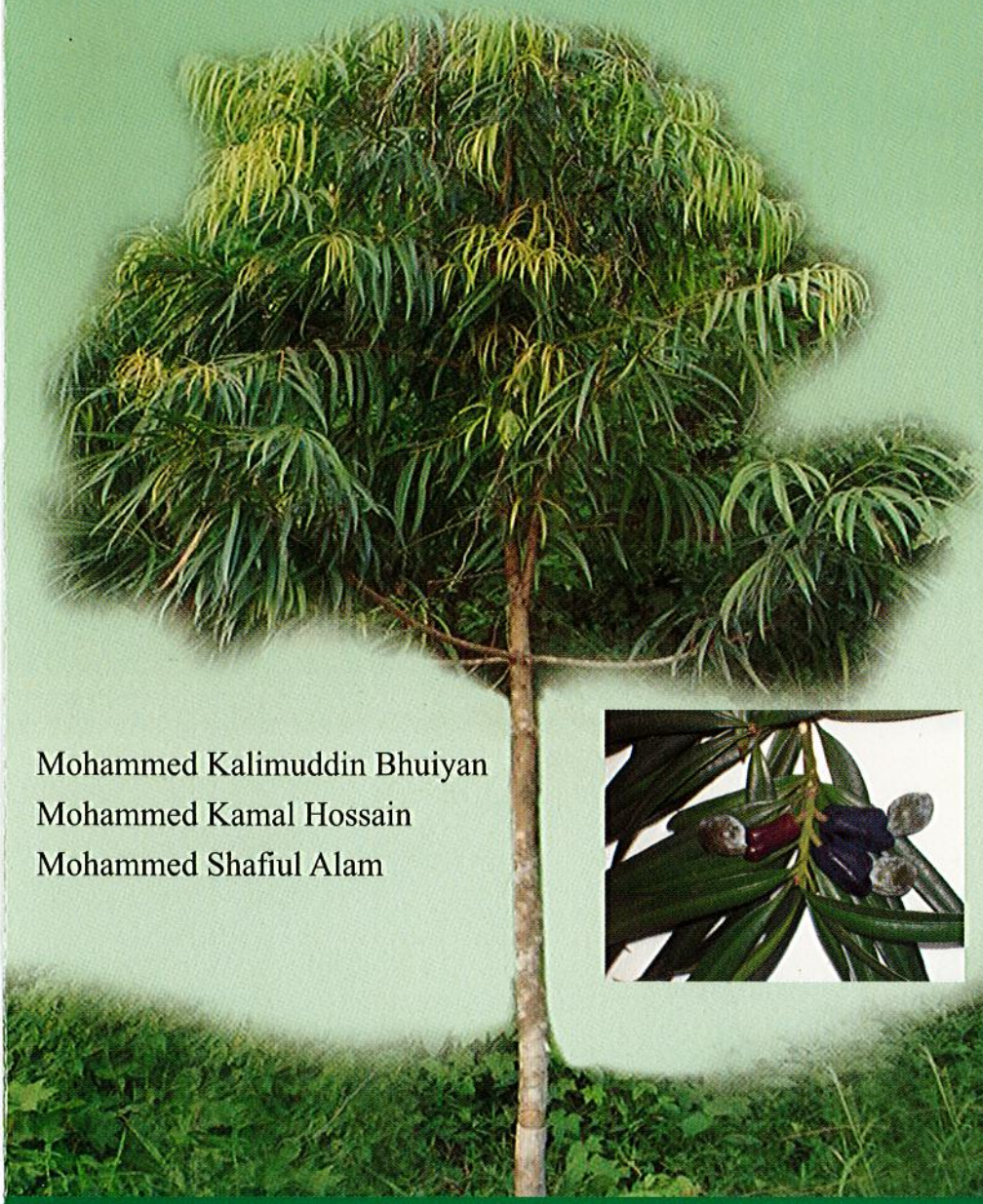
Banspata (*Podocarpus nerifolius*, D. Don)-
A Critically Endangered Tree Species of Bangladesh



Mohammed Kalimuddin Bhuiyan
Mohammed Kamal Hossain
Mohammed Shafiul Alam

Institute of Forestry and Environmental Sciences
University of Chittagong, Chittagong
Bangladesh

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Cover Photograph
Young Banspata tree at Sitakunda Eco-park

Foreword

Banspata (*Podocarpus nerifolius*), a native gymnospermic tree of Bangladesh is becoming one of the most critically endangered species. Arannayk Foundation initiated a project to conserve and restore this species. A research team of Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU) was vested with the responsibility of making an exploratory survey throughout different forests of Bangladesh including Botanical Gardens to identify its natural distribution and introduction to the plantations. After systematic survey in different forests including Botanical Gardens over a period of two years, the team could come up with only 111 trees in Bangladesh of which 6 are only naturally originated and the rest are in plantations. The research team started collecting seeds and scions for propagation. Though only a few seedlings could be raised from seeds, the team was successful in vegetative propagation. However, team had difficulty in protecting the seedlings from cutworm. At night, the cutworm used to cut young shoots of the seedlings making survival of the seedlings difficult. The team had to take special care to avoid cutworm infestation. Finally the team was successful in raising few thousands seedlings. About 3,500 seedlings were planted within Chittagong University Campus in order to make sure that at least a patch of *Podocarpus nerifolius* is conserved within the campus which will be the source of propagules in future. Rest of the seedlings were distributed to Bangladesh Forest Department, Tea Gardens, NGOs and several other organizations who loves to have rare species in their collection.

Thanks to the team for saving the species from extinction from Bangladesh. Thanks to the authors for documenting the study in the form of a publication. The publication describes the steps the team took to explore the species in its natural habitat, propagation methods tested and finally distribution to different organizations. It will encourage scientists and foresters to look into other species having similar fate and take appropriate measures for restoration, conservation and recolonization of the species.

Farid Uddin Ahmed
Executive Director
Arannayk Foundation

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Mohammed Kamal Hossain
M. Kalimuddin Bhuiyan
M. Shafiul Alam

Contents

Chapter 1: Introduction

Bangladesh has diversified forest types, with wetlands, evergreen, semi evergreen moist deciduous and mangrove forests comprising with diverse plants in each forest type. Floral diversity is richer in the tropical semi-evergreen forests distributed in the hills of Chittagong, Chittagong Hill Tracts and greater Sylhet region (Miah, 2001). The area of forestland is 2.5 mha which is 17.08% of the country's total surface area. Bangladesh Forest Department (FD) manages 1.52 mha of forestland. According to Forest Resource Assessment (FRA, 2007) 11% of the land area is under tree cover (FAO, 2010). Its flora includes as estimated 5700 species of angiosperms and 4 species of gymnosperms (Firoz *et al.* 2004) of which some 2,260 species are reported from the Chittagong region alone.

For increased population pressure and required increased food production forests were cleared for the production of agricultural crops (Dwivedi, 1993). The annual rate of deforestation in the tropics is 11.3 million hectares and in Bangladesh is 8,000 hectares. Jhum or shifting cultivation may be the main reason for massive deforestation in the hill forests of Bangladesh which has destroyed its biodiversity leading to severe soil exposure and erosion. Severe biodiversity loss in Bangladesh is the result of change in land use, tenure, legal status, civil and political unrest, insurgency, intercommunity conflicts, lack of policy implementation, lack of inter-departmental cooperation etc. In addition, about 73,000 hectares of land of Bangladesh forests have been lost due to encroachment for agriculture and aquaculture. Moreover, forest lands are being transferred continuously for non-forest purposes like human settlement, cultivation, industrialization, irrigation, energy and power, educational institution, communication, urbanization, establishment of ports, shrimp cultivation and salt production. These led the total destruction of our historic Chakoria Sundarban and the process is continuing for other forests. A number of invasive species like *Eucalyptus, Acacia* and Pine has been introduced in Bangladesh which affects the habitat and associated species along with weeds, insects and pests.

As a result, biodiversity of Bangladesh is deteriorating by disrupting the ecological condition (Dwivedi, 1993). Tobacco cultivation in the hill districts has accelerated the deforestation process in Bangladesh by converting the forest land, curing the leaves of tobacco, fuel wood collection which affects the breeding habitat of animals. Uncontrolled and unregulated grazing causes severe pressure on forests which led to the gene conservation problem by destroying natural regeneration of forest species (Dwivedi, 1993). Bangladesh is one of the most vulnerable countries to the impacts of global climate change, and these impacts are becoming more visible. Lack of awareness about the importance of conservation of biodiversity and forests is also a great reason for the loss of biodiversity in Bangladesh.

The natural forests of Bangladesh have been degraded seriously, resulting in serious erosion of forest genetic resources (Islam, 2003). There is a crying need to develop coordinated efforts to conserve and manage forest genetic resources. However, *Podocarpus nerifolius,* D. Don (Banspata) being a native gymnosperm need to be conserved, as its population is much depleted (Khan, 1996). Banspata or Pencil wood is a large evergreen gymnosperm. The tree occurs up to 1000 m in the eastern Himalaya from Nepal eastwards in the evergreen forests of the outer hill in Assam, Khasia hills, Wallich, Sikkim, Chittagong, Myanmar, Java, Sumatra, Borneo, the Malay Peninsula and the Andamans. It is the only conifer softwood naturally occurring in the forests of Bangladesh. The woods yield very good quality pulp and proved a substitute for boxwood. Pencils made from treated Banspata were of high quality and are considered to be acceptable substitute for pencils made from Eastern Red Cedar (*Juniperus virgeniana*).

Podocarpus nerifolius, (Banspata) can regenerate naturally (Das and Alam, 2001), but the natural regeneration is not enough for the conservation of the species, as naturally occurring seed sources have been seriously depleted. Moreover, Banspata is well known as 'Critically Endangered' in the Red data book because it meets any/all of the criteria of IUCN (Meylan and Donnelly, 1999; IUCN, 1994; IUCN, 2001).

Banspata is gradually becoming endangered due to over exploitation and uncontrolled biotic interferences. It is difficult to raise large scale seedlings in the nursery due to scarcity of seeds from the scarce stocks in the natural forest habitats. Moreover, the species does not bear seed every year, meaning the periodicity of the species is very high. Considering the magnitude of vulnerability of this hill forest species, steps have been taken for rapid propagation and *ex situ* conservation programs (Hossain, 2009). Scientists also pointed out that ex *situ* conservation, conservation of any species outside of their natural habitats, centralization of different genotypes could be an alternative approach for the production of abundant seeds having broad genetic variation. Besides this, clonal propagation of *P. nerifolius* can be the most effective alternative tool for getting quality planting materials for large-scale plantation programs. In addition, Banspata can be conserved by in *situ*-conservation in its natural habitats such as national parks, game reserves and wildlife sanctuaries. So, under the present circumstances the most appropriate approach to save *P. nerifolius* is likely to be clonal (vegetative) propagation. The technique of clonal propagation allows production of large and continuous supply of planting stocks together with the capture and multiplication of genetic variation. This when coupled with technique to select superior individuals can result in large genetic gain in both yield and quality.

For the restoration of the population of *Podocarpus nerifolius*, massive plantation and protection is essential. For this purpose, a clear understanding about the nursery practice and the production of propagules as well as the plantation techniques of the species is mandatory.

But, the information on the nursery practice and the production of propagules of Banspata (*Podocarpus nerifolius*, is very scarce. The country has only four wild gymnosperms, viz. *Cycas pectinata*, *Gnetum scandens*, *G. funiculare* and *Podocarpus nerifolius*. Loss of any one species will result the 25% diminishing of the gymnosperm diversity in the country. A research work on micro-clonal propagation technique on

Banspata was conducted at Bangladesh Forest Research Institute (BFRI), Chittagong. (Mannan *et al.* 2001). But, to date, authentic information about the status of *Podocarpus nerifolius* in Bangladesh is not satisfactory.

To overcome the situation and to face the challenges in growing and conserving Banspata in its natural habitats and in protected areas, an agreement was undertaken between the Arannayk Foundation (finaced by US Government through Tropical Forest Conservation Act), Dhaka as the First Party, and the Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU) as the Second Party, on 26 September 2006 in Dhaka. The name of the project undertaken was "Recolonization and mass propagation of Banspata (*Podocarpus nerifolius*)" under the program "Revamping conservation of endangered species with critical ecological significance". This agreement between First Party and Second Party was effective for 5 (five) years from 01 November 2006 up to 31 October 2011 and was extended up to December 2012 step by step.

Arannayk Foundation (AF) (with a mission and vision of Tropical Forest Conservation Program in Bangladesh) has rightly identified the importance of conservation of Banspata tree. This initiative will also address the importance of conservation of other threatened species in Bangladesh. Considering the regional and global importance, the program was undertaken by the Institute of Forestry and Environmental Sciences of Chittagong University (IFESCU). The study includes the natural distribution, silviculture, regeneration and domestication of the species with seed and clonal propagation approaches. The objectives are also to make inventory and assess the ruined Banspata stands and individuals in their natural habitats and explore the regeneration techniques in different habitats. Extension and promotional activities of Banspata with other stakeholders may save it from further ruination of the species.

Chapter 2: Species description and distribution in Bangladesh

Local name: Banspata

Family: Podocarpaceae

Timber group: Softwood

Scientific Name: *Podocarpus nerifolius*, D. Don

Synonyms: *Podocarpus discolor* Bl. (1847), *Podocarpus leptostachya* Bl. (1849), *Nageia neglecta* (Bl.) O. Ktze. (1891), *Podocarpus decipiens* Gray (1955), *P. junghuhniana* Miq. 1851; *Nageia discolor* (Blume) 1891; *N. leptostachya* (Blume) 1891; *P. neriifolia* (D.Don) 1891; *P. polyantha* (Wasscher) Gaussen 1976; *P. annamiensis* N.E. Gray 1958 (Siddiqui *et al.* 2007)

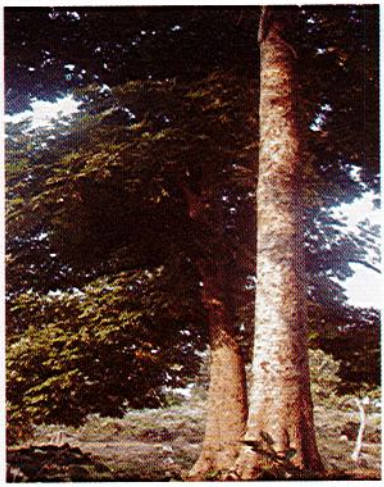
English name: Oleander Podocarpus, Brown pine

Vernacular Name: Podocarp (trade name), Belah-buloh at Sarawak in Malaysia, 'Buddhist pine' or 'Fern pine' in Japan, Hainan luohansong in Thailand (De Laubenfels, 1988; Lemmens *et al.* 1995; Fu and Jian, 1992), Jati bukit in Malay, Ka dong in Laos, Ki beling in Sabah fo Malaysia, Kayu cina at Irian Jaya in Indonesia, Khunmai in eastern side of Philippines, Mala adelfa in Philippines, Podo bukit in Peninsular of Malaysia, Thitmin, Thitmin-po in Myanmar. In Bangladesh, it is commonly called Banspata, sometimes, Raja-gach, Jinari, and Bao-patta (in Sylhet).

Description of the species

Banspata (*Podocarpus nerifolius* D. Don) is a large, glabrous evergreen tree (**Figure 1**) with whorled branches (**Figure 2**) (Das and Alam, 2001; Dey, 2006; Troup, 1986). It is a medium large canopy tree (up to 30 m high) with cylindrical straight bole (60-100 cm girth) or sometimes markedly fluted. This species belongs to the family Podocarpaceae. Leaves are scattered on the branch-lets arranged in two rows forming ached (**Figure 3**), linear, lanceolate, base narrowed, obtuse, acute or acuminate, thick leathery, petiole 1.2-1.6 cm long. Leaves are 15-25 cm long and 1.25 cm width, almost sessile, thick and healthy, mid rib prominent on both surfaces (Brandis, 1921; Siddiqui *et al*, 2007).

