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GROWTH AND DEVELOPMENT OF BAMBOO IN THE COASTAL INUNDATED AREA OF BANGLADESH

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Abstract

Bamboo has been introduced to coastal raised land under the *Sonneratia apetala* plantation and grew barren land in inundated areas in the western coastal belt of Bangladesh. This study aimed to quantify the bamboo growth in inundated areas at mini-mound, plain land, and barren land and under the *S. apetala* plantation and characterize the impact of inundation, soil pH, and soil salinity. The experimental plantation was carried out by *B. vulgaris* and *B. balcooa* on a mini-mound on barren coastal raised land in 2018. Other experiments of *B. vulgaris* were carried out on mini-mound and plain land under the *S. apetala* plantation in 2019 and 2020. Seedlings were raised by branch cutting. Mini mounds were prepared with soil. The soil sample was collected at different depths in off-peak and peak periods to determine soil pH, electrical conductivity (dsm^{-1}), and nitrogen%. The growth of *B. vulgaris* in survival (p-value 0.0004) and new culms initiation% (p-value 0.0068) were significantly higher than *B. balcooa* in the barren land. Soil electrical conductivity showed significantly higher in all soil depths at barren land than under *S. apetala* forest in off-peak (p-value 0.0000, 0.0000, 0.0016) and peak periods (p-value 0.0002, 0.0028, 0.0000). The higher soil salinity affects the growth of two bamboo species. The higher soil pH affected the growth of *B. balcooa* on barren land. The growth performance of *B. vulgaris* showed significantly better survival% (p-value 0.030), height (p-value 0.0010), girth (p-value 0.011), total culms per clump (p-value 0.0086), and new culms initiation% (p-value 0.022) on the mini mound than plain land under *S. apetala* forest in 2019 and 2020 except height growth. The present study observed an inundation impact on the growth of *B. vulgaris* in the plain land plantation. *B. vulgaris* performed better on mini-mound under the *S. apetala* forest in inundated coastal areas.

Keywords: *Bambusa vulgaris*, *Bambusa balcooa*, Inundation, Under *Sonneratia apetala* plantation, Growth performance, Soil salinity.

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Introduction

Bamboo species are dense plants on the ground in tropical and subtropical regions between 46^0 N and 47^0 S (Yeasmin *et al*., 2015, Bitariho and McNeilage, 2008). It has two subfamilies, namely Poaceae and Bambusoideae (Ruiz-Sanchez *et al*. 2019). It can grow from sea level to high altitude (Adekoya, 2003). It is growing very fast and has the highest yield, highest biomass, most important minor forest resources in tropic and sub-tropic, and efficient in high CO_2 fixation rate (Akwada and Akinlabi, 2016; Jiang *et al.*, 2011; Riano *et al.*, 2002). Adekoya (2003) noticed that some species attain a full height in 2-4 months. Bamboo generally matures within only three years, while wood needs approximately 20 years (Emamverdian *et al*., 2020). Above 31 million bamboo plantations have existed globally, which is 0.8% of the total forest area, and led to the growth of bamboo by more than 60% in China, Brazil, and India (FAO, 2010, Gu *et al*., 2019). About 1225-1500 species have approximately 75-105 genera (Zhu, 2001). Almost 1500 commercial goods are made of bamboo (Li and Kobayashi 2004). A new application of bamboo is found every few years (Emamverdian *et al*., 2020). Bamboo is very versatile; some species have special characteristics that change their habits according to nature (Agrahari *et al*., 2020).

In Bangladesh, about 33 bamboo species are growing throughout the country under nine genera (Latif, 2008; Rahman *et al*., 2017). About 5,000 hectares of bamboo plantations exist in Bangladesh (Rahman *et al*., 2017). Eighty percent of the raw materials for bamboo supply are sourced from villages, with the remainder from the forest (Islam *et al*., 2015a). Bamboo is widely cultivated in Bangladesh, with about 15 different types growing in the country's plains. The most common bamboo species in the plains of Bangladesh are *Bambusa balcooa*, *Bambusa vulgaris*, and *Bambusa nutans* (Latif, 2008).

