.998	1.065
112	0.794	0.286	0.368	0.448	0.525	0.601	0.675	0.749	0.821	0.892	0.963	1.033	1.102
114	0.830	0.296	0.381	0.463	0.543	0.621	0.698	0.774	0.849	0.922	0.995	1.067	1.139
116	0.867	0.306	0.393	0.478	0.561	0.642	0.721	0.799	0.877	0.953	1.028	1.103	1.176
118	0.905	0.316	0.406	0.494	0.579	0.663	0.745	0.825	0.905	0.984	1.062	1.139	1.215
120	0.944	0.326	0.419	0.509	0.598	0.684	0.768	0.852	0.934	1.015	1.095	1.175	1.254
122	0.984	0.336	0.432	0.525	0.616	0.705	0.793	0.879	0.963	1.047	1.130	1.212	1.293
124	1.025	0.347	0.446	0.542	0.635	0.727	0.817	0.906	0.993	1.080	1.165	1.249	1.333
126	1.067	0.357	0.459	0.558	0.655	0.749	0.842	0.933	1.023	1.112	1.200	1.287	1.373
128	1.110	0.368	0.473	0.575	0.674	0.772	0.867	0.961	1.054	1.146	1.236	1.326	1.415
130	1.154	0.379	0.487	0.592	0.694	0.794	0.893	0.990	1.085	1.179	1.273	1.365	1.456
132	1.199	0.390	0.501	0.609	0.714	0.817	0.919	1.018	1.117	1.214	1.310	1.404	1.498

GBH (cm)	One Way	Two-way Height in meter											
		6	8	10	12	14	16	18	20	22	24	26	28
134	1.245	0.401	0.515	0.626	0.735	0.841	0.945	1.047	1.148	1.248	1.347	1.445	1.541
136	1.292	0.412	0.530	0.644	0.755	0.864	0.971	1.077	1.181	1.283	1.385	1.485	1.585
138	1.340	0.423	0.545	0.662	0.776	0.888	0.998	1.107	1.213	1.319	1.423	1.526	1.629
140	1.390	0.435	0.559	0.680	0.797	0.913	1.026	1.137	1.247	1.355	1.462	1.568	1.673
142	1.440	0.447	0.574	0.698	0.819	0.937	1.053	1.167	1.280	1.391	1.501	1.610	1.718
144	1.492	0.459	0.590	0.717	0.841	0.962	1.081	1.198	1.314	1.428	1.541	1.653	1.764
146	1.544	0.471	0.605	0.736	0.863	0.987	1.109	1.230	1.348	1.466	1.582	1.696	1.810
148	1.598	0.483	0.621	0.755	0.885	1.013	1.138	1.262	1.383	1.503	1.622	1.740	1.856
150	1.653	0.495	0.637	0.774	0.907	1.038	1.167	1.294	1.418	1.542	1.664	1.784	1.904
152	1.709	0.507	0.653	0.793	0.930	1.064	1.196	1.326	1.454	1.580	1.705	1.829	1.952
154	1.766	0.520	0.669	0.813	0.953	1.091	1.226	1.359	1.490	1.620	1.748	1.874	2.000
156	1.824	0.533	0.685	0.833	0.977	1.118	1.256	1.392	1.527	1.659	1.790	1.920	2.049
158	1.883	0.546	0.702	0.853	1.000	1.145	1.286	1.426	1.563	1.699	1.834	1.967	2.098
160	1.944	0.559	0.718	0.873	1.024	1.172	1.317	1.460	1.601	1.740	1.877	2.013	2.148
162	2.005	0.572	0.735	0.894	1.048	1.199	1.348	1.494	1.638	1.781	1.922	2.061	2.199
164	2.068	0.585	0.752	0.914	1.072	1.227	1.379	1.529	1.676	1.822	1.966	2.109	2.250
166	2.132	0.598	0.770	0.935	1.097	1.255	1.411	1.564	1.715	1.864	2.011	2.157	2.302
168	2.197	0.612	0.787	0.957	1.122	1.284	1.443	1.599	1.754	1.906	2.057	2.206	2.354
170	2.263	0.626	0.805	0.978	1.147	1.313	1.475	1.635	1.793	1.949	2.103	2.255	2.406
172	2.331	0.640	0.822	1.000	1.173	1.342	1.508	1.671	1.833	1.992	2.150	2.305	2.460
174	2.399	0.654	0.840	1.022	1.198	1.371	1.541	1.708	1.873	2.036	2.197	2.356	2.514
176	2.469	0.668	0.859	1.044	1.224	1.401	1.574	1.745	1.913	2.080	2.244	2.407	2.568
178	2.540	0.682	0.877	1.066	1.250	1.431	1.608	1.782	1.954	2.124	2.292	2.458	2.623

Table 9: Conversion factors to estimate the under bark volumes and different top end girth for *L. speciosa* grown in Bangladesh

GBH (cm)	Conversion factor				
	F_{ub}	F_{30}	F_{35}	F_{40}	F_{45}
30	0.913	0.646	0.407	0.352	0.269
32	0.919	0.667	0.429	0.372	0.286
34	0.923	0.687	0.451	0.392	0.304
36	0.927	0.705	0.472	0.412	0.321
38	0.931	0.722	0.492	0.431	0.338
40	0.934	0.739	0.512	0.450	0.354
42	0.937	0.754	0.532	0.468	0.371
44	0.940	0.768	0.550	0.486	0.387

GBH (cm)	Conversion factor				
	F_{ub}	F_{30}	F_{35}	F_{40}	F_{45}
46	0.942	0.781	0.569	0.503	0.403
48	0.944	0.794	0.586	0.520	0.419
50	0.947	0.805	0.603	0.536	0.434
52	0.948	0.816	0.619	0.552	0.450
54	0.950	0.827	0.635	0.568	0.464
56	0.952	0.836	0.650	0.583	0.479
58	0.953	0.846	0.665	0.597	0.493
60	0.955	0.854	0.679	0.611	0.507
62	0.956	0.862	0.693	0.625	0.521
64	0.957	0.870	0.706	0.638	0.534
66	0.958	0.877	0.718	0.651	0.547
68	0.959	0.884	0.731	0.663	0.560
70	0.960	0.890	0.742	0.675	0.572
72	0.961	0.896	0.753	0.686	0.584
74	0.962	0.902	0.764	0.697	0.595
76	0.963	0.907	0.774	0.708	0.606
78	0.964	0.912	0.784	0.718	0.617
80	0.965	0.917	0.793	0.728	0.627
82	0.965	0.922	0.802	0.737	0.637
84	0.966	0.926	0.810	0.746	0.647
86	0.966	0.930	0.819	0.754	0.656
88	0.967	0.933	0.826	0.763	0.665
90	0.968	0.937	0.834	0.770	0.674
92	0.968	0.940	0.840	0.778	0.682
94	0.969	0.943	0.847	0.785	0.690
96	0.969	0.946	0.853	0.792	0.697
98	0.969	0.949	0.859	0.798	0.705
100	0.970	0.951	0.865	0.804	0.711
102	0.970	0.954	0.870	0.810	0.718
104	0.971	0.956	0.875	0.815	0.724
106	0.971	0.958	0.879	0.820	0.730
108	0.971	0.960	0.884	0.825	0.735
110	0.972	0.961	0.888	0.830	0.741
112	0.972	0.963	0.892	0.834	0.745
114	0.972	0.965	0.895	0.838	0.750
116	0.972	0.966	0.899	0.842	0.754
118	0.973	0.967	0.902	0.845	0.758
120	0.973	0.968	0.904	0.849	0.762

GBH (cm)	Conversion factor				
	F_{ub}	F_{30}	F_{35}	F_{40}	F_{45}
122	0.973	0.969	0.907	0.852	0.766
124	0.973	0.970	0.909	0.854	0.769
126	0.973	0.971	0.911	0.857	0.772
128	0.974	0.972	0.913	0.859	0.774
130	0.974	0.973	0.915	0.861	0.777
132	0.974	0.973	0.917	0.863	0.779
134	0.974	0.974	0.918	0.865	0.781
136	0.974	0.974	0.919	0.867	0.783
138	0.974	0.974	0.920	0.868	0.784
140	0.974	0.975	0.921	0.869	0.786
142	0.975	0.975	0.922	0.870	0.787
144	0.975	0.975	0.922	0.871	0.788
146	0.975	0.975	0.923	0.872	0.788
148	0.975	0.975	0.923	0.872	0.788
150	0.975	0.975	0.923	0.872	0.788
152	0.975	0.975	0.923	0.872	0.788
154	0.975	0.975	0.923	0.872	0.788
156	0.975	0.975	0.923	0.872	0.788
158	0.975	0.975	0.922	0.872	0.788
160	0.975	0.974	0.922	0.872	0.788
162	0.975	0.974	0.922	0.872	0.788
164	0.975	0.973	0.922	0.872	0.788
166	0.975	0.973	0.922	0.872	0.788
168	0.975	0.973	0.922	0.872	0.788
170	0.975	0.973	0.922	0.872	0.788
172	0.975	0.973	0.922	0.872	0.788
174	0.975	0.973	0.922	0.872	0.788
176	0.975	0.973	0.922	0.872	0.788
178	0.975	0.973	0.922	0.872	0.788

Discussion

In the present study, simple linear as well as non-linear models were tested. The use of volume equations to estimate yield in future studies may offer better estimates whilst avoiding destructive sampling (Nunifu and Murchinson 1999). Useful models must be based on easily and cheaply measured tree parameters (Phillips 1995) and ease of operation is an important consideration in the use of volume tables (Perez and Kanninen 2003).

This study selected two volume equations (one and two way) from 21 individual models for jarul grown in Bangladesh. The volume equations predict the total volume over bark and conversion factor equations to predict total volume under bark, under bark volume of different top end girth of 30, 35, 40 and 45 cm from total volume over bark. The data covers different climate regions around the country, represents different types of stands growing on different soil types and thus covers most of the site conditions suitable for forestry in Bangladesh. Regarding the sample trees within these were measured at different girth classes and used in this study. The descriptive statistics of dependent variable (volume) and independent variables (GBH and height) are represented in Table 3 which are performed to develop one way and two way volume equation of *L.speciosa.*

The volume equations were transformed to a logarithmic form, a common procedure to obtain constant variance of the residuals. Volume function [9] for one way [20] for two way which had GBH and H as independent variables gave the best results based on fit and validation statistics and was most suitable according to residual analyses and model comparison for the studies tree species. Fit statistics of each of the equations for each species showed in Table 4. The R^2 values were generally high and acceptable for the equations while *RMSE* values were very low. In this table also shows that *AIC* values are low which are closed to zero. The coefficients of determination for selected one way volume equations is 0.96 and two way volume equations is 0.98. This means that the selected one way models describe over 96% and two way models describe 98% for jarul of the total variations. The best fitted models were selected for estimation of volume on GBH and total height. Islam *et al*. (2012) confirmed the suitability of this two models for estimating total volume of *Albizia richardiana* King and Prain planted in the Southern Part of Bangladesh. The combined variable equation (equation [20]) showed more precision in the estimate as evinced by the values of absolute mean residual, root mean squared error, model efficiency and variance ratio (Table 4) and, hence, was considered the better option for volume prediction. Needless to mention that the combined variable equation, has been well recognised in volume predictions of many tree species with R^2 usually above 95% (Avery and Burkhart 2002). The models were fitted using the method of least squares. Logarithmic volume equations have the advantage of more nearly satisfying the homogeneity of variance assumption of ordinary regression but suffer from the disadvantage that a transformation bias is introduced (Avery and Burkhart 2002).