Figure 1: Banspata tree in the natural forest



Banspata planted near Hazarikhil forest office

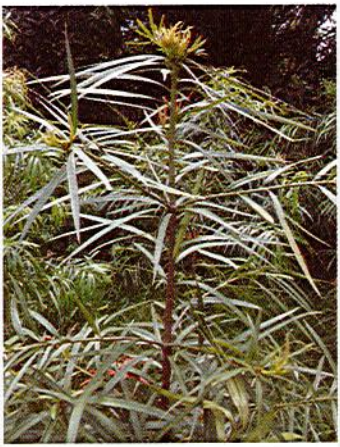


Figure 2: Whorled branch of Banspata

Separated twig with whorled branch

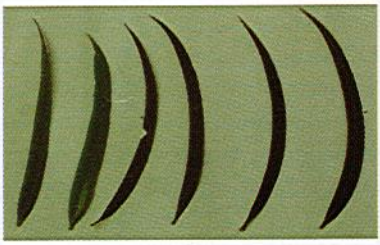


Figure 3: Dorsal view

Ventral view

Flowers are dioecious, male and female flowers are in separate trees. Male flowers are cylindrical, catkin like, auxiliary or terminal, filaments short, pollen grains with 2 large wings (**Figure 4**). Female flowers are with 2-4 scales, one or two of which bear a fertile scale folded over and united into an inverted ovule, usually one matures. The sterile ovules often fuse with the upper part of the stalk and edible receptacle upon which the seed is borne. Averge weight of fruit is 3.57 g and 3.61 cm in length (**Figure 5**). Seeds are ovate and dark green with shiny black colored fleshy part (somewhat like Black berry), 3-4 cm long (Das and Alam, 2001; Dey, 2006); 1-1.5 cm wide and 2.37 g weight (**Figure 6** and **Figure 7**).

Figure 4: Male inflorescence of Banspata (*Podocarpus neriifolius*, Don.)

Figure 5: Green and ripen fruits with naked seeds in the twig of Banspata

Figure 6: Collected ripen fruits and matured seeds of Banspata

Figure 7: Isolated fruit and seed of Banspata

Wood is fine textured and light brown. Bark is grayish brown, thin, peeling off papery flakes, crown often dome-shaped (Siddiqui *et al,* 2007) and suitable for picture frame, math scale, furniture, pencil making and turnery work (Das and Alam, 2001).

Taxonomy of Banspata

Domain: Eukaryote
Kingdom: Plantae
Sub-Kingdom: Viridaeplantae
Phylum: Trachaeophyta
Sub-Phylum: Euphyllophytina
Infra-Phylum: Radiatopses
Class: Pinopsida
Order: Pinales
Family: Podocarpaceae
Genus: *Podocarpus*
Specific epithet: *nerifolius*

Botanical name: *Podocarpus nerifolius* Don.

Phenology: Banspata is an evergreen gymnosperm tree species. Flowering time is from March to April and fruiting time June and July. Fruits ripen during November to December. Seed collection time in Bangladesh is from mid-November to first half of December. It is suggested to collect the ripen seeds from the branches and twigs of mother trees. However, Smitinand and Larsen (1975) reported that flowering and fruiting occurs during January – June. Sometimes flowering occurs twice in a year.

Uses of Banspata:

Podocarpus nerifolius are grown as garden trees, hedges, and used as screens. The wood of Banspata is fine textured, light brown in colour. This tree species is also a source of timber with light yellow and even grained wood, mostly used for furniture and cabinet work. It is also used for making oars, spars, and mats (Sahni, 1990; Siddiqui *et al* 2007). Besides,

the wood of Banspata is also suitable for picture frame, musical instrument, mathematical scales, photo frames, pulp wood, box wood, show pieces, curving or turnery work etc. (Das and Alam, 2001). It is mentionable that, pencils made from treated Banspata are of high quality and are considered to be acceptable substitute for Eastern Red Cedar (*Juniperus virgeniana*) pencils.

The ripen fruits of Banspata are edible and green fruits are cooked into jams or pies having a slightly sweet flavour. However, the fruits are slightly toxic and should therefore be eaten sparingly, especially when eaten raw (Anon, 2011). A decoction of the leaves is used against rheumatism and arthritis and juice from the leaves is used against sores in Papua New Guinea (de Laubenfels, 1988; Lemmens *et al.* 1995).

Distribution

Banspata generally does not form extensive stands instead occur as individual forest tree. The tree grows up to 900-1000 m in the eastern Himalaya from Nepal eastwards in the evergreen forests of the outer hills, Assam, Khasia hills, Wallich, Sikkim, Eastern India, Bhutan, Malay Peninsula, Southwest Chima, and the Sunda Islands, Chittagong, the tropical forests of Mynmar, the Malay Peninsula and the Andamans, Java, Sumatra, Borneo. In the Andamans it is sometimes common on the high hills in evergreen forests on serpentine and micacious sandstone along with *Mesua ferrea* and other trees spicesces (Troup, 1986).

In the forests of Bangladesh, it is only conifer (soft wood) species growing naturally in the forest of Chittagong Hill Tracts (Publakhali) and Cox's Bazar (Ukhia), Lawachara forest of Sreemongal (**Figure 8**), Kassalong and Massalong reserve in Bagaichari (Das and Alam, 2001; Siddiqui *et al* 2007). Coppicing of this plant has been found in the Ukhia natural forest of Cox's Bazar Forest Division (**Figure 9**).

However, due to clear felling of the forests this species has been concentrated in the forests of Cox's Bazar (Ukhia) and Chittagong Hill Tracts (Mandira Chara, Massalong reserve) and become endangered.

Figure 8: Natural regeneration of Banspata at Lawachara forest of Sreemongal

Figure 9: Coppicing of Banspata in Ukhia forest of Cox's Bazar

Chapter 3: Exploration of Banspata in its natural and plantation habitats

Extensive field visit was conducted for exploration of the present status of the species. The research team (**Figure 10**) visited different natural forests, wildlife sanctuaries, national parks, botanical gardens, forest department, homesteads, universities, different organizations and institutes to assess the status of Banspata. The important exploration areas are as follows:

Cox's Bazar North Forest Division: Ramu, Eidghar, Chakaria, Bhomarioghona beat, Bangabandhu Safari park Dulahazra, Fasiakhali, Fulchari Range.

Cox's Bazar South Forest Division: Silkhali, Whykheong, Swankhali, Monkhali, Inani, Duchari, Ukhia forests.

Chittagong North Forest Division: Hyanko, Ramghar, Hazarikhil, Sitakunda Eco-park, Korerhat.

Chittagong South Forest Division: Kalipur, Jaldi, Patiya, Dohazari, Padua, Chunati, Barabakia, Madarsa, Rangunia, Khurusia, Baraitoli, Tankabati, Dudpukuria- Dopachari Wildlife Sanctuary

Bandarban, Khagrachari, Rangamati (Chittagong Hill Tracts): Dochari of Tulatoli beat, Naikhyongchari range of Lama Forest division, Lemuchari near Myanmar border, Matamuhari reserve, Sangu reserve, Pablakhali Wildlife Sanctuary, Barkal reserve forests, Lama, Bamu forests, Sitapahar and Rampahar of Kaptai, Kaptaimukh beat, Alikheong, Naraichari range, Diginala, Bagaichari, Bariar hat, Mandirachara, Marissha, Kassalong and Massalong, Raikhali, Rajsvila, Rajthali.

Sylhet Forest Division: Lawachara forests of Sreemongal, Satchari National Park and Remakalenga Wildlife Sanctuary Forests in Habigang, Adampur & Khurma beat of Rajkandi range, Moulavi Bazar.

Dhaka: Baldha garden, Dhaka University Botanical garden, National Herbarium, Mirpur National Botanical garden, Bhawal National Park, Botanical garden of Jahangirnagar University Savar, Dhaka.

The team also visited Botanical Garden and Germ plasm centre of Bangladesh Agriculture University (BAU), Mymenshingh; Bangladesh Forest Research Institute (BFRI), Sholashahar, Chittagong.

In addition to the assessment in the field, the research team visited and consulted with the personnel of Bangladesh Forest Research Institute (BFRI), Forest Department (FD), Bangladesh Agricultural Research Council (BARC), different NGOs, and faculty members the department of Botany and Institute of Forestry and Environmental Sciences, Chittagong University.

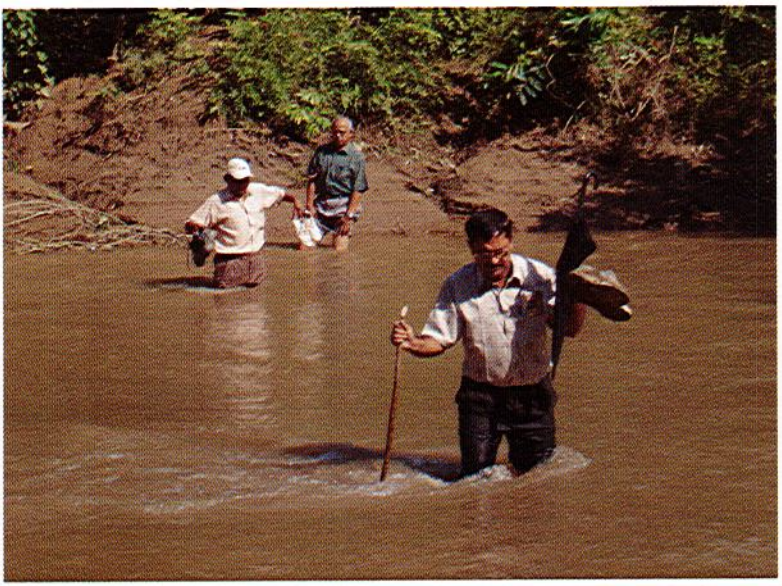


Figure 10: The Research team is desperate to cross Tankawati Khal for exploration of Banspata in Tankawati Forest

The findings from the field visits on the stocking of Banspata in Bangladesh are summarized in **Table 1**.

Table 1: Present Status of Banspata in Bangladesh (Natural and Plantation)

Nos.	Area/Site	No. of tree individuals	Status/Health of the individuals	Remarks
1.	Massalong reserve in Bagaichari, Rangamati	06	Naturally occurring, over mature and vulnerable	Extremely depleting trees
2.	Korerhat, Ctg. (N) Forest Division	01	Planted in guest house premises	Pole stage
3.	Near Padua Rest house, at Chittagong-Cox's Bazar Road, Chittagong Division	01	Planted in guest house premises	Pole stage
4.	Hazarikhill Forests, Ctg. Div.	03	Planted near Silviculture office	Trees
5.	Ukhia Forests, Cox'sBazar Div.	02	Naturally occurring, illicit cutting	Coppice was found in one stump
6.	Lawachara Forests	04	Planted and Natural	2 Trees and 2 poles
7.	Duapalong Beat office of Ukhia Range	02	Planted	Pole stage
8.	Lawachara at Sreemongal	02	Planted near Silviculture research office	Saplings
9.	Sitakunda Eco-park, Chittagong	05	Planted at Eco-park	Pole stage (one moribund)
10.	Silviculture nursery, BFRI, Chittagong	03	Planted at BFRI premises	Sapling and Pole stage
11.	Institute of Forestry and Environmental Sciences, University of Chittagong	03	Planted at IFESCU Campus	Pole stage

12.	Botanical Garden and Soil Research Institute, CU	02	Planted at CU Campus	Pole stage
13.	Baldha Garden,	01	Planted	Tree
14.	National Herbarium	01	Planted near the gate	Tree
15.	Botanical Garden, Dhaka	51	Planted, 3-5 died later	Saplings, poles and trees
16.	Ukhia, Cox's Bazar at homesteads	15	Planted in homesteads	saplings and poles
17.	BAU Mymensingh	05	Planted in the Botanical Garden	Tree, Pole
18.	Botanical garden, Jahangirnagar University	03	Planted in the Botanical Garden	sapling and seedling
19.	Keochia Silviculture Research Station	01	Planted near Silviculture office	Pole stage
Total		**111**		

Through the extensive field visits, the research team recorded 111 Banspata trees, poles and saplings in the explored forest areas and other places in the country (**Table 1**). Of them, only 10 trees are found in the natural forests. The remainings are planted for research or for aesthetic purposes. Besides, there are only three mother trees, two in the Mirpur Botanical Garden (Dhaka) and one in Lawachara National Park, Sreemangal are producing seeds occassionally.

Short description of some explored Banspata from field visits

A) **At Machalong reserve** near Mandirachara, west side of Kachalong river, one naturally grown Banspata of 17-18 m height and girth of 138 cm having 40-45 years old (**Figure 11**), one dead Banspata, one about 17 m height with clean bole of 12 m and about 100 cm girth, decaying one with fruiting, attaining Banspata of 17-18.5 m height and 125 cm girth and one depleted tree of the same height and girth were found.

Figure 11: Clear cylindrical bole of naturally grown Banspata in the forest of Massalong Reserve, Rangamati Forest Division

B) Baldha Garden, Dhaka: One Banspata tree in the Northern side of the garden about 12-14 m height and 61 cm girth with 35-40 years old and inflorescences were recorded.

C) Botanical Garden, Dhaka: Three big Banspata tree planted in 1973-74, one plot of 31 Banspata plants (mostly pole stage) planted in 1989-90, with average height 11-12 m and average girth of 76 cm.

D) Lawachara forests: One Banspata tree with about 25 m height and 39 cm girth and another one with 18.3 m height and 24 cm girth and with an approximate age of 45 years (**Figure 12**).

One healthy seedling and two saplings of Banspata by the side of silviculture office of Lawachara were found.

E) **Shishok Range**: Reported that there were 4 Banspata in Alikeong Natural forests but they were destroyed.

Figure 12: Two mature Banspata trees at Lawachara forest

F) **National Herbarium, Dhaka**: There is one pole stage of Banspata by the left hand side of the entry road of National Herbarium, Dhaka having 7.6 m height and 10 cm girth and with an approximate age of 15 years.

G) Three saplings of Banspata were planted at Botanical Garden, Jahangirnagar University, Dhaka. Among them, 2 were of about 3.66 m height and another one was of 1.22 m height with an age of about 4 years old.

H) **Hazarikhill Forest:** Two big trees of Banspata by the Northern side of Silviculture office at Hazarikhill with a height about 16m, 45 cm girth and about 14 m height 64 cm girth and one sapling of 7.62 m height and 15 cm girth (**Figure 13**), There is a number of natural regeneration surrounding the mother tree.

I) **Duapalong Beat, Cox's Bazar Forst Division:** There are only two Banspata poles by the side of beat office about 8 years old, 4.73 m height and 23 cm girth.

Figure 13: Mature Banspata trees near Hazarikhil Silviculture Research Station

Figure 14: Banspata planted at homestead in Thainkhali, Ukhia, Cox's Bazar

J) **Thainkhali village:** In Fakir Mohammad's house, there are 3 poles of Banspata about 3-4 years old with an average height of 3.6m and 25 cm girth. Nurul Kabir's house has 2 saplings of Banspata of 3-4 years old with a height of 2.9 m and 14 cm girth, while Nurul Islam's house has one pole of 4.12 m height and 23 cm girth having 7-8 years age (**Figure 14**). Besides, Hasan Fakir has one pole of Banspata at his homestead of same age and height and girth. Ayub Ali has only one pole of Banspata of same age, height, and girth. Rafiq Miah, Badsha Miah, Fakir Alam and Mrs. Shamsunnahar have 2, 1, 2, and 2 Banspata of different sizes, respectively.

Chapter 4: Propagation and nursery techniques of Banspata

Need of Mass Propagation for Banspata

Banspata is widely cultivated in Bangladesh for pencil and also extensively planted for variety of other uses requiring smooth, fine texture and dimensional stability. To date no large-scale plantation of *Podocarpus nerifolius* has been raised by Bangladesh Forest Department (BFD) due to lack of quality planting materials since the species produces little amount of seeds. Therefore, Basnpata is critically endangered due to over exploitation and uncontrolled biotic interferences in its natural habitat. It is difficult to raise seedlings in nursery in large number due to scarcity of seeds and planting materials. Moreover, the species do not bear seed every year. It is pointed out that ex-*situ* conservation of different genotypes could be an alternative approach for the production of abundant seeds having higher genetic variation. Besides, macro-clonal propagation of *P. nerifolius* can be the most effective alternative tool for getting quality planting materials for large-scale plantation program. Under the present circumstances, in Bangladesh, the most appropriate approach to save the endangered species *P. nerifolius* is clonal selection and propagation. Through clonal propagation method, both quantitative and qualitative large scale planting materials can be produced that can ensure adequate supply of planting materials to the stakeholders.

