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Propagation of an Endangered Gymnosperm Tree Species (*Podocarpus neriifolius* D. Don.) by Stem Cuttings in Non-mist Propagator

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ABSTRACT

Podocarpus neriifolius D. Don. (Podocarpaceae), an endangered and the only indigenous gymnosperm tree species, grows naturally in Bangladesh. Seed-based propagation of this species is challenging owing to its inadequate number of mother trees and irregular seed-setting attribute from among a few trees scattered throughout the country. This study weighs the significance and multiplication potentials of this species through rejuvenated stem cuttings with or without the application of Indole Butyric Acid (IBA). The rooting ability of the cuttings was evaluated by treating the cutting bases with 0%, 0.2%, 0.4% and 0.8% (w/v) IBA solution prior to place them in a low cost, non-mist propagation system. Steckling performances of the rooted cuttings were evaluated in the nursery conditions. The study found that the species was amenable to rooting with IBA treatments. The highest rooting percentage (61.3 ± 3.3 %; n = 90) and number of roots per cutting (9.8 ± 1.32; n = 90) were obtained in the 0.8% IBA treatment; however, the longest root and shoot, as well as the highest initial growth performances were obtained in 0.4% IBA treatment. Therefore, rejuvenated stem cuttings treated with 0.4% or 0.8% IBA solution in a non-mist propagator could potentially be an effective method for the clonal propagation of these tree species.

Keywords: Clonal propagation, endangered plant, IBA treatment, rooting ability, stem cutting

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INTRODUCTION

The Podocarps are considered one of the ancient plant groups on earth. Broad-leaved Podocarps, as identified in the Gondwanan fossil, used to be existing 144 million years back (Hill, 1994). Due to subannual light, darkness, and relentless cold weather conditions over extended period of year, broad-leaved foliage of this plant group in high altitude needs to be tough and versatile to endure such weather conditions (Mellick, 2012). Podocarps survived in the long term changing climate with certain physiological modifications including thick, hard, shiny, waxy, and leathery leaves, slow morphological adaptation to evolutionary senescence, restriction to mesic communities, and broad distribution.

Podocarpus neriifolius, Gymnosperm tree species, is one of the 110 species belonging to the genus *Podocarpus* under Podocarpaceae family. The family represents 173 species under 18 genera (Hill, 1994; Quinn & Price, 2003) among a total of 300,000 species of flowering plants including 630 species of conifer in the world (Hill, 1994). Podocarpaceae family was endemic to the ancient super continent of Gondwana and is a classic member of Antarctic floral community (Quinn & Price, 2003). Except for some taller individuals, the species usually grows up to 10-15 m in height and 100 cm in diameter at breast height (dbh) with a clear round bole. The species often bears a dome-shaped crown with whorled branches, brown thin bark, linear or lanceolate leaves of 10-20 cm in length (Figure 1A). While the male flowers of this dioecious tree species are cylindrical catkins with winged pollen (Sacci) grains (Figure 1B), the female flowers are with 2-4 scales (Figure 1C). Receptacles are