These volume tables should not be used to estimate volumes of individual trees in a stand. These tables may be used for the mean tree of a stand which may be multiplied by the number of stem to get the total volume of the stand. Estimation of volumes for the trees much outside the height and GBH ranges shown in the stand table should only be done with caution.

The predictive ability of the different equations was assessed using an independent data set (validating data set) for model validation. The volume equations obtained from the fitting data set were applied to the validating data set. The independent tests for validation were the chi-square test, paired t-test, absolute deviation percent (%AD) and 45 degree line test discussed as follows: The computed chi-square values of total volume over bark represented in Table 6 were less than the tabular values $\chi^2_{0.95,29}$=17.71. This implies that there is no significant difference between the actual values from the 30 test sample trees and the corresponding expected values as predicted by the selected models. The result of pared t-test for total volume over bark of studied tree species grown in Bangladesh are given in Table 6 computed t-ratio for all the estimation were less than the tabular values $t_{0.95,29}$=2.045. These imply that there were no significant differences between the observed and predicted values. Thus the prediction models might be accepted. Absolute deviation percent (%AD) between the observed and predicted values for total volume over bark with diameter at breast height and DBH and height for this study species was minimum, which also confirmed validity of the selected models. Graphs comparing the observed values and the predicted values were plotted in the graph paper. The observed values and the predicted values yielded slops very closed to 45 degrees, which have been presented in Table 6. It was observed that the models tend to make an angle 45 degrees with the axes, meaning there were no significant difference between the actual and the predicted values.

The use of Drigo *et al*. (1988) model is estimate local total volume of *L. speciosa* in southern Sylhet which produce variation in volume estimation. The best-fit total volume model of *L. speciosa* has shown a variation in estimating total volume compared to Drigo *et al*. (1988) model. However, the graphical presentation of 1:1 line indicated that our best-fit total volume model is capable to estimate total volume more accurately than other model in comparison (Fig. 1). The variation in estimated volume may be due to the differences in tree species, climatic conditions, site conditions, forest types with its composition and management practices which ultimately influence the architecture of tree and volume partitioning (Hossain *et al*. 2016).

Conclusion

The present study was to develop total tree volume models for *L. speciosa* in Bangladesh based on nondestructive sampling. Although the data were collected from a specific region, and plantation also natural, the volume models constructed can be expected to give a satisfactory estimate for the aggregate standing volume of natural and planted *L. speciosa* stands in Bangladesh. The results showed combined variable equation (model 20) performed well in both the fitting and validation process. Therefore, the developed models in this study are capable to predict total volume for *L. speciosa* in the study area at a higher accuracy. The contrasting results obtained between model fitting and validation emphasise the need for model validation as an important in the model construction process in order to get the best choices. But as with all volume equations, a test of applicability is always necessary if used outside the range of data and/or under other conditions.

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Influence of Pre-sowing Treatments on Seed Germination and Seedling Growth of *Calamus latifolius* Roxb. – an Important Rattan Species of Bangladesh

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Abstract

The paper deals with seed germination behavior and seedling growth performance of *Calamus latifolius* Roxb; with 5 pre-sowing treatments in the nursery and field conditions. The pre-treatments of seeds were i) seeds soaked in tap water for 24 hours, ii) soaked in tap water for 48 hours iii) soaked in 20% H_2SO_4 for 10 minutes iv) scarification with wire net and v) control (Seeds were sown without any treatment). Pre-treated seeds were sown in the seed bed filled with soil and decomposed cow dung at 3:1 ratio. The growth performance of the seedlings were determined by transferring 30-35 days old seedlings (having 2-3 leaves) from germination bed to the polybags filled with soil and decomposed cow dung media. Plantation in the field was made with one year old seedling. Germination percentage significantly ($p \leq 0.05$) enhanced with pre-sowing treatments and maximum germination percentage (70) was recorded in seed scarified by wire net and the lowest (44%) was in control. Growth performance was also influenced by pre-sowing treatments in the nursery and highest (1008) vigor index was found in seed scarified by wire net and lowest (475) in control. Seedlings survival percentage was over 92% after one year of plantation in the field. Average height was recorded 123.1 cm after two years of planting. Thus, seeds scarified by wire net can be suggested for nursery raising and one-year old seedlings may be out planted at 2m ×2m spacing for successful plantations of the species.

mvims‡¶c

বর্ণিত প্রবন্ধে পাঁচটি প্রি- ট্রিটমেন্ট প্রয়োগে *Calamus latifolius* Roxb. এর বীজের অঙ্কুরোদগমের হার নির্ণয়, নার্সারি ও মাঠে চারার বৃদ্ধি পর্যবেক্ষণ করা হয়। ট্রিটমেন্টগুলো হলো ১) নরমাল ট্যাপের পানিতে ২৪ ঘন্টা ভেজানো ২) নরমাল ট্যাপের পানিতে ৪৮ ঘন্টা ভেজানো ৩) ২০% H_2SO_4 এ ১০ মিনিট ভেজানো ৪) তার জালি দিয়ে স্কেরিফিকেশন ও ৫) কন্ট্রোল (ট্রিটমেন্ট বিহীন)। মাটি ও গোবর ৩:১ অনুপাতে মেশানো বেডে প্রি-ট্রিটেড বীজ বপন করা হয়। ৩০-৩৫ দিন বয়সের চারা (২-৩ টি পাতাযুক্ত) সীডবেড থেকে পলিব্যাগে স্থানান্তর করে বৃদ্ধি সংক্রান্ত তথ্য সংগ্রহ করা হয় এবং এক বছর বয়সী চারা মাঠে লাগিয়ে বৃদ্ধি পর্যবেক্ষণ করা হয়। *Calamus latifolius* এর অঙ্কুরোদগমের উপর প্রি-ট্রিটমেন্টের প্রভাব ($p \leq 0.05$) তাৎপর্যপূর্ণ। প্রাপ্ত ফলাফলে দেখা যায় যে, তার জালির সাহায্যে স্কেরিফাইড (scarified) বীজের অংকুরোদগম হার সর্বোচ্চ (৭০%) এবং কন্ট্রোলের ক্ষেত্রে সর্বনিম্ন (৪৪%)। চারার বৃদ্ধির উপরও প্রি-ট্রিটমেন্টের প্রভাব দেখা যায়, তার জালি দিয়ে স্কেরিফিকেশনকৃত বীজে সবচাইতে বেশি ভিগর ইনডেকস (১০০৮) পাওয়া যায় এবং সবচাইতে কম ভিগর ইনডেকস (৪৭৫) পাওয়া যায় কন্ট্রোল বীজের ক্ষেত্রে। মাঠে লাগানোর এক বছর পর চারার বাঁচন হার ৯২% এবং দুই বছর পর গড় উচ্চতা ১২৩.১ সে.মি.। অতএব পর্যবেক্ষণ হতে প্রতীয়মান হয় যে, *Calamus latifolius* Roxb. এর নার্সারি উত্তোলনের জন্য তার জালি দ্বারা স্কেরিফাইডকৃত বীজ বপন সবচেয়ে ভাল এবং সফল বাগান উত্তোলনের জন্য এক বছর বয়সী চারা ২ মি. x ২ মি.দূরত্বে লাগানো যেতে পারে।

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Keywords: *Calamus latifolius,* Scarified seeds, Germination percentage, Survival potential, Pre-sowing treatment, Seedling growth.

Introduction

Rattan is a spiny climbing palm belonging to the family Arecaceae (Moore 1973; Charles 2014) and comprises an integral part of the tropical forest ecosystem (Moore 1973). Rattans are second most important non timber forest products after bamboo in the tropical and sub-tropical countries of Asia and Africa (Uhl and Dransfield 1987; Sunderland 2002; Ogunwusi 2012; Haider *et al*. 2014; Wan *et al*. 2018). It has gained additional interest among the people because of increased awareness as well as their vital roles in socioeconomic development and socio-ecological research issues (Nagabatla *et al*. 2007). Rattans are important sources of income and employment for millions of people all over the world directly or indirectly (Manokaran 1990; ITTO 1997; Ogunwusi 2012; Renuka *et al*.1998).

Six hundred species of rattans under 13 genera were recorded in the world earlier (Renuka *et al*. 1998). However recent report shows existence of only 550 species (Dransfield *et al*. 2008). Out of these, 15 species were recorded so far in Bangladesh (Wong 1984; Alam 1990, 1991; Basu 1991, 1992; Ali 2003). However, recent investigation provided a list of 10 species under two genera growing in the country (Ara 2008; 2011). This rattan resource has been exhausted recklessly in recent years due to over exploitation and poor management (Siddiqi 1995). Moreover, steady loss of forest habitat due to urbanization and industrialization is also posing a serious threat to rattan supply. High demand for these resources, along with unabated harvesting and deforestation, has led the resources towards the depletion in many rattan-producing areas (Supardi *et al*. 1999). To cope up with ever increasing global demand, there is an imperative need for sustainable management of rattan resources. To achieve this goal, immediate attention is needed for establishing rattan plantations and also proper management of existing rattans in their natural habitats. Establishing rattan plantation requires appropriate knowledge about nursery development, plantation raising and stand management for sustainable development (Siddiqi 1995).

Calamus latifolius locally known as budum bet, occurs naturally in the dry hill slopes with sandy loam soil of evergreen forests of Chittagong, Chittagong Hill Tracts, Cox's Bazar, Sylhet and Gazipur district in Bangladesh (Alam 1990; Ara 2008). The species is found in robust clustering to form dense clumps, erect for climbing where support tree is available (Fig. 1). Leaves cirrate, 3 – 5 m long including petiole and cirrus; leaf sheath with prominent knee, armed with subulate, sub-regularly verticillate, dark brown, 3 cm long spines; ocrea liguliform; rachis terete in cross section, without claws on the ventral side, armed only with small spicules; leaflets not many, papery, in equidistant on rachis, broadly lanceolate or elliptic-lanceolate, slightly concavo-convex, to 50 cm long, 10 cm wide at broadest part, 5-7 nerved; nerves smooth on both sides. Fruit sessile, fruiting calyx broadly campanulate, about 12 cm. long. Seed almost half convex, grooved and regularly wrinkled. Flowering occurs in November to December and fruiting in May to June.

Figure 1. Leading shoot and spiny stem of *Calamus latifolius*

It is mainly used for making rough baskets, walking sticks, batons and furniture frames; split canes for weaving chair bottoms. With depletion of rattan resources *C. latifolius* is also depleted all over the country and hardly found in the natural condition in forests. To ensure sustainable development and continuous supply of rattans, several initiatives have already been taken to increase the rattan plantations and the overall production by involving the government, non-government and other agencies in the country. For the purpose sound knowledge on nursery raising and plantation development, updated techniques and management systems are required for the species.

Rattan research in Bangladesh was initiated about four decades back and considerable information relating to germination and nursery techniques for selected rattan species are available (Banik and Nabi 1979, Alim and Kalimuddin 1985, Mohiuddin *et al*. 1986, Rashid *et al*. 1993, and Ara *et al*. 1994, Haider *et al*. 2014). Rattan propagation largely depends on seed germination, wildings, suckers and tissue cultured materials for plantation. Among them, seedlings from seeds are the most important propagating materials for large-scale plantations program of rattan (Tan 1942 and Mohd *et al*. 1992). Variations has been seen in germination percentage and germination period of different rattan species. The seed viability after collection may affect the germination period and percentage. Moreover, hard seed coat in association with possible seed dormancy requires longer period to germinate in most of the species of rattan (Rashid and Mohiuddin 1988). Pre-sowing treatments, especially, removal of fleshy pulp or scales from the intact fruits has been reported to influence the seed germination and seedling growth performance in many tropical tree species. For instance, depulping of fruits and soaking of the seeds in water for 48 hours enhanced the seed germination and seedling growth of Terminalia bellerica (Ara *et al*. 1997, Hossain *et al*. 2005a), *T. chebula* (Nainar *et al*. 1999, Hossain *et al*. 2013) and Grevillea robusta (Anonymous 2000). The effect of pre-sowing treatments on seed germination process of some tropical forest tree species has been reported by a number of authors (Alamgir and Hossain 2005, Matin *et al*. 2006, Azad *et al*.