Not many studies have been done regarding propagation method of Banspata. However, the research work conducted at Bangladesh Forest Research Institute (BFRI), Chittagong reports that the species is amenable for mass clonal propagation by stem cutting. The findings from the present study also indicate high responsive of the species to clonal propagation by stem cutting.

Vegetative propagation

Vegetative propagation is the artificial process of reproduction in which plants are reproduced by using various vegetative parts like twigs, leaves, roots, buds, eyes or even a piece of meristem (Garner and Chaudhury, 1985). Vegetative propagation produces

individuals having exactly the same genotype as the parents. It is a means by which genotype of an individual can be perpetuated (Zabala, 1991). There are two types of vegetative propagation, i.e. macro vegetative propagation and micro vegetative propagation. Some of the macro vegetative propagation techniques in forestry are grafting (side veneer, whip and tongue and cleft), budding (T budding, patch budding and forkert budding), aerial layering or macro-rooting, stem cutting and enarching (Zabala, 1991). On the other hand, micro vegetative propagation is the process of vegetative propagation by using plant cells (Tissue culture).

There are many factors affecting vegetative propagation, such as age and freshness of the scion, season or time of propagation, rooting media, rooting hormone, nature of the species, treatment of cuttings and stock plants, selection of propagation system, adjustment of optimum condition for rooting, and their management (Kamaluddin, 1988; Zabala, 1991).

In this case, clonal propagation is only the promising way of regeneration. Clonal propagation is an alternative method of seed germination practice (Kamaluddin, 1996). There are several methods of clonal propagation, among which stem cutting is the most popular and easiest one. Another advantage of clonal propagation is the rapidity of the products, as it does not need to wait for seed production for the production of propagules.

Germination of Banspata Seeds

Germination of seeds of Banspata started within 25-30 days after sowing in poly bags and within 20-25 days in the propagator house sand bed (Sylhet sand). Germination of Banspata highly varies with surrounding environmental conditions and also with the types of media. The seeds were also sown in three different light conditions (full shade, direct sunlight and controlled temperature and humidity, in propagator house (**Figure 15**) and in two different media (soil with cow dung and Sylhet sand). Germination percentage of Banspata seeds varied from 16 to 98. Maximum germination was 98% (**Figure 17**) when seeds were sown in the Sylhet sand inside propagator house and the minimum germination was 16% (**Figure 18**) when they were

sown in poly bags and placed in directly exposed to the sunlight. It was also found that there was no significant difference in germination rate between poly bags placed in the full shade and poly bags kept in propagator house. However, germination in both the cases was found significantly ($P<0.05$) higher compare to germination in polybag placed under full sunlight. These results suggest that initial shade is essential for better germination of Banspata seed.

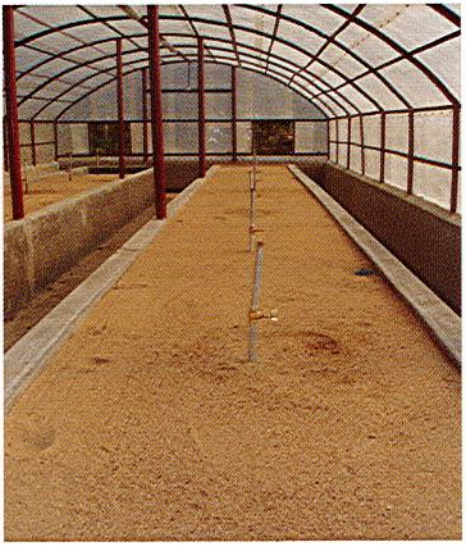
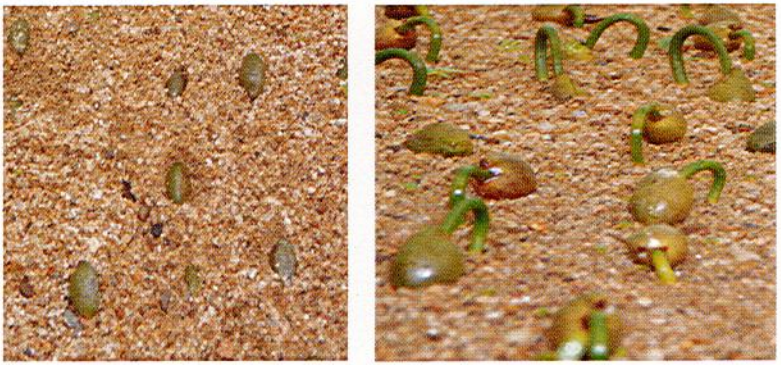


Figure 15: Propagator house at IFESCU nursery



(a) Seed buried in the sand bed (b) Seeds started germination in sand bed

Figure 16: Sequential stages of germination of Banspata in the sand bed

Figure 16: (c) Emerging Plomule

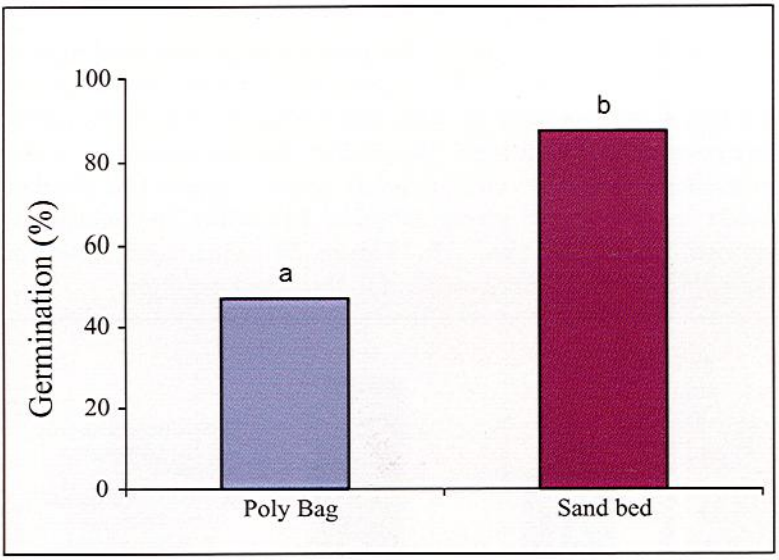


Figure 17: Effect of media on Banspata seed germination

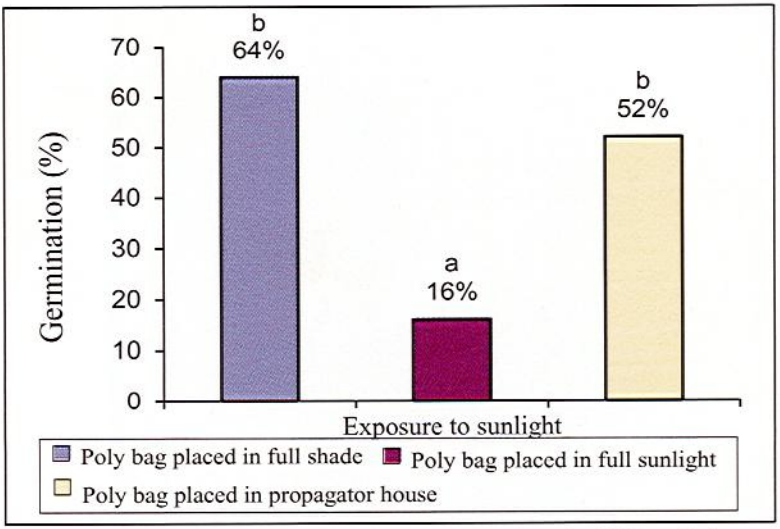


Figure 18: Germination percentage of Banspata seeds under different light conditions

Survival Percentage of seedlings

Shading is very important for the newly transplanted seedlings to the poly bags (Evans, 1986). Therefore, survival percentage of seedlings of Banspata is also influenced by the surrounding environmental conditions. We found that maximum survival percentage (85.71%) was in seeds sown in sand bed (Sylhet sand) in propagator house (**Figure 19**) while the minimum survival percentage was 53% (**Figure 20**) when seeds sown in the poly bags and placed exposed to the direct sun light.

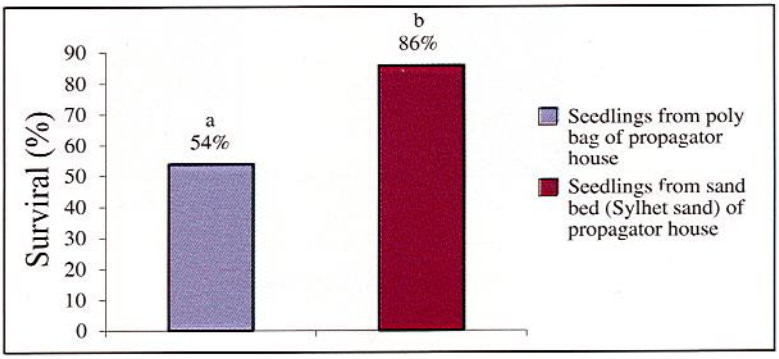


Figure 19: Effect of media on the survival rate of Baspata seedlings

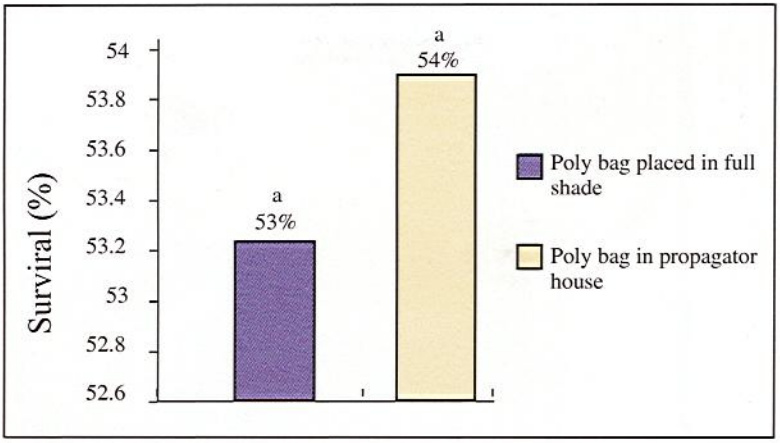


Figure 20: Survival percentage of Banspata seedlings under different light conditions

Rooting ability of Banspata cuttings

Rooting ability of certain tropical tree species have been found to be influenced by rooting hormones such as Auxin (Leakey *et al.* 1982, 1990), Indole-3-Acetic Acid (IAA), Indole-3-Butyric Acid (IBA), -Naphthalene Acetic Acid (NAA) and Gibberelic Acid (GA3) (Zabala, 1991), cutting size (Howland and Bowen, 1977; Kan and Hu, 1983), and leaf area of cuttings (Greay and Harding, 1984; Leakey, 1985, Leakey and Coutts, 1989).

Rooting ability

Cuttings were taken from three years old stock plants at Botanical Garden, Dhaka (**Figure 21**) and cut into 5.7-10.5 cm length with 2 leaves trimmed into half. Diameter of cuttings varies from 2 mm to 5.8 mm treating with 2000 ppm IAA (*Indole-3-Acetic Acid*). Cuttings were set in the propagator house for rooting (**Figure 22**). The rooting percentage of Banspata (**Figure 23**) cuttings was found in 5%, 39% and 23% in hard (**Figure 24 a**), semi-hard (**Figure 24 b**) and soft (**Figure 24 c**) shoots, respectively.

Figure 21: Collection and sorting of Banspata cuttings from the stock plants at Mirpur Botanical Garden

Figure 22: Cuttings having half leaf node placed in the sand bed of propagator house

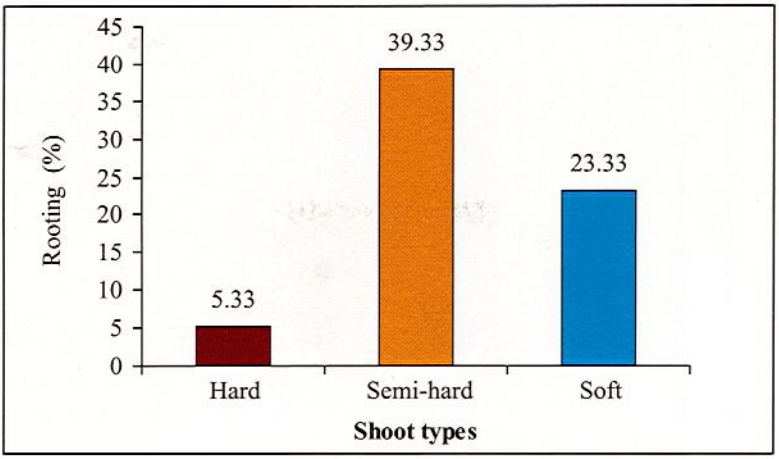
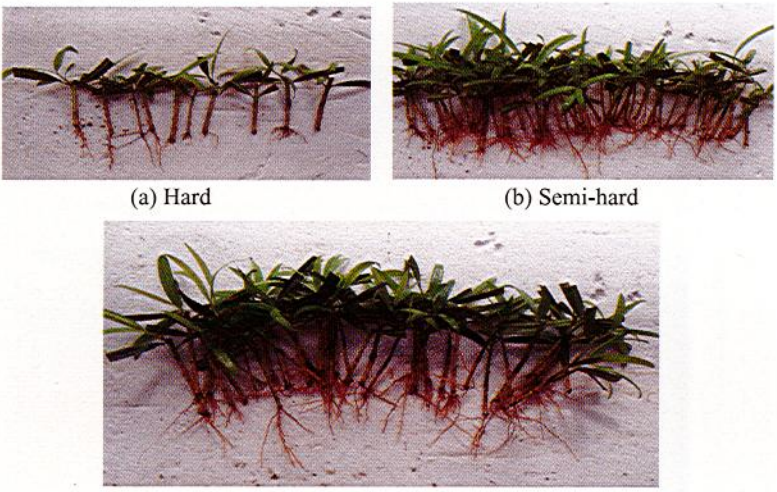


Figure 23: The rooting percentage of Banspata cuttings through different types of shoots



(a) Hard (b) Semi-hard

(c) Soft

Figure 24: Rooting of Banspata in different types (hard, semi-hard, soft) of shoot

Root number

Mean root number of Banspata cuttings varied from 3.25 (in hard shoot type) to 3.88 (in semi-hard) showing no significance different. The mean shoot number per cuttings was recorded 1.12, 0.72 and 0.86 in hard, semi-hard and soft shoots type cuttings, respectively (**Figure 25**).

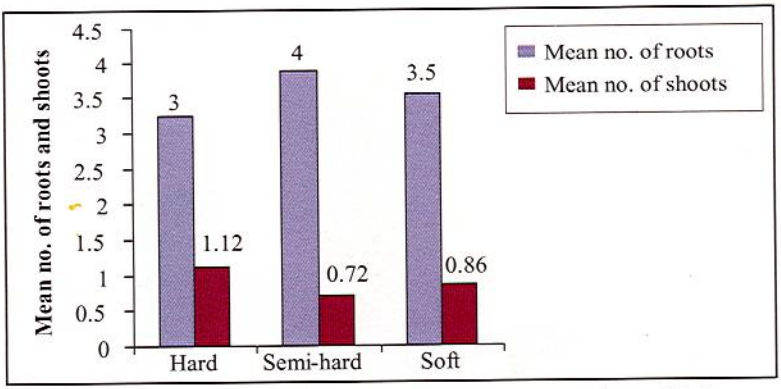


Figure 25: Mean number of roots and shoots of Banspata cuttings with three different types of shoot

Root and Shoot length

The mean highest root length of Banspata cuttings attained (4.94 cm) in semi-hard shoot and the lowest root length was 4.85 cm in the hard shoot. The mean highest shoot length was found 1.46 cm in hard shoots cuttings. In the semi-hard and soft shoot cuttings, the shoot length was found in 0.94 cm and 1.0 cm, respectively (**Figure 26**).

