ISSN 1021–3279

Vol. 32, No. 2 January - June 2013

Bangladesh Journal of Forest Science

BANGLADESH FOREST RESEARCH INSTITUTE
CHITTAGONG, BANGLADESH

ISSN 1021–3279

Bangladesh Journal of Forest Science

January - June 2013
Volume 32, Number 2

ISSN 1021–3279

Contents

Taxonomy of Bees of Bangladesh Forest Research Institute Campus, Chittagong, Bangladesh

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Abstract

A total of 19 species under four families belonging to Apiformes were identified from sweep net collections from Bangladesh Forest Research Institute (BFRI) Campus, Chittagong, Bangladesh. The identified species and families are: *Hylæus mixta* Smith under Colletidae; *Nomia iridescens* Smith and *Lasioglossum albescens* Smith under Halictidae; *Megachile disjucta* Fabricius, *M. umbripennis* Smith, *Cœlioxys cuneatus* Smith and *Euaspis carbonaria* Smith under Megachilidae; *Xylocopa æstuans* Linnaeus, *X. iridipennis* Lepeletier, *X. latipes* Drury, *Ceratina hieroglyphica* Smith, C. *binghami* Cockerell, *Nomada adusta* Smith, *Amegilla andrewsi* Cockerell, *A. fimbriata* Smith, *Thyreus histrio* Fabricius, *Trigona iridipennis* Smith, *Apis cerana* Fabricius and *A. dorsata* Fabricius under Apidae. The seven species namely *H. mixta, N. iridescens, M. umbripennis, C. cuneatus, E. carbonaria, A. andrewsi* and *T. iridipennis* are new records from Bangladesh.

সারসংক্ষেপ

বাংলাদেশ বন গবেষণা ইনস্টিটিউট ক্যাম্পাস হতে হাত জালের সাহায্যে সংগৃহীত সিরিজ Apiformes-এর চারটি পরিবারভূক্ত মোট ১৯ প্রজাতির মক্ষিকা শণাক্ত করা হয়েছে। শনাক্তকৃত প্রজাতি ও পরিবারগুলো হ'ল: Colletidae পরিবারভূক্ত *Hylaeus mixta* Smith; Halictidae পরিবারভূক্ত *Nomia iridescens* Smith ও *Lasioglossum albescens* Smith; Megachilidae পরিবারভূক্ত *Megachile disjucta* Fabricius, *M. umbripennis* Smith, *Coelioxys cuneatus* Smith ও *Euaspis carbonaria* Smith; Apidae পরিবারভূক্ত *Xylocopa aestuans* Linnaeus, *X. iridipennis* Lepeletier, *X. latipes* Drury, *Ceratina hieroglyphica* Smith, *C. binghami* Cockerell, *Nomada adusta* Smith, *Amegilla andrewsi* Cockerell, *A. fimbriata* Smith, *Thyreus histrio* Fabricius, *Trigona iridipennis* Smith, *Apis cerana* Fabricius এবং *A. dorsata* Fabricius। এর মধ্যে সাতটি প্রজাতি বাংলাদেশে নতুন রেকর্ড হিসেবে শণাক্ত করা হয়েছে। এগুলো হ'ল *H. mixta, N. iridescens, M. umbripennis, C. cuneatus, E. carbonaria, A. andrewsi* এবং *T. iridipennis*।

Keywords : Apoidea, Apidae, Colletidae, Halicidae, Megachilidae

Introduction

Bangladesh Forest Research Institute (BFRI) situated in the Chittagong Metropolitan City campus falls under tropical evergreen forest. The total area is 28 ha with very rich floral diversity. The arboretum of BFRI has 60 indigenous and 20 exotic timber species, 34 bamboo species and seven rattan species along with a good number of herbs, shrubs and undergrowths (Anon. 1999). The total floral population is

approximately 18,534, excepting bamboo and rattan. This area is inhabited by various animals including the diversified insect fauna due to presence of the various plant species.

The superfamily Apoidea of Hymenoptera, includes two series namely, Spheciformes (sphecoid wasps) and Apiformes (bees). The most important activity of bees is the pollination of natural vegetations (Michaner, 2007). In addition to this they provide honey, wax and other bee products. In Pakistan, mustard production was increased by 20% by the use of honey bee as pollinator (Alam *et al.* 1964, Verma 1990). Many workers worked on bees in different countries of the world (Michener 1990, 2000, 2007, O'Toole 1993, 1996, Wille 1979). O'Toole and Raw (1991) and Roig-Alsina and Michener (1993) gave an excellent review of phylogeny and classification of the long-tongued bees including an account of their taxonomic history and biology. O'Toole and Raw (1991) gave synoptic taxonomic information along with some sorts of biology and ecology of the bees of the world. Michener (2000, 2007) provided detailed taxonomic records on bees of the world.

In Bangladesh, Alam (1962) initially recorded 41 apidid, one megachilid and three xylocopid species. Chowdhury and Zethner (1971) recorded four carpenter bees from the forests of Bangladesh. Bhuiya and Miah (1990) reported four apidid, seven xylocopid, four megachilid, two anthophorid and one halictid bees from Chittagong. Tadauchi and Alam (1993) recorded one megachilid, two anthophorid, seven halictid bees from mustard fields in Bangladesh. Baksha (2000) gave a brief description, host record, nature of damage, biology and management of *Xylocopa aestuans* as a common timber pest. Baksha (2004) recorded three species of honey bees, *Apis dorsata, A. cerana*, and *A. florea*, available in the forests of Bangladesh. Baksha (2008) reported the foraging plants of *Apis dorsata* and its honey hunting in the Sundarbans of Bangladesh.

In Bangladesh taxonomic works on bees are fragmentary and insufficient, and area based work is not available. Keeping this in view, an area base work on taxonomy of bees was undertaken.

Materials and Methods

BFRI campus was selected as a study area, because it is an important forest area from conservation point of view and it is enriched with floral diversity. The area is interspersed with small hill ranging from 60-90 m high. Collection of the bee specimens was made randomly with the help of sweep net from different spots of BFRI campus during the period of June 2006 to March 2007. The specimens were brought to the insect laboratory of the Department of Zoology, University of Chittagong, Chittagong, Bangladesh. They were sorted out, preserved and identified with the help of Bingham (1975), Borror and Delong (1964), Goulet and Huber (1993), Michener (2000, 2007) and O'Toole and Raw (1991).

Results and Discussion

A total of 19 bee species of the series Apiformes under four families namely, Colletidae, Halictidae, Megachilidae and Apidae were identified. List of the identified species under respective higher taxa is shown in Table 1.

Diagnostic characters and short remarks of the identified species of bees are given below.

1. **SPECIES *HYLAEUS MIXTA*** Smith (Fig. 1A)

Diagnosis: Body length 5 mm; head, thorax, and abdomen smooth, a few scattered punctures on the apical margins of the second and following segments; face slightly elongate; clypeus flat, produced anteriorly,

Table 1. List of bee species found in Bangladesh Forest Research Institute Campus, Chittagong.

Family	Subfamily	Tribe	Species
Colletidae	Hylaeinae	No tribe	*Hylaeus mixta* Smith*
Halictidae	Nomiinae	No tribe	*Nomia iridescens* Smith*
	Halictinae	Halictini	*Lasioglossum albescens* Smith
Megachilidae	Megachilinae	Anthidiini	*Euaspis carbonaria* Smith*
		Megachilini	*Megachile disjuncta* Fabricius
			M. umbripennis Smith*
			Coelioxys cuneatus Smith*
Apidae	Xylocopinae	Xylocopini	*Xylocopa aestuans* Linnaeus
			X. latipes Drury
			X. iridipennis Lepeletier
		Ceratinini	*Ceratina hieroglyphica* Smith
			C. binghami Cockerell
	Nomadinae	Nomadini	*Nomada adusta* Smith
	Apinae	Anthophorini	*Amegilla andrewsi* Cockerell*
			A. fimbriata Smith
		Melectini	*Thyreus histrio* Fabricius
		Meliponini	*Trigona iridipennis* Smith*
		Apini	*Apis cerana* Fabricius
			Apis dorsata Fabricius

* New records from Bangladesh.

front above it carinate, the carina forking below the anterior ocellus, the lateral branches running one on each side up to the posterior ocelli; a deep hollow round the base of each antenna; median segment roundly steep at the sides and posteriorly, the enclosed space at base above slightly concave, finely rugose; black, shining; the clypeus, the face just above it, and the tubercles yellow; the apical four joints of the tarsi and the apical margins of abdominal segments 2-5 rufo-testaceous; the tibiae and tarsi, the apical half of the second, and the whole of the following abdominal segments clothed thinly with pale glittering hairs; wings hyaline and iridescent, veins and tegulae very pale testaceous.

Remarks: Distributed in India (Bingham 1975). In the present study it was found to foraging on flowers of different beans and Marigold. It is a new record from Bangladesh.

2. **SPECIES *NOMIA IRIDESCENS*** Smith (Fig. 1B)

Diagnosis: Body length 8-10 mm; head, thorax, and abdomen very minutely and densely punctured; clypeus convex, with coarser punctures, and a medial sharp vertical carina, its anterior margin transverse;

mesonotum broad, slightly convex, and in certain lights showing several fine abbreviated longitudinally-impressed parallel lines on the disc; enclosed space at base of median segment longitudinally rugose; black; head and thorax opaque; abdomen shining, iridescent in certain lights, segments 2-4/5 with transverse bright green or blue fasciae on their apical margins, pubescence on the head and thorax and legs griseous with a fulvous tint, most dense on sides of face, cheeks, and sides of median segment; wings hyaline and iridescent, veins and tegulae testaceous.

Remarks: This species is distributed in Tenasserim of Myanmar and Singapore (Bingham 1975). It is a new record from Bangladesh.

3. **SPECIES *LASIOGLOSSUM ALBESCENS*** Smith (Fig. 1C)

Diagnosis: Body length 7-11 mm; head closely and finely, thorax more sparsely punctured; median segment at the sides and apex and the abdomen smooth, shining; front flattish, not carinate, elongate; eyes distinctly convergent below; median segment with sides compressed, apex concavo-truncate, with a medial vertical carina; lunate space at base restricted, with outwardly divergent striae; 1st and 2nd abdominal segments with a distinct transverse groove across the middle; black, abdomen obscurely chalybeous; face, sides of thorax, and median segment with thin white pubescence; postscutellum, a broadly interrupted band at base of 1st abdominal segment, and entire regular transverse bands at base of segments 2-5 covered with snow-white pubescence; legs with pale glittering pubescence, tarsi and anal rima fulvous; wings hyaline and iridescent, wing veins ferruginous.

