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ENRICHMENT OF MANGROVE ECOSYSTEMS THROUGH *Kandelia candel* (L.) DRUCE SPECIES IN THE SUNDARBAN MANGROVE FOREST OF BANGLADESH

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Abstract

Kandelia candel (L.) Druce play an important role in creating habitats for a diverse community of organisms ranging from bacteria and fungi to fishes and mammals. A field experiment was conducted to enrich mangrove ecosystems through establishment and conservation of the mangrove species *K. candel* (L.) Druce in the moderate saline zone of the Sundarban in Bangladesh during the period of 2012 to 2017. Assessing the performance of *K. candel* plantations were done annually by monitoring the survival rate and one or more structural characteristics of the stand, including height (H), diameter at breast height (DBH) and mean annual increment (MAI). The height (m), DBH (cm), MAI (m) and survival (%) of *K. candel* trees differ significantly at different spacing. The highest height (m), dbh (cm) and survival (%) have been found 2.99m±0.09, 3.83cm±0.10 and 90%, respectively in the spacing 2m x 2m as well as the highest mean annual increment (MAI) for height 0.60 m and for dbh 0.77 cm were found in the same spacing. The calculated values were $F_{.05}$ (2) = 64.60 which was highly significant at the 5% level, LSD = 0.23for height and $F_{.05}$ (2) = 40.71, LSD = 0.25 for DBH. There were significant differences in the mean total height (m) and mean DBH (cm) among the spacing 2m x 2m, 1.5m x 1.5m and 1m x 1m. On the other hand coefficient of variation (CV) at different spacing was found 9.36, 11.54 and 13.64 for height and 8.62, 4.17 and 10.79 for DBH. All these findings reflect that growth performance of *K. candel* species was better on 2m x 2m compared to 1.5m x 1.5m and 1m x 1m spacing. Artificial regenerations of *K. candel* species can improve degraded habitats to facilitate recolonization by native mangrove species. To ensure sustainability of mangroves in the Sundarban, it is necessary to protect all the existing mangrove wetlands under *in situ* conservation by setting up natural reserves and excluding further anthropogenic destruction as well as developing a long-term scientific program.

Key words: Sundarban; Mangrove; Conservation; Growth; Spacing; Anthropogenic.

Introduction

Kandelia candel (L.) Druce is a mangrove species in the family Rhizophoraceae. Locally it is known as *vathkathi*. It grows as a shrub or a small tree up to 5 meters tall with DBH (Diameter at Breast Height) less than 16cm, found around the Sundarban of Bangladesh. It thrives on soft mud along in inland river banks associated with *Aegiceras corniculatum*, and as gregarious undergrowth on the same habitat (Peng and Xin-men 1983). According to Tomlinson (1986), it is found from the Ganges Delta, Myanmar through Southeast Asia to China, the Ryu Kyu Islands and southern Japan.

At least 40% of the animal species that are restricted to mangrove habitat and have previously been assessed under IUCN Categories and Criteria are at elevated risk of extinction due to extensive habitat loss (Luther and Greenburg 2009). It is assessed that 26% of mangrove forests worldwide are degraded due to over-exploitation for fuelwood and timber production (Valiela *et al.* 2001). Given their accelerating rate of loss, mangrove forests may at least functionally disappear in as little as 100 years (Duke *et al.* 2007). The loss of individual mangrove species is also of great concern, especially as even pristine mangrove areas are species-poor compared with other tropical plant ecosystems

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(Alongi 2002). In Sundarban, the population of the globally endangered species, *H. fomes*, is estimated to have declined by 76% since 1959 and about 70% of the remaining *H. fomes* trees are affected by the 'top dying' diseases (Chowdhury *et al.* 2008). Dramatic declines in other dominant mangrove species (*eg*., *E. agallocha* and *X. mekongensis*) have also been reported (Iftekar and Saenger 2008). In our observation, *K. candel* species in the Bangladesh Sundarban are declining rapidly. Therefore an experiment was conducted to evaluate the morphology, phenological observations, and growth performance of five years old *K. candel* species planted in moderate saline zone at different spacing in the Sundarban.