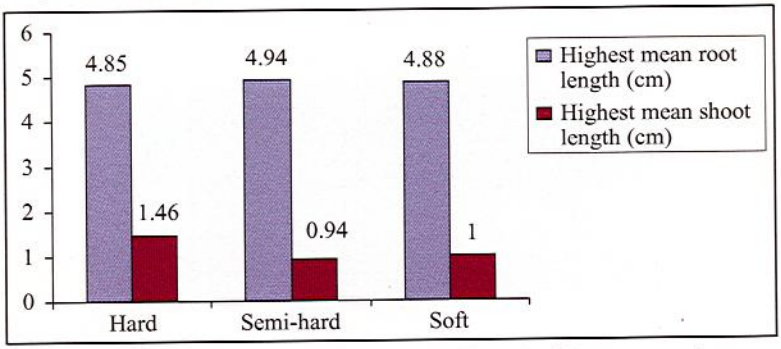


Figure 26: Highest mean roots and shoots length (cm) of Banspata cuttings collected from three different shoot types

Size of the poly bag for transplanting seedlings

Although not significant, the height and diameter growth of all species increases with the increase of poly bag size and survival of the seedlings was also influenced by the sizes of the poly bags (Matin and Banik, 1993) (**Table 2** and **Figure 27**).

Table 2: Effects of poly bag size on the survival of cuttings of *Podocarpous nerifolius*

Poly bag size	No. of cuttings transplanted to the poly bags	No. of stecklings survived	Survival (%)
4″×6″	163	140	86
6″×9″	180	150	83

Figure 27: Seedlings and rooted cuttings (Stecklings) transplanted to polybags of size 4″ x 6″ and 6″ x 9″, respectively

Effects of growing media on Banspata cuttings

The rooting media greatly influenced the rooting percentage of Banspata cuttings. Following the previous experiment, cuttings were set in the propagator house in different media (soil, fine sand and sawdust) for rooting. The rooting percentage of Banspata (**Figure 28**) cuttings was found 53.3%, 15.0% and 6.7% in soil (**Figure 29a**), fine sand (**Figure 29b**) and sawdust (**Figure 29c**), respectively. Soil seems to be better media for rooting of Banspata cuttings.

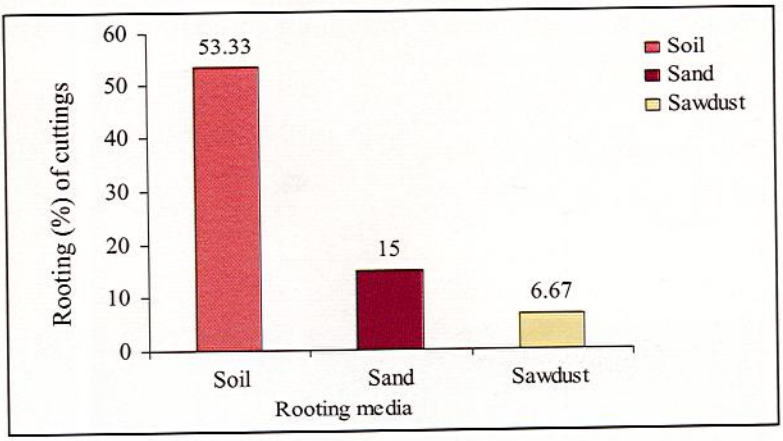


Figure 28: The rooting percentage of Banspata cuttings with three different growing media

Figure 29 (a): Cuttings grown in soil media

Figure 29 (b): Cuttings grown in fine sand media

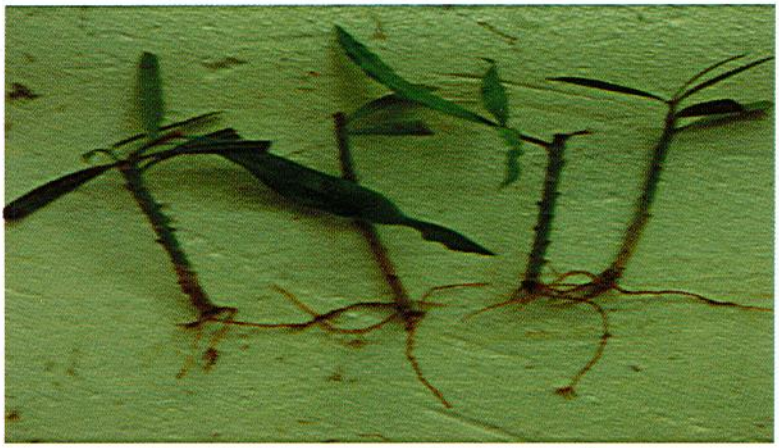


Figure 29 (c): Cuttings grown in sawdust media

The study also showed that the mean number of roots of Banspata cuttings was 3.75, 2.33 and 1.75 in soil, fine sand and sawdust respectively in propagator house. Whereas, the mean number of shoots of Banspata cuttings was 0.97, 0.78 and 1.0 in soil, fine sand and sawdust media, respectively (**Figure 30**).

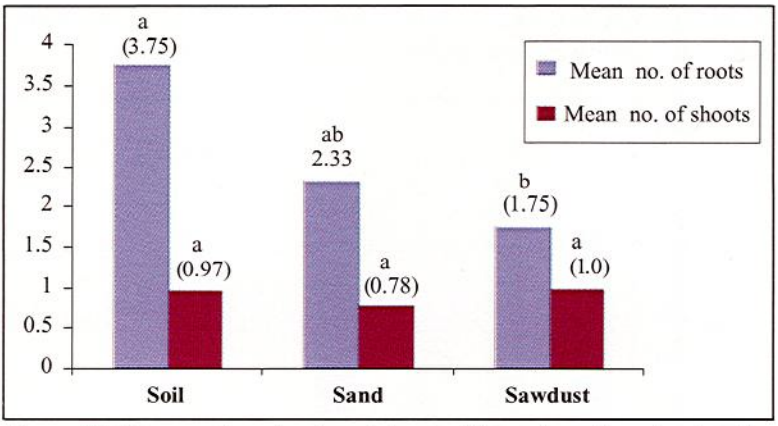


Figure 30: Mean number of roots and shoots of Banspata cuttings developed with three different media

Mean number of roots and root length was found significantly higher in soil media ($p<0.05$) compare to other two media. However, such difference was not observed in case of shoots (**Figure 31**).

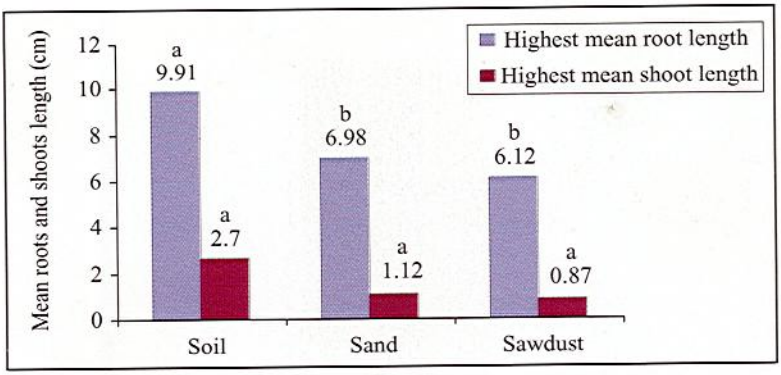


Figure 31: Highest mean roots and shoots length (cm) of Banspata cuttings grown in three different rooting media

Rooting percentage of Banspata cuttings

Cuttings were graded as leaf trimmed to no leaf, ¼, ½, 2/3rd and full leaf retention, respectively. Cuttings were treated with 2000 ppm IAA and set in the propagator house for rooting. Highest (71%) rooting percentage (**Figure 32**) was found in 2/3rd leaf cuttings (Figure 33) followed by ½ leaf cuttings (58%), full leaf cuttings (51.67%) and ¼ leaf cuttings (23.33%), respectively. The cuttings with no leaf did not produce any root at all.

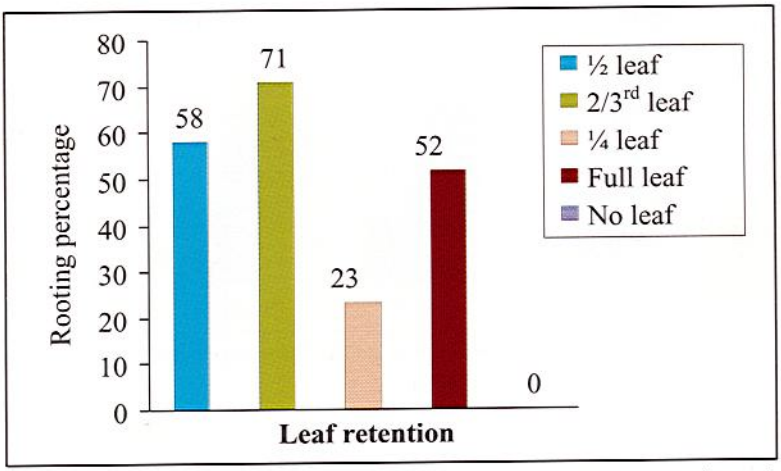


Figure 32: Rooting percentages of Banspata cuttings with different portions of leaf retentions

Figure 33 (a): Rooting of Banspata cuttings with leaf trimmed to ½ of the original size

Figure 33b: Rooting of Banspata cutting with leaf trimmed to 2/3rd of the original size

Figure 33c: Rooting of Banspata cutting with leaf trimmed to 1/4th of the original size

Figure 33d: Rooting of Banspata cutting with full leaf retention

It was found that the mean number of roots of Banspata cuttings was 3.11, 5.11, 0.85, 4.8 and 0 in ½ leaf, 2/3rd leaf, ¼ th leaf, full leaf and without leaf retention, respectively in propagator (**Figure 34**). Whereas, the mean number of shoots of Banspata cuttings was found 0.31, 0.72, 0.93, 0.55 and 0 in cuttings having ½ leaf, 2/3rd leaf, ¼ th leaf, full leaf and no leaf retention, respectively (**Figure 34**).

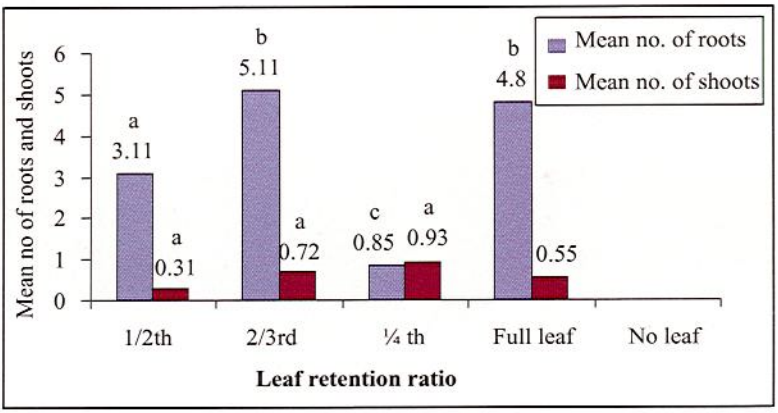


Figure 34: Mean number of roots and shoots initiation of Banspata cuttings having different leaf retention ratio

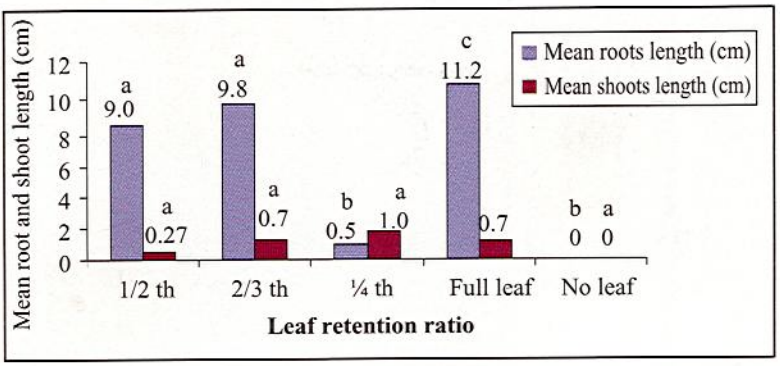


Figure 35: Highest mean root and shoot length (cm) of Banspata cuttings with different portions of leaf retentions

The rooting ability of Banspata cuttings

Cuttings were collected from both 3 years old plantations raised from seedlings (**Figure 36**) and stecklings (**Figure 37**). The mean rooting percentage of cuttings taken from 3 years old seedlings originated plant was 40%, whereas the rooting percentage of cuttings taken from 3 years old stecklings originated plant was 25% only (**Figure 38**).

Figure 36: Three years old saplings of Banspata raised from seeds

Figure 37: Three years old Banspata sapling raised from stecklings

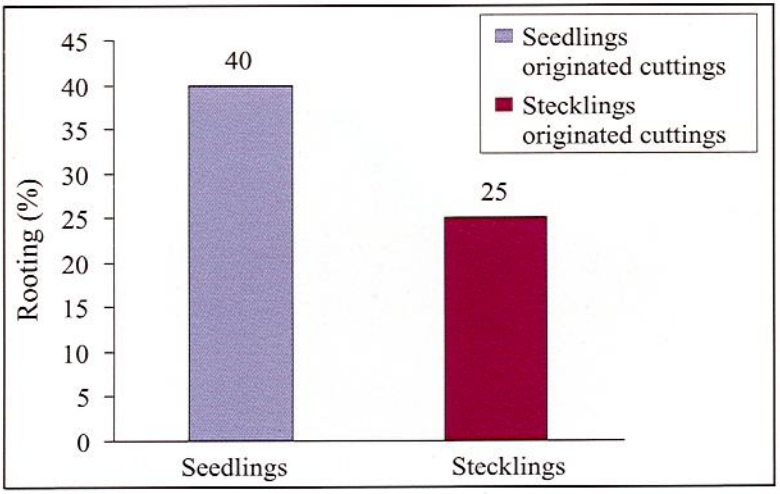


Figure 38: Rooting percentages of Banspata cuttings originated from seedlings and stecklings

The study revealed that the mean number of roots of Banspata cuttings from seedlings origin was 3.93 and stecklings origin was 3.16. The mean number of shoots of Banspata cuttings from seedlings origin was 0.43 and stecklings origin was 0.36 (**Figure 39**).

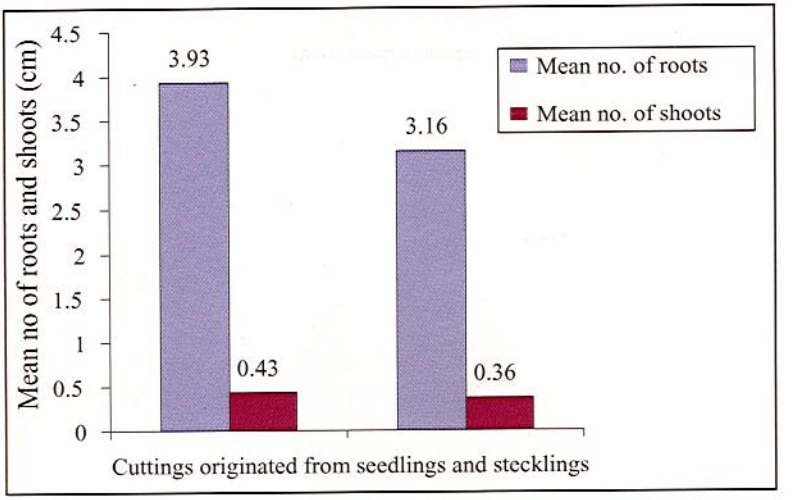


Figure 39: Mean number of roots and shoots of Banspata cuttings origins from seedling and stecklings

The highest mean roots length (cm) of Banspata cuttings was from seedling origin (8.6) and 8.32 for stecklings origin. The corresponding mean shoots length (cm) of Banspata was 0.46 cm and 0.3 cm, respectively (**Figure 40**).