Remarks: It is distributed in Punjab, Nepal, Malaya (Bingham 1975) and Bangladesh (Tadauchi and Alam 1993). This species was found to forage flowers of beans and Marigold.

4. **SPECIES *EUASPIS CARBONARIA*** Smith (Fig. 1D)

Diagnosis: Body length 8-12mm; head, thorax, and abdomen black and closely, evenly and not so coarsely punctured; clypeus boldly convex, the front and space between bases of antennae slightly raised, with a medial carina beneath running on to base of clypeus; apical margins of abdominal segments narrowly smooth, impunctate; sides and apex of clypeus, sides of face and occiput with white pubescence; wing fuscous, with a rich purple effulgence, hyaline towards the base.

Remarks: This species is distributed in Asia (Iwata and Sakagami 1966). It was recorded from different plant species (Gupta 1992).

5. **SPECIES *MEGACHILE DISJUNCTA*** Fabricius (Fig. 1E)

Diagnosis: Body length 12-17 mm; head, thorax, and abdomen densely and somewhat coarsely punctured, margins of abdominal segments 1-5 broadly depressed, middle of the 4th just before the depressed portion always, and of the 2nd, 3rd, and 5th segments very often smooth, shining, impunctate; clypeus from front subtriangular, its apical margin transverse; mandibles broad at apex, outer tooth acute; vertex broad, flatish, produced back; back of head roundly emarginated; face and front, prothorax at sides and beneath, and legs on the outside with black pubescence; the pubescence on the inside of the tibiae and tarsi fuscous; median segment and basal segment of abdomen covered with thick long white to rusty-yellow pubescence; pollen-brush jet-black; wings hyaline fuscous, for their apical three-fourths with a brilliant purple effulgence.

Remarks: This species is distributed in India, Tenasserim (Myanmar), and France (Bingham 1975). . Bhuiya and Miah (1990) recorded it from Chittagong, Bangladesh. In the present study it was found to visit flower of beans and Marigold.

6. **SPECIES *MEGACHILE UMBRIPENNIS*** Smith (Fig. 1F)

Diagnosis: Body length nearly 13 mm; head, thorax, and abdomen closely punctured and pubescent; disc of the clypeus, vertex except round the ocelli, and apical two-thirds of 2nd and following abdominal segments bare; clypeus convex, transverse anteriorly; black; front, thorax, basal abdominal segment, and the base narrowly of the 2nd with dense fulvous pubescence; 3rd segment with a narrow fringe of the same generally much obliterated, 4th and 5th segments with a narrow white lateral fascia; legs black, tarsi beneath of the posterior legs with fulvous pubescence; pollen-brush white, with apical portion black; wings hyaline at base, fuscous for the apical four-fifths of their length.

Remarks: This species is distributed in Nepal, Sikhim, Tenasserim of Myanmar (Bingham 1975). Chourykaew *et al*. (2004) reported the species as a pollinator of *Afgelia sericea*, an endemic leguminous plant of Thailand. It is a new record from Bangladesh.

7. **SPECIES *COELIOXYS CUNEATUS*** Smith (Fig. 2A)

Diagnosis: Body length 11 mm; head, thorax densely and not very coarsely, abdomen more densely and finely punctured; punctures on apical segment above very close and minute, giving it an opaque appearance; clypeus slightly convex and densely pubescent; scutellum short, narrow, very slightly arched posteriorly, nearly transverse; basal three segments narrow but deep transverse grooves, apical margins of segments 1-5 narrowly recurved, apical segment deeply grooved at apex and armed with four teeth, and a lateral tooth on fifth ventral segment.

Remarks: This species is distributed in India and Tenasserim of Myanmar (Bingham 1975) and it is a new record from Bangladesh.

8. ***SPECIES XYLOCOPA AESTUANS*** Linnaeus (Fig. 2B)

Diagnosis: Body length 21-23 mm; head, thorax and abdomen finely punctured, thorax above densely pubescent, disc of mesonotum smooth and impunctate under the pubescence; clypeus flat, transverse in middle anteriorly; clypeus and front not carinate; black; pubescence on head and face, on sides of thorax and beneath, and on abdomen black, on the thorax above it bright yellow; wings dark fuscous with a purple effulgence.

Remarks: It occurs throughout India, Myanmar and Sri Lanka, extending to Africa on the west and Malayan region on the east (Bingham 1975). The tunnels are bored by both sexes in dead wood or in timber used in building. The larval cell contains an egg and a ball of bee-bread about half inch in diameter (Beeson 1941). Chowdhury and Zethner (1971), Bhuiya and Miah (1990) and Baksha (2002) recorded this species from Chittagong.

9. **SPECIES *XYLOCOPA LATIPES*** Drury (Fig. 2C)

Diagnosis: Body length 32-35mm; head, thorax and abdomen punctured; clypeus, mesonotum anteriorly, and abdomen most densely so; front with two deep sulcations from below the base of antennae to beyond the posterior ocelli,; eyes very large, meeting or nearly meeting on vertex; anterior tibiae and tarsi flattened and yellow, tibiae twisted, tibiae and tarsi fringed anteriorly and posteriorly with long, thick, curled hairs; intermediate and posterior legs longer in proportion; colour black, with black

pubescence thick and velvety on mesonotum anteriorly and long and tufted on lateral margins of abdominal segments, the pubescence on posterior tibiae long, dense and stiff; wings much narrower, the apex of anterior wing acute; wings dark fuscous, with vivid coppery, green and purple effulgence.

Remarks: This species is distributed in India, Sri Lanka and Tenasserim (Myanmar), extending to China and Malayan Region (Bingham 1975). Beeson (1941) reported that in timber the bee bores a tunnel which is nearly cylindrical being slightly constricted at interval to form separate cells; at the end of each tunnel a single egg is laid and a store of bee-bread or pollen is added. Chowdhury and Zethner (1971) and Alam (1962) recorded it from Bangladesh.

10. **SPECIES *XYLOCOPA IRIDIPENNIS*** Lepeletier (Fig. 2D)

Diagnosis: Body length 25-27 mm; punctures on head, thorax and abdomen, on the last, finer, closer and deeper; pubescence on sides of abdomen longer and dense; black with black pubescence; wings very different, being deep metallic blue at base, turning to greenish and deep rosy coppery red towards apex of fore wing.

Remarks: It is regarded as wood pest and sometimes completely damaging the wood, bamboo, etc. used in construction of houses. Beeson (1941) reported that the bee bores energetically into dead branches and trunks of trees and posts and rafters of houses and hollow bamboos and reeds. The species occurs in Bangladesh, India, Myanmar, Sumatra and China (Alam 1967, Bingham 1975).

11. **SPECIES *CERATINA HIEROGLYPHICA*** Smith (Fig. 2E)

Diagnosis: Body length 9-11mm; head above and the hollow on the front below the ocelli somewhat coarsely, thorax and abdomen more finely punctured, punctures on abdomen emitting short decumbent hairs; clypeus, disc of the mesonotum, and basal abdominal segments smooth and shining, clypeus having a few scattered fine punctures; median segment narrowed at apex and rounded posteriorly; colour black; a -shaped mark on clypeus, a lunate spot above it, a stripe on each side broadened below, a spot above each antenna, a broad stripe on each cheek, another on pronotum, two parallel longitudinal lines on the mesonotum, another short one on each side over tegulae, a broad squarish mark on middle of scutellum, tubercles, legs except the coxae, trochanters, and femora above, and transverse subapical fasciae on segments of abdomen, yellow; fascia on the 1st abdominal segment broadened in middle and roundly incised anteriorly on each side, that on the 2nd broad, laterally attenuated on each side of middle, facia on the 3rd segment broadly interrupted in middle and widest laterally, on 4th broadest in middle where it is narrowly interrupted, 5th segment with a broad truncate cone-shaped spot in the middle, 6th segment black; legs slightly pubescent; wings hyaline, more or less fuscescent; vein and tegulae testaceous.

Remarks: This species is distributed in India, Myanmar, China and Malayan region (Bingham 1975). In the present study nest of this species was found in dead stem of Mussunda, and found to visit bean and Marigold flower for collecting pollen. Alam (1967) recorded this species from Sylhet of Bangladesh.

12. **SPECIES *CERATINA BINGHAMI*** Cockerell (Fig. 2 F)

Diagnosis: Body length 8-10 mm; head, thorax, and abdomen finely and closely punctured, granular; clypeus elongate triangular, margined all round, and with a

medial longitudinal carina; mesonotum convex, with two medial parallel impressed lines, and an abbreviated impressed line on each side of and parallel to them; abdomen with segments 1-5 marked with short obscure impressed line on each side above, just before the apical margin; bright green, sometimes blue, metallic and shining; clypeus and a line on all the tibiae above yellow; mandibles, labrum, antennae, legs, and the impressed lines on the thorax and abdomen black, the legs sometimes with a greenish or bluish tint and covered with hoary white pubescence; wings hyaline and iridescent, veins and tegulae testaceous brown.

Remarks: This species is distributed throughout India, Myanmar, Sri Lanka, China and Malacca; the specimens from the Punjab and Western India have a golden-bronzy tint and those from Sri Lanka and Myanmar are darker (Bingham 1975). In the present study a swarm of this species was found to visit flower of beans. Alam (1967) recorded this species as *C. viridissima* from Sylhet.

13. **SPECIES *NOMADA ADUSTA*** Smith (Fig. 3A)

Diagnosis: Body length 6-8 mm; head and thorax densely punctured, giving them a granular appearance; basal abdominal segment smooth and polished, 2nd and following segments minutely and densely punctured, broadly along their base; clypeus flat, transverse anteriorly, sides mounded; and obscure short medial vertical carina between bases of antennae; median segment rounded posteriorly and steep, space at base densely and somewhat coarsely punctured; punctures running into oblique striae; large spot on each side at base of 2nd abdominal segment, sometimes forming a subinterupted broad fascia, a fascia at base of 3rd, and two contiguous spots at base of 4th segment, yellow; basal abdominal segment w ith a black spot on each side; face, sides of thorax and of median segment and 6th abdominal segment with a thin silvery white pubescence; wings hyaline, fuscous at their apical margins.