Bambusa vulgaris is a species native to the tropics. It is widely grown in rural Bangladesh and has multiple uses. Furthermore, the abundance of *B. vulgaris* populations in coastal areas is poor (Islam *et al*., 2015a). It is a medium-sized bamboo, not densely tufted, with 8-20-meter-tall culms. Its culms have yellow or green stripes; flowering is not common. Internodes are 25-35 cm long, 5-10 cm in diameter, and have a wall thickness of 7-15 mm. Inflorescence panicles have many spikelets but no seeds (Rao *et al*., 1998). It is cultivated mostly on river banks, roadsides, wastelands, and open ground, generally at low altitudes, and can be grown under a wide range of moisture and soil conditions (Ohrnberger, 1999). *Bambusa balcooa* Roxb. is another species. It is a tall bamboo that grows in distinct tufts, groups, or clumps; culms are 20-24 m long, 8-15 cm in diameter, grayish-green to light white, thick-walled 2-2.5 cm, nodes are prominent, internodes are 40-45 cm long, and the leaf blade is oblong (Rao *et al*., 1998). *B. balcooa* grows up to 700 m above sea level in tropical monsoon climates with an annual rainfall of 2,500-3,000 mm. The ecological niche modeling prediction map showed that the natural distribution of *B. balcooa* was more favorable in coastal areas than inland areas of India (Viswanath *et al*. 2021). It grows on any soil but prefers heavy-textured soils with good drainage and a low pH of about 5.5. Gregorian flowering and seed-setting usually occur every 35-45 years; flowering was last reported between 1983 and 1988 in Bangladesh (Schröder, 2011; Rahman *et al*., 2017). *Bambusa balcooa* is native to Vietnam, Bangladesh, India, Laos, Myanmar, and Nepal, where it is also widely distributed. The demand for bamboo is increasing at a much higher rate than its supply because of the rapid growth of the population (Rahman *et al*., 2017). Growing bamboo on a large scale villages of Bangladesh and forests is one option to increase bamboo resources.

Bangladesh is a pioneer country in coastal afforestation (Siddiqi and Khan, 1990; Spalding, 1997). The coast of Bangladesh is 710 km long, a transition zone with land-water interface linking various ecological and economic systems (Hossain, 2001; Iftekhar, 2006). The afforestation program along the coastal belt was initiated in 1966 (Das and Siddiqi, 1985). Mangrove forest plantation areas have grown in Bangladesh over the last 20 years (Hasan, 2013). Until 2013, mangrove species were planted on a total of 0.192 million hectares of accreted land in the coastal regions (Hasan, 2013). In coastal mangrove plantation programs, the two most successful plant species are *Sonneratia apetala* Buch. Ham and *Avicennia officinalis* (baen) L. (Siddiqi, 2001a). The mortality of planted seedlings of these species in coastal areas is also high (Siddiqi and Das, 1988, Miah *et al*., 2014). Due to the mortality of planting seedlings, huge gaps are created inside *S. apetala* plantations (Serajuddoula *et al*., 1995). Moreover, insufficient regeneration appeared under these plantations, and the productivity of man-made coastal forests in Bangladesh is also poor compared to other Asian countries (Islam *et al*., 2015b; Howlader, 1999). Islam *et al*. (2015b) reported that the density of *S. apetala* plantations per hectare stock was 1201 at the age of 17-42 years in the different coastal areas of Bangladesh. The planted *S. apetala* density at Mirersarai, Chattogram coastal areas was 650 trees per hectare at ages 20-29 years (Uddin *et al*., 2014). Approximately 1,26,000 hectares of plantations aged 21 to 55 years old throughout the coastal belt, including plantation failure areas (Hasan, 2013). The maximum areas are now raised, and inundation is limited to only a few months during the full moon and new moon periods. As a result, the raised lands are no longer suitable for the growth of *S. apetala* and other mangrove species (Siddiqi, 2001b). Islam *et al*. (2014) found seven mainland species suitable for this raised land. Islam *et al.* (2015a) stated that now is the time to pay attention to growing bamboo in coastal homesteads and raised forests. We aimed to assess the growth performance of *B. vulgaris* and *B. balcooa* on the coastal raised land and under the older *S. apetala* plantation and the growth performance of bamboo under inundated conditions. In addition, evaluate soil properties such as pH, electrical conductivity, and nitrogen percentage of experimental plots with bamboo growth.