2011, 2012; Haider *et al*. 2014, 2016). There are some reports on pre-sowing treatment and germination of some rattan species. For example, pre-treatment of *Daemonorops jenkinsiana* clean seeds with 10% H_2SO_4 or HCl enhanced seed germination by 68.14% with both the treatments (Ara *et al*. 1994). Haider *et al*. (2014) reported that depulped clean seed of *C. longisetus* enhanced the seed germination by 73.3%. However, information about the regeneration of *C. latifolius* with seed treatments is very scarce. Further research related to the nursery raising techniques including seed germination, pre-sowing treatments and initial seedling growth performance of this species is therefore required with an ultimate objective of raising successful rattan plantation. Therefore, the present study was undertaken to investigate the effects of pre-sowing treatments on seed germination and seedling growth performance of *C. latifolius* in nursery and field condition.

Materials and Methods

The research was carried out in the nursery of Bangladesh Forest Research Institute (BFRI), Chattogram, Bangladesh, over a period of four years from June 2014 to June 2017. The study area was located between 22°22·27′′ and 22°29·0′′ North latitude and 91°46·30′′ and 91°46·30′′ East longitude having a tropical climate, characterized by hot humid summer and cool dry winter. The maximum and minimum temperature in the area is 28.3 - 31.9°C and 15.2 - 25.2°C (Hossain and Arefin 2012). Relative humidity is usually low in winter (November - February) and high in summer (June - September). Mean annual rainfall is around 3000 mm mainly occurring from June to September.

Seed collection and pre-sowing treatments

Ripe fruits of *C. latifolius* were collected from Salna seed orchard center, under Gazipur district of Bangladesh in the first week of June 2014. To determine the effect of pre-sowing treatment on seed germination and seedling growth performance, five different treatments of seeds were applied namely; i) seeds soaked in tap water for 24 h, ii) soaked in tap water for 48 h iii) soaked in 20% H_2SO_4 for 10 minutes iv) scarification by wire net and v) control (seeds were sown without any treatment). Seeds were cleaned by removing the scale and pulp by rubbing (Fig. 2). The number of whole fruits and cleaned seeds per kg were 600 - 650 and 1200-1400, respectively. Then the seeds were sown in seed bed prepared with soil and decomposed cow dung mixed at a ratio of 3:1 by volume. Randomized Complete Block Design (RCBD) was adopted for the experiment with three replications. One hundred fifty (150) seeds were sown in each treatment at the rate of 50 seeds in each replication and a total of 750 seeds were required for five treatments of the germination trial.

(A) (B)

Figure 2. Whole fruits (A) and clean seeds (B) of *C. latifolius*

Assessment of seed germination and seedling growth performance

The effects of pre-sowing treatments on seed germination and seedling growth performance were recorded periodically by counting the germinated seeds and assessing initial growth performance of the seedlings. Cumulative germination was recorded at three days interval from the day of sowing and continued till completion of germination. Germination phase was determined by counting the number of days required for the commencement of germination and germination period is the number of days required for completion of germination from sowing the seeds. For assessing the growth performance, height of all seedlings were measured, and number of leaves counted at one month age of seedlings. Besides these ten seedlings from each replicate (30 from each treatment) were randomly uprooted and measured for total length (root length and shoot length separately). Seedling vigor index (VI) was calculated according to Abdul-Baki and Anderson (1973) through multiplying the germination percent by total length of seedlings (i.e. sum of shoot and root length).

Assessment of seedling growth performance in the nursery and the field

Since, seed germination percentage and initial growth performance of seedlings was highest in the seeds scarified with wire net in the previous experiment, only the scarified *C. latifolius* seeds were sown for assessing the seedling growth performances in the nursery and field. Three thousand scarified seeds were sown in three blocks (considered as replications) in nursery bed for the purpose. When the seedlings were about one month old (with 2 - 3 leaves), they were transferred in to the polybags (23 cm x 15 cm) filled with soil and cow dung mixture. The polybags were kept under full shade for one week and then placed under direct sunlight where they were allowed to grow. When the seedlings were about one-year old, 500 seedlings were out planted in five plots in the field at the beginning of the monsoon, e.g. June. Another 500 seedlings were allowed to grow in the nursery for one more year. Data on shoot and root length and leaf number of these seedlings were recorded at 3, 6, 12 and 24 months after transferring them in polybags. Seedlings in the field were planted at 2 m × 2 m spacing at Hinguli Research Station, Chattogram, Bangladesh. The soil was sandy-loam with a pH 5.7- 6.0. Average rainfall of the area was about 3200 mm and average maximum and minimum temperature was 34.7°C and 20.7°C respectively, indicating the suitable eco-physiological conditions for rattan plantations (Xu 1985). Weeding were done at every 3 months in the field. However, no fertilizer or water was added after planting. Data on height of all plants in each plot were recorded at 6, 12 and 24 months after planting. Survival percentage of the planted seedling in the field was determined 1 year after planting.

Data analysis

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

Results

Seed germination and initial growth performance of the seedlings

Pre-sowing treatments were found to influence the germination period and germination percentage of *C. latifolius* seeds significantly. The seeds scarified by wire net showed the maximum germination (70%) within 54-74 days after sowing (DAS). Seeds soaked in 20% H_2SO_4 for 10 minutes showed 50% germination within 60-80 DAS. Seeds soaked in tap water for 24 and 48 hours showed 46% and 48% germination within the 62-88 and 60-84 DAS respectively. The lowest (44%) germination was recorded for control within 62-90 days (Fig 3 A, B). Germination percentage in seeds scarified by wire net was found significantly ($p \leq 0.05$) higher than the other treatments. However, no significant variation was observed among the seeds treated with 20% H_2SO_4 for 10 minutes and seeds soaked in tap water for 24 and 48 hours.

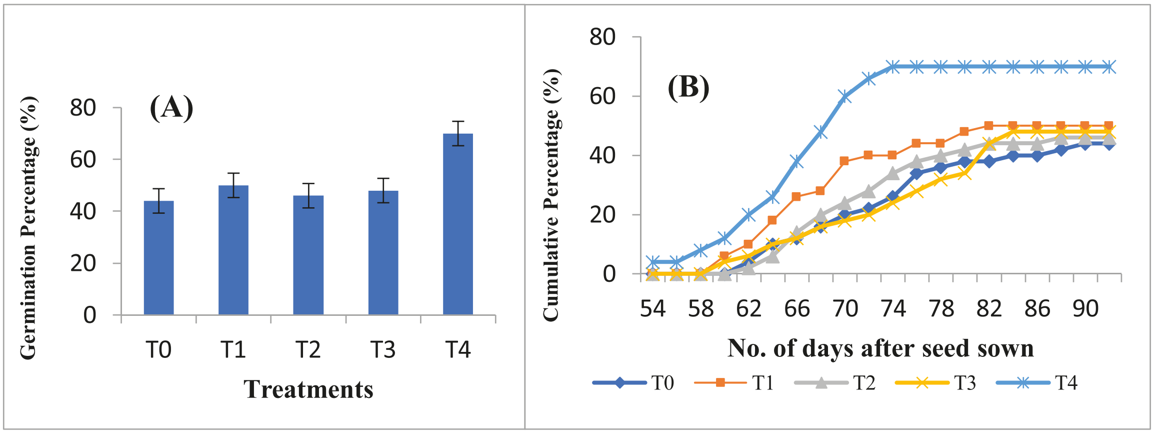

Figure 3. Germination percentage (%) of *C. latifolius* (A) and trend lines showing progress of germination under different treatments (B).

[Note: T0= control, T1= Soaked in 20% H2So4 for 10 minutes, T2= Soaked in tap water 24 h, T3= Soaked in tap water 48 hours, T4= Scarification by wire net].

The initial growth performance of the *C. latifolius* seedlings was also significantly influenced by the pre-sowing treatment of the seeds. The shoot length (from base to leaf tip), root length, leaves number and vigor index are shown in Table 1. The highest length of shoot (8.40 cm) and root (6.0 cm) and vigor index (1008) was found in the seeds scarified by wire net, which values were much higher than that of other treatment. However, there was no significant variation in the leaf number among the treatments.

Table 1. Growth performance of *C. latifolius* seedlings germinated from various treatment one months after germination

Treatments	**Growth parameters**			
	Ave. shoot length (cm)	**Ave. root length (cm)**	**Ave. no. of leaves per seedlings**	**Vigor index**
Soaked in tap water for 24 h	6.80± 0.20 ^{bc}	4.60± 0.24 ^{b}	2.00± 0. 00 ^{a}	524.4 ^{cd}
Soaked in tap water for 48 h	7.20± 0.20 ^{bc}	4.60± 0.24 ^{b}	2.00± 0. 00 ^{a}	566.4 ^{c}
Soaked in 20% H_2So_4 for 10 minutes	7.80± 0.37 ^{ab}	5.40± 0. 24^{ab}	2.00± 0.00 ^{a}	660 ^{b}
Scarification by wire net	8.40± 0.51 ^{a}	6.00± 0. 32^{a}	2.20± 0. 20 ^{a}	1008^{a}
Control	6.20± 0.37 ^{c}	4.60± 0. 24 ^{b}	1.800± 0. 20 ^{a}	475.2 ^{d}

Note: Treatment values associated with same letters indicates no significance difference among the treatments at $p \leq 0.05$; ± indicates standard error of means

Seedlings growth performance in polybag

The study reveals that the germination percentage of *C. latifolius* was higher in scarified seeds than other treatments (Fig. 3). The initial growth performance of seedlings in terms of shoot and root length and vigor index was also found significantly higher than other treatments (Table 1). Therefore, we sowed only the scarified seeds in the seed beds for assessing the seedling growth performances in polybag and field condition. Three thousand scarified seeds were sown in three blocks (considered as replications) in nursery bed for this purpose. The germination percentage (71 ± 2.3) was almost similar of the previous experiment (Fig. 3). One-month old seedlings having 2-3 leaves were transferred to the polybags filled with soil - cow dung media and allowed to grow there.

(A)

(B)

Figure 4. One-month old seedlings of *C. latifolius* in nursery bed (A) and one-year old seedlings in polybag (B).

After one year of transferring the seedlings in the polybags, 500 seedlings were out planted in the field. Rest of the seedlings (500) was grown in the nursery for another one year. The seedling mortality in the nursery bed and after transplanting the seedlings to the polybags is around 1-2 % which is very negligible. Seedlings growth performance was recorded in polybag at different age is shown in Table 2. The seedlings attained 15.4 cm height with average length of root 8.4 cm and 3.2 leaves in three months. Seedlings were found to become quite tough and attained a height of 21.6 cm with 12 cm root and 7.2 leaves at six months. The average height (28.4 cm) with 14.8 cm root and 8.2 number leaves was recorded at 12 months. The seedlings attained a height of 65.8 cm with 22 cm long root and 11 leaves at 24 months (Table 2 and Fig 4 B).