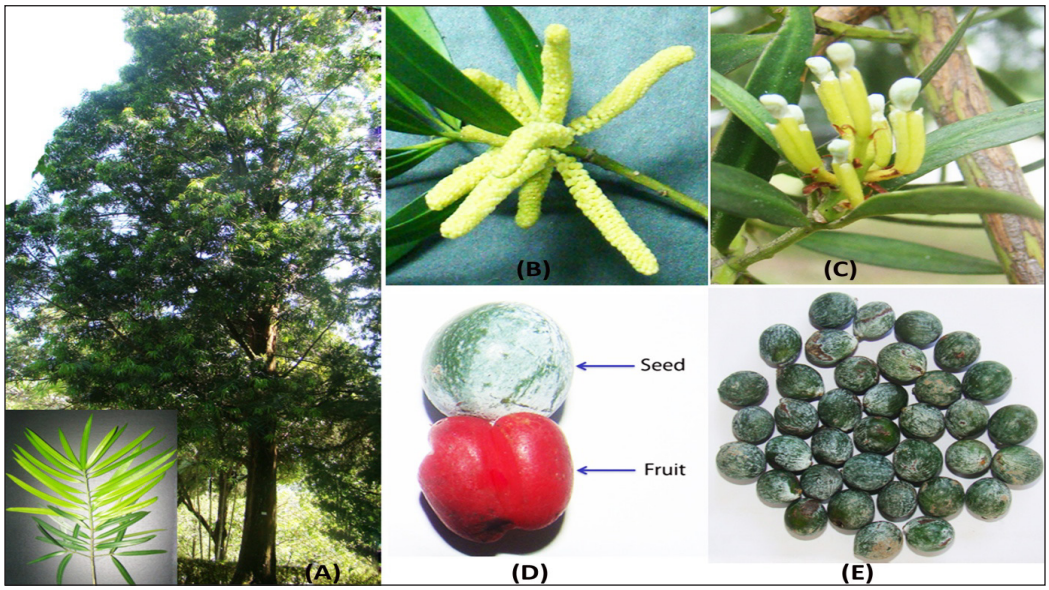


Figure 1. A full grown tree with leaves (inset) (A), male flowers (B), female flowers (C), seed attached with fruit (D) and separated seeds (E) of *P. neriifolius*

thick, fleshy, berry-like swollen, bright red or purple (Figure 1D), edible, and usually eaten by birds. The dark green ovate seeds are 2-3 cm long and 1-2 cm wide (Figure 1E) often with shiny black fleshy parts on ripening. These are also recalcitrant and quickly loss the viability. The species grows in tropical and subtropical closed forests of the eastern Asia and Australia. More specifically, the species is distributed in Nepal, India, Thailand, Vietnam, Malaysia, Indonesia, Philippines, China, Myanmar, Laos, Cambodia, New Guinea, Solomon, and Fiji Islands. In Bangladesh, it is the only conifer species that grows naturally in the forests of Chittagong, Chittagong Hill Tract, Cox's Bazar and Sylhet districts (Bhuiyan et al., 2009). The plant is commonly known as yellow wood, brown wood, brown or black pine, and in Bangladesh, it is called *Banshpata* (Bhuiyan et al., 2009).

Wood of the species is light in weight (Specific gravity 0.46-0.47) and easy to work with (Forest Inventory and Planning Institute [FIPI], 1996). It is also known as pencil wood and being used for making high quality pencils, photo frames, curving, wooden scales, cabinet works, and showpiece frames. The wood yields good quality pulp and can also be used as boxwood. The fruit is edible raw or can be cooked into jam (Bhuiyan et al., 2009). Besides, the species is planted for ornamental purposes around homes and avenues. However, this valuable tree species is now critically endangered in Bangladesh (Anon, 2009) with only 105 trees so far identified in the forests of Chittagong, Chittagong Hill Tracts, and different botanical gardens of the country (Anon, 2009). While some of the trees are over matured with no more reproductive growth, many are immature or unable to produce seed regularly. Due to clear felling, indiscriminate conversion of forest lands to housing, agriculture, transportation, industrialization and lack of mass awareness about the ecological and historical importance of the species, it became endangered and is likely to on the brink of extinction if conservation and much needed propagation measures are not taken immediately. However, it is difficult to propagate the species largely through seed germination due to scarce availability of seed trees in natural forests (Mannan et al., 2001). Only few scattered trees are growing throughout the country and the male and female trees are too far apart to produce profuse seeds. Vegetative propagation is therefore the only alternative to save the species from potential threats of extinction. Among the vegetative propagation means, stem cutting and tissue culture are the most widely used methods for mass clonal propagation for large-scale plantation programs. However, tissue culture involves large-scale investment in initial set up and sub-sequent operational activities, and also requires uninterrupted supply of electricity, which appears to be challenging in many developing countries like Bangladesh. The propagation technique through stem cutting in non-mist propagator (Kamaluddin, 1996) could be a viable solution to this problem. Stem cutting is a severed twig whose base is placed in a moist rooting media to

develop adventitious roots. The method is simple, cost-effective and can be operated in small spaces, anywhere even inside the forest or remote areas without the supply of electricity. The method when coupled with selection of plus trees can result in maximum genetic gain both in yield and quality. It allows continuous production and supply of high quality uniform planting materials with desirable characteristics (Hossain et al., 2014) for large-scale afforestation and reforestation programs (Kamaluddin et al., 1996).