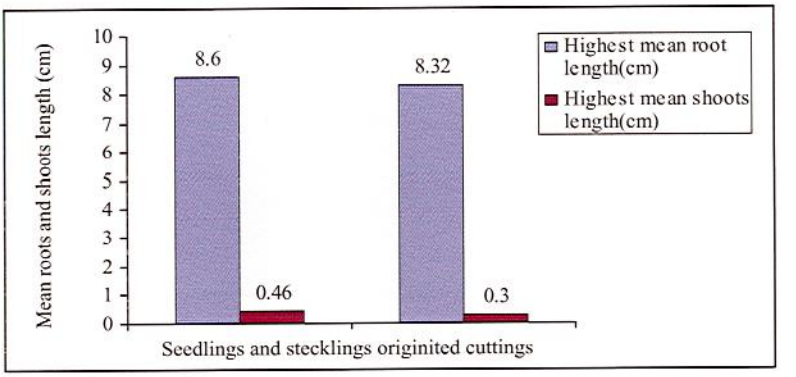


Figure 40: Highest mean root and shoot length (cm) of Banspata cuttings collected from seedlings and stecklings origin

Height of Seedlings (cm) in different light conditions

The initial growth of Banspata seedlings is influenced by the availability of sunlight, i.e. full shade, partial shade and full sunlight condition. The height of seedlings within 6 months in

full sunlight showed that the maximum height (5.86 cm) was attained in the partial shade condition, compared to full sunlight (4.11cm) and full shade (1.92 cm) (**Figure 41**).

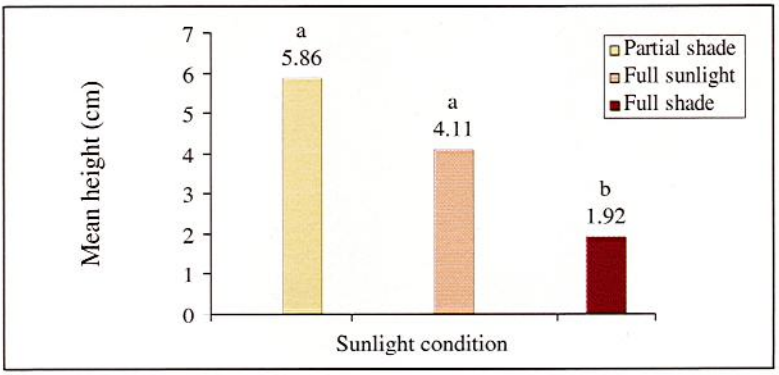


Figure 41: Effect of different sunlight duration on the growth of seedlings height

The collar diameter of 6 month old seedlings was 3.09 mm, 3.02 mm and 2.96 mm in the full sunlight, full shade and partial shade condition, respectively (**Figure 42**).

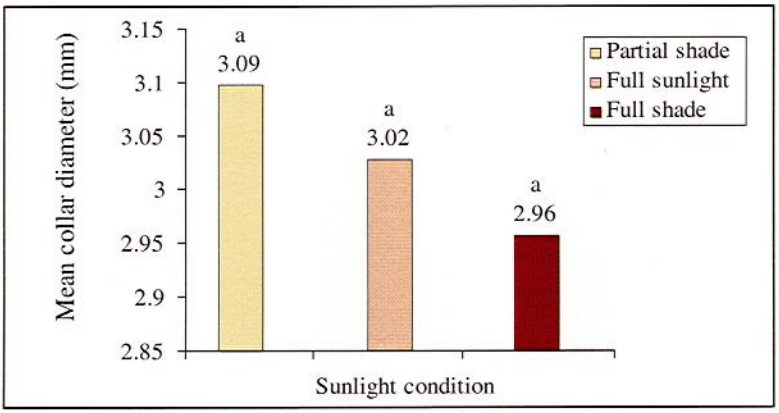


Figure 42: Effect of different sunlight condition on the growth of collar diameter (mm) in the seedlings

Number of leaves of seedlings in different sunlight conditions

The mem numbers of leaves was found maximaum (20.98) when seedlings were kept in the partial shade. But minimum number of leaves (7.67) was produced when seedlings were grown in full shade conditions (**Figure 43**).

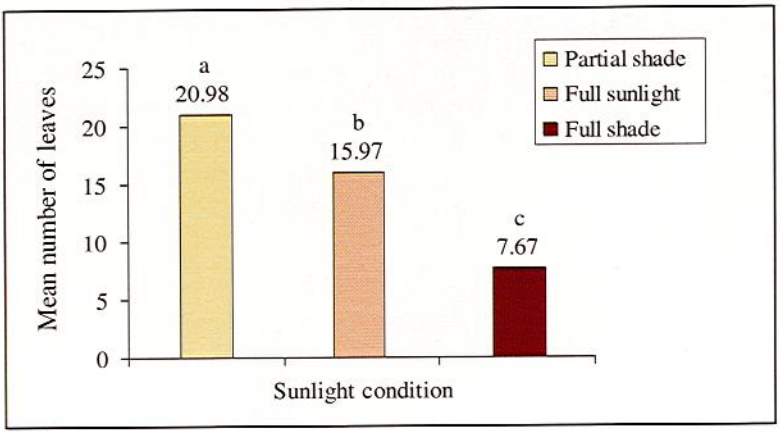


Figure 43: Effect of different light condition on growth of leaves of the seedlings

Cuttings height in different sunlight conditions

In the nursery, different sunlight conditions, i.e. full shade, partial shade, and the full sunlight of Banspata's cuttings height growth was 1.59 cm, 3.34 cm, 2.98 cm, respectively (**Figure 44**). There is no significant difference ($p<0.05$) between the growth of cuttings height in the full sunlight and full shade conditions, but significant difference was found between partial shade and full shade conditions.

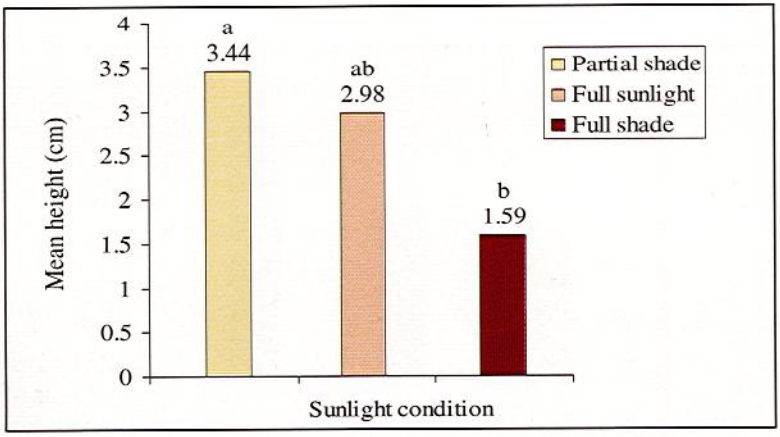


Figure 44: Effect of different light condition on the growth of cuttings height (cm)

Number of leaves of cuttings in different sunlight exposures

The mean number of leaves of cuttings of Banspata is greatly influenced in availability of sunlight. Mean number of leaves development in cuttings was 6.82, 10.53, and, 8.81, respectively in full shade, partial shade, and full sun light condition (**Figure 45**).

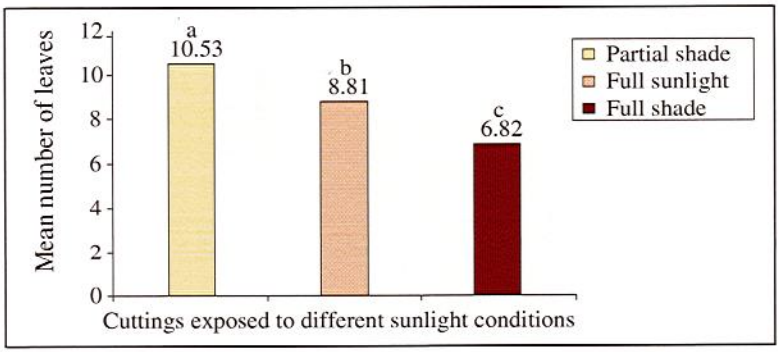


Figure 45: Exposure to sunlight effects on the growth of cuttings' leaves number

Survival percentage of seedlings in different sunlight exposures

Survival percentage of Banspata (*Podocarpus nerifolius*) seedlings in the nursery also varied with initial sunlight exposures. Survival percentage ranges from 53.3 to 100.0. The study showed that the survival percentage of seedlings was 66.7, 100.0, and 53.3, respectively in the full shade, partial shade, and full sun light exposures (**Figure 46**).

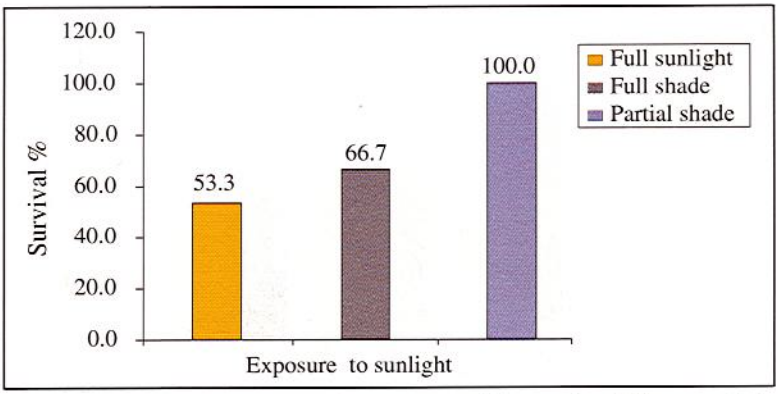


Figure 46: Survival percentage of Banspata seedlings under different sunlight conditions

Survival percentage of cutting in different light conditions

Survival percentage of Banspata cutting was also different in different light conditions. It was found from the study that survival percentage of Banspata cutting was 86.67, 71.11 and 62.97 in the partial shade, full sun light and full shade conditions, respectively (**Figure 47**).

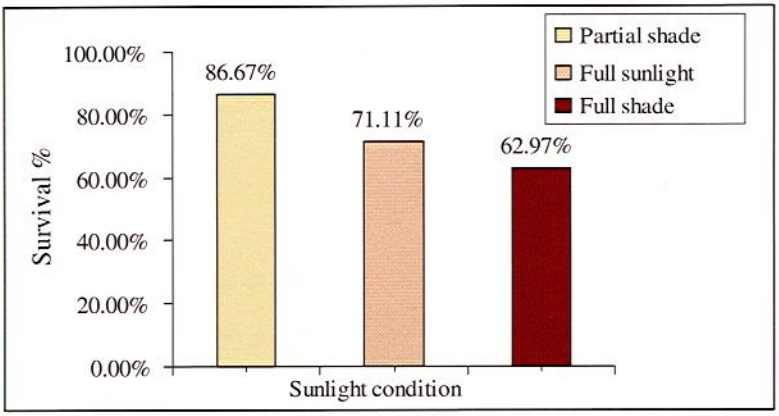


Figure 47: Survival percentage of Banspata cuttings under different light conditions

Rooting behavior of cuttings

Rooting percentage of Banspata (*Podocarpus nerifolius*) ranges from 56.7 to 86.1 for the cuttings collected from different sources. It was found that the maximum rooting percentage of cuttings was 86.1 (Sitakunda Eco-park) and the minimum rooting percentage was 56.7 (Soil Science Research Center). The rooting percentage of cuttings collected from IFESCU, Mirpur Botanical Garden and Hazarikhil were 82.6, 73.6 and 66.7, respectively **(Figure 48)**.

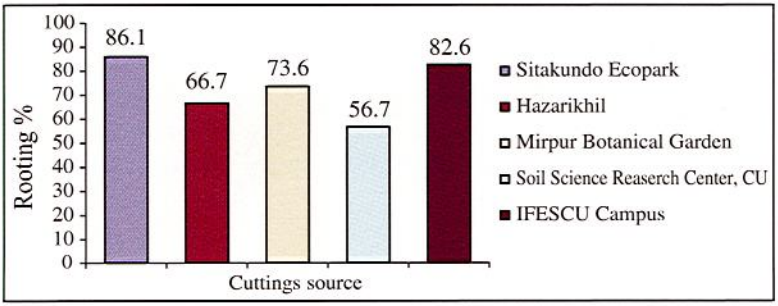


Figure 48: Rooting percentage of Banspata cuttings collected from different sources

Survival percentage of cuttings

Survival percentage of cuttings of Banspata (*Podocarpus nerifolius*) also varies with the sources of collection (geographic location) of cuttings. Survival percentage ranges from 60.9 to 89.2. The maximum survival percentage was 89.2 for the cuttings collected from IFESCU campus and the minimum survival percentage was found in cuttings collected from Sitakunda Eco-park (60.9). The survival percentage of cuttings collected from Mirpur Botanical Garden, Soil Science Research Center, University of Chittagong and Hazarikhil were 71.6, 69.6 and 65.3, respectively (**Figure 49**).

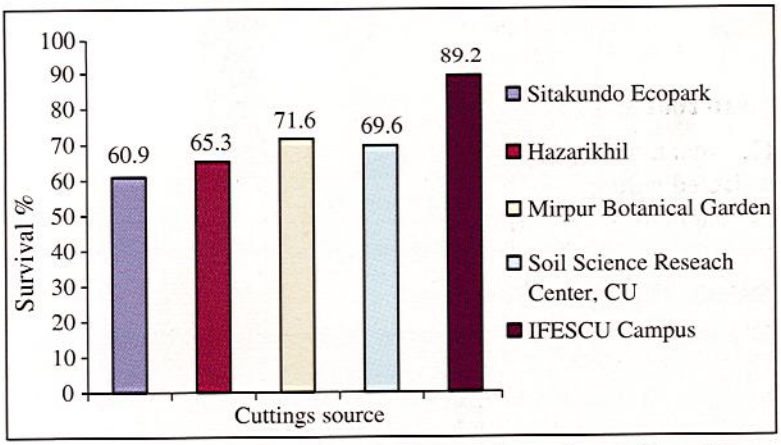


Figure 49: Survival percentage of Banspata cuttings collected from different sources

Number of roots per cutting

Cuttings collected from different sources vary significantly from each other. It was found that the shoots collected from Hazarikhil produce maximum number of roots per cutting (8.67) (**Figure 50**), while shoots collected from Mirpur Botanical Garden, Soil Science Research Center, IFESCU campus and Sitakunda Eco-park yield 4.13, 4, 3.33, and 3.33 roots per cutting, respectively (**Figure 50**).

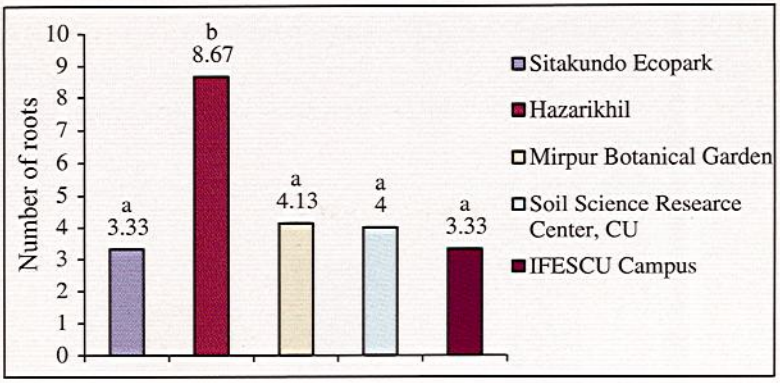


Figure 50: Number of roots per cutting collected from Sitakunda Ecopark, Hazarikhil, Mirpur Botanical Garden, Soil Research Center, IFESCU campus

Mean root length

The mean root length ranges from 2.63 cm to 5.11 cm in collected cuttings. The longest root length was found in cuttings collected from Hazarikhil (5.11 cm) followed by 4.3 cm, 3.95 cm, 3.63 cm, and 2.63 cm for the cuttings collected from Soil Science Research Center, Mirpur Botanical Garden, IFESCU campus, and Sitakunda Eco-park, respectively (**Figure 51**). The highest mean root length (5.11 cm) was found in the cuttings collected from Hazarikhil, and significantly different (at 5% level of significance) from cuttings collected from Sitakunda Eco-park and IFESCU campus.