Materials and Methods

The experiment was conducted during the period of 2012 to 2017 to enrich mangrove ecosystems by establishment and conservation of the mangrove species through *K. candel* (L.) Druce. This study presents data concerning growth performance of the species at moderate saline zone of the Bangladesh Sundarban. For the purpose of raising seedlings of *Kandelia candel*, intertidal mangrove nurseries were established in the moderate saline zone of Sundarban in Bangladesh. To raise seedlings of *K. candel* species in the nursery, perforated polybags of 12cm x18cm size were filled with sandy/silt clay soil. The polybag seedlings ware set in a Complete Randomized Design (CRD) at 1.0m x 1.0m, 1.5m x 1.5m and 2.0m x 2.0m spacing with ten replications in moderate saline zone. The number of seedlings were planted in each plot is 81(9 x 9). Thus a total of 2430 (81 x 10 x 3) seedlings were planted in intertidal region where they were inundated by water regularly. Experimental plantations were initially protected by fencing against browsing up to the period it reached beyond the browsing height. Growth and survivability data of planted *K. candel* species were recorded twice in a year. Meteorological data were recorded. Data on water salinity, soil salinity, soil pH, sedimentation, soil erosion and inundation were recorded. Microsoft excel programs are to be used to process all collected information and in preparing tables, charts and graphs. The analysis of variance (ANOVA) was done to note whether there any difference existed in the species and between different spacing. All the nursery techniques and intercultural operations were done according to Rahman (2018).

Results and Discussion

Three mangrove nurseries were established in the setting of this research work in the Sundarban mangrove forest of Bangladesh. Gregarious growth of *Kandelia candel* seedlings at mangrove nursery in the Sundarban were shown in figure 1.

Figure 1: One year old seedlings of *K. candel* at mangrove nursery in moderate saline zone of the Sundarban

K. candel planted on July 2012 in the moderate saline zone of the Sundarban. The first flowering appeared in November 2014. However, the number of flowers on different saplings was not same. The better growing saplings had an average of 12-16 flowers at the anthesis stage. Its propagules were mature in April then ripened and fell in May - June. Flowers are whitish with numerous stamens. Propagules are viviparous and smooth. It becomes reddish at the tips when it matures. A five years old experimental plantations of *K. candel* species at 1.0m x 1.0m spacing in moderate saline zone of the Sundarban are shown in figure 2.

Figure 2: Monitoring the growth performance of five years old experimental plantations of *K. candel* at 1.0m x 1.0m spacing in moderate saline zone (Photo: November 2016)

Figure 3: Monitoring the growth performance of five years old experimental plantations of *K. candel* at 1.5m x 1.5m spacing in moderate saline zone (Photo: April 2017)

Assessing the performance of *K. candel* plantations depend largely on the objectives of the planting exercise, and monitoring parameters were selected accordingly. Assessment were done annually by monitoring the survival rate and one or more structural characteristics of the stand, including height (H), diameter at breast height (DBH) and mean annual increment (MAI). Five years old experimental plantations of *K. candel* species at 1.5m x 1.5m spacing in moderate saline zone of the Sundarban, bearing propagules are shown in figure 3.

The young seedlings require regular watering (daily in the summer months and 3-4 times a week in the dry season). Weeding the plants regularly as well as protecting them from pests and stray animals may also ensure the health of the trees for planting. Depending on the age of the young seedlings and the time of the year, proper shading is necessary. In their first 2-3 months, partial shade should be ideal, before gradually moving them to areas with full sun. Polybag seedlings are economical sources of planting materials and the easiest to transport. Raising seedlings of *K. candel* in nursery before planting out can increase the survival up to 100% and growth. This allows the seedlings to develop a healthy root system before planting. The average of germination percentage of *K. candel* was 100 and average height after one year was 40cm (Table1).

Table 1. Propagule morphology, phenological observations and germination performance of planted *K. candel* species in the Sundarban of Bangladesh

Sl. No.	Parameter	Moderate Saline Zone of the Sundarban
1.	Propagule collecting time	May - June
2.	Number of seed/fruit	1
3.	Number of propagule/kg	55 - 60
4.	Length of propagule (cm)	25 - 35
5.	Propagule storage time (days)	7
6.	Number of propagules sown	3000
7.	Initiation of germination (days)	5
8.	Completion of germination (days)	12
9.	Germination percentage (%)	100
10.	Average height after one year (cm.)	40

The experimental sites were selected for *K. candel* species trials in the moderate saline zone of the Sundarban. These were poorly regenerated and covered with grasses or non-commercial species like gilalata (*Derris trifoliate*), chandalota (*Dalbergia candenatensis*), tiger fern (*Acrostichum aureum*), dhanshi (*Myriostachya wightiana*), nalkhagra (*Phragmites karka*) and kewakatta(*Pandanus foetidus*). Detailed site descriptions of the experimental plots for *K. candel* species in the moderate saline zone of the Sundarban is given in table 2.