We hypothesized that bamboo could be introduced to coastal raised land where periodic inundation occurs for three to five months at high tides, and bamboo growth is influenced by inundation, soil salinity, and soil pH. We tested this hypothesis by addressing three scientific questions: (1) Do *B. vulgaris* and *B. balcooa* differ in several growth parameters in the inundated area? (2) Are mini mounds used to reduce the impact of inundation on bamboo growth performance? (3) Do soil pH and soil salinity regulate bamboo growth?

Materials and Methods

In 2018, the Plantation Trial Unit Division of the Bangladesh Forest Research Institute conducted experiments on the mini mound on barren land with two bamboo species, *B. vulgaris* and *B. balcooa*, at Char Nazir under Rangabali in Bangladesh's western coastal belt. Other experiments were carried out by *B. vulgaris* planted on the mini mound and plain land under the *S. apetala* plantation at the same location as Char Nazir from 2019 to 2020. The experiment sites are 21 ^{0}58' 066 N and 90 ^{0} 30' 344 E (GPS = 3 m), respectively. The annual rainfall is 2377 mm, and the mean annual temperature is a minimum of 12.20°C and a maximum of 25.0°C (Patukhali District Statistics, 2011). The soil is alluvium, non-calcareous. The combined actions of the rivers Meghna, Brahmaputra, and Ganges have formed the landscape. The experiment sites almost experienced ebb and tide in the rainy season. These sites were inundated for about 3-5 months (Photograph 1). It was fully inundated for up to 4 months, from July to October, and in June only for the new moon and full moon periods. The water height observed in experimental plots was 91-95 cm in August, and the duration of inundation was about two hours. The average tree density of *S. apetala* was 325 trees per hectare in the experiment sites in 2019 and 2020.

Seedling raising: The seedlings were raised in the nursery using branch-cutting technology on *B. vulgaris* and *B. balcooa*. Branch cuttings were collected from one- to two-year-old bamboo stalks and cut using a hand saw from March to August. The branch length was kept at 3-5 nodes, or 70–80 cm, and was prepared by clipping leaves and small branches. The collected cuttings were inserted into the sand bed. The sand bed was used as a rooting medium, and the placed branch cuttings were 7-10 cm deep with a spacing of 3-5 cm. For up to a month, the branches were watered regularly. Each cutting produced functional roots within 30–45 days and was left very plentiful. At this time, the cut bamboo branches were transferred in polybag with a size of 25 cm × 15 cm, which was filled with a mixture of powdered loam soil and cow dung at a ratio of 3:1. The transferred cutting bags were kept in the shade for one week. Afterward, seedlings were maintained in a normal nursery bed by weeding, watering, etc., for the next 10-12 months.

Site preparation: Sites were prepared by weeding, jungle cutting, and clearing.