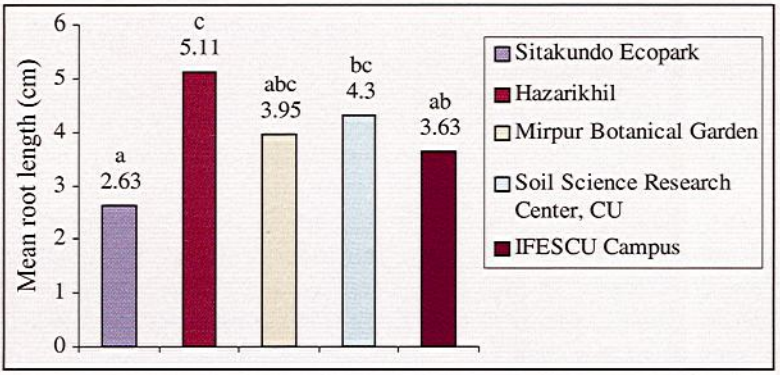


Figure 51: Mean root length of cuttings collected from different sources

Survival percentage of seedlings and stecklings

The survival percentage of seedlings and stecklings were 48.17 and 71.32, respectively and significantly different from each other (**Figure 52**).

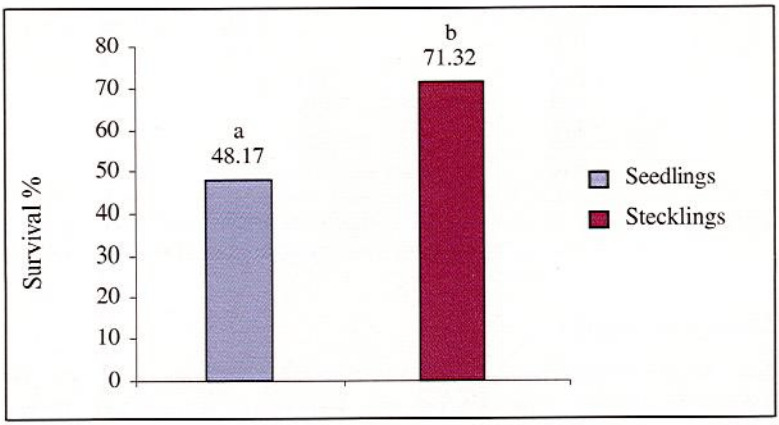


Figure 52: Survival percentage of seedlings and stecklings

Tissue Culture

Tissue culture is the culture and maintenance of somatic growth plant cells or organs in sterile, nutritionally and environmentally supportive conditions. This is basically of growing many undifferentiated cells with the capacity to regenerate new plants. A controlled environment, freedom from competition, removal of nutrients and waste product, using of different chemicals such as amino acids, minerals, vitamins, sugars, hormones, antibiotics etc. are essential for tissue culture.

Tissue culture is a potentially useful tool in forest tree breeding because of reproducing thousands of individuals with the same genotype. The process normally starts with the production of callus which can be generated from many different types of plant tissues including leaves, stems, and roots (Zabala, 1991). More than 60 different media have been used for tissue culture of various woody species. It is difficult to regenerate plantlets using tissues of mature trees due to loss of regenerative potential in such tissues (Bonga, 1982; Zabala, 1991).

Importance of Tissue Culture

Tissue culture derives benefit in vitro over traditional propagation methods with faster rate of growth. In vitro plants are multiplied specially which are difficult by other traditional methods. Large numbers of genetically identical clones may be produced. Plant material may be stored under certain conditions in vitro for certain periods without maintenance. Germination of seeds may take place without the risk of damping off and other predation.

Tissue culture techniques may be used for plant improvement through propagation in basic research. This technique may also be used for virus eradication, genetic manipulation, and somatic hybridization.

Tissue culture and Banspata

An experiment was executed at IFESCU's laboratory using a laminar air flow (Clean Bench) to develop a protocol for the low cost propagation method through tissue culture for mass clonal propagation (**Figure 53**). The study revealed that Banspata cell culture started with the nodal explants and callus was formed (**Figure 54**) which subsequently used for multiplication and production of propagules (**Figure 55**). The experiment also revealed that small piece calluses produced shoot generation (**Figure 56**). However, this study concludes that tissue culture is not well suited for clonal propagation, and suggests to further research for tissue culture of Banspata.

Figure 53. Laminar air flow (Clean Bench) for tissue culture program

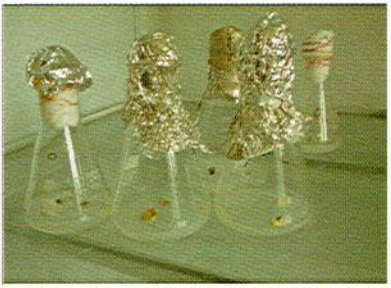


Figure 54: Banspata cell culture and callus formation in the tissue culture lab at IFESCU

Figure 55: Callus ready for multiplication

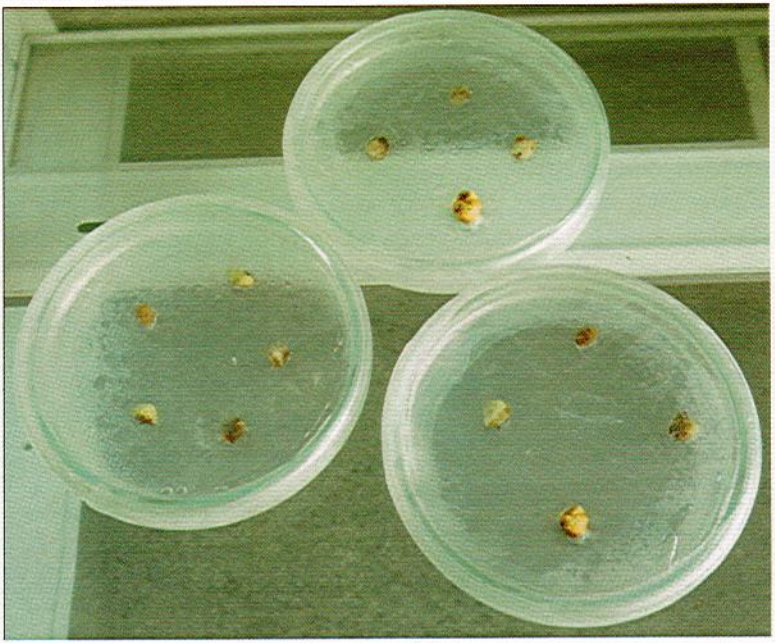


Figure 56: Culture and multiplication of Banspata for shoot generation

Chapter 5: Growth and Yield

Growth performance of Banspata in the plantations

Plantations of Banspata are raised in three different locations at Chittagong University campus using both seedlings and stecklings. The plantation sites are located near the hills of Institute of Forestry and Environmental Sciences (IFES)'s administrative building, West hill of Nipoban School and South-eastern side of Deshnetri Begum Khaleda Zia Hall, respectively.

The first plantation plot of Banspata (**Figure 57**a) is located at the eastern side of a small hill with moderate slope near the administrative building of IFESCU. Previously the site was reclaimed with Akasmoni (*Acacia auriculiformis*). The soil type of the site is sandy loam with moderate fertility. Plantation plot of Banspata was divided into two parts -south part and north part. 50 seed originated seedlings were planted in the south part and in the north part, 50 cutting originated stecklings were planted. Both the seedlings and stecklings were planted with 2 m x 2 m spacing.

A mixed plantation of Banspata (**Figure 57**b) with Civit (*Swintonia floribunda*) was located at the Eastern side of a small hill with moderate slope besides the western side of Nipoban school. Another plantation plot (**Figure 58**) of Banspata is located at the Northern aspect of a small hill with moderate slope near the Khaleda Zia Hall at University of Chittagong.

a) b)

Figure 57: Plantations of Banspata near (a) IFESCU administrative building and (b) Nipoban School of the university campus

Figure 58: Plantation plot of Banspata near Khaleda Zia Hall of the CU Campus

The survival percentage of seed originated saplings was 94%, 70% and 59% in the plantation site at IFESCU, near Nipoban School and near Khaleda Zia Hall, respectively. On the other hand, the survival percentage of cuttings was 82%, 22% and 30% in IFESCU, near Nipoban school and near Khaleda Zia Hall, respectively (**Figure 59**).

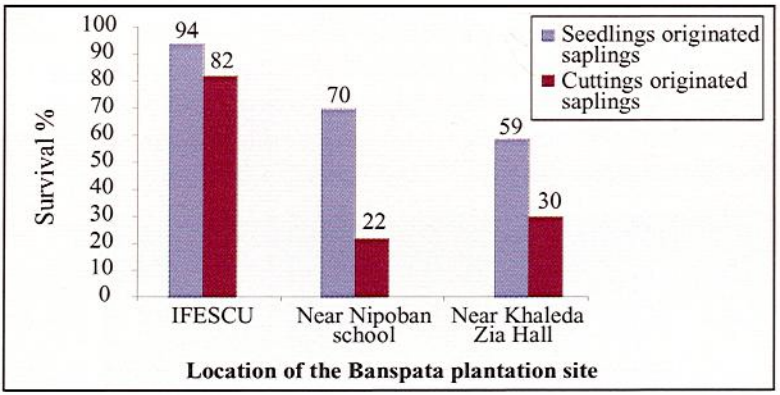


Figure 59: Survival percentage of seedlings and stecklings in three locations

Survival percentage of seedlings and stecklings

The survival percentage of seedlings and stecklings in the plantation site was 82% and 76% respectively (**Figure 60**) showing slightly better survival capacity of the seedlings than the stecklings.

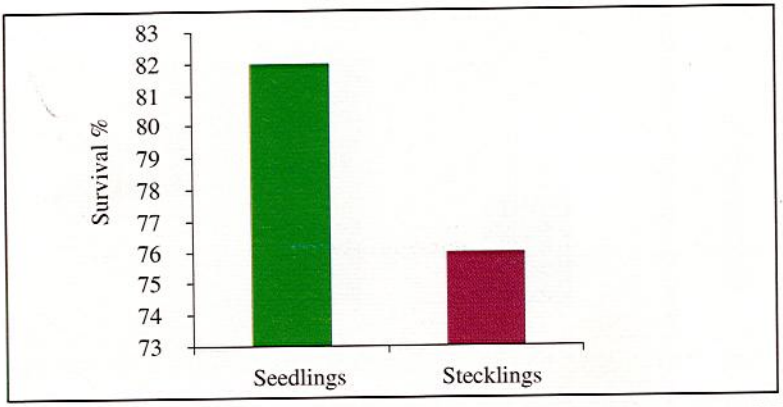


Figure 60: Survival percentage (%) of seedlings and stecklings in the CU campus plantation

Initial growth of Banspata in plantation sites

The growth performances of Banspata were assessed in the plantation site. No significant difference in height and collar diameter growth was observed between seedlings and stecklings. Mean height of seedlings and stecklings after planting 1.5 year in the plantation site was 37.86 cm, 38.11 cm, respectively (**Figure 61**).

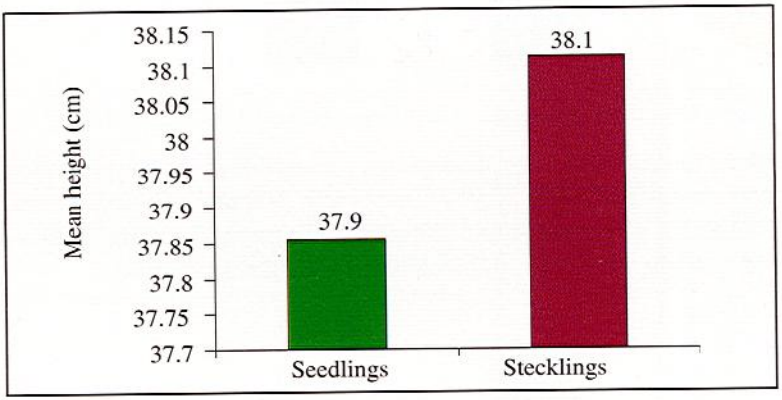


Figure 61: Height of seedlings and stecklings in the plantation sites

It was found that the mean collar diameter of seedlings and stecklings after 1.5 year planting were 5.87 mm and 5.93 mm, respectively (**Figure 62**).

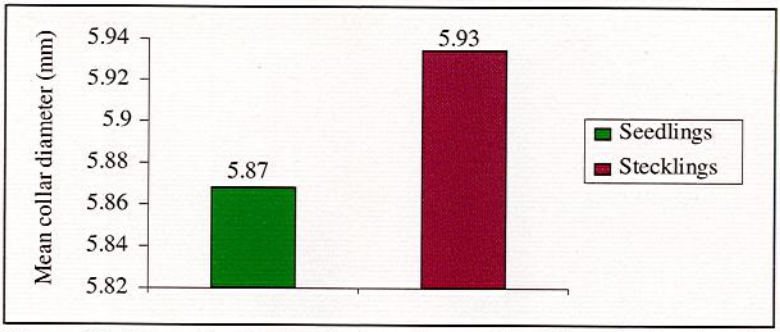


Figure 62: Collar diameter (mm) of seedlings and stecklings in the plantation sites

The study shows that the mean number of branches of seedlings and stecklings in the plantation site were 3.83 and 2.41, respectively (**Figure 63**).

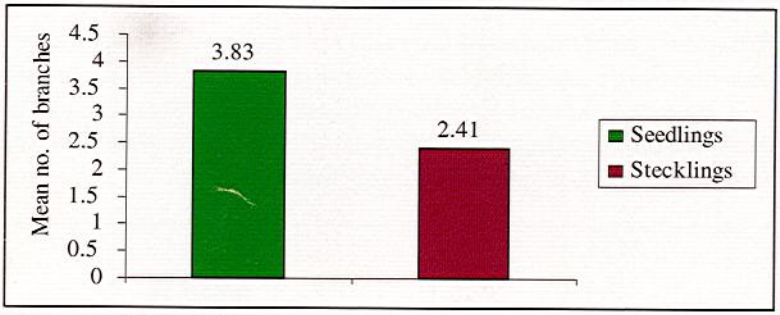


Figure 63: Number of branches of seedlings and stecklings in the plantation site

Mean number of leaves of seedlings and stecklings in the plantation sites were 73.02 and 57.75, respectively (**Figure 64**). It was also found that there was significant difference ($p<0.05$) of leaf number between the seedlings and stecklings in the plantation sites.