Table 2. Site descriptions of the experimental plots for *K. candel* species in the Sundarban

Sl. No.	Parameter	Moderate Saline Zone of the Sundarban
1.	GPS of the experimental site	Latitude: 22^0 26′ 51″ Longitude: 89^0 35′ 53″
2.	Year of plantation	2012
3.	Area of plantation (ha)	1.5
4.	Spacing	2.0m x 2.0m,1.5m x 1.5m, &1.0m x 1.0m
5.	Soil texture	Silty-clay
6.	Soil pH	7.5
7.	Soil salinity (m mhos)	2.7
8.	Water salinity (ppt)	12.0
9.	Inundation condition	Inundation by all tides in monsoon
10.	Initial vegetation	Dense cover of gilalata (*Derris trifoliate*), chandalota (*Dalbergia candenatensis*), tiger fern (*Acrostic humaureum*), dhanshi (*Myriostachya wightiana*), nalkhagra (*Phragmites karka*) and kewakatta (*Pandanus foetidus*)

Experimental plantations of *K. candel* were raised with the raised polybag seedlings and monitored regularly to assess their success and growth rate. After three months of planting, growth and survival data were recorded twice a year. In case of mortality, it is important to investigate the underlying causes and initiate appropriate remedial measures.

K. candel species have adaptations that allow them to tolerant medium levels of salinity. Salinity is an important factor in reducing competition between mangrove species and other vascular plants. *K. candel* species need freshwater for their germination, initial growth and survival. Due to the fact that mangroves are halophytes, it might seem strange that these species required freshwater, but some mangrove species even grow well in only slightly brackish conditions. Restoration planners need to take into consideration of the dominant mangrove species in the restoration site and determine the optimum salinity levels or thresholds for those plants (Field 1998; Waycott *et al.* 2011).

Table 3. Phenology of raised *Kandelia candel* species in the Sundarban

Sl. No.	Parameter	Moderate Saline Zone of the Sundarban
1.	Flowering age of the plant (year)	3 (including one year in the nursery)
2.	Flowering period	November - December
3.	Fruiting period	January - April
4.	Propagule dropping time	May - June

Phenological studies are involved with the observation and documentation of the timings of life history events of plants. There was no information on the phenology of *K. candel* species in the Sundarban of Bangladesh in the past. In the last few years, observations have begun to be made at *K. candel* plantations in the Sundarban. Initial studies have shown that flowering is precocious among the Rhizophoraceae, commencing from about 3 to 4 years of age. K. candel started flowering at moderate saline zone of the Sundarban 2 years after being planted. The first flowering appeared in November. Fruiting and propagule production of *K. candel* is annual and prolific, the propagule production occurs mainly in the rainy season from January to June (Table 3).During the rainy season, the salinity of tidal water decreases facilitating the sprouting of propagules and growth of seedlings, so that they can gradually tolerate the higher salinity of soil and water in the dry season.

The total height, diameter at breast height (DBH), mean annual increment (MAI), coefficient of variation (CV), survival %, F-value and LSD-value of *K. candel* trees as a view of growth performances of five years old monoculture plantations under moderate saline zone in the Sundarban were shown in the table 4. The height (m), DBH (cm), MAI (m) and survival (%) of *K. candel* trees differ significantly at different spacing. The highest height (m), DBH (cm) and survival (%) have been found 2.99m±0.09, 3.83cm±0.10 and 90% respectively in the spacing 2m x 2m as well as the highest mean annual increment (MAI) for height 0.60 m and for DBH 0.77 cm were found in the same spacing. A gregarious growth of five years old experimental plantations of *K. candel* at 2.0m x 2.0m spacing in moderate saline zone of the Sundarban are shown in figure 4. The most suitable spacing was recorded for *K. candel* species was 2.0m x 2.0m in moderate saline zone of the Sundarban.

Considering height and DBH data, analysis of variance (ANOVA), least significant difference (LSD) and coefficient of variation (CV) have been done. The calculated values were $F_{.05}$ (2) = 64.60** which was highly significant at the 5% level, LSD = 0.23for height and $F_{.05}$ (2) = 40.71**, LSD = 0.25 for DBH. There were significant differences in the mean total height (m) and mean DBH (cm) among the spacing 2m x 2m, 1.5m x 1.5m and 1m x 1m. On the other hand CV at different spacing was found 9.36, 11.54 and 13.64 for height and 8.62, 4.17 and 10.79 for DBH (table 4). All these findings reflect that growth performance of *K. candel* species was better on 2m x 2m compared to 1.5m x 1.5m and 1m x 1m spacing.