Mound preparation and plantation: The mound plantation is innovative in coastal areas on saline soil with non-mangrove tree species (Miah *et al*., 2021). The mound system land use in coastal areas of Bangladesh is an established practice for avoiding inundation risks and diversifying vegetation with non-mangrove plantations and crops (Nandy *et al*., 2013). A mini mound was prepared for each seedling to avoid inundation impact on new seedlings. Mounds were prepared by soil, size at 0.60 m × 0.60 m × 0.60 m. Totals of 384 mounds were prepared for *B. vulgaris* and *B. balcooa* for barren land in 2018. Sixty-four seedlings were planted on a mound in each species in each plot, with three replications at both treatments (*B. vulgaris* and *B. balcooa*). Another experiment was established in 2019 and 2020 for *B. vulgaris* species on the mini mound and plain land under the *S. apetala* forest. One hundred twenty-one seedlings of *B. vulgaris* were used in each plot, with three replications at both treatments (Mound and plain land) in 2019 and 2020. These 726 branch-cutting seedlings were planted each year. A total of 1452 seedlings were used in these two years' experiments. Both experiments were laid out with Random Complete Block Design (RCBD). Mounds were prepared in late March to mid-April. About ten kilograms of cow dung were mixed in each mound. The plain land hole was prepared like mound and every hole size was 0.60 m× 0.60 × 0.60 m. The hole was filled with 10 kg of cow dung with soil. Seedlings were planted in mid-April to mid-May after heavy rain. The spacing was maintained from seedling to seedling 3 m × 3 m both bare land and under the *S. apetala* forest. The experimental plantation was securely fenced to keep grazing animals out. Weeding and repearing of mounds onee in a year.

Mounds are repaired once a year, and weeding is also done. The data concerning survival, height (m), girth (cm), culm production, culms per clump, new culm production, and shoot/culm initiation percentage were collected in December 2020. All statistical analyses was performed using the MINITAB statistical package. The relationships among the two bamboo species in growth and mound and plain land plantations (survival, height, girth, shoot, culm production, and new shoot/culm production) were determined by a t-test. The significance level was set at p 0.05, and p values less than 0.05 were considered statistically significant.

Soil sample collection and analysis: Soil samples were collected from experimental plantation at three depths viz. 0-10 cm, 11-20 cm, and 21-30 cm in December and April to analyze soil pH, nitrogen percentage, and soil electrical conductivity (dS m^{-1}). The soil samples were analyzed in the Bangladesh Soil Resource Development Institute (SRDI) laboratory, Barishal and methodology followed as per SRDI's recommended practices (SRDI 2012).

Results and Discussion

The growth performance of *B. vulgaris* and *B. balcooa* planted on mini-mounds under open land (open land) where inundation occurs every 3-5 months in the western coastal belt is shown in Table 1. Survival rates for *B. vulgaris* and *B. balcooa* were 95.30% and 20.33%, with shoot initiation rates of 99.67 and 54.67%, respectively. The average dominant culm height for *B. vulgaris* and *B. balcooa* was 2.99 m and 2.26 m, respectively, and the girth was 5.66 cm and 4.29 cm; total culm production per clump was 3.64 and 2.11 in number at the age of 2.5 years on barren or open coastal raised land.

Table 1. Growth performance of *B. vulgaris* and *B. balcooa* on mini mound coastal raised land at the age of 2.5 years.

Name of Species	Survival (%)	Mean height of dominant culms (m)	Mean girth of dominant culms (cm)	Number of culms/ clump	New culms initiation (%)
Bambusa vulgaris	95.30	2.99	5.66	3.64	99.67
Bambusa balcooa	20.33	2.26	4.29	2.11	54.67
P value	0.0004	0.11	0.17	0.11	0.0068

Bambusa vulgaris outperformed *B. balcooa* in terms of survival and shoot initiation (p values = 0.0004, and 0.0068, respectively), but there were no significant differences in height growth (p = 0.11), girth (p = 0.17), or shoot production (p-value = 0.11) (Table 1).