Remarks: Bingham (1975) reported its distribution in Bangladesh, India, Sri Lanka, Nepal and Myanmar. In the present study it was found to visit flowers of beans, gourd, sweet gourd, ribbed gourd and Marigold for collecting pollen. Alam (1962, 1967) recorded this species from Chittagong Hill Tracts of Bangladesh.

14. **SPECIES *AMEGILLA ANDREWSI*** Cockerell (Fig. 3B)

Diagnosis: Body length 11-13 mm; clypeus and bases of abdominal segments thinly pubescent; head and thorax finely and closely punctured under the pubescence, bases broadly of abdominal segments finely aciculate; colour black; labrum, base of mandibles, sides and apical margin of clypeus, with a narrow medial line on the same, yellowish white; labrum with a lateral spot and a line along its base black; a small transverse triangular spot above base of clypeus and front of scape of antenna pale yellowish white; front and vertex above base of antenna, and thorax above clothed with dull rufo-fulvous pubescence mixed with black hairs; legs covered with a thin cinereous pubescence; cheeks behind eyes, head and thorax beneath, and posterior tibiae above with snow white pubescence, last with a short line of black hairs at base dividing the white; pubescence on the abdomen black, apical margins of segment 1-4 with transverse bands of metallic blue scale-like hairs; wings nearly clear hyaline, sometimes with a fulvous tint, veins and tegulae testaceous.

Remarks: The species is distributed in Bangladesh, India, Myanmar and Sri Lanka through the Malay regions to Australia

(Bingham 1975). It usually forages at the forest edges and open habitats. In the present study it was found to visit flowers of gourd, sweet gourd for collecting pollen. This is a new record from Bangladesh.

15. **SPECIES *AMEGILLA FIMBRIATA*** Smith (Fig. 3C)

Diagnosis: Body length 16-20 mm; head and thorax pubescent, closely and finely punctured under the pubescence, which on the clypeus and front below the antennae is thin and sparse, and on the vertex of the head and on the thorax dense but not very long; abdomen smooth, dull, the surface minutely aciculate; clypeus strongly convex, transverse anteriorly and margined; black; a spot at each lateral angle of the clypeus jointed by a transverse line, an elongate cone-shaped median spot, and a transverse triangular spot above the base of the clypeus white; the front, vertex of the head, and thorax above with grey, the cheeks, the sides of the thorax in front, the anterior legs, and the median segment with white pubescence, thin and sparse on the legs, dense and long on the median segment; abdomen with a little black pubescence along the sides; intermediate and posterior legs with black pubescence, very dense and long on the outside of the posterior tibiae and tarsi; wings dark fuscous, with a slight purple effulgence.

Remarks: Bingham (1975) reported its distribution in Bangladesh and Myanmar. Alam (1962) recorded this species as *Anthophora fimbriata* from Sylhet of Bangladesh.

16. **SPECIES *THYREUS HISTRIO Fabricius*** (Fig. 3D)

Diagnosis: Body length 15-17 mm; head above the antennae finely and closely punctured; thorax and abdomen finely and closely aciculate; antennal carina prominent; scutellum with a Ë-shaped incision at apex; black; the clypeus thinly, sides of face, the cheeks, and a spot on each side on the occiput covered with dense white pubescence; a spot on each side of the pronotum spreading to mesonotum, a medial short longitudinal line on latter anteriorly, a spot on each side of it, a spot over each tegula, a spot on it posteriorly, a spot on each side of mesonotumat apex, a spot beneath Ë-shaped incision, a broad line under base of wings reaching posteriorly to median segment, a broader patch anteriorly on the mesoplurae, a broad line on the tibiae and the basal joint of tarsi above, and lateral spots on abdominal segments 1-5 above, covered with dense pubescence; spot on 1st segment elongate and produced perpendicularly at its posterior margin; fore wing dark fuscous, with some hyalne spots on discs; hind wing hyaline, fuscescent at apex.

Remarks: This species is distributed in Bengal and Southern India (Bingham 1975). Raju and Rao (2003) recorded 13 bee species including *T. histrio* associated with approximately 100 plant species. Alam (1962, 1967) recorded this species as *Crocisa histrio* from Bangladesh.

17. **SPECIES *TRIGONA IRIDIPENNIS*** Smith (Fig. 3E)

Diagnosis: Body length 3-4 mm; head, thorax, and abdomen smooth and shining and black, pile silvery; face in front, sides of thorax and of median segment with a thick silky pile; labrum, mandibles, palpi, antennae, and apical joints of tarsi testatecous, sides of mesonotum and scutellum fringed with fuscous pubescence.

Remarks: This species is distributed in India, Myanmar and Sri Lanka (Bingham 1975). It was found to construct very small nest in the holes of trees, crevices of rocks, in the holes of walls and also in branches and leaves of small trees. It is found to live in a small colony (Michener 2000). In the present

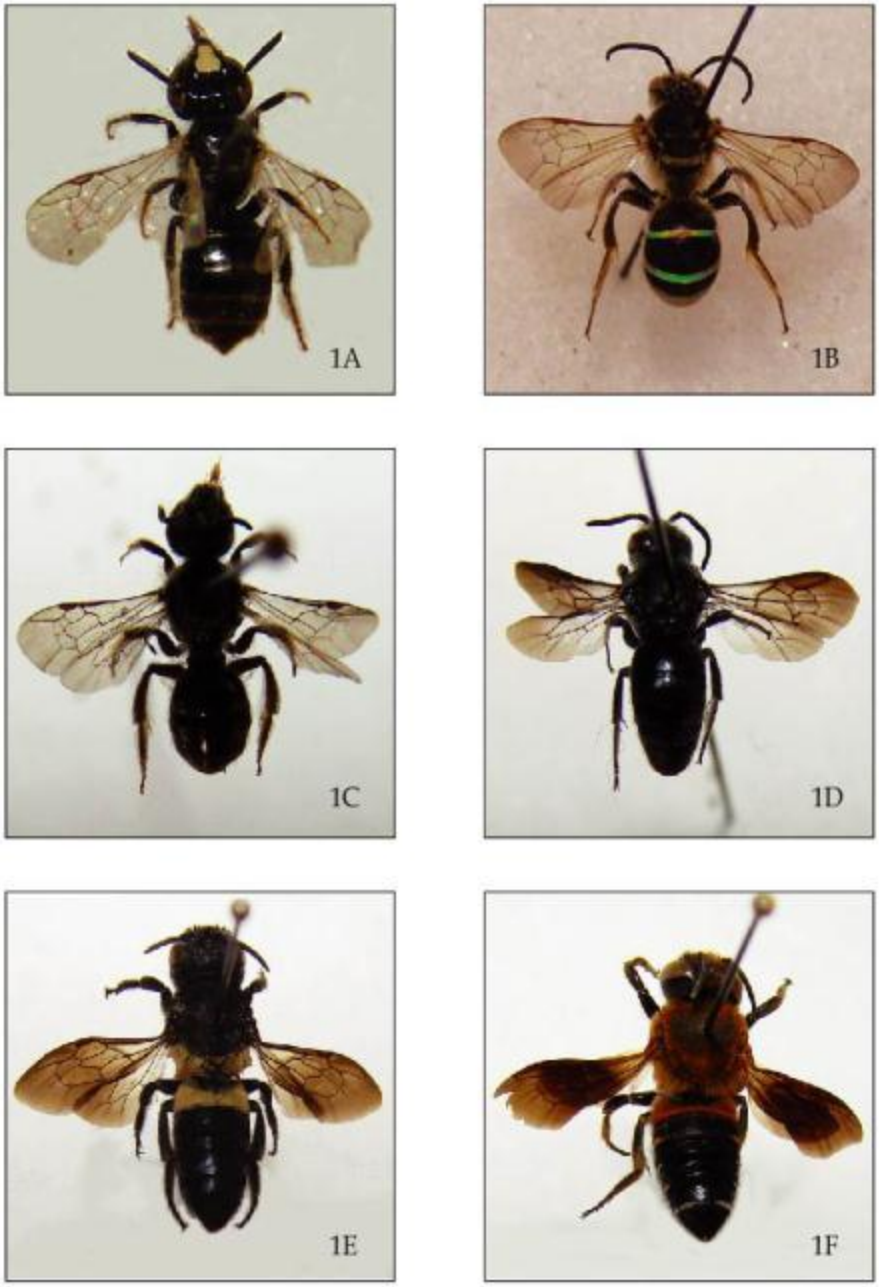

Figure. 1A. ***Hylaeus mixta*****, 1B.** ***Nomia iridescens*****, 1C.** ***Lasioglossum albescens*****, 1D.** ***Euaspis carbonaria*****, 1E.** ***Megachile disjuncta*** **and 1F.** ***Megachile umbripennis***

Note: All insects are not of same scale.