Table 2. Seedlings growth performance of *C. latifolius* at different age in the nursery (polybag)

Age of seedlings (months)	Ave. height (shoot) (cm)	Ave. length of roots (cm)	Ave. No. of leaves Per seedlings
3	15.4± 0.51	8.4± 0.68	3.2± 0.37
6	21.6± 0.68	12± 0.55	7.2± 0.37
12	28.4± 1.17	14.8± 0.86	8.2± 0.37
24	65.8± 3.12	22± 0.71	11± 0.71

Note: The figure in each column mean followed by standard error (SE) of means.

Seedling survival and growth performance in the field

One year old seedlings of *C. latifolius* developed from scarified seeds grown in polybags were planted in the field. Survival and seedlings growth performances were determined at 6, 12 and 24 months after planting in the field (Table 3). Survival percentage varied from 90 - 96 with an average of 92.4 among the plots. The seedling height varied from 51.4 - 65.44 cm at six months, 67.7 - 80.7 cm in one year and 116 . 3 - 130.1 cm in two years after planting in the field (Table 3).

Table 3. Survival percentage and seedling growth performance of *C. latifolius* after out planting

Plots	Survival % at 12 months	Average Height (cm)		
		6 months	12 months	24 months
Plot-1	93	$53.8 \pm .9391^{cd}$	72.5 ± 2.1331^{bc}	118.5 ± 1.7292^{b}
Plot-2	96	65.44 ± 2.1248^{a}	80.7 ± 1.3903^{a}	130.1 ± 1.2830^{a}
Plot-3	91	61.3 ± 1.0416^{ab}	78.88 ± 3.2914^{ab}	128.58 ± 3.1026^{a}
Plot-4	92	58.4 ± 2.3611^{bc}	69.2 ± 1.1904^{c}	122.16 ± 1.4194^{b}
Plot-5	90	$51.4 \pm .6943^{d}$	67.7 ± 2.5020^{c}	116.3 ± 1.4866^{b}

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

Discussion

Resembling to the other members of the family Palmeae, the species *Calamus latifolius* required long time to germinate. Generalao (1980) reported that cane seeds take weeks to six months to germinate depending on the species and method of treatment. Sumantakul (1989) reported that *C. longisetus* seed in different media starts to germinate from 30 days and continues till 60 days. Banik and Nabi (1979) mentioned that the seeds sown with intact sarcotesta require two to three months to start germination and give poor germination percentage (10- 26% only). Haider *et al*. (2014) reported that clean seeds of *C. longisetus* showed 60% germination within 70-80 days. The findings of the present research are also alike to those previous studies mentioned here.

The initial growth performance of the *C. latifolius* seedlings was also found to affect significantly by the pre-sowing treatment of the seeds. The highest length of shoot and root and vigor index was noticed in the scarified seeds than other treatments. However, there was no significant variation in the leaf number among the treatments. Hossain *et al*. (2013) mentioned that the seedling growth including root, shoot and total length of *T. chebula* was significantly increased with pre-sowing treatment specially by depulping the fruits. Haider *et al*. (2014) reported that root, shoot and total length was significantly enhanced by pre-sowing treatment in *C. longisetus*. Findings of present study also agree with those of previous studies mentioned here.

The vigor index of the seedlings in this study was increased from 475.2 in the control to 1008 in the scarified seeds (Table 1). The vigor index depends on the germination percentage and the seedling length. The study reveals that there was marginal variation in seedlings length among the treatments. However, the germination percentage with scarified seed was much higher than the other treatment which leads the vigor index considerably higher in the scarified seeds than other treatments. The findings almost similar to the findings of Haider *et al*. (2014b, 2016).

The height growth of seedlings in the field was always significantly higher in plot 2 than in the other plots and lowest in plot 5. This variation of the seedlings height growth was probably due to the microclimate of the plots. Since the survival percentage of the seedlings in the field was quite satisfactory, one-year old seedlings may be considered for planting the species in the field. The finding is similar to the report made by Haider *et al*. (2014b) in case of *C. longisetus* in Bangladesh. Kerala Forest Research Institute, India also noticed similar report and mentioned that rattan seedlings were out planted at the age of one year (Fewa 1994).

Conclusion

Due to scaly seed coat and stony nature of seed, germination behavior of *Calamus latifolius* is similar to other members of the family Palmeae and needs longer time to germinate. *C. latifolius* seeds start germination after 54 days of sowing and complete within 90 days. Maximum seed germination and highest initial growth performance of the seedlings was observed in scarified seeds which was much higher than the other treatments. Pricking of the seedlings after 30-35 days of germination from nursery bed to polybags ensures negligible mortality. Survival of seedlings and growth performance in the field was satisfactory when one year old seedlings were out planted at 2 m × 2 m spacing. Thus, clean scarified seeds are suitable for nursery raising and one-year old seedlings might be recommended for plantation program of the species.

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Germination and Growth of Teli garjan (*Dipterocarpus turbinatus* Gaertn.) and Chapalish (*Artocarpus chama* Buch. –Ham.) Seedlings in Three Different Growing Media at Nursery

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Abstract

The study was conducted at Bangladesh Forest Research Institute, Chattogram to assess the effect of different growing media on germination and growth of *Dipterocarpus turbinatus* and *Artocarpus chama* seedlings in the nursery. The media used in the experiment were T_1: Soil and Cow dung (3:1), T_2 : Cocomoss/ processed coir dust and T_3: Processed saw dust. Experiment was conducted by using Completely Randomized Design (CRD) with five replications of each three media. Germination percentage, survival percentage and growth performance of both species were recorded and analyzed. The result showed that the highest germination percentage (78%) of *Dipterocarpus turbinatus* in T_3 and highest survival % in T_1 while T_2 had shown the highest rate of height (28.5cm), root collar diameter (3.8 mm), leaf number (10) and root length (30.2cm) of seedlings of *D. turbinatus*. On the other hand, highest rate of germination percentage (82%), survival percentage (78%), height (32.5cm), root collar diameter (4.52 mm), leaf number (9.0) and root length (29.7cm) for seedlings of *A. chama* also found in T_2 media than two others media T_1 and T_3. Both species showed the highest growth performance in T_2. The findings also explored T_2 as a good quality co-supplement and substitute of T_1 media for raising the seedlings of selected species in the nursery.

mvims‡¶c

নার্সারিতে তেলি গর্জন (*Dipterocarpus turbinatus*) এবং চাপালিশ (*Artocarpus chama*) দুইটি গুরুত্বপূর্ণ বনজ উদ্ভিদ এর বৃদ্ধির উপর তিনটি উৎপাদন মাধ্যমের প্রভাব নির্ধারণের লক্ষ্যে বাংলাদেশ বন গবেষণা ইনস্টিটিউট, চট্টগ্রামে একটি পরীক্ষা পরিচালিত হয়। উৎপাদন মাধ্যম তিনটি হল টি১ ঃ মাটি ও গোবর (৩ঃ১), টি২ ঃ কোকোমস/প্রক্রিয়াকৃত নারিকেলের ছোবড়ার গুঁড়া এবং টি৩ ঃ প্রক্রিয়াকৃত কাঠের গুড়া। পরীক্ষাটি তিনটি ভিন্ন উৎপাদন মাধ্যমের প্রত্যেকটির পাঁচটি র‌্যাপলিক্যাশনসহ সম্পূর্ণরুপে র‌্যান্ডমাইজড ডিজাইনে (সিআরডি) করা হয়। উভয় প্রজাতির অঙ্কুরোদগম হার, জীবিতের হার এবং বৃদ্ধির হার এর উপাত্ত সংগ্রহ এবং বিশ্লেষণ করা হয়। *D. turbinatus* প্রজাতিতে টি৩ মাধ্যমে সর্বোচ্চ বীজের অঙ্কুরোদগম হার (৭৮%) ও টি১ মাধ্যমে সর্বোচ্চ চারা জীবিতের হার (৫৮%) এবং টি২ মাধ্যমে সর্বোচ্চ হারে চারার উচ্চতা (২৮.৫ সে.মি.) চারার গোড়ার বেড় (৩.৮ মি.মি.) পাতার সংখ্যা (১০) এবং মূলের দৈর্ঘ্য (৩০.২সে.মি.) পরিলক্ষিত হয়। *A. chama* প্রজাতির ফলাফলেও অন্য দুটি মাধ্যম টি১ এবং টি৩ অপেক্ষা টি২ মাধ্যমে সর্বোচ্চ বীজের অঙ্কুরোদগম হার (৮২%), সর্বোচ্চ জীবিতের হার (৭৮%) এবং সর্বোচ্চ উচ্চতা (৩২.৫ সে.মি.), সর্বোচ্চ চারার গোড়ার বেড় (৪.৫২ মি.মি.), সর্বোচ্চ পাতার সংখ্যা (৯.০) এবং সর্বোচ্চ মূলের দৈর্ঘ্য (২৯.৭ সে.মি) পরিলক্ষিত হয়। উভয় প্রজাতির ক্ষেত্রেই টি২ মাধ্যমে সর্বোচ্চ বর্ধন হার দেখা যায়। ফলাফলে নার্সারিতে

নির্বাচিত প্রজাতির চারা উত্তোলনের জন্য টি₂ মাধ্যম টি₁ মাধ্যমের চেয়ে একটি ভাল মানের সহ-পরিপূরক এবং বিকল্প হিসেবে পরীক্ষিত হয়।

Keywords: *Dipterocarpus turbinatus, Artocarpus chama, Cocomoss, Coir dust, Saw dust, Seedlings growth.*

Introduction

In many tropical and sub-tropical countries, top soil based potting media is common for raising seedlings in the containers (Norman and Miller 1995). On the other hand commonly used soil itself is not a good potting medium because of poor organic matter, lacking sufficient water and air holding capacity for fast growth of seedlings. Despite soils contain less organic matter for production of quality seedlings, large scale tree plantation generally concentrate on soil with mixture of cow dung. Bangladesh Forest Research Institute conventionally used forest top soil with cow dung in 3:1 proportion for the production of containerized seedlings (Nandy 1999). Shortage of forest top soil for the production of containerized seedlings in the nursery, a supplementary media mix is necessary as substitute of forest top soil. The medium for container grown seedlings with high mineral fractions supports good shoot development but do not permit high quality root system (Miller and Jones 1995). Due to diverse climatic conditions and soil types, growing plants in soil is unpredictable with a range of challenges, such as changing temperature, moisture holding capacity, available nutrient supply, poor root aeration, disease and pest control (Maboko and Du Pooly 2014). Soilless cultivation in a protected environment has gained popularity due to improved yield and quality (Niederwieser 2001). Some researches indicate that coir dust and saw dust are the suitable media for containerized seedlings (Sawan and Eissa 1996; Okalebo *et al*. 2002; Parry 2007 and Garner 2014). These are the waste product and used as fuel but have good quality for the production of seedlings (Oludare *et al*. 2018). Coir dust is an agricultural by-product obtained after the extraction of fiber from the coconut husk (Abad *et al*. 2002). Quality of coir dust is most suitable which contains more basic characteristic of quality media such as porosity, Cation exchange capacity, water holding capacity, low shrinkage, low bulk density, and slow biodegradation etc. (Marjenah *et al*. 2016, Evans *et al*.1996 and Prashad 1997). Seedlings grow faster and more vigorously in pure coconut husk medium than other mixture of sand, soil and husk that were tested (Kijkar 1991). Because of the superior properties of the coir and saw dust, pest disease and weed seeds possibility is lessen. For this reason watering, weeding and other cultural activities are less required. That's why those media are less labor intensive, less costly and economically beneficial than conventional material. It also provides environmental benefits, avoided ecosystem damage caused by soil or peat extraction (Apaolaza *et al*. 2005). Miller and Jones (1995) also reported saw dust is widely used throughout the world because of its low cost, high moisture retention, and availability. Sawdust has been standard growing medium for the greenhouse industry in Alberta and Argentina for several decades (Sawan and Eissa 1996). In Bangladesh, saw dust is available in sawmills. The information obtained from physical survey reports that about 117 thousand Metric Ton saw dust is produced annually (Moral and Rahman 2001). A lot of research activities were done on ornamental and crop plants whereas research on coir dust and saw dust media for the production of forest tree species is not well reported. Yahya and Mokhlas (1999) as well as Yau and Murphy (2000) reported that, a growing medium, coco peat can be used to produce a number of crop species with acceptable quality in the tropics. The use of coconut dust in potting media has proved successful for several species in Thailand. They developed a cost-effective media from pulverized coconut husk (Norman and Miller 1995). In addition, Bangladesh has about 2800 ha of coconut land and the average annual coconut production is about 316000MT (BBS 2009). The by-products of coconut oil industries are coconut husk and coconut shell. Coconut husk is used in coconut fiber industries for extracting fiber which is usually used in making ropes, mattress, household products like doormats, floor mats, brushes, floor tiles, sacking, twine, etc. The waste of coconut fiber industries is coir dust which is obtained after extracting fiber from coconut husk and has a very limited usage. In Bangladesh, a small amount of coir dust is used for making bio-compost and most of the coir dust is left as waste product. So as a growing media, coir dust has a great prospect in Bangladesh (Saha *et al*. 2014).