The survival of *B. vulgaris* under the vacant *S. apetala* forest on the mini mound and plain land was 87.00% and 61.67%, respectively, in 2019, when the stand age was 1.5

years. The shoot initiation, dominant culm height, girth, and total culm production per clump were recorded in the understory of the vacant *S. apetala* forest for mini-mound 99.64%, 4.89 m, 6.31 cm, and 5.24 individuals, respectively. For plain land shoot initiation, dominant culm height, girth, and culm production per clump was recorded at 72.67%, 1.89 m, 1.49 cm, and 3.38 individuals, respectively. When the stand age was 1.5 years, the survival performance ($p = 0.030$), shoot initiation rate ($p = 0.022$), height ($p = 0.0010$), girth ($p = 0.011$), and total culm production ($p = 0.0086$ 0.05) were significantly differed between the mini mound and plain land plantations (Table 2).

Table 2. Growth performance of *B. vulgaris* on mini mound and plain land under the *S. apetala* forest in the coastal raised land at the age of 1.5 years.

Plantation types	Survival (%)	Mean height of dominant culms (m)	Mean girth of dominant culms (cm)	Number of culms/ clump	New culms initiation (%)
Mini mound	87.00	4.89	6.31	5.24	99.67
Plain land	61.67	1.89	1.49	3.38	72.67
P value	0.030	0.0010	0.011	0.0086	0.022

In another experiment, *B. vulgaris* was planted in 2020 under a vacant *S. apetala* forest, and the survival rates for mini-mound and plainland plantations were 99 and 54%, respectively. The shoot initiation rate, new culms per clump, and culm production were recorded for mini-mounds at 88%, 1.69 individuals, and 2.4 individuals. For plain land shoot initiation percentage, new culms per clump and culm production were recorded at 8%, 0.077, and 1.08 individuals, respectively. The mean height of dominant culms for the mini-mound was recorded at 1.63 m and plain land at 0.9 m. The results of survival percent ($p = 0.0076$), shoot initiation percent ($p = 0.0013$), new culms per clump ($p = 0.0400$), and culm production per clump ($p = 0.0282$) at the age of 0.5 years revealed a significant difference between from mini-mounds and plain land plantation. However, there was no statistically significant difference in height growth performance ($p = 0.21$) (Table 3).

The growth performance of *B. vulgaris* planted on a mound in coastal barren land and under *S. apetala* forest was studied at 1.5 and 2.5 years (Table 4). The results showed mean survival of 95.30% and 87%, mean heights of dominant culms of 2.99 m and 4.89 m, mean girths of dominant culms of 5.66 mm and 6.31 mm, and total culm production of 3.64 individuals and 5.24 individuals for barren land and under the *S. apetala* forest at the ages of 2.5 years and 1.5 years, respectively. The mean height and girth of dominant culms were significantly better in 1.5 years under the *S. apetala* forest plantation than in 2.5 years under the older plantation of vacant land.

Table 3. Growth performance of *B. vulgaris* on mini mound and plain land under the *S. apetala* forest in the coastal raised land at the age of 0.5 years.

Plantation types	Survival (%)	Mean height of dominant culms (m)	Mean girth of dominant culms (cm)	Number of culms/ clump	New culms initiation (%)
Mini mound	99.00	1.63	-	1.69	88.00
Plain land	54.00	0.90	-	0.077	8.00
P value	0.0076	0.21		0.028	0.0013

Table 4. Growth Performance of *B. vulgaris* on mini mound in coastal barren land and under the vacant *S. apetala* forest at different ages.

Year of Plantation and age	Plantation type	Survival (%)	Mean height of dominant culms (m)	Mean girth of dominant culms (cm)	Total culms/ clump	Culms/shoot initiation (%)
2018 (2.5 years)	Barren land	95.30	2.99	5.66	3.64	99.67
2019 (1.5 years)	Under *S. apetala* forest	87.00	4.89	6.31	5.24	99.66
P value		0.36	0.0023	0.014	0.11	-