Root development in the cuttings of many tree species is often difficult. Therefore, various rooting hormones are used to enhance rooting ability of desired cuttings. Rooting response can substantially be intensified by applying exogenous rooting hormone IBA, which has already been proved in *Artocarpus heterophyllus* (Hossain et al., 2002), *Pinus caribaea* (Henrique et al., 2006), *Stereospermum suaveolens* (Baul et al., 2009), *Flacourtia jangomas* (Hossain et al., 2011), *Anisoptera scaphula* (Hossain et al., 2014) and *Vitellaria paradoxa* (Akakpo et al., 2014). IBA is more effective in rooting response of cuttings than the NAA and IAA (Henrique et al., 2006; Husen & Pal, 2007; Shen et al., 2010). However, there is a great dearth of published information on the clonal propagation efforts of *P. neriifolius*. That being said, this study was designed to investigate the multiplication potentials of *P. neriifolius* through rejuvenated stem cuttings.

MATERIALS AND METHODS

This study was carried out in the nursery of the Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh. The nursery is situated at the intersection of 22°30' N latitude and 91°50' E longitude, which enjoys typically tropical climate, characterized by hot humid summer and dry winter. Mean monthly temperature varies from 21.8°C to 29.2°C in summer and 15°C to 26°C in winter. Relative humidity is the lowest (64%) in February and highest (95%) in June through September. Annual rainfall in the area is about 3000 mm that mostly takes place between June and September.

Stock Plant Management and Shoot Production

Cuttings were collected from the hedge orchard established with vegetative propagules from a 20-year old *P. neriifolius* tree in the nursery. Branches of the stock plants in the hedge orchard were trimmed at the beginning of the study in March, for shoot production. The sprouted juvenile shoots developed on the trimmed branches were collected for cutting preparation in June. Shoots were soaked in water immediately after getting them separated from the stock plants and brought to the laboratory for further processing.

Preparation of Cuttings and Setting in the Propagator for Rooting

Two to four nodal cuttings with two leaves trimmed to one third were used for rooting trials. Cutting length (5.8 - 6.6 cm) and

diameter (3.5 - 3.7 mm) were kept indifferent to avoid possible non-treatment variation among the treatments (Table 1). The cuttings were then briefly treated with fungicide, Diathane M45 (Rohm & Co. Ltd., France; 2g L^{-1} of water), to avoid potential fungal infection and kept in shade for 10 minutes. Effects of exogenous rooting hormone IBA on the rooting ability of the cuttings were explored by treating the cuttings with 0%, 0.2% (2000 ppm), 0.4% (4000 ppm) and 0.8% (8000 ppm) (w/v) IBA solutions. Cutting bases were dipped into the IBA solution for one minute and planted into rooting media (perforated plastic trays filled with coarse sand mixed with fine gravel at a ratio of 4:1) and finally placed into a non-mist propagator for rooting. The trays with cuttings were arranged in the propagator following randomized complete block design.

In the design, 30 cuttings were assigned to each of the four treatments (0%, 0.2%, 0.4% and 0.8% IBA solution). Each block was replicated thrice making a total of 360 cuttings in the experiment. Cuttings of each treatment (90 cuttings) were then planted in 9 trays, 3 trays (10 cuttings each) for each replication. The cuttings were watered once only just after setting them in the propagator. A light water spray was done every day early in the morning (before 7 am) and late afternoon (after 6 pm) until transferring the rooted cuttings from the propagator.