However, *D. turbinatus* and *A. chama* are two important forest tree species and produced quality timber for multipurpose use (Hossain 2015). Though these species are regenerate naturally but quality seed source and natural seedlings are not sufficient for plantation establishment. To develop quality planting materials in a stipulated time, an attempt was taken to observe the production of seedlings of important two forest tree species *D. turbinatus* and *A. chama* using coir and sawdust as alternative of soil media in the nursery. Present investigation was made to find the effect of soil, coir dust and saw dust media on seed germination, survival and growth of *D. turbinatus* and *A. chama* seedlings in the nursery.

Materials and Methods

The experiment was designed with three different seedling production media in the nursery of Silviculture Research Division, BFRI in June 2015. Raw Materials of potting media were soil, cow dung, coir dust and saw dust (mixture of gamar, rain tree, mahagany and acacia spp.). Three treatments T_1 (soil and cow dung; 3:1) T_2 (cocomoss, processed coir dust) and T_3 (processed saw dust.) were used for raising seedlings in polybags.

Soil media preparation

Soil was collected from the top soil of forest floor. The soil and cow dung were heaped separately in the nursery during the dry period (November – December 2014). Then the soil was allowed to decompose for 2 or 3 months under shade to improve aeration, reduce instances of damping off diseases to seedlings, reduce competition of nutrients from weeds, and increase water retention capacity. Before filling polybag soil and cow dung mixtures were crushed and sieved using 2 mm mesh wire.

Processing of coir dust and saw dust

Coir dust was collected from coir foam industry and saw dust from saw mill. Coir and saw dusts were sieved with the wire mesh containing ½ cm size pores. Then the dusts were spread on brick raised bed with the alternate layers of chemical fertilizer specially urea, building 2 meter long, 1 meter wide and 16 cm. high linear pile. Total 1.5kg urea fertilizer was spread on each layer for decompose (Begum *et al*. 2018). Then the pile moistened with water and the whole pile was covered with asbestos providing air passing facility. Black polythene sheet may also be used. The pile was turned at intervals of 2 to 3 weeks and watered when needed. Within 3 months it was found to change in dark brown/blackish color. Finally, decomposed dusts was dried in the sun light and stored in plastic bag for raising seedlings in the nursery.

Seedling raising

Fresh and uniform seeds of *D. turbinatus* were collected in June, 2015 and mature ruptured fruits of *A. chama* in July, 2015 from the selected mother trees. Both seeds were sown in polybags of size 12cm x 17 cm within 24 hours of collection. Polybags were arranged on permanent nursery bed in line. For each treatment 200 seeds were used. The trial was set up in Completely Randomized Design (CRD) with five replications for each treatment. Each replication contains 40 polybags with one seed. Seeds of *D. turbinatus* germinated within 7days (Fig. 1b and 1c) and seeds of *A. chama* germinated 8-10 days after sowing in three media (Fig. 1a). Data were recorded on germination daily up to the completion of the germination. Watering was done regularly and weeding done when needed. Partial shade used till the completion of germination.

a. *A. chama* seedlings in three different germination media

b. *D. turbinatus* in coir dust

c. *D. turbinatus* in saw dust

Figure. 1 Seedlings of *A. chama* (a) and *D. turbinatus* (b and c) in nursery at different germination media.

Seed germination was recorded 7 days after sowing. Data were taken from 10 representative sample seedlings from each replication at the age of 6 months. Seedlings were harvested at the age of 6 months for measuring root length. The survival percentage of seedlings were calculated by using the following formula (Olasupo *et al*. 2016)

$$\text{Survival rate (\%)} = \frac{\text{Number of survived seedling}}{\text{Number of germinated seeds}} \times 100$$

Height, root collar diameter and root length of seedlings of each species for each treatment were measured. Root length was measured by uprooting seedlings and washing soil with tap water in the plastic strainer. Root collar diameter of seedlings was measured with digital slide calipers with an accuracy of 0.00. The number of leaves was also counted.

Statistical analysis

The collected data were statistically analyzed through SPSS software version-22. Analysis of variance (ANOVA) was done with post hoc comparison using Least Significant Difference (LSD) in order to determine the significant ($p \leq 0.05$) variations among the treatments.

Results

Germination and Survivability

A one way between groups ANOVA was conducted to compare the mean germination % and mean survival % of *D. turbinatus* and *A. Chama* for three different treatments (T_1= soil & cow dung, 3:1, T_2=cocomoss, processed coir dust; T_3= processed saw dust).

Table 1. Germination % and survival % of *D. turbinatus* and *A. chama* seedlings

	D. turbinatus		*A. Chama*	
	Germination%	Survival %	Germination%	Survival %
F value	$F_{.05}(2)$=47.5	$F_{.05}(2)$=43	$F_{.05}(2)$=793.44	$F_{.05}(2)$=202.76
p value	0.00	0.00	0.00	0.00

There was a significant difference in the mean germination % [F (2)= 47.5, p=0.00] and mean survival % [F (2)= 43.0, p=0.00] of *D. turbinatus* for three different treatments at the 0.05 level and in the mean germination % [F (2) = 793.44, p=0.00] and survival (%) [F(2)= 202.76, p=0.00] of *A. chama* for three different treatments at 0.05 level. (Table-1)

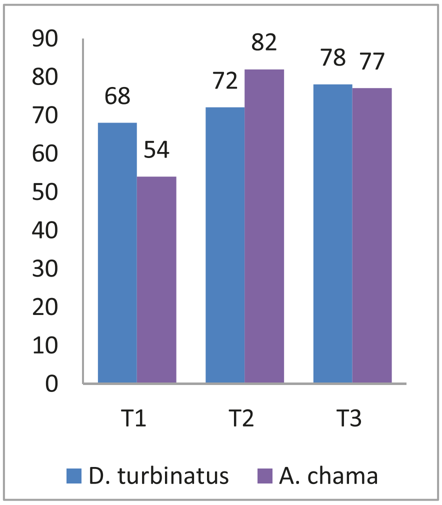

Figure 2. Germination % of *D. turbinatus* and *A. chama*

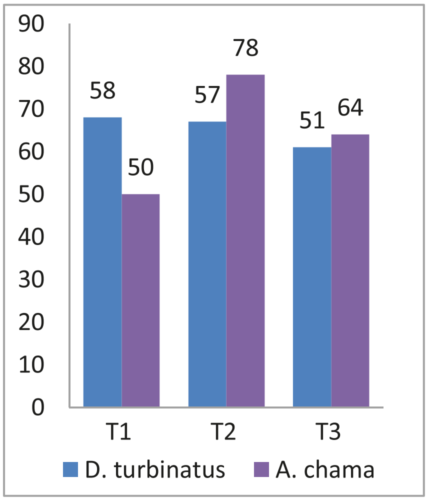

Figure 3. Survival % of *D. turbinatus* and *A. chama*

From Fig. 2 and Fig. 3, germination % of seeds and survival % of seedlings of *D. turbinatus* indicated that the mean germination % for T_3 media (78%) showed better result than two other media and it was 68% for T_1 and 72% for T_2. For survival %, T_1 media showed the highest percentage (58%) than the two other media T_2 (57%) and T_3 (51%). Germination % of seeds and survival % of seedlings of *A. chama* indicated that the mean germination % for T_2 media (82.4%) showed better result than the two other media T_1 (54%) and T_3 (77%). For survival % also indicated T_2 media (78%) showed better result than the two other media T_1 (50%) and T_3 (64%).

Growth performance

The growth characteristics (height, root collar diameter, leaf number and root length) of *D. turbinatus* and *A. chama* seedlings in T_2 media showed better performance in comparison to T_1 and T_3 media.

For comparing growth performance of *D. turbinatus* for three different treatments, an ANOVA was conducted to compare the mean height (cm), mean root collar diameter (mm), average leaf number and mean root length (cm). There was a significant difference in mean height (cm) [F(2)= 68.63, p=0.00], mean root collar diameter (mm) [F(2)= 26.81, p=0.00], average leaf nymber [F(2)= 8.61, p=0.005], and mean root length(cm) [F(2)= 236.25, p=0.00] of *D. turbinatus*. (Table 2.)

Table 2. Growth performance of *D. turbinatus* in different germination media

D. turbinatus				
Treatment	**Ave. height (cm)**	**Ave. root collar diameter (mm)**	**Ave. no. of leaves**	**Ave. root length (cm)**
T_1	23.1±2.21	3.29±0.03	9±1.58	27.5±0.61
T_2	28.5±0.98	3.80±.35	10±1.58	30.2±0.32
T_3	16.6±1.37	2.84±0.06	6±1.58	23±0.61
Sig. difference	$F_{.05}(2)=68.63^*$	$F_{.05}(2)=26.81^*$	$F_{.05}(2)=8.61^*$	$F_{.05}(2)=236.25^*$

Note: In a column values are significantly different at p≤0.05, according to Post hoc comparisons using LSD test. (±) indicates the standard deviation of mean. (*) Indicates 5% level of significance.

The result showed that, the better growth performance of *D. turbinatus* seedling were found for four indicators- mean seedling height (28.5 cm), root collar diameter (3.8 mm), leaf number (10), and mean root length (30.2 cm) in T_2 media then T_1 and T_3 media. For T_1 media, mean seedling height was 23.1 cm, collar diameter 3.29 mm, leaf number 9 and mean root length 27.5 cm. For T_3 media, mean seedling height was 16.6 cm, root collar diameter 2.84 mm, leaf number 6 and mean root length 23.0 cm.

For *A. chama* mean height (cm) [F(2)= 826.28, p=0.00], mean root collar diameter (mm) [F(2)= 43.73, p=0.00], average leaf number [F(2)= 6.55, p=0.012], and mean root length(cm) [F(2)= 1239.290, p=0.00] at 0.05 level of significant.