The soil characteristics of this experimental site were calculated and shown in the Table. 5. The soil pH was found in the off-pick period (December) at 7.5, 7.6, and 7.7, and in the pick period (April) at 8.4, 8.4, and 8.3 at 0 to 10 cm, 11-20 cm, and 21 to 30 cm soil depth under the *S. apetala* plantation, respectively. The soil pH was found to be 8.3, 8.2, and 8.2 at a soil depth of 0-10 cm. 11.20-20 cm, and 21-30 cm. in the off-pick period, and 8.3, 8.2, and 8.8 cm in the pick period at the barren land plantation, respectively. 9.90 ds/m was found in 0-10 cm of soil depth at the barren land plantation, and at the same time, 5.98 ds/m was observed under the *S. apetala* forest in the same soil depth. Furthermore, the lowest was found at 2.70 ds/m in 21-30 cm soil depths in December

Table 5. Soil pH and Soil EC (ds/m) and nitrogen % of experimental bamboo plantation land in off-pick (December) and pick period (April) in 2019 and 2020 at different soil depths at barren land and under the *S. apetala* forest of experiment sites.

Land type	Soil pH December/2019 (Soil depth in cm)			Soil pH April/2020 (Soil depth in cm)			Soil EC (ds/m) (December/2019) (Soil depth in cm)			Soil EC (ds/m) (April/2020) (Soil depth in cm)			Nitrogen% (Av. 0-30 cm soil depth)
	0-10 cm	11-20 cm	21-30 cm	0-10 cm	11-20 cm	21-30 cm	0-10 cm	11-20 cm	21-30 cm	0-10 cm	11-20 cm	21-30 cm	
Barren/ Open	8.3	8.2	8.2	8.3	8.2	8.8	7.08	4.58	4.04	9.90	9.43	8.76	0.054
Under *S. apetala*	7.5	7.6	7.7	8.4	8.4	8.3	4.65	4.01	2.70	5.98	5.45	5.04	0.06
P value	-	-	-	-	-	-	0.000	0.000	0.0016	0.0002	0.0028	0.000	-

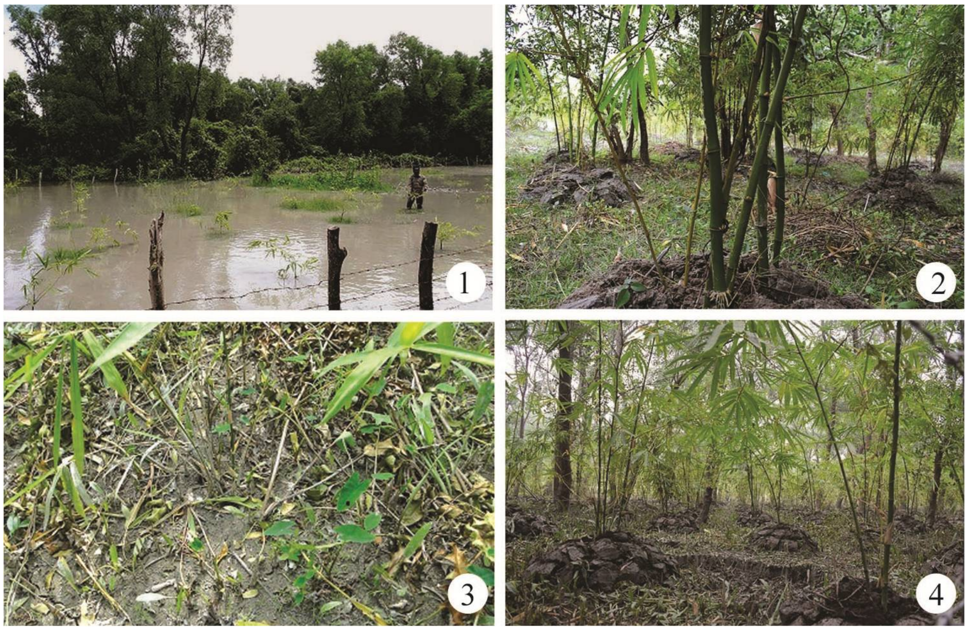
2019 under the *S. apetala* forest. Soil electrical conductivity measurements revealed significantly different values between barren land and *S. apetala* forest in all soil depths At 0–30 cm soil depth, the average nitrogen percent was 0.054% in barren land and 0.06% in *S. apetala* forest, respectively.