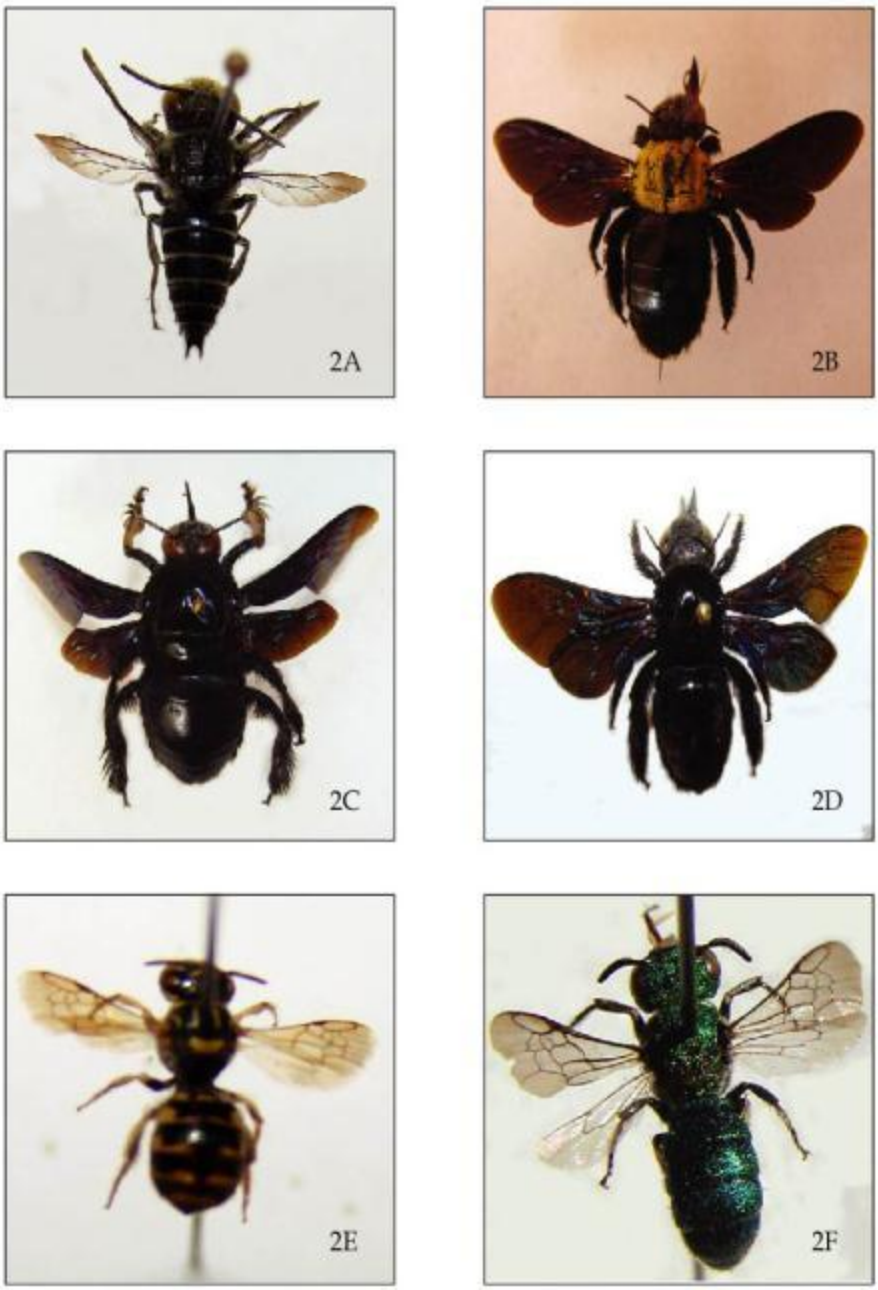

Figure. 2A. ***Coelioxys cuneatus,*** **2B.** ***Xylocopa aestuans,*** **2C.** ***Xylocopa latipes,*** **2D.** ***Xylocopa iridipennis,*** **2E.** ***Ceratina hieroglyphica*** **and 2F.** ***Ceratina binghami***

Note: All insects are not of same scale.

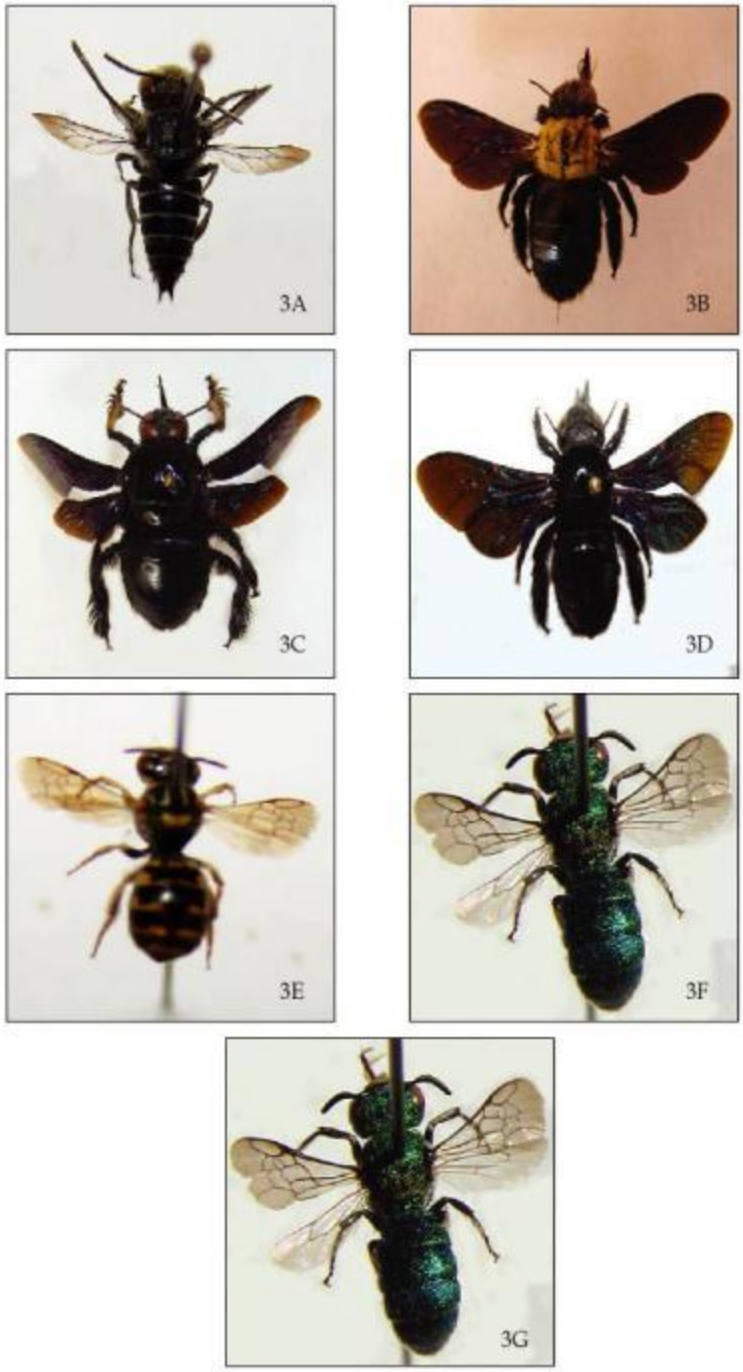

Figure. 3A. ***Nomada adusta*****, 3B.** ***Amegilla andrewsi*****, 3C.** ***Amegilla fimbriata*****, 3D.** ***Thyreus histrio*****, 3E.** ***Trigona iridipennis*****, 3F.** ***Apis cerana*** **and 3G.** ***Apis dorsata***

Note: All insects are not of same scale.

study a large number of this species was found to visit flower of bean, Marigold for collecting pollen.

18. **SPECIES *APIS CERANA*** Fabricius (Fig. 3F)

Diagnosis: Body length 11-12 mm; head, thorax and abdomen smooth and shining, sparsely pubescent, sometimes densely; head, thorax and apical abdominal segment black; scutellum and basal five segments of abdomen testaceous yellow; legs rufo-fuscous, pubescence cinereous; wings hyaline and iridescent.

Remarks: This species is found in southern and southeastern Asia, including all the countries of the Himalayan region (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan) as well as Indonesia, Japan, Malaysia, Papua New Guinea, Thailand, Vietnam, and probably other countries. The subspecies of *A. cerana* are: *Apis cerana cerana Fabricius* (= "sinensis")- Afghanistan, Pakistan, north India, China and north Vietnam; *Apis cerana heimifeng* Engel; *Apis cerana indica* Fabricius- South India, Sri Lanka, Bangladesh, Burma, Malaysia, Indonesia and the Philippines; *Apis cerana japonica* Fabricius - Japan; *Apis cerana javana* Enderlein; *Apis cerana johni* Skorikov; *Apis cerana nuluensis* Tingek, Koeniger and Koeniger; *Apis cerana skorikovi* Engel (="himalaya")- Central and east Himalayan mountains (Ruttner 1987). Alam (1962), Bhuiya and Miah (1990), Baksha (2002) recorded it from Bangladesh. In the present study *A. cerana* was found to visit flowers including those of jujube, mango, coconut, jamrul, guava, bean, sunflower and flowering vegetables.

19. **SPECIES *APIS DORSATA*** Fabricius (Fig. 3G)

Diagnosis: Body length 16-18 mm; head, thorax and abdomen with short pubescence; head and mesonotum finely punctured under pubescence; a short, medial vertical groove below anterior ocellus; head, thorax, legs and three apical abdominal segments and also basal three segments black; three basal abdomen segments honey-yellow; pubescence fuscous on head, thorax in front, legs above, and apical segments of abdomen; posterior tibiae and tarsi with short ferruginuous pubescence; wings pale fuscous or fusco-hyaline.

Remarks: *Apis dorsata,* the Giant honey bee, is a honey bee of southern and southeastern Asia mainly in forested areas. It is recorded from all over India, Myanmar and Sri Lanka, extending into China and Malayan region to Java. Engel (1999) recognized the following subspecies: *Apis dorsata dorsata-* India; *Apis dorsata binghami* Cockerell- Malaysia and Indonesia; *Apis dorsata breviligula* Maa- Philippines; *Apis dorsata laboriosa* Fabricius- Myanmar, Laos, and southern China. Bhuiya and Miah (1990) reported that it usually constructs more or less regular shaped hive on the branches of large mango, banyan, jujube, mandar and chalta trees. Alam (1962) and Baksha (2002, 2008) also recorded this species from Bangladesh.

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Natural Regeneration Potential of Native Tree Species in Dudhpukuria-Dhopachori Wildlife Sanctuary of Chittagong, Bangladesh

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Abstract

Natural regeneration status of native tree species in Dudhpukuria-Dhopachori Wildlife Sanctuary (DDWS) in Chittagong South Forest Division, Bangladesh was assessed through stratified random sampling method. A total of 120 tree species belonging to 36 families were recorded from 125 plots of 5 m x 5 m in size. Moraceae and Euphorbiaceae families were represented by maximum number (11) of species, where maximum individuals (378) no. were recorded for Dipterocarpaceae family from the sampled area (0.3125 ha). Family Relative Density (FRD), Family Relative Diversity (FRDI) and Family Importance Value (FIV) index of the regenerating tree species were highest for Dipterocarpaceae (15.59%), Moraceae (9.17%) and Euphorbiaceae (20.5) family respectively. *Dipterocarpus turbinatus* was represented by maximum seedlings per hectare (1078) followed by *Grewia nervosa* (464) and *Aporosa wallichii* (464). Seven biological diversity indices were also calculated which ensures promising regeneration status of DDWS. Percentage distribution of seedlings of all species was maximum (80.62%) for the height range of 0-50 cm. Number of seedlings were found to reduce proportionately with height growth that indicates poor recruitment of the seedlings in the Wildlife Sanctuary area. However, *Artocarpus chama* was found to show maximum (8.91%) seedling recruitment percentage. Considering the findings, it is emphasized the need of a management plan based on natural regeneration potential for the effective functioning of Dudhpukuria-Dhopachori Wildlife Sanctuary.