Figure4: Five years old experimental plantations of *Kandelia candel* at 2.0m x 2.0m spacing in moderate saline zone (Photo: April 2017)

Table 4. Growth performance of five years old *K. candel* species planted in moderate saline zone at different spacing in the Sundarban

Indicators	Spacing					
	2m x 2m		1.5m x 1.5m		1m x 1m	
	Height m ±se	DBH cm ±se	Height m ±se	DBH cm ±se	Height m ±se	DBH cm ±se
Mean data	2.99 ±0.09	3.83 ±0.10	2.08 ±0.08	3.12 ±0.04	1.76 ±0.08	2.78 ±0.09
Mean annual increment (MAI)	0.60	0.77	0.42	0.62	0.35	0.56
Coefficient of variation (CV)	9.36	8.62	11.54	4.17	13.64	10.79
Survival (%)	90		65		40	
Analysis of variance (ANOVA)	$F_{.05}$ (2) = 64.60** for height and 40.71** for dbh					
Least significant difference (LSD)	LSD = 0.23 for height and 0.25 for dbh					

Discussion

The mangrove plantation approaches use hand planting of desired propagules/seedlings and saplings at selected areas to restore mangrove forests. There are different techniques used in the plantation approach with *K. candel* species. First technique is to transplant seedlings from a mangrove forest to the plantation site. Second technique is to collect ripe propagules and directly plant them at the plantation site. Third technique is desired seedlings or propagules may be raised under nursery conditions and then transplanted at the plantation site. In this research study it was followed the third technique for raising experimental plantations with *K. candel* species.

K. candel in Longhai, Fujian, China, started flowering and producing propagules at about eight years old, and the number and density of flowers varied among plants of different ages (Chen 2000). In the

experimental plantations, it was recorded that *K.candel* species begins to flower and produce propagules after three years. In South East Asia, *K. candel* grows best on the banks of tidal rivers, or the landward side of the mangrove community, in brackish water (Watson 1928). In Hong Kong, *K. candel* mangroves were replanted in an intertidal mudflat area of 1,000 m^2 as a mitigation project to compensate from the damage from coastal construction activities from 1990 to 1991(Laulikitnont 2014). In Ha Tinh Province of Vietnam, a mudflat area of 580 ha was planted with mangrove species *K. candel* from 1989 to 1993 (Laulikitnont 2014). Mangroves around the world are affected by human activities, and all may be influenced by global changes in climate or sea level. Because mangrove coverage is being reduced, and hope that future exploitation of mangroves will be preceded by environmental impact assessments that will include estimates of biomass.Apart from the geographical location and forest structural attributes, the net primary productivity depends on abiotic factors such as hypoxic conditions, tidal height, and frequency of tidal inundation, availability of nutrients, salinity, and climatic factors (Aksornkoae 1993; Hutchings and Saenger 1987). *K. candel* grows on soft mud along in inland river banks associated with *Avicennia officinalis, Sonneratia apetala, Xylocarpus granatum, Nypa fruticans, Aegiceras corniculatum,* and as gregarious undergrowth on the same habitat in the Sundarban. The best growths of *Aegiceras corniculatum* were recorded in moderate saline zone and significantly lower growths were recorded in strong saline zone of the Sundarban (Rahman 2016a). The growth performance of *Rhizophora mucronate* was better on 2.5m x 2.5m compared to 2.0m x 2.0m and 1.5m x1.5m spacing in the moderate saline zone of the Sundarban (Rahman 2016b).

Through this experiment it was presented and demonstrated the growth performance of *K. candel* species at moderate saline zone of the Sundarban in Bangladesh. This approach should be applicable to other species of the Rhizophoraceae family, which bear similar imprints of their growth history. Artificial regenerations of *K. candel* species can improve degraded habitats to facilitate recolonization by native mangrove species. To ensure sustainability of mangroves in the Sundarban, it is necessary to protect all the existing mangrove wetlands *in situ* by setting up natural reserves and excluding further anthropogenic destruction as well as developing a long-term scientific program for restoration and must be managed as an ecosystem.