Islam *et al*. (2015a) recorded survival (30%), height (16.30 m), DBH (5.29 cm), and culms per clump (15.50) for *B. vulgaris* at coastal homesteads of the Rangabali Islands at the age of four years. They also recorded survival (51%), height (5.61 m), DBH (4.27 cm), and total culms per clump (5.93) for *B. vulgaris at* Noakhali coastal homesteads at the age of four years. In other experiments, the authors discovered that after three years of plantation, Char Osman had the highest survival rate (41%), Char Kukri-Mukri Island had the lowest (30%), and coastal homesteads on Rangabali Island had the highest (31%). They also recorded the highest mean height of dominant culms at 13.21 m at Rangabali. The lowest (3.74 m) at Char Osman under Noakhali, and the average total culms per clump at four locations of coastal homesteads, namely Rangabali, Char Kukri-Mukri, Char Osman, and Sitakundu, were found to be 11.50 individuals at the age of 3.0 years. Serajuddoula *et al*. (2001) found the average height of *B. vulgaris* was 7.9 m at the age of three years, and after four years, it attained 13.7m and a DBH of 6.41 cm on plain land. Bhol and Nayak (2014) found that the growth of dominant culms of *B. vulgaris was 8.31 m*-*9.15* m, and the total number of culms produced was 14.9 **-** 20.3 at Bhubaneswar, India. DBH for *B. vulgaris* was 5.90 cm at 3 years in the southern ecological zone of India. The highest culm production for *B. vulgaris* was found at 6.81, 13.21, and 19.57 at the Cauvery delta zone after one year, two years, and three years, respectively (Krishnakumar *et al.*, 2017). Asari and Suratman (2010) found an average height of 14.27 m, a DBH of 6.5 cm, and a culm production of 4.28 clumps per year for *B. vulgaris* in Malaysia. At Balipara, Assam, India, Dutta and Baruah (2016) recorded the maximum shoot number and maximum shoot length of *B. balcooa* as 4 individuals and 6 meters, respectively.

The study found significant differences in growth parameters such as survival and culm production on mound plantations, with *B. vulgaris* outperforming *B. balcooa* on barren land. The growth of bamboo in the coastal barren land. Both species were found to have less performance than other plantations. This could be due to soil salinity. Soil salinity was found to be higher in barren land (9.90 dS m^{-1}) than in the *S. apetala* forest (5.98 dS m^{-1}) (Table 5). In this study, soil pH was also high on barren land. The growth of *B. balcooa* was also affected by high soil pH because it prefers a low soil pH of 5.5 and a suitable pH range of 4.5-6.0 for its cultivation (Khanikar 2020). Uddin and Hossain (2013) found that the soil salinity was higher in barren land than in older coastal plantations in Nolchira, Hatiya, and Noakhali coastal districts. Miah *et al*. (2021) observed less growth performance of some non-mangrove species in mound plantations than in embankment plantations at Kattoli Forest Beat under the Chattogram Coastal areas. They explained that the higher soil salinity observed in mound plantation sites had a greater impact on growth than in embankment plantation sites. Moreover, the present study found significantly better growth of *B. vulgaris* in the mean height of dominant culms and the mean girth of dominant culms at the age of 1.5 years under the *S. apetala* forest than at 2.5 years of plantation on barren land. This is due to the impact of salinity.