Propagator Environment

Relative humidity of around 85-95% was maintained in the propagator. Propagator was kept open for a short period of time once in the morning (before 7:0 am) and once in the afternoon (after 6:0 pm) every day for facilitating gas exchange. A bamboo shed lined with jute mat was placed over the propagator to avoid excessive solar heat. Thus, the photosynthetic photon flux measured with quantum sensors (SKP 215, Skye Instruments Ltd., UK) and data logger (Datahog2, SDL5360, Skye Instruments Ltd., UK) inside the propagator was reduced to 12% of the full sun. During the rooting experiments, mean maximum and minimum temperature ranged between 31°C and 23°C.

(A) (B)

Figure 2. Non-moist propagator (A) and the cuttings in rooting media (B) inside the propagator

Transferring the Rooted Cuttings to Polybags

The cuttings rooted after 14 weeks of setting them in rooting media in propagator. The rooted cuttings were weaned (hardened) before transferring them to polybags by keeping the propagator open at night for three subsequent days and at day and night for another three days. After weaning, all the rooted cuttings were transferred into polybags filled with forest soil mixed with decomposed cow dung at a ratio of 3:1. Before planting into the polybags, rooted cuttings were assessed for length and diameter, root and shoot number and the length of longest root and shoot developed in each cutting. After transferring the rooted cuttings into the polybags, they were kept under shade for one week and then placed under sun for growing. One year after transferring the rooted cuttings into the polybags, survival percentage and total height of each rooted cutting were measured for their growth assessment.

Data Recording and Statistical Analysis

Mean growth variations attributed to treatments were evaluated using the analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT). Rooting percentages were adjusted accordingly using arcsine transformation formula before placing the data into analysis of variance (Islam et al., 2011). Rooting percentages, number and length of roots and shoots developed for control and the treatments were compared at $p \leq 0.05$ (ANOVA and DMRT).

RESULTS

Rooting Ability of *Podocarpus neriifolius* Cuttings

Cuttings of *P. neriifolius* started rooting from the 10th week and completed in the 14th week in propagator (Figure 2). However, shoot development started from the 12th week and continued until 15th week. Rooting performance of the stem cuttings was assessed after 15 weeks of setting the cuttings for rooting trial in the non-mist propagator. Percentage of cuttings rooted ranged from 30 to 61 among the treatments. IBA was found to significantly enhance the rooting in the cuttings. The highest rooting percentage (61%) was recorded when cuttings were treated with 0.8% IBA solution followed by 57% with 0.4% IBA and the lowest (30%) in non-treated cuttings (Figure 3). The rooting percentage in 0.4% IBA treatment did not significantly vary from that in 0.8% IBA treatment.

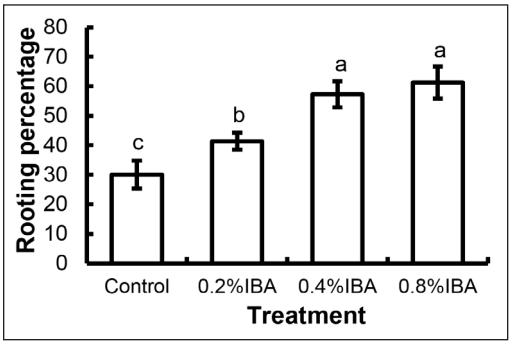


Figure 3. Percentage of *P. neriifolius* cuttings rooted in different IBA concentrations 15 weeks after setting them in propagator for rooting