Table 3. Growth performance of *A. chama* in different germination media

A. Chama				
Treatment	**Ave. height (cm)**	**Ave. root collar diameter (mm)**	**Ave. no. of leaves**	**Ave. root length (cm)**
T_1	25.83±0.07	3.92±0.04	6±1.58	18.5±0.38
T_2	32.5±0.61	4.52±0.17	9±3.16	29.7±0.75
T_3	23.1±0.22	3±0.41	4±1.41	14.2±0.26
Sig. difference	$F_{.05}(2)$=826.28*	$F_{.05}(2)$=43.73*	$F_{.05}(2)$=6.55*	$F_{.05}(2)$=1239.29*

Note: In a column values are significantly different at p≤0.05, according to Post hoc comparisons using LSD test. (±) indicates the standard deviation of mean. (*) Indicates 5% level of significance.

From the experiment it was also found that, *A. chama* seedlings attained maximum height (32.5 cm), root collar diameter (4.52 mm), leaf number (9), and mean root length (29.7cm) in T_2 media followed by T_1 and T_3 media. For T_1 media, mean seedlings height was 25.83 cm, root collar diameter 3.92 mm, leaf number 6 and mean root length 18.5 cm. For T_3 media, mean seedling height was 23.1 cm, root collar diameter 3.0 mm, leaf number 4 and mean root length 14.2 cm. (Table 3.).

Discussion

Maximum growth of seedlings in treatments with soil and cow dung (3:1), cocomoss/ processed coir dust and processed saw dust was realized in this study implying the potential of coir dust as a growth media when used with other media. From the experiment it was found that *D. turbinatus* showed highest germination 78% in T_3 media followed by 72% in T_2 media. Whereas *A. chama* achieved highest germination 82% in T_2 followed by 77% in T_3. Early germination of *D. turbinatus* seeds was enhanced by sawdust which supports Peter-onoh *et al*. (2014) findings. T_1 media showed poor germination percentage (68%) for *A. chama* in comparison to other two media T_2 and T_3.

D. turbinatus species showed highest survival 58% in T_1 followed by 57% in T_2 and lowest survival was 51% in T_3 media. But *A. chama* achieved highest survival 78% in T_2 media followed by 64% in T_3 media and lowest survival 50% was found in T_1 media. These results revealed that survival % in T_2 media can be categorized as a good growing media for seedlings raising of *A. chama* because it survival rate was > 65% (Nirawati *et al*. 2013). According to Villagra and Cavagnaro 2006, physical properties of growing medium are important factors such as aeration, mineral nutrients and moisture contents could affect the growth, establishment and survival of the seedling which supported the findings.

Maximum height of both species were found in T_2 media and it was 28.5cm for *D. turbinatus* and 32.5 cm for *A. chama* followed by T_1 which were 23.1cm for *D. turbinatus* and 25.83 cm for *A. chama*. T_3 (saw dust) showed lowest height in both species and it were 16.6 cm for *D. turbinatus* and 23.1cm for *A. chama*. Peter-onoh *et al*. (2014) reported that, saw dust consistently produced dwarf plants when compared with other media. He also reported that wood residues contain all the minor elements essential for plant growth but by nature it is low in mineral nutrients. Greater porosity is responsible for the reduction of growth of seedlings which found in T_3 (sawdust) media. Agbogidi *et al*. (2007) observed that growth reduction in the seedlings planted in the sharp sand and sawdust could be due to a greater porosity these media have relative to the other media thereby accommodating more spaces for air and water. The water supplied and the little nutrients available could have been washed away at a rate faster than the seedlings could cope with thereby leaving little or nothing for the plants for their normal growth and other metabolic processes. This observation agreed with prior reports of Obi (1990) who noted that coarse soil particles may reduce plant growth due to low water retention capacity and inadequate nutrients necessary for plant growth. Garner (2014) reported that saw dust as stale media for plant growth and low nutrient content could be a reason for poor growth. But in case of *A. chama* showed plantable height in T_3 media whereas *D. turbinatus* as a slow growing species could not reach standard plantable height at the age of 6 months. T_2 was superior media, compared to the rest of the two other growing media T_1 and T_3 with respect to seedling height at the age of 6 months. Maximum root collar diameter of *D. turbinatus* and *A. chama* were found 3.8 mm and 4.52 mm in T_2 media. According to Ashiono *et al*. (2017), high root collar diameter contributes to sturdiness of the seedlings that enhance field survival which supports this experiment. In T_3 media showed lowest root collar diameter for both species where 2.84 mm in *D. turbinatus* and 3.0 mm in *A. chama* at the age of 6 months. Whereas, seedlings of *Eucalyptus* saligna which grown in sawdust also had the lowest root collar diameter at the age of 6 months due to poor growth for low nutrients (Ashiono *et al*. 2017).

The number of leaves raised in T_2 media showed highest result than the two other media T_1 and T_3 for both species. Highest mean value of leaf number of both species in T_2 media were found 10 for *D. turbinatus* and 9 for *A. chama* followed by T_1 which were 9 for *D. turbinatus* and 6.0 for *A. chama* respectively. Increase in the number of leaves elevated the photosynthetic reaction and increased carbohydrates which ultimately enhence yield (Logendra *et al*. 2001) or growth. T_3 showed the lowest number of leaves in both species were 6.0 for *D. turbinatus* and 4.0 for *A. chama* at the age of 6 months influenced by stunted growth.

D. turbinatus species showed maximum root length 30.2 cm in T_2 media followed by 27.5 cm in T_1 media. Similarly, *A. chama* species also achieved highest root length 29.7cm in T_2 media followed by 18.5cm in T_1 media. Both species (*D. turbinatus* and *A. chama*) showed lowest root length in T_3 media which were 23cm for *D. turbinatus* and 14.2 cm for *A. chama* at the age of 6 months. Seedling survival also depends on root development (Mhango *et al*. 2008). Ashiono *et al*. (2017) reported that seedlings in sawdust treatment had severe stunted growth because of deficiency of essential nutrients in this media which supports our experiment.

Conclusion

Growth characteristics of *D. turbinatus* and *A. chama* differed according to the growth media in the study. Germination percentage, survival percentage and different morphological features (height and root collar diameter, leaf number and root length) in cocomoss, processed coir dust (T_2) media showed the highest result as compared to the soil and cow dung; 3:1 (T_1) and processed saw dust (T_3) media. Depending on the quality, T_2 media may be consider as a quality co-supplement as well as good substitute of soil media for raising seedlings of *D. turbinatus* and *A. chama* in the nursery. But T_1 and T_3 media has showed the lowest growth performance of both species because saw dust alone did not favor seedling growth. Based on the above observation and other reports saw dust media needs mineral nutrients for plant growth because physical properties of growing medium are important factor for growth, establishment and survival of the seedling. Therefore, further investigation is needed to improve the saw dust and cow dung or other compost media for the production of quality seedlings of forest tree species.

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Plant Diversity in Sitakunda Botanical Garden and Eco-park of Chattogram, Bangladesh

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Abstract

This paper presents the assessment of both the natural and planted species diversity of the Sitakunda Botanical Garden and Eco-park, Chattogram. A total of 267 plant species from 101 families are recorded in three zones namely disturbed, undisturbed and planted areas. Among them 153 plant species recorded from the natural undisturbed area belonging to trees (45 species), shrubs (44 species), herbs (34 species) and 30 species of climbers. Fifty two species were documented from disturbed and planted areas. *Mikania cordata, Chromolaena odorata, Hyptis suaveolens, Mimosa pudica* and *Ageratum conyzoides* are dominant species in the disturbed zone and *Ficus hispida* are the most dominant tree species in the undisturbed zone. The highest Importance Value Index (IVI) showed 28.08 for *Holarrhena antidysenterica* and the lowest 1.05 for *Mangifera sylvatica* in natural patch. *Syzygium fruticosum* showed the highest IVI of 27.81 and *Pinus caribaea* showed the lowest (0.93) IVI in plantation site. Most of the species are regenerating from the root suckers. Protection measures shall help the regeneration and conserve the species diversity in this Botanical Garden and Eco-park.

mvims‡¶c

চট্টগ্রামের সীতাকুণ্ড বোটানিক্যাল গার্ডেন ও ইকো পার্কে লাগানো এবং প্রাকৃতিকভাবে জন্মানো উদ্ভিদ বৈচিত্র্যের পরিবর্তন এই প্রবন্ধে উপস্থাপন করা হয়েছে। তিনটি জোন, যথা- ডিস্টার্ব, ডিস্টার্ব ছাড়া ও লাগানো এলাকা হতে ১০১ পরিবারের অধীনে ২৬৭ প্রজাতির উদ্ভিদ রেকর্ড করা হয়েছে। ডিস্টার্ব হয় না এমন এলাকায় প্রাকৃতিকভাবে জন্মানো ১৫৩টি উদ্ভিদ প্রজাতি রেকর্ড করা হয়েছে, তাদের মধ্যে ৪৫টি বৃক্ষ প্রজাতি, গুল্ম ৪৪টি, বীরুৎ ৩৪টি এবং ৩০টি লতা জাতীয় উদ্ভিদ প্রজাতি শনাক্ত করা হয়। ডিস্টার্ব এবং লাগানো এলাকা হতে ৫২টি করে উদ্ভিদ প্রজাতি রেকর্ড করা হয়েছে। ডিস্টার্ব এলাকায় আসামলতা, আসাম গাছ, তোকমা, লজ্জাবতী এবং ফুলকুড়ি উদ্ভিদ বেশি পরিমাণে দেখা গেছে। ডিস্টার্ব ছাড়া এলাকায় কুরচি, ধারমারা, ধলিবাটনা, শীলভাদী এবং জগ্যা ডুমুর নামক বৃক্ষের আধিক্য বেশী। ডিস্টার্ব নাই এরূপ ন্যাচারাল পেচ এলাকায় কুরচি প্রজাতির সর্বোচ্চ গুরুত্ব নির্দেশক মানে (IVI) ২৮.০৮ দেখা গেছে এবং সর্বনিম্ন গুরুত্ব নির্দেশক মানে (IVI) ১.০৫ দেখা গেছে উরি আমের। প্লান্টেশন এলাকার মধ্যে সর্বোচ্চ গুরুত্ব নির্দেশক মানে (IVI) ২৭.৮১ দেখা গেছে পুতি জামের ও সর্বনিম্ন (IVI) ০.৯৩ দেখা গেছে পাইন গাছের। অধিকাংশ উদ্ভিদ প্রজাতির রিজেনারেশন হয়েছে root suckers থেকে। উক্ত বোটানিক্যাল গার্ডেন ও ইকো পার্কটি সংরক্ষিত হওয়ায় উদ্ভিদ প্রজাতি সংরক্ষণ ও রিজেনারেশন হতে সাহায্য করবে।

Keywords: Plant diversity, Natural and planted species, Quantitative, Eco-park, Sitakunda.

Introduction

Sitakunda is an upazila in the Chattogram district of Bangladesh. The first eco-park in Bangladesh Sitakunda Botanical Garden and Eco-park was established in 2001 along with a botanical garden consisting of 808 hectares of the Chandranath Hills in Sitakunda (Khair 2003). The Eco-park is located between 22º 36' 22º 39' north latitude and 91º 40' – 91º 42' east longitude (Anonymous 1970). The Eco-park is containing the Chandranath Reserved Forest under the jurisdiction of Chattogram North Forest Division. It has two ranges one of "Punarbasan and rest of Parjaton range''. The hills and hillocks are elevated from the south and west towards the east and north. The eco-park was established to facilitate biodiversity conservation, natural regeneration, new plantations and infrastructure development as well as to promote nature based tourism to generate income. The climatic, edaphic and topographic conditions of the study area are favorable for natural regeneration (Alam 2001). Ecologically, the vegetation of Chattogram is composed of mostly tropical evergreen forests (Champion 1936) and this Eco-park is included in this type of forest. Most of the Sitakunda hills were covered by forests dominated by grasses, bamboos and mixed evergreen vegetation characterized tall trees and an under growth of gingers, bryophytes and pteriodophytes (Rahman and Uddin 1997).