সারসংক্ষেপ

বাংলাদেশের চট্টগ্রাম দক্ষিণ বন বিভাগের দুধপুকুরিয়া-ধোপাছড়ি বন্যপ্রাণী অভয়ারণ্যের দেশীয় বৃক্ষ প্রজাতির প্রাকৃতিকভাবে জন্মানো চারাসমূহের অবস্থান (Status) স্তরভিত্তিক (Stratified) দৈবচয়ন পদ্ধতিতে গনণা করা হয়েছে। ৫ মি. x ৫ মি. আয়তনের ১২৫টি প্লটে ৩৬ পরিবারের মোট ১২০টি বৃক্ষ প্রজাতি সনাক্তকরণ করা হয়। মোরেসি এবং ইউফরবিয়েসি পরিবার সবচেয়ে বেশী প্রজাতি (১১টি প্রজাতি) প্রদর্শন করে, যেখানে সার্ভেকৃত এলাকায় (০.৩১২৫ হে.) ডিপটেরোকারপেসি পরিবারে চারার সংখ্যা ছিল সবচেয়ে বেশি (৩৭৮)। দুধপুকুরিয়া-ধোপাছড়ি বন্যপ্রাণী অভয়ারণ্যে ডিপটেরোকারপেসি (১৫.৫৯%), মোরেসি (৯.১৭%) এবং ইউফরবিয়েসি (২০.৫%) পরিবারে প্রাকৃতিকভাবে জন্মানো বৃক্ষ প্রজাতিসমূহের যথাক্রমে পরিবার আপেক্ষিক ঘনত্ব (FRD), পরিবার আপেক্ষিক বৈচিত্র (FRD) এবং পরিবার গুরুত্ব নির্দেশক মান (FIV) সবচেয়ে বেশী পাওয়া গেছে। *Dipterocarpus turbinatus* এ চারা পাওয়া গেছে হেক্টর প্রতি সবচেয়ে বেশি সংখ্যক (১০৭৮), পরবর্তী অবস্থানে রয়েছে *Grewia nervosa* (৪৬৪) এবং *Aporosa wallichii* (৪৬৪)। তাছাড়া, সাতটি জীববৈচিত্র নির্দেশক তালিকা হিসেব করা হয়েছিল যা দুধপুকুরিয়া-ধোপাছড়ি বন্যপ্রাণী অভয়ারণ্য এলাকায় বৃক্ষ

প্রজাতির প্রাকৃতিক পুনর্জন্মের ভাল অবস্থান নির্দেশ করে। অন্যদিকে, ০-৫০ সে.মি. উচ্চতার মধ্যে সকল প্রজাতির আনুপাতিক চারার সংখ্যা সবচেয়ে বেশী (৮০.৬২%) ছিল। উচ্চতা বৃদ্ধির সাথে সাথে চারা সংখ্যা আনুপাতিক হারে কমে গেছে যা কম সংখ্যক চারার পরবর্তী ধাপে উন্নীত হওয়া নির্দেশ করে। যাহোক, *Artocarpus chama* প্রজাতিতে সবচেয়ে বেশি সংখ্যক (৮.৯১%) প্রতিষ্ঠিত চারা পাওয়া গেছে। গবেষণা ফলাফল বিবেচনা করে বলা যায় যে, দুধপুকুরিয়া-ধোপাছড়ি বন্যপ্রাণী অভয়ারণ্যটির কার্যকর উন্নয়নের জন্যে প্রাকৃতিক পুনর্জন্মের সম্ভাবনার উপর গুরুত্বারোপ করে এর ব্যবস্থাপনা পরিকল্পনা (Management plan) প্রণয়ন করা প্রয়োজন।

Keywords: Biodiversity indices, Diversity indices, Dudhpukuria-Dhopachori, Natural regeneration, Wildlife Sanctuary,

Introduction

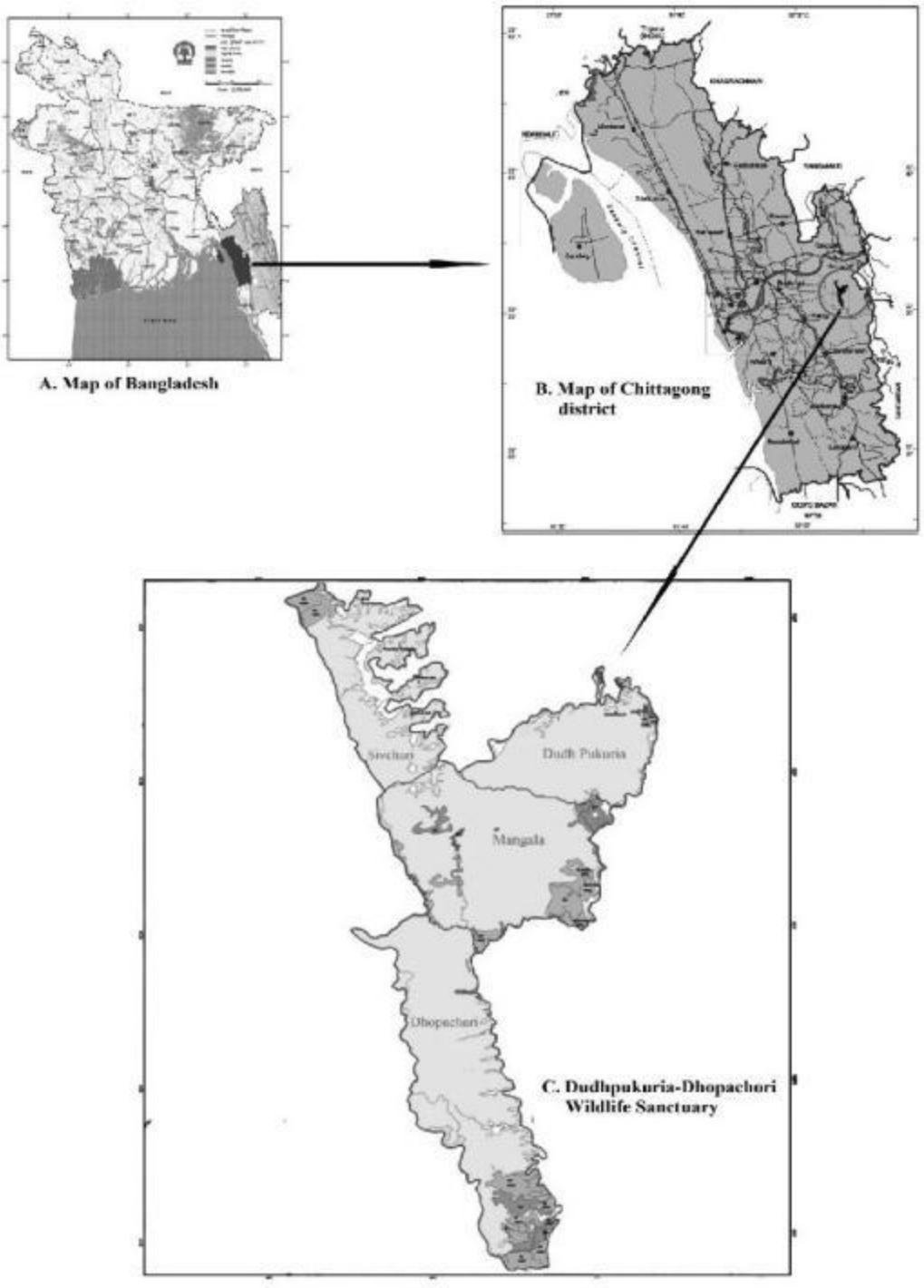
Natural regeneration of plant species is essential for preservation and maintenance of biodiversity (Hossain *et al.* 2004). Natural regeneration ensures maintenance and expansion of plant population of an area in time and space. It is a complex ecological process in an ecosystem involving dispersal of germs, reproduction and establishment of seedlings in relation to environmental factors (Barnes *et al.* 1998). Physical and biotic factors of regeneration along with disturbance regimes strongly influence regeneration process, species abundance and status of plant species. The dynamics of soil seed banks, seedlings of forest vegetation and population structure are most important parameters of natural regeneration. Knowledge of plant regeneration status helps in developing management strategies and setting priorities (Zegeye *et al.* 2011).

The total forest area of Bangladesh is 1.442 mha and natural forests cover 1.204 mha (Altrell *et al.* 2007). The natural forests passed through severe biotic and abiotic interferences in the last decades due to population pressure, inappropriate and inadequate management practices and land use changes (Khan *et al.* 2008). Till now the vegetation resources, including forests, are being destroyed at an alarming rate (Muhammed *et al.* 2008). In such circumstances, regeneration of forest crops by appropriate artificial or natural process is of prime importance in protecting forests flora and maintaining sustainability of yield of forest goods and services (Haque and Alam 1988). In Bangladesh, studies that focused on the natural regeneration status in different natural forests provide potential information on regeneration status of many native plant species, which are important for management and conservation programs (Hossain *et al.* 1999, Miah *et al.* 1999, Hossain *et al.* 2004, Motaleb and Hossain 2007, Rahman *et al.* 2011). But, there is no such information about the newly declared Dudhpukuria-Dhopachori Wildlife Sanctuary which is essential for its improvement and sustainable management. Hence, the present study was conducted to assess the regeneration composition, status and diversity of dominant tree species occuring in the natural ecosystem of Dudhpukuria-Dhopachori Wildlife Sanctuary.