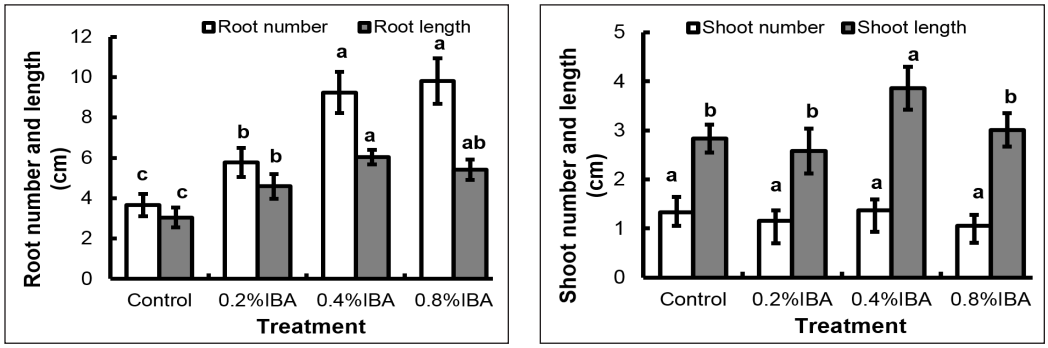
Root Number and Length

Average number of roots produced in each cutting varied from 3.7 to 9.8 among the treatments. The maximum number of roots

(9.8) was produced in cuttings treated with 0.8% IBA solution followed by 9.2 in 0.4% and the lowest (3.7) in the control. IBA application remarkably enhanced the number of roots produced per cutting. However, the number of roots was not significantly different in the cuttings treated with 0.4% and 0.8% IBA solutions (Figure 4A and Figure 5). Like rooting percentage and root number, length of the longest root for cuttings was also significantly affected by IBA treatment. The longest root (6.0 cm) was recorded in the cuttings treated with 0.4% IBA solution followed by 5.4 cm in 0.8%, 4.6 cm in 0.2% and the shortest 1.4 cm in the control.

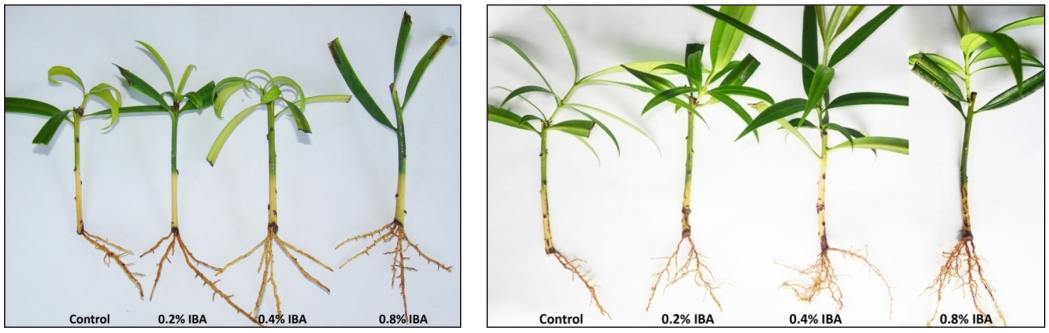
Number of Shoot and Shoot Length

Although there was no significant difference in the number of shoot developed in cuttings, shoot length remarkably increased when treated with IBA solutions. Average number of shoot and shoot length produced per cutting ranged from 1.0 to 1.4 and 2.6 cm to 3.8 cm among the treatments, respectively. Shoot length was significantly higher in the cuttings treated with 0.4% IBA solution than in other treatments (Figure 4B). However, there was no meaningful variation in shoot length developed in the cuttings in other treatments.



(A) (B)

Figure 4. Development of roots (A) and shoots (B) in the cuttings 15 weeks after planting in the propagator



(A) (B)

Figure 5. Rooting in cuttings treated with different concentrations of IBA solution 12 weeks (A) and development of shoots 15 weeks (B) after setting the cuttings in the non-mist propagator