Conclusion

With the enrichment of a healthy mangrove forest by establishing *K. candel* plantations, the ecosystem may experience many benefits such as soil stabilization, enhancement of natural regeneration in future, sequestering and storing huge quantities of carbon, host a variety of plants that have adapted to grow in salt water**,** protecting shorelines and coastal communities against storms, sanctuary for juvenile fish, and the filtration of sea water. Despite their economic and ecological importance, these forests have been threatened mainly due to human activities, which necessitate the need for protecting and developing these ecosystems. *Ex situ* conservation, which aims to transfer a species to right place for preservation and development, is one of the most effective ways of protecting these forests. It is obvious that the successful transfer of a species in order to protect it as *ex situ* conservation requires a comprehensive environmental assessment. A wide range of plant species have been used in mangrove planting program. Proper spacing for *K. candel* species was determined. Nursery and planting techniques differ significantly among different mangrove species. Nursery and planting techniques for *K. candel* species were determined. Incorporating *K. candel* species for coastal green engineering is to use multi-species planting on certain prearranged environmental engineering structures and other biodegradable structures. These innovative structures may help to boost mangrove formations, accrete sediments and perhaps even enriching recruitment of seedling. The purpose of raising plantations of *K. candel* are to check soil erosion; enhancement of natural regeneration in future; to produce improved sources of planting materials, plus trees are selected from seed sources, seed production areas are established as well as seed orchards; production of fuel wood; beautification of coastal area; improvement of habitat; to support fisheries, apiculture, *etc.*, as well as eventually enrich the mangrove ecosystems.

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References

Aksornkoae, S. (1993). Ecology and management of mangroves. Dyna Print, Bangkok, p. 175.

Alongi, D. M. (2002). Present state and future of the world's mangrove forests. Environmental Conservation, 29: 331–349.

Chen, X.Y. (2000). Effects of plant density and age on the mating system of *Kandelia candel* Druce (Rhizophoraceae), a viviparous mangrove species. Hydrobiologia 423: 189–193.

Chowdhury, M.Q., Schmitz, N.,Verheydens, A., Sass-Klaassen. U., Koedam, N. And Beeckman, H. (2008). Nature and periodicity of growth rings in two Bangladeshi mangrove species.Iawa Journal 29 (3): 265-276.

Duke, N.C., Meynecke, J.O., Dittmann, S., Ellison, A.M., Anger, K. (2007). A world without mangroves? Science 317: 41-42.

Field, C.D. (1998). Rehabilitation of mangrove ecosystems: an overview.Marine Pollution Bulletin 37:383–392.

Hutchings, P. and Saenger, P. (1987). Ecology of Mangroves.Brisbane, Australia, University of Queensland, p 388.

Iftekar, M.S. and Saenger, P. (2008) Vegetation dynamics in the Bangladesh Sundarban mangroves: a review of forest inventories. *Wetlands Ecology and Management*16: 291-312.

Laulikitnont Penluck, (2014). Evaluation of Mangrove Ecosystem Restoration Success in Southeast Asia.University of San Francisco, Master's Projects.Paper 12.

Luther, D. and Greenburg, R. (2009). Mangroves: a global perspective on the evolution and conservation of their terrestrial vertebrates. Bioscience 59: 602–612.

Peng, L. and Xin-Men, W. (1983). Ecological notes on the mangroves of Fujian, China. In: Teas HJ (ed) Biology and ecology of mangroves. Dr W Junk Publishers, The Hague, pp 31-36.

Rahman, M. M. (2016a). Development of nursery and plantation techniques of *Aegiceras corniculatum* (L.) Blanto and its site suitability in the Sundarban of Bangladesh. Bangladesh Res Pub J 12(1): 50-59.

Rahman, M. M. (2016b). *Ex situ* Conservation of *Rhizophora mucronata* Lam. In the Sundarban Mangrove Forest of Bangladesh. Int. J. Bus. Soc. Sci. Res 5(1): 103-110.

Rahman, M. M. (2018). Growth Performance and Site Suitability of *Lumnitzera racemosa* Willd. in the Sundarban Mangrove Forest of Bangladesh. *Int. J. Bus. Soc. Sci. Res.* 6(2): 88-98.

Tomlinson, P.B. (1986). The botany of mangroves. Cambridge University Press, Cambridge, p 413.

Valiela, I., Bowen, J.L. and York, J.K. (2001). Mangrove forests: one of the world's threatened major tropical environments. BioScience 51: 807–815.

Watson, J.G. (1928). Mangrove forests of the Malay Peninsula. Malayan Forest Records 6:1–275.

Waycott, M., McKenzie, L.J., Mellors, J.E., Ellison, J.C., Sheaves, M.T., Collier, C., Schwarz, A., Webb, A., Johnson, J.E., and Payri, C.E. (2011). Vulnerability of mangroves, sea grasses, and intertidal flats in the tropical Pacific to climate change.In: Bell JD, Johnson JE &HobdayAJ (eds)Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Secretariat of the Pacific Community, Noumea, New Caledonia, pp 297-368.