On the other hand, in both the 2019 and 2020 plantations, we observed superior growth performance of *B. vulgaris* beneath the *S. apetala* forest on the micro mound than on plain land plants (Photographs 2, 3, and 4). Promising *B. vulgaris* growth was seen on mounds in the *S. apetala* woodland. According to Islam *et al.* (2015a), Bangladesh's coastal homesteads have low *B. vulgaris* seedling survival rates because of flooding and grazing. Except for the height growth of the 2020 planting at the age of 0.5 years, the present study indicated that the growth of *B. vulgaris* in other parameters under the *S. apetala* forest on the mound was considerably better than plain land. This is due to age-related.

According to all characteristics, the growth of *B. vulgaris* shows that mound plantations are less affected by flooding than plain land plantings on coastal raised ground. Islam *et al*. (2015a) findings are relevant to the current study because they found that plain land had lower growth and survival rates in 2019 and 2020 than mound plantations. In comparison to earlier tests at household plantations, *B. vulgaris* fared better in our three experiments on mounds.



Photographs 1-4: 1. *Bambusa vulgaris* plantation on mini-mound at open land (2 months old) in the coastal inundated areas. 2. *B. bulgaris* plantation on mini-mound in 2019 (1.5 years old) under *S. apetala* forest in the western coastal belt of Bangladesh. 3. *B. vulgaris* plantation in 2019 (1.5 years old) on plain land under the *S. apetala* forest in the western coastal belt of Bangladesh. 4. *B. vulgaris* plantation in 2019 (1.5 years old) under *S. apetala* forest in the western coastal belt of Bangladesh.

More than 87% of *B. vulgaris* plants survived in three mound plantations, showing that the bamboo species can thrive on mounds under most of the current soil and climatic conditions. The growth and survival of *B. vulgaris* can be affected by inundation, as is currently being shown at a plantation on the plains. In both years of the experiment, *B. vulgaris* growth performances on the mound beneath the barren *S. apetala* forest were noticeably better in all growth indications. On the other hand, high soil salinity and pH have a greater impact on *B. balcooa* growth.

Bamboo has beneficial effects on the environment, including being a significant carbon sink, a good phytoremediation option, improving soil structure, and preventing soil erosion (Emamverdian *et al*., 2020). Additionally, it is crucial for preserving both the global carbon balance and the local natural ecosystem (Zhou and Jiang, 2004; Mao *et al*., 2016). Bamboo has a deep root system and underground rhizomes, which prevent soil and water loss and landslides (Liese, 2001; Zhou *et al*., 2005). According to Zhihua *et al*. (2014), bamboos improves soil fertility and increases biodiversity in coastal habitats.

According to Liese (2001), coastal regions that may be covered and productive will be chosen for salt-tolerant bamboo species. Bamboo exhibits unique biological traits and some varieties of bamboo can grow in wetlands because their rhizomes have well-developed air canals (Ding *et al*., 1993). Recently, bamboo plantations have been introduced in the coastal sandy area of China as a shelter belt. It is an effective method for increasing the diversity of tree species in coastal sandy lands (Zhang *et al*., 2007).

However, compared to its area, Bangladesh has a very high population. Infrastructure projects like new homes, roads, and other projects result in the loss of agricultural and forest areas. The vast raised land is in Bangladesh's coastal regions, which are submerged for a few months during the full and new moon phases. This wide, raised area would be ideal for growing bamboo. This can be introduced as a novel tree species for shelter belts in coastal locations, boosting coastal forest productivity, reducing soil erosion, and landslides, and increasing soil fertility. It will provide cash and job opportunities for people who live along the coast.

Conclusion

Tree growth performance is useful indicator for deciding the species to use in an evaluation program. The present study reveals that inundation and soil salinity can regulate the growth of bamboo species. Besides, high soil pH impacts in the growth of *B. balcooa*. The study suggests that *B. vulgaris* should be planted extensively on the mound beneath the older, elevated *S. apetala* plantation and on the raised desolate area. Due to their early supremacy over *Bambusa vulgaris* on dry terrain and underneath the elevated *S. apetala* forest, more advancement is required. Additionally, we must determine how both bamboo species are affected by greater soil pH and salinity levels in coastal areas.

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