Cutting Morphology

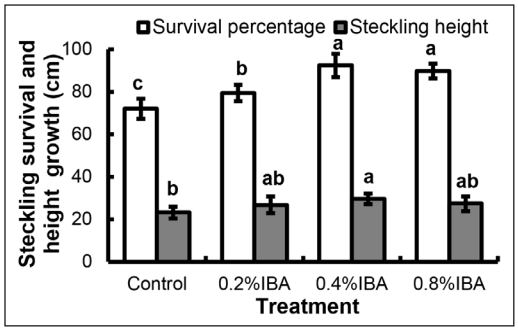
The average length and diameter of the cuttings varied from 5.5 cm to 6.1 cm and 3.5 mm to 3.7 mm, respectively, among the cutting types. There was no significant difference in the mean cutting length and mean diameter among the treatments at $p \leq 0.05$ (ANOVA and DMRT) (Table1). Therefore, there was no remarkable effect of cutting length and diameter on rooting percentage, root number, root length, shoot number and shoot length in the cuttings. Actually, the cutting length and diameter were kept indifferent in various treatments purposively to avoid non-treatment variation among the cuttings.

Table 1
Mean length and diameter (±SE of mean) *of cuttings rooted under different concentrations of IBA solution. The same superscript letter(s) indicates no significant difference at p≤0.05 level (ANOVA and DMRT)*

Variables	Treatments			
	Control	0.2% IBA	0.4% IBA	0.8% IBA
Mean cutting length (cm)	5.76^{a}±0.17	5.5^{a}±0.62	6.1^{a}±0.29	5.9^{a}±0.31
Mean cutting diameter (mm)	3.73^{a} ± 0.25	3.6^{a} ± 0.17	3.59^{a} ± 0.25	3.71^{a} ± 0.26

Steckling Growth in the Nursery Condition

The survival percentage of *P. neriifolius* stecklings (rooted cuttings) was also pointedly enhanced when treated with IBA solutions. Almost 72% to 93% stecklings were thriving among the treatments in the nursery one year after transferring them into the polybags (Figure 6). The highest survival percentage was recorded in the stecklings developed with 0.4% IBA treatment followed by 0.8% IBA and the lowest (72%) was in the control (Figure 6). Gradual increment of survival percentage was also noticed with increasing concentration of IBA up to 0.4% IBA solution. The average height in the stecklings was also the maximum (29.6 cm) in the cuttings developed with 0.4% IBA solution followed by 0.8% or 0.2% IBA and lowest (23.1 cm) was in the control. The survival percentage and initial growth performance of the out-planted stecklings were satisfactory (over 90%) one year after transplanting in the field. However, due to insufficient number of plantable stecklings from the treatment with 0.2% IBA and control, stecklings treated with 0.4% and 0.8% IBA were only planted for observation in the field. No significant variation was observed in steckling survival percentage and height growth between these two treatments.



(A)

(B)

Figure 6. Survival percentage and steckling height of *P. neriifolius* cutlings developed in different concentration of IBA treatments one year after transferring in the polybags

DISCUSSION

Rooting Ability of *Podocarpus neriifolius* Cuttings

Podocarpus neriifolius D. Don. is an endangered and the only naturally grown indigenous gymnosperm tree species in Bangladesh (Mannan et al., 2001). Due to the scarcity of mother trees or scattered dioeciuos productive trees with irregular seeding habit, regeneration of the species by seed germination is not practical. Initiatives have been taken for mass propagation of this endangered tree species through rejuvenated stem cuttings with IBA treatment in low-cost non-mist propagation system. From our study, the species was found amenable for vegetative propagation through stem cutting with or without rooting hormone. However, rooting ability of the cuttings was greatly influenced with IBA treatments. The maximum rooting percentage (61) was recorded in the cuttings treated with 0.8% IBA followed by 0.4% IBA and the minimum (30) was observed in the cuttings without any treatment (control). Formation of roots is a complex process and a vital step for plant propagation through stem cutting for many important species (Pop et al., 2011). Among the rooting hormones IBA was considered as the most effective in rooting in the cuttings. Henrique et al. (2006) reported that *Pinus caribaea* var. hondurensis cuttings treated with IBA produced higher percentage of rooted cuttings than those treated with NAA. Husen and Pal (2007) reported that overall rooting response was better in the treatment with IBA rather than with NAA in *Tectona grandis* stem cuttings. Shen et al. (2010) recorded the highest rooting percentage (68%) on medium supplemented with 5 mM IBA where IAA and NAA failed to root. Rooting percentage of cuttings has been reported to influence with application of exogenous rooting hormone IBA. Therefore only IBA was tested to intensify the root formation in *P. neriifolius* cuttings in this study. Applied auxin (IBA solution) remarkably increased the rooting percentage in cuttings of both conifer and broad leaved tree species including *Pausinystalia johimbe* (Tchoundjeu et al., 2004), *Baccaurea sapida*