Materials and Methods

Study area

Dudhpukuria-Dhopachori Wildlife Sanctuary (DDWS) covering 4,716.57 ha area is situated at the south of Rangunia upazila in Chittagong district and in the border of Chittagong, Bandarban and Rangamati districts. It lies between 22°09′ to 22°22′ north



Map 1 : Map showing the location of the study area

latitude and 92°05′ to 92°10′ east longitudes and divided into three beats namely Dudhpukuria (830 ha), Kamalachori (891 ha) and Dhopachori (2996 ha). The Wildlife Sanctuary is comprised of hill and hillocks (about 80% of total area) and plain lands (about 20% of total area) covered with forests and grasses and crisscrossed by numerous creeks (Map 1). The climate of this area is typically subtropical. The average annual rainfall is 2200-3400 mm and maximum rainfall occurs in June to September. Soil of the area is sandy loam and mostly suitable for regeneration and plant growth. Previously the forest possessed rich, well stratified and dense vegetation, but the forest is depleted continuously as a result of illegal and overexploitation of forest resources. Till now it inhibits a better patch of forest vegetation and wildlife in comparison to other Protected Areas (PAs) of Bangladesh.

Field survey methods

A stratified random quadrate method was used to determine the regeneration status of the tree species of Dudhpukuria-Dhopachori Wildlife Sancturay. Sample plots were selected for all the aspects and slopes of the hills in the three beats. 125 sample plots of size 5 m x 5 m (31 from Dudhpukuria, 31 from Kamalachori and 63 sample plots from Dhopachori beat) were taken for the regeneration survey during January 2011 to May 2012. The seedlings were identified by local people in the field and authenticated with the help of taxonomists in the Department of Botany, Chittagong University and Bangladesh Forest Research Institute (BFRI). The seedlings were counted by species and their height was measured.

Data analysis

The Relative Density, Relative Frequency, Relative Abundance and Importance Value Index (IVI) were calculated according to the methods of Shukla and Chandal (2000), Odum (1971), Michael (1990), Kent and Coker (1992), Pielou (1966) and Magurran (1988). The following equations were considered for calculation of the diversity indices.

Species diversity index, $S_{Di} = S/N$

Margalef's index, $R = (S-1)/Ln(N)$

Shannon-Wiener's diversity index, $H = \sum_i^n=1\ P_i \ln P_i$

Shannon's maximum diversity index, $H_{max} = Ln(S)$

Species evenness index, $E = H/Ln(S)$

Simpson's diversity index, $D = \sum_i^n=1\ P^2$

Dominance of Simpson index, $D' = 1-D$

Family relative density, $F_d(\%) = N_f/T_i \times 100$

Family relative diversity, $F_r(\%) = N_s/T_s \times 100$

Here, S = Total number of species,

N = Total number of individuals of all the species,

H = Shannon-Wieneris diversity index,

P_i = No. of individuals of one species ÷ Total no. of individuals in all the samples

N_f = No. of individuals in a family

T_i = Total No. of individuals

N_s = No. of species

T_s = Total number of species

Results and Discussion

Natural regeneration status

A total of 2,425 seedlings of 120 species belonging to 36 families were recorded from the 125 sample plots of Dudhpukuria-Dhopachori Wildlife Sanctuary. 36% families were represented by only one species and 42% by more than three species. Euphorbiaceae and Moraceae families were represented by maximum 11 species. Highest Family relative density (FRD) was found for

Table 1. Species and seedlings number, FRD (%), FRDI (%) and FIV index of different family for regeneration in Dudhpukuria-Dhopachori Wildlife Sanctuary

Family	Species (No.)	Seedlings (No.)	FRD (%)	FRDI (%)	FIV
Alangiaceae	1	4	0.16	0.83	1.00
Anacardiaceae	5	28	1.15	4.17	5.32
Apocynaceae	3	55	2.27	2.50	4.77
Arecaceae	3	17	0.70	2.50	3.20
Bignoniaceae	3	44	1.81	2.50	4.31
Bombacaceae	1	7	0.29	0.83	1.12
Burseraceae	2	111	4.58	1.67	6.24
Caesalpiniaceae	4	20	0.82	3.33	4.16
Clusiaceae	1	80	3.30	0.83	4.13
Combretaceae	2	49	2.02	1.67	3.69
Datiscaceae	1	2	0.08	0.83	0.92
Dilleniaceae	1	24	0.99	0.83	1.82
Dipterocarpaceae	5	378	15.59	4.17	19.8
Ebenaceae	1	2	0.08	0.83	0.92
Elaeocarpaceae	3	22	0.91	2.50	3.41
Euphorbiaceae	11	264	10.89	9.16	20.1
Fabaceae	2	4	0.16	1.67	1.83
Fagaceae	4	154	6.35	3.33	9.68
Flacourtiaceae	1	46	1.90	0.83	2.73
Lauraceae	5	141	5.81	4.17	9.98
Lythraceae	2	16	0.66	1.67	2.33
Meliaceae	4	34	1.40	3.33	4.74
Mimosaceae	5	48	1.98	4.17	6.15
Moraceae	11	206	8.49	9.17	17.7
Myristacaceae	1	3	0.12	0.83	0.96
Myrsinaceae	1	8	0.33	0.83	1.16
Myrtaceae	6	51	2.10	5.00	7.10
Rhizophoraceae	1	1	0.04	0.83	0.87
Rubiaceae	8	80	3.30	6.67	9.97
Rutaceae	4	63	2.60	3.33	5.93
Sapindaceae	1	15	0.62	0.83	1.45
Sonneratiaceae	1	1	0.04	0.83	0.87
Sterculiaceae	4	105	4.33	3.33	7.66
Tiliaceae	4	159	6.56	3.33	9.89
Ulmaceae	1	1	0.04	0.83	0.87
Verbenaceae	7	182	7.51	5.83	13.3

Dipterocarpaceae (15.59%) followed by Euphorbiaceae (10.89%), Moraceae (8.49%) and Verbenaceae (7.51%) family. Moraceae (9.17%) showed highest family relative diversity index (FRDI) followed by Euphorbiaceae (9.16%), Rubiaceae (6.67%) and Verbenaceae (5.83%). Maximum Family Importance Value (FIV) index was found for Euphorbiaceae (20.1%) followed by Dipterocarpaceae (19.8%), Moraceae (17.7%) and Verbenaceae (13.3%). Rhizophoraceae, Sonneratiaceae, and Ulmaceae showed the lowest (0.67) FIV index. Species and seedlings number FRD, FRDI and FIV value of the 36 families found in Dudhpukuria-Dhopachori Wildlife Sanctuary are presented in Table 1.

Number of naturally regenerating species

Among the 120 regenerating plant specis the highest number of seedlings per hectare were found 1078 for *Dipterocarpus turbinatus* followed by *Grewia nervosa* (464), *Aporosa wallichii* (464) and *Lithocarpus acuminata* (445). The lowest number of seedlings per hectare (3.2 seedlings/ha) was found for *Anisoptera scaphula, Carallia brachiata, Duabanga grandiflora,* and *Trema orientalis*. Maximum relative density (13.90%) was calculated for *Dipterocarpus turbinatus* followed by *Aporosa wallichii* (5.98%), *Grewia nervosa* (5.98%) and *Lithocarpus acuminata* (5.73%). Maximum relative frequency (5.30%) was found for *Grewia nervosa* and *Aporosa wallichii* followed

Table 2. Seedling per hectare, relative density (RD), relative frequency (RF), relative abundance (RA) and Importance Value Index (IVI) of 30 dominant regenerating plants in DDWS.

Scientific Name	Seedling/ha	RD (%)	RF (%)	RA (%)	IVI
Acronychia pedunculata	154	1.98	2.55	0.74	5.28
Actinodaphne angustifolia	198	2.56	2.74	0.89	6.19
Antidesma bunius	58	0.74	0.95	0.75	2.44
Aphanamixis polystachya	58	0.74	1.14	0.63	2.50
Aporosa wallichii	464	5.98	5.30	1.08	12.36
Artocarpus chama	202	2.60	2.74	0.91	6.25
Artocarpus lacucha	157	2.02	2.46	0.79	5.27
Callicarpa arborea	61	0.78	0.95	0.79	2.52
Cryptocarya amygdalina	99	1.28	1.61	0.76	3.65
Dillenia scabrella	77	0.99	1.61	0.59	3.19
Dipterocarpus costatus	122	1.57	0.57	2.64	4.78
Dipterocarpus turbinatus	1,078	13.90	1.23	10.81	25.94
Ficus hispida	96	1.24	1.32	0.89	3.46
Garcinia cowa	256	3.30	3.12	1.01	7.43
Garuga pinnata	58	0.74	1.04	0.68	2.47
Glochidion multiloculare	99	1.28	1.89	0.65	3.82
Grewia nervosa	464	5.98	5.30	1.08	12.36
Holarrhena antidysenterica	138	1.77	1.89	0.9	4.56
Hydnocarpus laurifolius	147	1.90	1.70	1.07	4.67
Lithocarpus acuminata	445	5.73	5.01	1.09	11.84

Scientific Name	Seedling/ha	RD (%)	RF (%)	RA (%)	IVI
Litsea glutinosa	131	1.69	2.37	0.68	4.74
Protium serratum	298	3.84	3.22	1.14	8.19
Pterospermum semisagittatum	198	2.56	2.08	1.18	5.81
Sterculia foetida	90	1.15	1.32	0.83	3.31
Stereospermum colais	102	1.32	1.61	0.78	3.71
Tarenna campaniflora	118	1.53	1.80	0.81	4.14
Terminalia bellirica	112	1.44	2.27	0.61	4.32
Trewia nudiflora	51	0.66	0.66	0.95	2.28
Vitex peduncularis	362	4.66	3.60	1.24	9.49
Vitex pinnata	93	1.20	1.04	1.10	3.34

by *Lithocarpus acuminata* (5.01%) and *Vitex peduncularis* (3.60%). The highest relative abundance was found for *Dipterocarpus turbinatus* (10.81%) followed by *Syzygium tetragonum* (2.71%) and *Dipterocarpus costatus* (2.64%). The maximum Importance Value Index (IVI) was calculated for *Dipterocarpus turbinatus* (25.94) followed by *Aporosa wallichii* (12.36), *Grewia nervosa* (12.36), *Lithocarpus acuminata* (11.84) and *Vitex peduncularis* (9.49). Seedlings per hectare, RD, RF, RA, Importance Value Index (IVI) of 30 dominant regenerating plants in DDWS are given in Table 2.