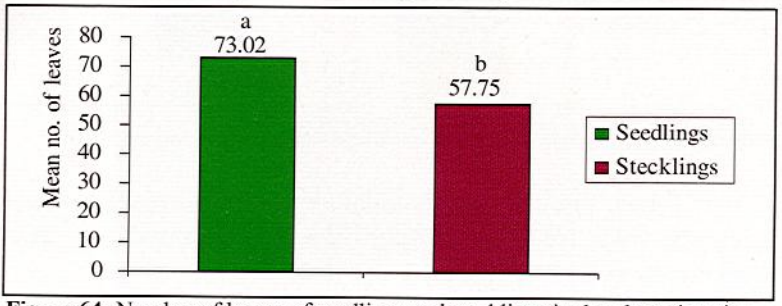
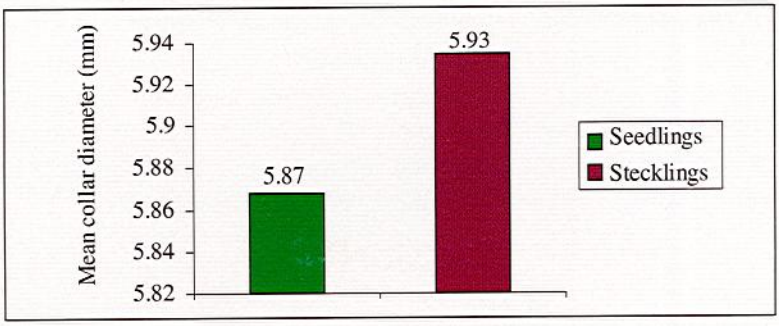


Figure 64: Number of leaves of seedlings and stecklings in the plantation sites



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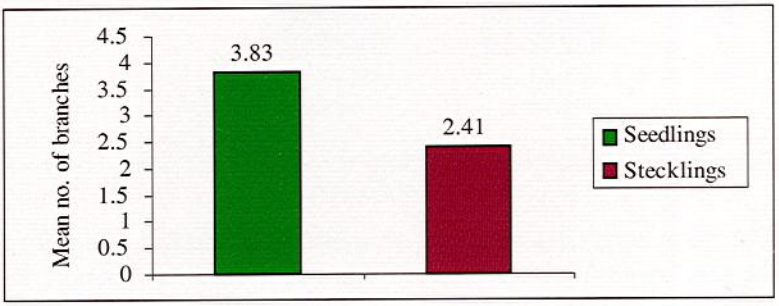

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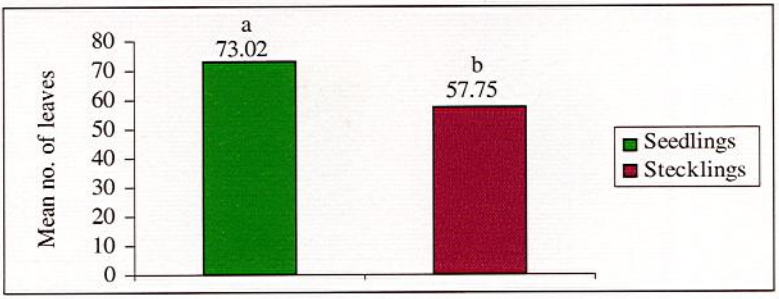

Figure 64: Number of leaves of seedlings and stecklings in the plantation sites

Growth performance of Banspata in the plantations

The mean height of seed originated saplings and cuttings originated sapling, 3 years after planting near the Director's office of IFES was 1.47 m and 1.08 m, respectively. The mean diameter of seedlings originated saplings and cuttings originated sapling was 2.3 cm and 2.0 cm, respectively (**Figure 65**).

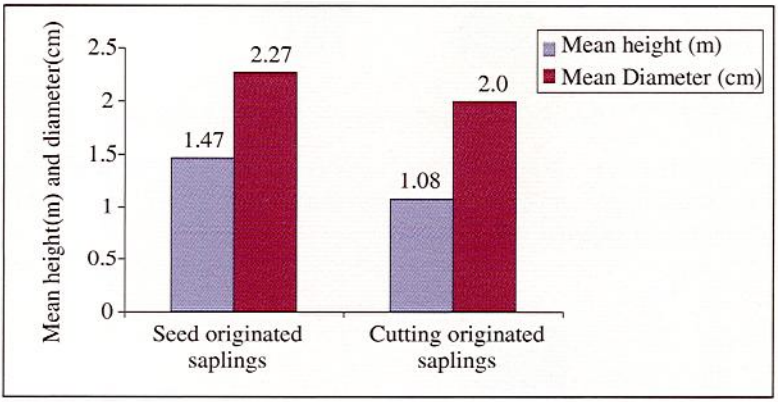

Figure 65: Mean height (m) and diameter (cm) of seed and cutting originated sapling in the plantation of IFESCU

The mean height and diameter of seedlings originated saplings in the plantations after 3 years near Nipoban School was found 1.26 m and 2.48 cm, respectively, while in cuttings originated saplings was 1.16 m and 2.05 cm, respectively (**Figure 66**).

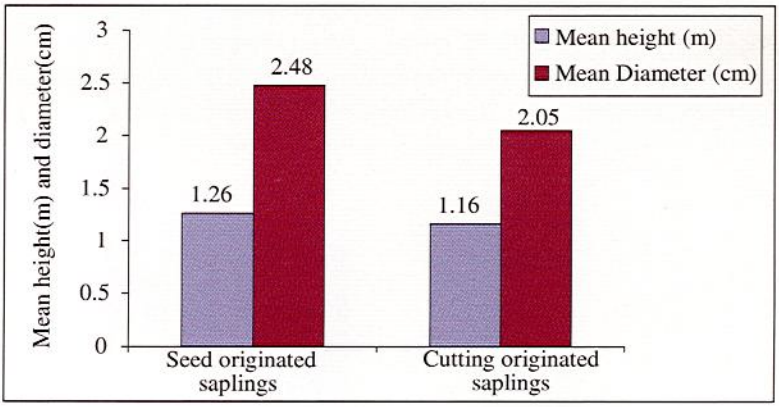

Figure 66: Mean height (m) and diameter (cm) of seed and cutting originated saplings in the plantation near Nipoban school

The mean height of seedlings originated saplings and cuttings originated sapling 2 years after planting near Khaleda Zia Hall was 1.57 m and 1.0 m, respectively. The mean diameter of seedlings originated saplings and cuttings originated sapling was 2.7 cm and 2.07 cm, respectively in the plantation sites (**Figure 67**).

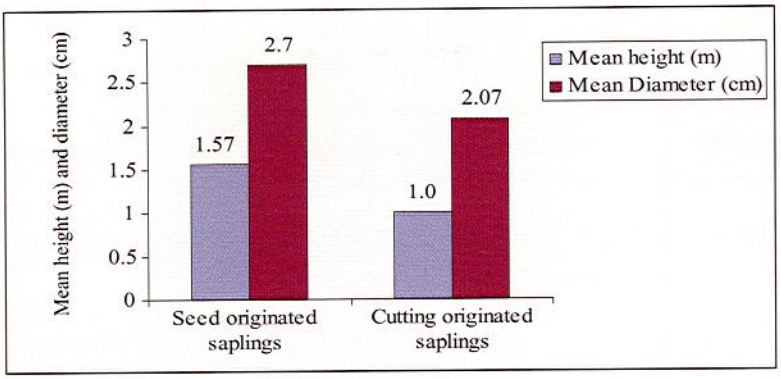

Figure 67: Mean height (m) and diameter (cm) of seed and cutting originated saplings in the plantation near Khaleda Zia Hall

Effect of light intensity on growth of Banspata

The mean height (m), diameter (cm) and light intensity (lux) of Banspata seedlings and stecklings in the plantation sites was 1.68 m, 2.58 cm, 4,600 lux in the partial shade condition. On the other hand, the mean height of stecklings was 1.12 m and the mean diameter was 1.93 cm and the light intensity was 83,010 lux in the full sunlight condition (**Table 3**).

Table 3: Growth of Banspata in relation to light intensity in the plantation sites

Seedlings Partial shade			Stecklings Full sunlight		
Mean height (m)	Mean diameter (cm)	Mean light intensity (lux)	Mean height (m)	Mean diameter (cm)	Mean light intensity (lux)
1.681	2.57	4,600	1.12	1.93	83,010

Young Banspata trees in the Mirpur National Botanical Garden

A block and a strip plantation around the pond were established in 1990. Besides, three trees, planted in 1973, were available. Mean height of Banspata trees in the block plot and strip plantation was 5.64 m, and 5.33 m, respectively (**Table 4**) with mean diameter of 7.85cm, and 8.60 cm, respectively. Mean height and diameter of 1973 planted trees was 15.3 m and 26.6 cm, respectively. Considering the young trees, volume of Banspata was 0.43 m^3 $ha^{-1}y^{-1}$ and 0.90 m^3 $ha^{-1}y^{-1}$, in the block plot and in the strip plantation, respectively.

Table 4: Growth performance of Banspata trees in the National Botanical Garden

Location	Age (yr)	Mean height (m)	Mean diameter (cm)	Total volume of tree $ha^{-1}y^{-1}$ (m^3)
Banspata in a square plot	19	5.64	7.85	0.43
A strip of Banspata around the pond	19	5.33	8.60	0.90
Trees of Banspata raised in 1973	36	15.33	26.60	-

Growth of Banspata in plantation sites at CU campus

The growth of young Banspata at plantation sites near IFESCU was not satisfactory. The mean height (m) and collar girth (cm) was 2.37 m and 8.56 cm, respectively (**Table 5** and **Figure 68**). On the other hand, the mean height (m) and collar girth (cm) at Nipoban school was 2.59 m and 11.05 cm, respectively (**Figure 69**). The growth of Banspata height and collar girth was high at plantation site near Khaleda Zia Hall of CU campus with a mean height (m) and collar girth (cm) was 2.64 m and 13.34 cm, respectively (**Table 5** and **Figure 70**).

Table 5: Growth of Banspata at Chittagong University Campus, Chittagong

Plantation site	Plantation year	Average height (m)	Average girth (cm)
Near Director's Office, IFESCU	2008	2.37	8.56
Near Nipoban School	2009	2.59	11.05
Near Khaleda Zia Hall	2009	2.64	13.34

Figure 68: Dominant saplings of Banspata after 3 years near IFESCU Director's office

Figure 69: Saplings of Banspata in the plantation near Nipoban School of CU campus

Figure 70: Saplings of Banspata in the plantations beyond Khaleda Zia Hall of CU campus

Chapter 6: Pest and Diseases

Two types of nursery diseases were identified for Banspata during the research work.

1. **Top dying:** Top dying is one of the destructive diseases of Bansptata which starts from the apical bud of the stecklings and top of the seedling and can drastically reduce the growth and survival percentage of both seedlings and stecklings. But, it is the worst in cutting originated stecklings. This may cause ultimate death of the stecklings. The upper leaves turn brown and gradually proceeds towards the base of the stecklings and ultimately the stecklings die (**Figure 71**). By uprooting the diseased stecklings it was found that the roots remained healthy.

Figure 71: Symptoms of top dying disease of Banspata in the nursery

2. **Leaf spot:** Leaf spot may hamper the normal physiological activities but it may not cause immediate death to the seedlings and stecklings. About 53% seedlings and stecklings were infected by leaf spot disease. Green leaves gradually become gray and eventually turns into black. Irregular spots develop on the dorsal surface of the leaves and rotting starts at the advanced stage of spot development (**Figure 72**). For both the diseases, the causal organism was identified as *Uromyces* (**Figure 73**).

Figure 72: Symptoms of leaf spot disease of Banspata

Figure 73: Infected leaf portion in the agar media in a petridish for fungal colony formation

It was observed that the seedlings originated from seeds were more susceptible to insect attack than the stecklings obtained from the stem cuttings. Cutworm attacked 8% seedlings from seed originated, while only 2% stecklings (seedlings from cuttings) were attacked by the cutworms. Cutworms cut the seedlings at the base within 3- 4 days after planting. Sometimes, cutworms cut one or two year old seedlings also. The basal or collar region of seedling is softer than that of the stecklings, which may be a reason for more susceptibility of seedlings to cutworm attack than stecklings. Eradication of cutworm by physical killing is the only control measure.

Chapter 7: Future Seed Sources

It is to be mentioned that Banspata is monoecious, i.e. male and female flowers are found in different trees. So, cross pollination is essential for this species which may sometime not occur properly resulting no production of seeds for certain years. Due to scarcity of seeds, it is the best option to go for stecklings production from stem cuttings though it takes longer time to produce large scale propagules as revealed from the present study.

One Seedling Seed Orchard (SSO) of seed originated seedlings and one Clonal Seed Orchard (CSO) of cutting originated stecklings of Banspata were established in 2008 (0.25 ha) and 2009 (0.35 ha) in the Chittagong University campus for future seed sources of this critically endangered gymnosperm tree species. Care and maintenance were taken regularly for both these successful orchards and plantations established in the campus.

Old mother trees:

The research team visited most of the accessible hill forest areas of Bangladesh and found only a few mother trees from where seeds are produced.

- **Lawachara National Park:** Only one mother tree (**Figure 74**) is available at Lawachara national park which produces seed with strong periodicity. There is indication of natural regeneration around the tree. If proper protection could be given the seedlings could come up and grow properly and could be established.

Figure 74: Banspata tree at Lawachara forest

- **Mirpur National Botanical Garden:** There are two mother trees (**Figure 75**) at Mirpur National Botanical Garden, Dhaka which produces seeds with regular periodicity. There are 31 poles of Banspata near the nursery and 10 by the side of the pond of this garden. Some of them will also produce seeds in future.

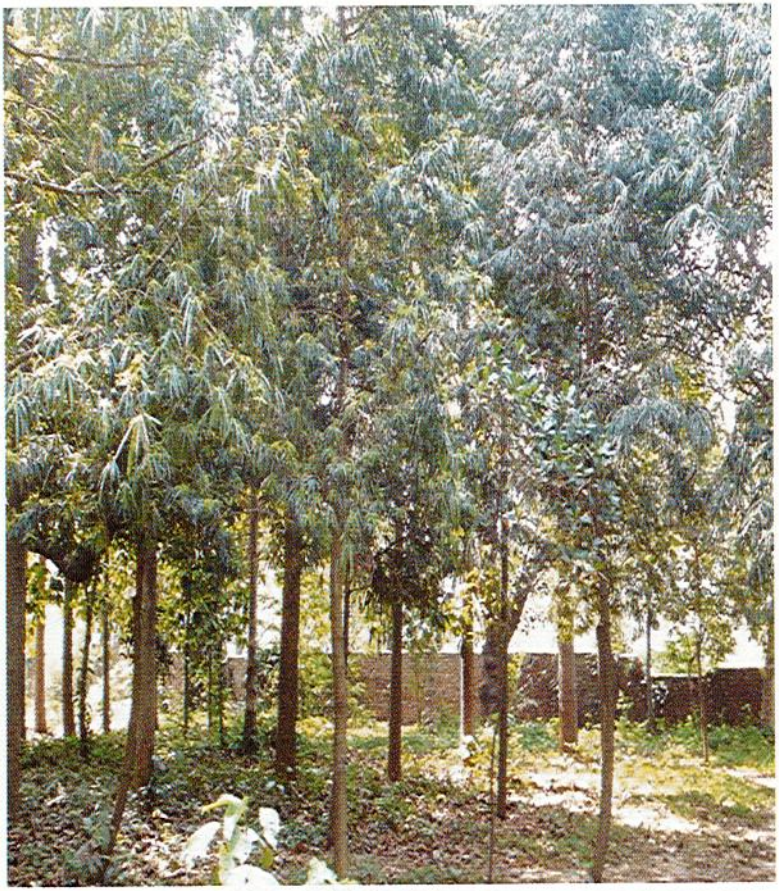

Figure 75: Banspata trees at Mirpur National Botanical Garden, Dhaka

- **Sitakunda Eco-park:** There are five poles and saplings of Banspata planted at Sitakunda Eco-park (**Figure 76**) which may be used as future seeds sources and cuttings.

Figure 76: Pole stage of Banspata at Sitakunda Botanical Garden and Eco-park

Other sources: There are a few trees, poles and saplings near Podua rest house, Korerhat rest house, BFRI, Baldha garden, Dhaka, Dhaka University Botanical garden, Jahangirnagar Unviersity Botanical garden, (**Figure 77**), Bangladesh Agriculture University Botanical garden (**Figure 78**), Lawachara Silviculture research station, Keochia silviculture research station, Duapalong beat office of Cox's Bazar forest division and homesteads of Ukhia (**Figure 79**), Chittagong University Botanical garden and Soil Research Center may be use as future seed sources. There are six big banspata trees at Massalong natural reserve forests which are in extreme depleted condition. Though they are supposed to produced seeds but due to deterioration, cannot take them into consideration for seed production in future.

Figure 77: Banspata planted at Botanical Garden, JU, Savar

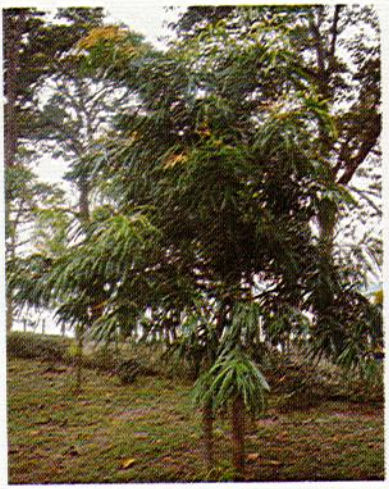

Figure 78: Banspata pole at Botanical Garden,BAU, Mymenshingh

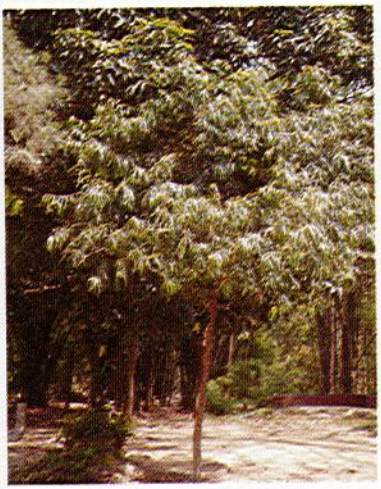

Figure 79: Banspata at homesteads of Ukhia, Cox's Bazar

- **CU Campus:** About 3,500 individual seedlings/ stecklings were planted in the Chittagong University Campus under the present program. Both Seedling Seed Orchard (SSO) and Clonal Seed Orchard (CSO) were established in different locations of Chittagong University campus (**Figure 80**) may be used for ensuring sustain and easy supply of planting materials of Banspata in future.