(Abdullah et al., 2005), *Sloanea suaveolens* (Baul et al., 2009), *Flacourtia jangomas* (Hossain et al., 2011), *Anisoptera scaphula* (Hossain et al., 2014) and *Velleia paradoxa* (Akakpo et al., 2014). In this study, we noticed the highest rooting percentage (61) in the cuttings treated with 0.8% IBA solution, which was significantly higher in the cuttings treated with 0.2% IBA or in control. Similar results were reported by Hossain et al. (2014) and mentioned that maximum rooting percentage was obtained in *A. scaphula* cuttings with 0.8% IBA treatment. However, other researchers noticed significantly higher rooting percentage with 0.4% IBA solution. For examples, Hossain et al. (2002, 2004) reported significantly enhanced rooting percentage in the cuttings of *Artocarpus heterophyllus*, *Swietenia macrophylla* and *Chukrasia velutina*, respectively with 0.4% IBA solution. Tchoundjeu et al. (2004) obtained better rooting percentage with 0.4% IBA treatment in *P. johimbe*, and Abdullah et al. (2005) in *B. sapida* cuttings. Again, Baul et al. (2009) stated better rooting performance in *S. suaveolens* cuttings with 0.4% IBA solution. Neghas (2002) noticed suggestively decreased rooting percentage and root number in *Juniperus procera* when they were treated with more than 0.4% IBA concentration. Actually the required concentration of exogenous IBA for rooting varied based on species, nature (woody or soft cuttings) and state of the cuttings. The doses ranged from 0.1% (Baul et al., 2011) to 10.0% (Lee & Bilderback, 1990). In the present study we noticed that 0.8% IBA solution was suitable for rooting of *P. neriifolius* in 10 to 14 weeks, seemingly a hard-to-root species.

Root number per cutting was also significantly enhanced with the treatments of exogenous rooting hormone IBA. Maximum number of root per cutting (9.8) was achieved with 0.8% IBA solution followed by 9.2 with 0.4% and lowest number was exhibited in the cuttings without IBA treatment. Similar results were reported by Hossain et al. (2014). They mentioned that the highest number of root was produced in *A. scaphula* stem cuttings treated with 0.8% IBA. Akakpo et al. (2014) explored maximum number of root (11) in *V. paradoxa* cuttings with 5000 ppm (equivalent to 0.5%) IBA solution. Number of root produced per cutting in different species with various concentrations of IBA was reported by several authors. Hossain et al. (2002) reported significant increment of root number when cutting bases were dibbed in 0.4% IBA solution. Kamaluddin and Ali (1996) reported significantly increased number of roots in *Azadirchta indica* cuttings with IBA treatment. Again Kamaluddin et al. (1998), in a separate experiment, noticed that significantly enhanced rooting ability of *C. velutina* cuttings by applying exogenous rooting hormone. Besides, Hossain et al. (2004) stated that mean root number of *S. macrophylla* cuttings was suggestively higher in the cuttings treated with rooting hormone IBA. Number of roots per cutting in the 0.8% IBA treatment was almost similar with the cuttings treated with 0.4% IBA without any significant variations.