Plant diversity means includes both qualitative and quantitative enumeration of floristic inventories of an area. Quantitative information provides a data base on the vegetation structure of an area. Status of plant diversity estimation is an essential for conservation of biodiversity and genetic resources. Forests and Plant diversity provides the food, medicine, industrial raw materials for mankind. The variability of the plant communities and the ecological complexes they inhibits is collectively known as floral diversity (Michael 1990). Besides, a plant population is showed that an environment relationship of abiotic factor. We depend on plant diversity for our survival and quality of life (Kartikeya 2005). The any forest area is supports a large number of plant species and would be contribute to the forest green economy of Bangladesh. It also offers feeding, nesting sites and breeding ground of a large number of wild animals for the human being. In a word, plant diversity provides various opportunities of education, research, tourism and associated employment.

A Flora is a basic tool for identification and utilization of the plant diversity of a particular area. The status of the flora is also the benchmark indicator for understanding the vegetation dynamics of an area. Various indigenous and exotic tree species occur through hilltops and valleys. In Sitakunda area 203 plant species under 154 genera and 54 families were reported to naturally growing (Rahman and Udiin 1997). Heinig (1925) recorded 36 tree species under 24 angiosperm families from Sitakunda area. It reveals the impact of such exotic tree plantations on the native tree population through conservation of biodiversity and dynamic plant diversity of the Eco-park.

Materials and Methods

The study was conducted during July' 2012 to June' 2014 in different seasons and made about 50 trips through the whole area. Botanical samples and documented qualitative and quantitative data from representative sampling plots were collected. Phytosociological investigation was carried out from the sample plots using stratified random quadrat methods (Mueller- Dombois 1974). The optimum quadrat size was (10 m x 10 m) for tree species. For shrubs, herbs and climbers optimum quadrat size was (5m x 5m). In each quadrat GBH (girth at breast height) ≥ 05 cm of natural and planted tree species were identified, measured and recorded. In the number of shrubs, herbs and climbers were also documented. The naturally growing and plantation tree species were identified consultation with the pertinent literature of viz. Prain (1903), Kanjilal *et al*. (1934, 1938, 1940), Khan (1972), Heinig (1925) and Ahmed *et al*. (2008): Encyclopedia of Flora and Fauna of Bangladesh. The specimen vouchers were verified with the specimens preserved at Bangladesh Forest Research Institute Herbarium (BFRIH) and National Herbarium (NH). All voucher specimens are preserved in the BFRI herbarium.

Data analysis

In order to express dominance and ecological status of species, Importance Value Index (IVI) was worked out. Other basic parameters like density, relative density, relative frequency, relative abundance were also analyzed following to the methods of Shukla and Chandel (2005), Michael (1990), Kent and Coker (1992), Magurran (1988) and Dallmeier *et al*. (1992).
Tree species were calculated following the methods

$$\text{Density} = \frac{\text{Total no. of individual of the species}}{\text{Total no. of the quadrat}}$$

$$\text{Relative density} = \frac{\text{Total no. of individuals of the species} \times 100}{\text{Total no. of individuals of all the species}}$$

$$\text{Frequency} = \frac{\text{Total no. of quadrats in which the species occurred}}{\text{Total no. of the quadrat studied}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of one species} \times 100}{\text{Total frequency}}$$

$$\text{Abundance} = \frac{\text{Total no. of individuals of a species in all the quadrats}}{\text{Total no. of quadrats in which the species occurred}}$$

$$\text{Relative abundance} = \frac{\text{Abundance of the species} \times 100}{\text{Total abundance}}$$

$$\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative abundance}$$

Results

Taxonomic diversity

The floristic compositions of the Sitakunda area were classified tree, shrub, herb and climber on the basis of habit. A total of 267 species belonging to 172 genera under 101 families have been listed. Natural undisturbed plants were represented by 153 species under 125 genera in 48 families. Among them trees were 45 species, shrubs 44 species, herbs 34 species and climber 30 species. Natural disturbed habitats were represented by 52 species 45 genera in 28 families. Among them trees were 16, shrubs 13, herbs 16 and climber 7 species. Fifty five commercially important forest species under 25 families have been planted in different sites. Among the identified plants 10 grasses and 26 herbaceous species were recorded (Table 1 and Table 2).

Table 1. List of most common and abundant grasses of disturbed, undisturbed and planted area

Local name	Scientific name	Family
Kamakher	*Cymbopogon nardus* (L.) Rendle	Poaceae
Durba Ghas	*Cynodon dactylon* (L.) Pers.	Poaceae
Chanch	*Cyperus compressus* L.	Cyperaceae
Kusha	*Cyperus cyperoides* (L.) O. Ktze.	Cyperaceae
Unknown	*Eragrostis coarctata* Stapf	Poaceae
Koni Ghas	*Eragrostis tenella* (L.) P. Beauv. *ex* Roem. & Schult.	Poaceae
Unknown	*Kyllinga nemoralis* (J. R. Forst. & G. Forst.) Dandy *ex* Hutchins.	Cyperaceae
Kanduli	*Murdannia nudiflora* (L.) Brenan	Commelinaceae
Unknown	*Panicum notatum* Retz.	Poaceae
Unknown	*Pogonatherum crinitum* (Thunb.) Kunth	Poaceae

Table 2. List of common herbaceous vegetation of disturbed, undisturbed and planted area

Local name	Scientific name	Family
Apang	*Achyranthes aspera* L.	Amaranthaceae
Barakesuti	*Adenosma indianum* (Lour.) Merr.	Scrophulariaceae
Mohicharan Sak	*Ampelygonum chinense* (L.) Lindley	Polygonaceae
Shialkanta	*Argemone mexicana* L.	Papaveraceae
Barokukshim	*Blumea lacera* (Burm. f.) DC.	Asteraceae
Assam-lata	*Chromolaena odorata* (L.) King & Robinson	Asteraceae
Kanchira	*Commelina benghalensis* L.	Commelinaceae
Unknown	*Commelina diffusa* Burm. f.	Commelinaceae
Kesuti	*Eclipta alba* (L.) Hassk.	Asteraceae
Unknown	*Elephantopus scaber* L.	Asteraceae
Sadusi	*Emilia sonchifolia* (L.) DC.	Asteraceae
Dudhia	*Euphorbia hirta* L.	Euphorbiaceae
Unknown	*Evolvulus nummularious* (L.) L.	Convolvulaceae
Lal Bichuti	*Laportea interrupta* (L.) Chew	Urticaceae
Unknown	*Lepidagathis incurve* Buch.- Ham. *ex* D. Don	Acanthaceae
Shetodron	*Leucas indica* (L.) R. Br. *ex* Vatke	Lamiaceae
Unknown	*Lindernia anagallis* (Burm.f.) Pennell	Scrophulariaceae
Unknown	*Lindernia rotundifolia* (L.) Alston	Scrophulariaceae
Assam-lata	*Mikania cordata* (Burm. f.) Robinson	Asteraceae
Amrul Sak	*Oxalis corniculata* L.	Oxalidaceae
Bhuiamla	*Phyllanthus niruri* L.	Euphorbiaceae
Bondhone	*Scoparia dulcis* L.	Scrophulariaceae
Ahtharogia	*Spermacoce articularis* L. f.	Rubiaceae
Ghuiojhil Shak	*Spermacoce latifolia* Aublet	Rubiaceae
Marhata Tiga	*Spilanthes calva* DC.	Asteraceae
Kuksim	*Vernonia cinerea* (L.) Less.	Asteraceae

Quantitative Analysis

The phytosociological works have been statistically analyzed. Percentage frequency, abundance, density and Importance Value Index (IVI) were calculated for all the species for respective sites. Vegetation analysis and distribution pattern of natural tree species reveals that in the whole study area the highest relative frequency are showed by *Streblus asper* (7.91%), *Holarrhena antidysenterica* (7.57%) followed by *Lithocarpus thomsonii* (7.48%), *Grewia nervosa* (7.31%), *Ficus hispida* (6.02%), *Stereospermum colais* (4.90%), *Artocarpus lacucha* (4.73%), whereas *Phoenix sylvestris* (0.17%), *Dillenia pentagyna* (0.17%) and *Sterculia villosa* (0.86%). The results also revealed that highest IVI is attained by *Holarrhena antidysenterica* (28.08) and *Mangifera sylvatica* (1.05) showed the lowest IVI (Table 3).

Table 3. Phyto- sociological study of the natural tree species of Sitakunda Eco-park.

Species	**D**	**RD**	**A**	**RA**	**RF**	**I V I**
Holarrhena antidysenterica	6.05	14.71	6.91	5.80	7.57	28.08
Lithocarpus thomsonii	5.28	12.83	6.03	5.06	7.48	25.37
Grewia nervosa	3.68	8.95	4.32	3.63	7.31	19.89
Streblus asper	3.25	7.90	3.51	2.95	7.91	18.76
Stereospermum colais	4.25	10.33	7.39	6.21	4.90	17.44
Ficus hispida	2.00	4.86	2.86	2.40	6.02	13.28
Lannea coromandelica	1.8	4.38	6.00	5.04	2.58	12.00
Artocarpus lacucha	1.43	3.48	2.59	2.17	4.73	10.38
Callicarpa arborea	1.18	2.87	3.36	2.82	3.01	8.70
Litsea glutinosa	1.18	2.87	3.13	2.63	3.18	8.68
Eurya acuminata	1.18	2.87	3.13	2.63	3.18	8.68
Lepisanthes rubiginosa	1.02	2.48	3.15	2.65	2.84	7.97
Litsea monopetala	0.75	1.82	3.00	2.52	3.27	7.61
Lophopetalum wightianum	0.10	0.24	1.33	1.12	6.00	7.37
Mitragyna rotundifolia	0.68	1.65	2.45	2.06	2.32	6.03
Cycas pectinata	0.53	1.29	3.50	2.94	1.72	5.95
Mallotus tetracoccus	0.40	0.97	1.23	1.03	2.75	4.75
Trema orientalis	0.48	1.17	1.19	0.10	3.44	4.71
Pterospermum acerifolium	0.43	1.04	2.12	1.79	1.72	4.55
Vitex peduncularis	0.40	0.97	2.29	1.92	1.46	4.35
Oroxylum indicum	0.33	0.80	1.3	1.09	2.15	4.04
Bombax insigne	0.48	1.17	2.38	1.10	1.72	3.99
Castanopsis indica	0.30	0.73	1.33	1.12	1.89	3.74
Dillenia pentagyna	0.30	0.73	1.50	1.26	1.72	3.71
Sapindus saponaria	0.30	0.73	2.00	1.68	1.29	3.70
Protium serratum	0.28	0.68	1.83	1.54	1.29	3.51
Maesa ramentacea	0.55	1.34	2.20	1.85	0.17	3.36
Zanthoxylum rhetsa	0.30	0.73	1.71	1.44	1.03	3.20
Ficus racemosa	0.23	0.56	1.80	1.51	1.03	3.10

Species	D	RD	A	RA	RF	I V I
Antidesma bunius	0.13	0.32	2.50	2.10	0.43	2.85
Trewia nudiflora	0.18	0.44	1.40	1.18	1.03	2.65
Sterculia villosa	0.15	0.36	1.50	1.26	0.86	2.48
Cassia nodosa	0.15	0.36	1.50	1.26	0.86	2.48
Adina haldina	0.10	0.24	2.00	1.68	0.43	2.35
Artocarpus chama	0.10	0.24	2.00	1.68	0.43	2.35
Alstonia scholaris	0.13	0.32	1.25	1.05	0.86	2.23
Dillenia indica	0.05	0.12	2.00	1.68	0.17	1.97
Spondias pinnata	0.08	0.19	1.50	1.26	0.43	1.88
Bischofia javanica	0.08	0.19	1.50	1.26	0.43	1.88
Ficus benghalensis	0.08	0.19	1.50	1.26	0.43	1.88
Barringtonia acutangula	0.02	0.04	1.00	0.84	0.17	1.05
Mangifera sylvatica	0.02	0.04	1.00	0.84	0.17	1.05
Pongamia pinnata	0.02	0.04	1.00	0.84	0.17	1.05
Garcinia cowa	0.02	0.04	1.00	0.84	0.17	1.05
Neolamarckia cadamba	0.02	0.04	1.00	0.84	0.17	1.05

The relative density, relative frequency, relative abundance and important value index of the planted tree species from study area are shown in Table 4.