Figure 80a: Plantation near IFESCU Director's office

Figure 80b: Banspata plantation near Nipoban School of CU campus

Figure 80c: Plantation of Banspata near Khaleda Zia Hall of CU campus

- **Hedge bed:** Four hedge beds (**Figure 81**) were established in the nursery of Institute of Forestry and Environmental Sciences (IFESCU) from where cuttings may be obtained for the production of future planting materials.

Figure 81: Hedge bed of Banspata at IFESCU Nursery

Chapter - 8: Challenges

Seed production and sources: Banspata tree does not produce seeds every year. Sometimes very small number of seeds are produced. The species is unisexual. Male and female flowers are found in separate tree. So, a severe loss of pollen grains occurs during pollination. Seedling production from the seeds is time consuming and very difficult. At present, there is only one tree at Lawachara forest and two trees at Mirpur National Botanical Garden, Dhaka from where seeds are produced.

Slow growth: The growth of seedlings in the nursery as well as in the planting sites is very slow. So, it is very difficult to establish them in the nature or in the plantation having competition with other fast growing and medium growing species.

Peoples' perception: People are not willing to plant Banspata at homestead for their slow growth and not having any commercial value. For this reason, the nurserymen are not motivated to raise and rare this species in the nursery. So, it is a great challenge to restore the species in its natural habitat and as well as in the plantation. But, opportunity exists in planting at parks, gardens, University campus, Botanical gardens and Patanga Air Force Base.

Deforestation: Serious deforestation and depletion is going on in the natural hill forests in Bangladesh. So, it is a very challenging job to re-establish Banspata in its natural habitat like Ukhia, Teknaf, Lawachara forests, Kassalong and Massalong reserve and in other hill forests of Bangladesh. The silviculture of the species needs to be established for reforestation.

Cutworm attack: When the seedlings and stecklings of Banspata are planted in the field, the cutworm cut the seedlings from the collar region during night time. Sometimes it becomes very severe. Trapping the worms by net, killing the insect manually with the help of torch light, pouring water in the hole to kill the insect etc. were tried several times to destroy this insect. But, controlling them is very difficult job. This is a great challenge for Banspata restoration.

Fungal infestation: Fungal infestation occurs in the nursery and the whole seedling in the nursery bed is damaged with in a very short time. For the leaf spot and top dying diseases, the causal organism for this disease seems to be *Uromyces*. It is also a challenging job to keep the seeding healthy in the nursery.

Clonal propagation and tissue culture: Development of a protocol for low cost propagation method through cuttings and tissue culture for mass clonal propagation was found very difficult. Because of, it takes about four months to start rooting from the cuttings. Tissue culture was found very difficult in the laboratory. After callus formation, the tissue starts dying in the growing media.

Recolonization of Banspata: Recolonization of Banspata in its natural habitat is almost not possible. The project supplied seedlings in different natural habitats, i.e. Bandarban and Sitakunda Eco-park, Chittagong, but they could not survive after planting despite of special care taken. This is the main challenge to restore this plant in natural forests as well as plantations. But, we could overcome the situation by planting propagules in Chittagong University Campus.

Chapter 9: Conclusion

Conclusion

Banspata (*Podocarpus nerifolius*) or pencil wood is one of the five native gymnosperms in Bangladesh. It is one of the critically endangered species growing in the hill forests of Bangladesh. A sporadic presence of Banspata has been observed in Ukhia forests of Cox's Bazar, Lawachara forests of Sreemongal and the Kassalong and Massalong resrve forests in natural condition. The present status of the species in Bangladesh has been explored in this study through extensive field surveys. Total 111 individual plants were found both in the natural and in the plantations. The study found that the species is Critically Endangered (CR) in Bangladesh and facing an extremely high risk of extinction.

Some methods of production of propagules of Banspata have been tried for the mass propagation of the species. Hossain (2008) reported that Banspata can be multiplied both from seed and clonal propagation. However, the study revealed that Banspata shows high germination (98%) in the propagator house providing Sylhet sand bed. As the natural seed sources are very limited and uncertain, clonal propagation is only the potential way of mass multiplication for the restoration and recolonization of the species.

The growth of Banspata seedlings and cuttings in the nursery with different light conditions (full sunlight, full shade and partial shade)was studied. It was found that the growth of height, collar diameter and number of Banspata leaves was maximum in partial sunlight condition. The growth of Banspata in the full shade condition in the nursery is low. The survival percentage of seedlings and cuttings was also more in partial shade condition which indicates that the species prefers partial shade at least in the early stage of the growth and development.

It was revealed from the study that the highest and lowest rooting percentage was found in semi-hard shoots and hard shoots, respectively. Similar trend was observed in case of mean number of roots.

The highest mean number of shoot (1.12) was found in semi-hard shoot cuttings and the lowest (0.72) in hard shoot cuttings. From the experiment, it was also revealed that the rooting of Banspata (*Podocarpus nerifolius*) is influenced by the maturity of shoots cuttings. The rooting percentage of Banspata cuttings is also influenced by the rooting media. The rooting hormone can significantly increase the number of root per cutting, mean root length and rooting percentage.

In the plantation site, the growth of height, collar diameter, number of branches was not much different between the seedlings and stecklings. The survival percentage of stecklings was higher than the seedlings in the plantation sites. Moreover, it was observed that in the plantations of Mirpur Botanical Garden, Dhaka, Banspata volume is lower compared to other tree species.

Unexpectedly, in the plantation phase, cutworms frequently damage the planted seedlings and attacked by the fungus. Seedlings are more susceptible to cutworms than stecklings. The base or collar region of the seedlings is softer than the collar region of stecklings, which may be a reason for more susceptibility of seedlings to cutworm attack than the stecklings.

Finally, this study concludes that for the germination of Banspata, Sylhet sand is most suitable. The seedlings should be kept under full or partial shade after transplanting to the poly bags. The study also suggests that clonal propagation is more suitable for large-scale production of propagules of Banspata, as because the species does not produce adequate seeds.

Recommendations

Day long workshop were organized twice on the 16 June, 2008 and 25 March, 2009 on Banspata and Civit Projects in the conference room of the Institute of Forestry and Environmental Sciences, CU (IFESCU) (**Figure 82**a). Twenty seven and thirty two participants, respectively attended the workshops from IFESCU, BFRI, Forest Department, BCSIR, AF Nursery, UNDP, SUST, Forest Academy and Botany Department of CU (**Figure 82**b).

Figure 82: Participants of workshop on Banspata (a) at conference room and (b) in the nursery of IFESCU

The following recommendations were put forward from the workshops and from our practical experiences:

1. Both *ex situ* and *in situ* conservation program should be under taken for the species. Recolonization of Banspata should be done in its natural habitat.
2. Clonal propagation is more suitable for large-scale production of propagules of Banspata. Seedlings and cuttings should be grown in the partial shade condition.
3. Saplings and poles should be given preference over mature trees for shoot collection to prepare cuttings. Cuttings from more than 1 year old branches are not suitable for the propagation of Banspata and should be avoided. For producing rooted stem cuttings semi-hard shoots should be chosen for this species.
4. 4000 ppm IBA or 6000 ppm IAA should be used for Banspata cuttings for root development.
5. Sylhet sand should be used as growth media to ensure maximum germination of Banspata seeds. Rural nurserymen may use soil as rooting media where Sylhet sand is not available.
6. Government should come forward with both financial and technical support for the conservation of Banspata.
7. Threatened species might be included in the mainstream plantation programs of FD keeping minimum quota for the native threatened and endangered species i.e. Banspata.

8. Greater emphasis should be given to the nursery managers to produce the propagules and to distribute among the interested stackholders. Propagules may be distributed to protected areas, different public, private organizations and NGOs for planting and conservation.

9. Grass-root level nurserymen should be involved in raising seedlings of native and threatened tree species and incentives should be given to them for the purpose by forest department. Documentation of best nursery practices and plantation procedure should be published and distributed.

10. As the study found the species is Critically Endangered (CR) and facing an extremely high risk of extinction in the wild condition, extensive plantation should be carried out to conserve the species.

11. The detailed Silviculture of the species Banspata should be properly documented.

12. Actions should be taken to pass knowledge and information to all relevant organizations to ensure the flow of expertise and technology to the relevant agents in the field. Planting of Banspata should be included in the homesteads, academic institutions and marginal land plantation programs.

13. Awareness should be developed among the people about the importance of native tree species and the conservation of threatened species.

14. Further integrated research work should be under taken and results should be sent to the relevant stakeholders. Research must be focussed on the fastest growth and development of the species in the plantations.

15. More study should be conducted to prove the pathogenicity of causal organism of top dying and leaf spot and other diseases of Banspata.

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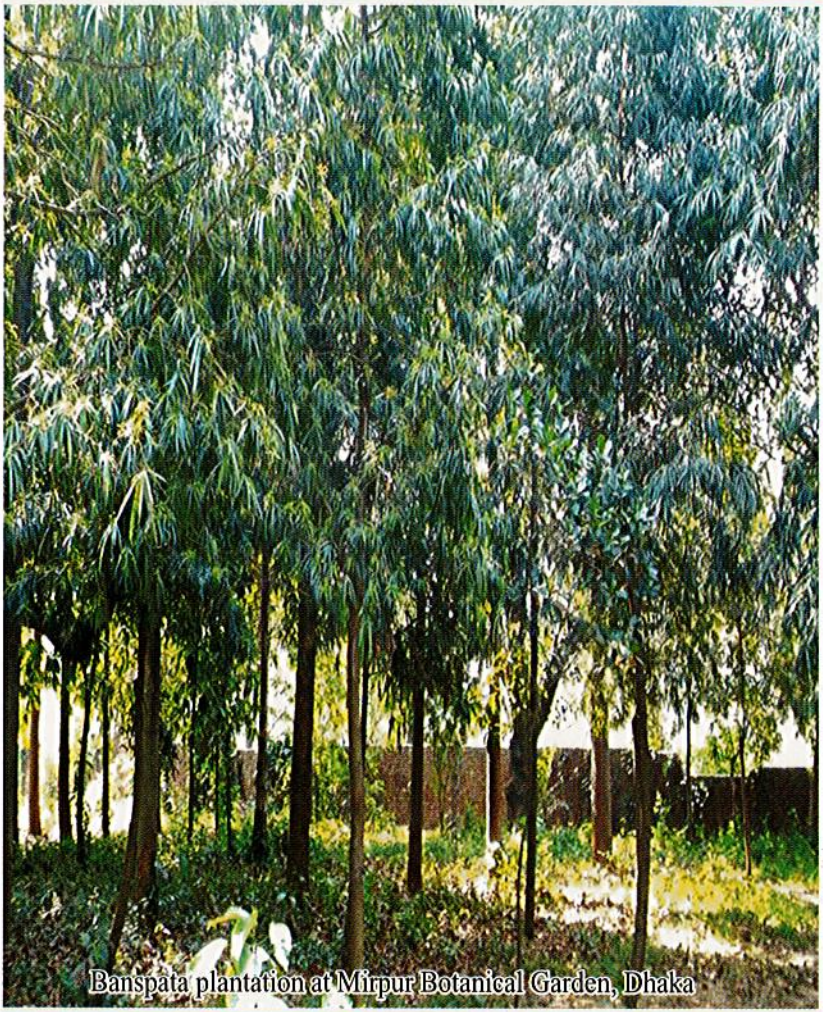
MOHAMMED KALIMUDDIN BHUIYAN is a Professor in the Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU). Mr. Bhuiyan joined as Assistant Professor in the Institute in 1984. In addition of teaching and research work he performed administrative responsibilities as Director of IFESCU and National Project Director of FAO/UNDP funded project BGD/85/011 from 1987-1990. Earlier he served as a Warden Forestry Hostel and a Plantation Coordinator IFESCU and worked as Provost, Shah Amanat Hall from 2009 - 2013. Earlier he served as a Research Officer at Bangladesh Forest Research Institute and as a lecturer of Botany in different colleges. He did B.Sc. Honours in 1970 and M.Sc. in 1971 in Botany from Dhaka University and M. Sc. in Forestry from Pakistan Forest Institute, Peshawar University in 1983. He has published 45 scientific papers in repoted national and international Journals. He participated / attended 30 National and 23 International Short Courses/Training/ Conferences/ Seminars/ Symposium/ Workshops and Study Tours. He guided 50 under graduate and 40 post graduate students in IFESCU. He visited India, Greece, Indonesia, Italy, Qatar, Kenya, Nepal, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Thailand, UK and Russia.

DR. MOHAMMED KAMAL HOSSAIN, Professor, Institute of Forestry and Environmental Sciences, Chittagong University, Chittagong- 4331 was born in Kutubdia, Coxs Bazar. He obtained B. Sc (Hons) and M. Sc in Botany from Chittagong University (1st class 1st position in both the examinations); PhD from the Department of Forestry (Silviculture), University of Aberdeen, UK with a Commonwealth Scholarship in 1993 and also was a Commonwealth Post-Doctoral fellow in 2002-2003. He has published 95 research papers (45 National and 50 International referred journals); 38 publications in proceedings and in book chapters in the field of silviculture, biodiversity and plantation forestry. Dr. Hossain is the co-author of 4 books and supervised 3 PhD, 53 MS/MSc and 84 BSc (Hons.) students successfully. Dr. Hossain serves as Senior Professional of Arannayk Foundation support nursery project; Team Leader of the Civit project; National Biodiversity Consultant (Flora) in IUCN Bangladesh Country Office; Tree Plantation Specialist for IFSP of CARE- Bangladesh; Director, Institute of Forestry and Environmental Sciences; Director (Administration), Chittagong University Agricultural Development Project (CUADP) etc. Dr. Hossain holds the life membership of Bangladesh Botanical Society; Bangladesh Association for the Advancement of Science (BAAS); Asiatic Society of Bangladesh; Vice-President, Institution of Environmental Professionals, Bangladesh; Member, Editorial Board, Journal of Forestry and Environment, Chittagong University; Editorial Board Member, Journal of Forestry Research, China (2009 - 2013). Countries visited for academic programs are UK, Malaysia, Thailand, Singapore, Indonesia, Finland, Denmark, Sweden, Turkey, South Korea, Switzerland, Canada, China, Taiwan, Nepal, USA, Japan, India, Sri Lanka, Australia and Viet Nam.

DR. MOHAMMED SHAFIUL ALAM is the Professor of Institute of Forestry and Environmental Sciences at Chittagong University, Bangladesh. He obtained his Ph.D degree from the Aberdeen University, UK under the World Bank Scholarship in 2002. He started his career as Research Officer in Bangladesh Forest Research Institute and later joined to the Institute of Forestry and Environmental Sciences as Lecturer in 1990. He was the Director of IFESCU from 2004-2007 and also served as a Plantation Coordinator of IFESCU from 2008-2011. In addition to his academic responsibilities at IFESCU, he worked as Registrar of Chittagong University from 2011-2013. He has contributed 28 research articles in national and international journals on Plantation forestry, Forest resources management, Environmental pollution and Pollution effects on plant and soil systems related area. To enhance professional excellence and attending international conference/workshops Prof. Shafiul visited India, Nepal, Thailand, Malaysia, Philippines, Viet Nam. and the United Kingdom.



Banspata plantation at Mirpur Botanical Garden, Dhaka

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