Biological diversity indices

Different biological diversity indices, e.g. Species diversity index (S_{Di}), Margalef's index (R), Shannon-Winner diversity index (H), Shannon's maximum diversity index (H_{max}), Species evenness index (E), Simpson index (D) and Dominance of Simpson index

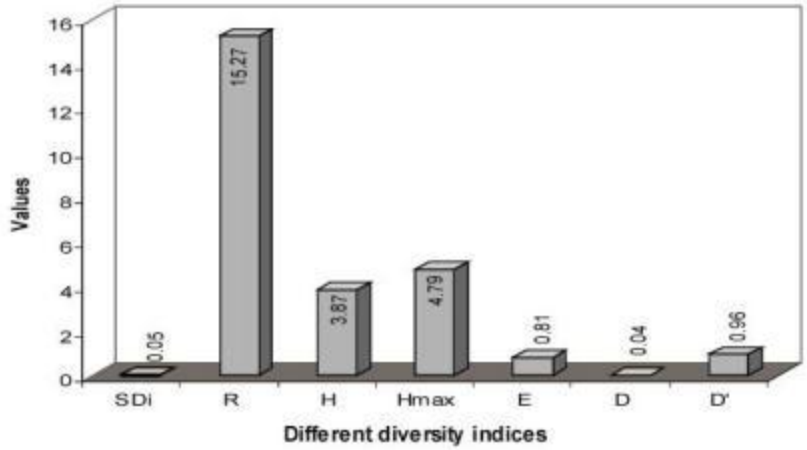


Figure 1. Different biological diversity indices for plant regeneration in DDWS

[Here, S_{Di} = Species diversity index, R = Margalef's index, H = Shannon-Winner diversity index, H_{max} = Shannon's maximum diversity index, E = Species evenness index, D = Simpson index and (D' = Dominance of Simpson index].

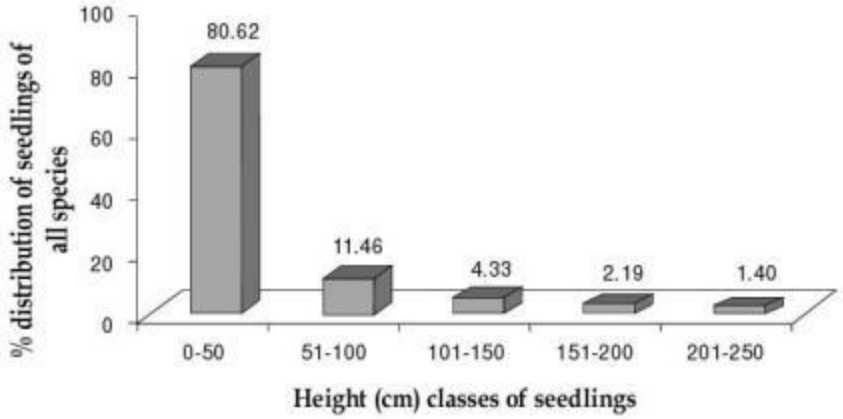


Figure 2. Percentage distribution of all the seedlings into different height (cm) classes

(D') were explored for Dudhpukuria-Dhopachari WS to depict natural regeneration status of recorded plant species (Figure 1). Margalef's index (15.269) for the regenerating species indicated higher species richness in DDWS (Margalef 1958). On the other side species diversity index (0.049) and Shannon-Winner's diversity index (3.865) revealed higher diversity in regenerating plant species. Less variation in the plant community was also revealed by higher value of species evenness index (0.807 out of 1). There were no single dominant regenerating plant species as represented by Simpson's dominance index (0.041). The different diversity indices of the regenerating plants are represented in figure 1.

Distribution of seedlings in different height classes

Plants below 251 cm in height were considered as seedling. The percentage (%) distribution of all seedlings of all species into five height (cm) classes is shown in Figure 2. It was found that maximum (80.62%) seedlings were within the height range of 0-50 cm, whereas, only 1.40% seedlings were

Table 3. Stock of 10 major dominating seedlings with their stems per hectare showing recruitment percentage at DDWS

Scientific Name	Tree stems/ha	Seedlings/ha	% Recruitment
Artocarpus chama	18	202	8.91
Lithocarpus acuminata	22	445	4.94
Aporosa wallichii	21	464	4.53
Grewia nervosa	19	464	4.09
Protium serratum	12	298	4.03
Vitex peduncularis	11	362	3.04
Pterospermum semisagittatum	5	198	2.53
Dipterocarpus turbinatus	26	1078	2.41
Actinodaphne angustifolia	4	198	2.02
Garcinia cowa	5	256	1.95

found in 201-250 cm height range (Fig. 2). Poor survival of seedlings is the result of both biotic and abiotic disturbances.

Seedlings Recruitment Percentage

All the height classes seedlings are considered as recruit for the respective species. A comparison between the major dominating seedlings with the corresponding tree stems per hectare showed that *Artocarpus chama* had maximum 8.91% seedlings recruitment percentage followed by *Lithocarpus acuminata* (4.94%) and *Aporosa wallichii* (4.53%). The stocking of the 10 major dominating seedlings with their stems per hectare is given in Table 3.

Information on regeneration potential leads to conservation measures of biological diversity (Verma *et al.* 1999). It is an important indicator for evaluating overall condition of forest ecosystem (Rahman *et al.* 2011). There is scarce information on the regeneration status of native species of DDWS. In the present study, 120 regenerating tree species belonging to 36 families were recorded and the number of species is much higher than earlier reports on similar natural forests of Bangladesh. Hossain *et al.* (2004) recorded 64 regenerating tree species in natural forests of Chittagong (South) Forest Division. Alamgir and Al-Amin (2007) reported 39 species under 18 families from a proposed biodiversity conservation area namely Bamerchara and Danerchara of Chunuti Wildlife Sanctuary, Chittagong, Bangladesh. Motaleb and Hossain (2007) reported 29 regenerating tree species under 16 families from a semi-evergreen forest of Chittagong (South) Forest Division. Rahman *et al.* (2011) found 55 regenerating plant species in Khadimnagar National Park and Tilagor Eco-Park. The higher regeneration status of DDWS may be the result of minimum human interferences and fire hazards as the Government strengthened conservation programs of the wildlife sanctuary in recent years. This may be the main reason of higher number of seedlings in the initial stages of seedling development.

Euphorbiaceae, Dipterocarpaceae, Moraceae and Verbenaceae showed higher regeneration potential due to maximum seed dispersal capability, and favorable conditions prevailing for natural regeneration. The forest was previously known as Dipterocarp forest because of the dominance of *Dipterocarpus alatus, D. costatus, D. turbinatus* and *Hopea odorata* in Dudhpukuria-Dhopachori Wildlife Sanctuary. The dominant regeneration of *D. turbinatus, Grewia nervosa, Aporosa wallichii, Lithocarpus acuminata* and *Vitex peduncularis* were found. This was due to their profuse seed production and convenient environmental conditions for regeneration success. Seedlings of *Acacia auriculiformis, Gmelina arborea* and coppice shoots of *Tectona grandis* were also recorded from the plantations raised by Forest Department.

The diversity indices of the present study show more promising regeneration in DDWS in comparison to the diversity indices reported by Rahman *et al.* (2011) from biodiversity conservation areas of northeastern Bangladesh. They reported 0.01 for Species diversity index, 4.92 for Species richness index, 3.62 for Shannon-Winner diversity index, 3.69 for Shannon's maximum diversity index, 0.98 for Shannon's equitability index, 2.26 for Species evenness index, 0.03 for Simpson index and Dominance of Simpson index was 0.97.

The DDWS forest is in a high risk of deforestation and degradation as many forest dependent local communities are residing around the forest. But recent co-management initiatives and conservation programs with the participation of local people are seems to be good initiatives in biodiversity conservation programs of the Wildlife Sanctuary. Results of the present study

acquaint an over-view of regeneration status of DDWS. It is obvious that the forest possess much higher regeneration potential for many economic and ecologically important tree species. But till now there are many causes prevailing that may be destructive to the occurrence and establishment of natural regeneration of DDWS. So, the Protected Area (PA) authority should be careful in implementing the conservation measures and should enhance more effective co-management and protection programs involving local people to ensure effective conservation of the Wildlife Sanctuary.

Acknowledgements

The authors cordially acknowledge to the Arannayk Foundation (Tropical Forest Conservation Programs of US Government and Bangladesh Government) for providing financial support for the field visits. Thanks to Forest Department for permission and support in the field works.

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Growth Performance of Underplanted Mangrove Species in *Sonneratia apetala* (Keora) Plantations along the Western Coastal Belt of Bangladesh

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Abstract

Coastal plantations mainly with *Sonneratia apetala* have been established by the Forest Department on the newly accreted lands in the coastline of Bangladesh since 1965-66. An underplanting trial of 11 mangrove species was conducted in the existing *S. apetala* plantations along the western coastline (Patuakhali and Bhola) to assess the site-suitability and growth performance of these species. Survival, height and diameter growth data from 16-21 years old experimental stands of these species were analyzed. The highest survival was found in *Excoecaria agallocha* (62% and 59%) followed by *Heritiera fomes* (51% and 39%) and *Xylocarpus mekongensis* (48% and 26%) among the tree species at Rangabali island of Patuakhali and Char Kukri-Mukri island of Bhola district. Among the shrub and palm species, the highest survival was found in *Aegiceras corniculatum* (63%) followed by *Phoenix paludosa* (58%) and *Nypa fruticans* (40%) at Rangabali and the highest survival in *P. paludosa* (71%) followed by *N. fruticans* (56%) and *A. corniculatum* (46%) at Char Kukri-Mukri. The mean maximum height growth was observed in *E. agallocha* (9.31 m and 9.29 m) followed by *X. mekongensis* (6.84 m and 6.84 m) and *H. fomes* (6.19 m and 5.65 m) in both the areas. The mean maximum diameter growth was also observed in *E. agallocha* (9.83 cm and 9.49 cm) followed by *X. mekongensis* (7.97 cm and 7.34 cm) and *H. fomes* (5.87cm and 5.34 cm) in both the areas. Among the shrub and palm species, *A. corniculatum, P. paludosa* and *N. fruticans* showed good height growth performance in both the study areas. Therefore, these promising mangrove species (*E. agallocha, H. fomes, X. mekongensis, A. corniculatum, P. paludosa* and *N. fruticans*) may be suitable for raising second rotation crops inside *S. apetala* plantations for sustainable management of coastal forests.