Like rooting percentage and root number per cutting, root length was also enhanced with the IBA treatment in the cuttings. However, the longest root length (6.0 cm) was recorded in the cuttings treated with 0.4% IBA solution followed by 5.4 cm with 0.8%, 4.6 cm with 0.2% and shortest roots in control cuttings. There are some reports mentioning the enhancement of root length in the cuttings. Hossain et al. (2004, 2011) and Alam et al. (2007) reported significant increase of root length in presence of 0.4% IBA solution. However, Hossain et al. (2014) reported maximum root length (7.7 cm) in 0.8% IBA treated cuttings followed by 0.4% IBA and minimum (2.5) in the control. In fact, the applied IBA indirectly influences the speed of translocation and movement of sugar at the base of cuttings and subsequently accelerates rooting in the cutting base (Haissig, 1974, 1982). Basically, speeding up of root formation in cuttings is considered as an advantage and the earlier the development of roots, the greater the chances for survive and thrive later on.

Shoot Number and Length

There was no significant difference in the number of shoot developed in cuttings. However, shoot length was remarkably increased with IBA application. Shoot length was significantly higher in the cuttings treated with 0.4% IBA solution than that in other treatments (Figure 4B). However, there was no relevant report found that explained the variation in shoot length of the cuttings under different treatments. The maximum shoot length was recorded in the cuttings treated with 0.4% IBA which might be due to the optimum energy partitioning for the production of root and shoot with the help of 0.4% IBA solution. Whereas the cuttings with low concentration (0.2%) or without IBA treatment did not get sufficient amount of rooting hormone to develop the root or shoot in the similar fashion of 0.4% IBA treatment. On the other hand, the cuttings treated with comparatively higher concentration (0.8%) of IBA produced more roots than the shoots. This indicates that the rooting hormone influenced the cuttings for allocating more energy for root than the shoot development.

Steckling Capacity of *P. neriifolius* Cutlings

Survival percentage and initial growth performance of the cutlings (rooted cuttings) of *P. neriifolius* was greatly influenced when rooted with IBA treatment. The highest survival percentage (93) was in the cutlings rooted with 0.4% IBA solution followed by 85% with 0.8% IBA and lowest (73) from the control in nursery condition one year after transferring them into the polybags. Likewise, the maximum height growth was observed in the same treatment with lowest in control. The average steckling height was also maximum (29.6 cm) in the cuttings rooted with 0.4% IBA followed by 0.8% or 0.2% IBA and the lowest (23.1 cm) in the controlled cuttings. Similar outcomes were reported by Hossain et al. (2011) for *F. jangomas* cutlings and mentioned that the highest survival and

initial growth performance were found in the cutlings rooted with 0.4% IBA solution. In a separate study Hossain et al. (2014) also mentioned higher survival percentage (83.3%) and initial growth of *A. scaphula* cutlings developed with 0.8% IBA solution compared to the other treatments including control which is unidirectional with the findings of Nath and Barooah (1992). However, the factors affecting the survival potentials of the stecklings rooted with IBA were not possible to clarify due to the lack of related references. Higher number of root in the cuttings developed with 0.8% or 0.4% IBA solution might have contribution in better survival and initial growth performance of the stecklings in the nursery and field condition.

CONCLUSION

Podocarpus neriifolius is the critically endangered and the only naturally growing gymnosperm in Bangladesh that needs additional management treatments for its survival in the natural stands. In this study, efforts have been made for mass clonal propagation of the species through stem cutting for large-scale plantation programs. The results revealed that the species is hard-to-root but amenable to rooting with rooting hormone. Cuttings treated with 0.4% to 0.8% IBA solution can significantly enhance the rooting ability, survival potential, and initial growth performance in the nursery and in the field. Rooting percentage and root number per cutting were maximum in the 0.8% IBA treated cuttings, but were not significantly higher than those in the 0.4% IBA treatment. Moreover, average shoot length, survival percentage and initial growth performance of the stecklings in nursery condition were significantly higher in the rooted cuttings developed with 0.4% IBA treatment. Survival potentials of the out-planted cutlings developed through 0.4% or 0.8% IBA treatment were also satisfactory one year after transplanting. Therefore, it can be concluded that the species could successfully be propagated from rejuvenated stem cuttings with 0.4% or 0.8% IBA treatment in the low-cost, non-mist propagator for mass clonal propagation and plantation programs.

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