Table 4. Phyto- sociological study of the planted tree species of Sitakunda Eco-park.

Species	D	RD	A	RA	RF	I V I
Syzygium fruticosum	5.50	16.17	7.33	4.46	7.18	27.81
Eucalyptus camaldulensis	2.65	7.79	3.53	2.15	7.18	17.12
Syzygium cumini	2.53	7.44	8.42	5.13	2.87	15.44
Albizia odoratissima	2.03	5.97	3.00	1.83	6.46	14.26
Terminalia bellirica	1.63	4.79	2.32	1.41	6.70	12.90
Lagerstroemia speciosa	1.30	3.82	13.00	7.92	0.96	12.70
Acacia auriculiformis	1.38	4.06	11.00	6.70	1.20	11.96
Cassia fistula	1.25	3.67	2.00	1.22	5.98	10.87
Albizia procera	1.30	3.82	8.67	5.28	1.44	10.54
Phyllanthus emblica	1.20	3.53	2.29	1.39	5.02	9.94
Palaquium polyanthum	0.20	0.59	2.00	1.39	5.02	9.94
Shorea robusta	1.13	3.32	3.46	2.10	3.11	8.53
Mimusops elengi	0.93	2.73	2.18	1.33	4.06	8.12
Gardenia coronaria	0.93	2.73	6.17	3.76	1.44	7.93
Hopea odorata	0.85	2.50	2.27	1.38	3.59	7.47
Xylia xylocarpa	0.68	1.10	9.00	5.48	0.72	7.30
Terminalia chebula	0.73	2.15	2.23	1.36	3.11	6.62
Pterocarpus indicus	0.60	1.76	4.00	2.44	1.44	5.64
Michelia champaca	0.55	1.62	2.45	1.49	2.15	5.26

Species	D	Rd	A	RA	RF	I V I
Gmelina arborea	0.38	1.12	1.25	0.76	2.87	4.75
Delonix regia	0.48	1.41	2.71	1.65	1.67	4.73
Aquilaria agallocha	0.48	1.41	2.71	1.65	1.67	4.73
Terminalia arjuna	0.38	1.12	3.75	2.28	0.96	4.36
Caesalpinia pulcherrima	0.35	1.03	1.40	0.85	2.39	4.27
Psidium guajava	0.30	0.88	4.00	2.44	0.72	4.04
Azadirachta indica	0.35	1.03	1.75	1.07	1.91	4.01
Syzygium firmum	0.28	0.82	1.38	0.84	1.91	3.57
Protium serratum	0.28	0.82	2.75	1.67	0.96	3.45
Terminalia catappa	0.28	0.82	1.83	1.11	1.44	3.37
Toona ciliata	0.28	0.82	2.20	1.34	1.20	3.36
Artocarpus heterophyllus	0.28	0.82	2.20	1.34	1.20	3.36
Swietenia macrophylla	0.15	0.44	3.00	1.83	0.48	2.75
Elaeocarpus floribundus	0.18	0.53	2.33	1.42	0.72	2.67
Polyalthia longifolia	0.18	0.53	2.33	1.42	0.72	2.67
Albizia lebbeck	0.15	0.44	2.00	1.22	0.72	2.38
Dipterocarpus turbinatus	0.15	0.44	2.00	1.22	0.72	2.38
Averrhoa carambola	0.15	0.44	2.00	1.22	0.72	2.38
Mesua ferrea	0.15	0.44	1.50	0.91	0.96	2.31
Senna siamea	0.08	0.24	3.00	1.83	0.24	2.31
Chukrasia tabularis	0.15	0.44	1.50	0.91	0.96	2.31
Swintonia floribunda	0.13	0.38	1.67	1.02	0.72	2.12
Mangifera indica	0.13	0.38	1.67	1.01	0.72	2.11
Casuarina equisetifolia	0.13	0.38	1.25	0.76	0.96	2.10
Samanea saman	0.08	0.24	1.50	0.91	0.48	1.63
Saraca asoca	0.08	0.24	1.50	0.91	0.48	1.63
Lagerstroemia parviflora	0.05	0.15	2.00	1.22	0.24	1.61
Tectona grandis	0.05	0.15	2.00	1.22	0.24	1.61
Acacia mangium	0.05	0.15	2.00	1.22	0.24	1.60

RF. – Relative frequency, A. – Abundance, RA. – Relative abundance, RD.– Relative density, IVI – Importance Value Index.

The distribution pattern of planted tree species revealed that in the whole study area the highest IVI was represented by *Syzygium fruticosum* (27.81) followed by *Eucalyptus camaldulensis* (17.12), *Syzygium cumini* (15.44), *Albizia odoratissima* (14.26), *Terminalia bellirica* (12.90), *Lagerstroemia speciosa* (12.70), *Acacia auriculiformis* (11.96), *Cassia fistula* (10.87) and *Albizia procera* (10.54) whereas *Pinus caribaea* (0.93) and *Flacourtia jangomas* (0.93) showed the lowest IVI. In plantation areas: *Syzygium fruticosum* (75%) and *Eucalyptus camaldulensis* (75%) exhibits the highest relative frequency followed by *Terminalia bellirica* (70%), *Albizia odoratissima* (67.5%), *Palaquium polyanthum* (52.5%) whereas *Averrhoa carambola* (2.5%), *Flacourtia jangomas* (2.5%), *Pinus caribaea* (2.5%), *Acacia mangium* (2.5%) and *Tectona grandis* (2.5%) were showed the lowest relative frequency.

For individual species, *Holarrhena antidysenterica* was the highest IVI (28.08) followed by, *Lithocarpus thomsonii* (25.37). *Holarrhena antidysenteric, Lithocarpus thomsonii, Grewia nervosa, Streblus asper, Stereospermum colais, Ficus hispida, Lannea coromandelica, Litsea glutinosa and Artocarpus lacucha* were the most common naturally growing tree species in this Eco-park. On the other hand, *Syzygium fruticosum, Eucalyptus camaldulensis, Syzygium cumini, Terminalia bellirica, Cassia fistula, Terminalia chebula, Phyllanthus emblica, Mimusops elengi* and *Hopea odorata* were the most dominant planted tree species in the Eco-park. *Clerodendrum viscosum, Urena lobata , Ixora cuneifolia, Mimosa pudica, Phyllanthus reticulatus, Grewia nervosa, Mikania cordata, Lantana camara, Hyptis suaveolens* and *Ficus hispida* species were most common and dominant plant species of the both natural and planted areas of the Eco-park. Some of the rare species namely *Podocarpus nerifolius, Cycas pectinata* and *Swintonia floribunda* were found in the study area.

Discussion

It has been reported that in Bangladesh there are a total of 3,611 species of angiosperms belonging to 198 families of which, 2,623 species under 158 families belong to dicotyledons and 988 species under 41 families belong to monocotyledons (Ahmed *et al*. 2008). Species composition of Sitakunda Botanical Garden and Eco-park revealed in this study that a total of 267 species belonging to 172 genera under 101 families recorded covering an area of 808 ha. and it seems to be very encouraging. The present study found the number of the species composition is higher than that of same area, e.g. 203 plant species under 154 genera in 54 families reported by Rahman and Uddin (1997). Also, 46 tree species were found in this study and higher in comparison to other forest areas, i. e. 36 tree species in Sitakunda area by Heinig (1925) and 38 tree species in Ukhia range of Cox'sbazar (Ahmed and Haque 1993). On the other hand, the tree species composition is comparatively lower than 238 tree species reported from the Bangladesh Forest Research Institute Campus (Alam *et al*. 2015), 183 tree species reported from the Dudhpukuria- Dhopachari Wildlife Sanctuary (Hossain *et al*. 2013) and 64 regenerating tree species from Baraitali Forest of Chattogram (South) Forest Division (Hossain *et al*. 2004). However, considering the results of these similar studies, it can be incidental that the Sitakunda area possesses comparatively well diversified natural and plantation forests with higher number of tree species in comparison to other natural forests of the country. A very few researches were done on herb and shrub species richness in the Sitakunda botanical garden and eco-park. The study found that habit diversity of the classified as shrubs 44 species, herbs 34 species and climber 30 species. The present study revealed that, the herbaceous vegetation on the natural disturbed and undisturbed zone were showed good diversity in the open patches. As a result, the biodiversity has been changed the Sitakunda botanical garden and eco-park after over the time.

Importance Value Index (IVI) indicates the dominancy of species in heterogeneous plant community. The IVI value helps the planner to select priority indigenous species for conservation program. So, the *Holarrhena antidysenterica* (28.08) was found the most dominant in natural undisturbed zone and *Syzygium fruticosum* (27.81) was dominant in plantation site. The *Holarrhena antidysenterica* needs a slight amount of shade but it develops best in full light. It is sensitive to frost, but has good powers of recovery from the base when killed down and may often be found in abundance persisting on grassy areas subject to severe frost. It shoots up readily after severe damage by fire. It produces root-suckers in abundance (Troup 1921). All the dominant tree species found in the study area regenerate by root suckers and coppice.

Local people practice agro-forestry, collect litter, cut regeneration and non-woody plants from the disturbed zone which might impact species diversity. There is very less variation for the climber and shrub species between zones. Most of the time, when local people collect fuel wood, they cut climbers and use it to bind the fuel wood together. It can be observed from this study that some of the dominant tree species were a lower proportion than all other tree species found in both zones at their regeneration stage.

Conclusion

Sitakunda Botanical Garden and Eco-park is one of the important place for *in situ* conservation of Bangladesh. The plant diversity of Eco-park has been changed after its establishment on 2001. The present finding indicates that protection help to conserve the species diversity through baseline information of the Eco-park. The study results will also provide an assessment on tree species diversity, density, abundance and composition which will helpful for preparing a sustainable management plan. Habitat is the key indicator for conservation of biodiversity in Sitakunda Botanical Garden and Eco-park. However excessive exploration of the Eco-park should be controlled. Fire protection is the major threat for Eco-park. The top breaking and hollow trees under Moraceae family will not be removed from the Eco-park which is suitable for biodiversity conservation. Recently gathering and harvesting dry leaves, bamboo branches and wood collection for fuel is one of the major notable threats for the depletion of biodiversity in this Eco-park.

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