সারসংক্ষেপ

বন বিভাগ বাংলাদেশের উপকূলীয় এলাকায় ১৯৬৫-৬৬ সন থেকে নতুন জেগে উঠা চরে প্রধানতঃ কেওড়া প্রজাতির উপকূলীয় বাগান প্রতিষ্ঠা করেছে। পশ্চিমাঞ্চলীয় উপকূলীয় এলাকায় (পটুয়াখালী ও ভোলা) প্রতিষ্ঠিত কেওড়া বাগানের অভ্যন্তরে ১১টি ম্যানগ্রোভ প্রজাতির ভূমির উপযুক্ততা ও বৃদ্ধির হার নির্ণয়ের জন্য একটি আন্ডারপ্লান্টিং পরীক্ষা পরিচালনা করা হয়। উক্ত প্রজাতিগুলির ১৬-২১ বছর বয়সের বাগানসমূহের বেঁচে থাকার হার, উচ্চতা ও ব্যাস বৃদ্ধির উপাত্ত বিশ্লেষণ করা হয়। পটুয়াখালী জেলার রাঙ্গাবালী এবং ভোলা জেলার চর কুকরী-মুকরী দ্বীপাঞ্চলে বৃক্ষ প্রজাতির মধ্যে গেওয়ার বেঁচে থাকার হার সর্বাধিক (৬২% এবং ৫৯%), এরপর সুন্দরী (৫১% এবং ৩৯%) ও পশুর (৪৮% এবং ২৬%) উল্লেখযোগ্য। গুল্ম ও পাম প্রজাতির মধ্যে রাঙ্গাবালী চরাঞ্চলে খলসী প্রজাতির বাঁচার হার সর্বাধিক (৬৩%)। তারপর যথাক্রমে হেঁতাল (৫৮%) এবং গোলপাতার (৪০%) বাঁচার হার ভাল। চর কুকরী-মুকরীতে হেঁতাল প্রজাতির বাঁচার হার সর্বাধিক (৭১%)। এরপর গোলপাতা (৫৬%) ও খলসী (৪৬%) প্রজাতির বাঁচার হার ভাল। বৃক্ষ প্রজাতির মধ্যে উভয় এলাকায় গেওয়া প্রজাতির গড়

উচ্চতা বৃদ্ধির হার সবচেয়ে বেশী (৯.৩১ মি. এবং ৯.২৯ মি.)। তারপর পশুর (৬.৮৪ মি. এবং ৬.৮৪ মি.) ও সুন্দরী (৬.১৯ মি. এবং ৫.৬৫ মি.) প্রজাতির উচ্চতা বৃদ্ধির হার ভাল। উভয় এলাকায় গেওয়া প্রজাতির গড় ব্যাস বৃদ্ধির হার সর্বোচ্চ (৯.৮৩ সে.মি. এবং ৯.৪৯ সে.মি.), এরপর পশুর (৭.৯৭ সে.মি. এবং ৭.৩৪ সে.মি.) ও সুন্দরী (৫.৮৭ সে.মি. এবং ৫.৩৪ সে.মি.) প্রজাতির ব্যাস বৃদ্ধির হার ভাল। আবার গুল্ম ও পাম প্রজাতির মধ্যে খলসী, হেঁতাল ও গোলপাতার উচ্চতা বৃদ্ধির হার ভাল দেখা যায়। অতএব, উপকূলীয় বনের টেকসই ব্যবস্থাপনার জন্য কেওড়া বনের অভ্যন্তরে এই সম্ভাবনাময় ম্যানগ্রোভ প্রজাতিগুলি (গেওয়া, সুন্দরী, পশুর, খলসী, হেঁতাল ও গোলপাতা) ২য় পর্যায়ের বন সৃজনের জন্য উপযোগী হতে পারে।

Keywords: Coastal belt, growth performance, mangrove plantation, survival, underplanting.

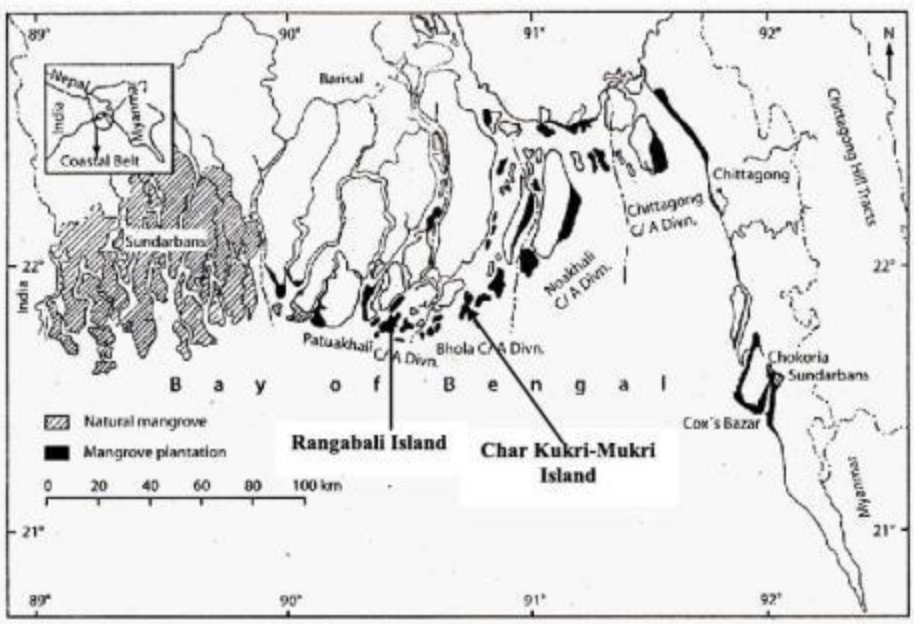
Introduction

The coastal belt of Bangladesh extends over 710 km long along the Bay of Bengal (Siddiqi 2001). There are newly accreted chars and off-shore islands of varying sizes in the coastal belt. Forest Department initiated coastal plantations in 1965-66 with an objective of protecting the lives and properties of the people suffering from the frequent cyclones and tidal bores (Das and Siddiqi 1985). Subsequently coastal afforestation was expanded to reclamation and stabilization of newly accreted lands (Saenger 1987). Initially most of the commercial mangrove species were tried on newly accreted lands, but *Sonneratia apetala* (keora) was the most successful in all along the coastline followed by *Avicenia officinalis* (baen) in the eastern belt. *S. apetala* accounted 94.4% and *A. officinalis* 4.8% of the successful mangrove plantations (Siddiqi and Khan 2004), and to date, approximately 0.19 million hectares of accreted land have been brought under mangrove plantations (Nandy 2010).

In the coastal areas, dynamic geomorphological changes, species succession and insect infestation threaten the sustainability of the pioneer *S. apetala* plantations (Siddiqi *et al.* 1992, Siddiqi 2001). Land accretion, removal of the keora trees and rotation of the species created gaps inside *S. apetala* plantations. In these plantations no regeneration appard due to rising of forest floor, soil compactness and absent of seed sources of other mangrove species. As a result more land become vacant. After harvesting of mature *S. apetala* trees, there will be no second rotation crops for sustainability of this forest. There is little chance for the development of tree cover by a natural process of succession because of rapid physical changes and heavy biotic interferences. Therefore, underplanting trial in the existing *S. apetala* plantations with different mangrove species were laid out since 1990-1995. The objective of this study was to find out suitable species for coastal areas inside *S. apetala* plantations for the establishment of a permanent forest cover with the mangrove species. Initial reports on this trial showed success and suitability of underplanting species (Siddiqi *et al.* 1992, Siddiqi and Khan 1996, Siddiqi 2001, Islam and Nandy 2001). However, the present study describes a comprehensive report on suitability and growth performance of 11 mangrove species planted inside *S. apetala* plantations in the western coastline of Bangladesh.

Materials and Methods

The Plantation Trial Unit Division of Bangladesh Forest Research Institute carried out the experiments along the western coastline in two offshore islands, Rangabali under Patuakhali district and Char Kukri-Mukri under Bhola district. Rangabali is located at latitude 21°92′ N and longitude 90°45′ E. Char Kukri-Mukri is located at



Map 1. Coastline of Bangladesh showing the locations of natural, planted mangroves and the study areas.

latitude 21°85′ N and longitude 90°72′ E (Map 1). Soil of the sites was silt-clay-loam. Soil salinity in the monsoon and dry season was remarkable varying between 1.5-4.0 dS/m. Soil pH was slightly alkaline (7.5-8.0).

Commercially important 11 mangrove species, e.g. *Heritiera fomes* (sundri), *Excoecaria agallocha* (gewa), *Xylocarpus mekongensis* (passur), *Xylocarpus granatum* (dhundul), *Bruguiera sexangula* (kankra), *Aegiceras corniculatum* (khalshi), *Cynometra ramiflora* (shingra), *Ceriops decandra* (goran), *Lumnitzera racemosa* (kirpa), *Phoenix paludosa* (hantal) and *Nypa fruticans* (golpata) were included in the trial. The seeds or propagules of these mangrove species were collected from the Sundarbans. Seedlings of all mangrove species except golpata were raised in polybags of 25 cm x 15 cm or 15 cm x 10 cm in size and kept in the nursery for about ten months. The golpata seedlings were raised in muddy soil near the canal side or in the marshy land.

The plots were established in Nursery Khal (N) and Pashar Khal (P) of Char Kashem, Soner Char, Madarbunia and Baher Char nearby Rangabali island; and Char Zamir, Char Shafi, Zylar Khal and Nursery Khal of Char Kukri-Mukri island. The experiment was laid out in a Randomized Complete Block Design with three replications. Each plot was planted with 100-121 seedlings at a spacing of 1.2 m x 1.2 m and the size of each plot was 144-174 m^2. The plots were fenced to prevent grazing animal up to five years of the plantations. Ten-month-old seedlings of the species were planted in 9-12 years old *S. apetala* plantations, except for *N. fruticans* seedlings, which were planted with 3 months old seedlings. Weeding was made up to five years after out planting. The data in relation to survival, height and diameter growth were collected in June, 2011 when the stand age varied from 16-21 years. Data were analyzed according to the standard statistical packages.

Results and Discussion

The growth performances of the eleven mangrove species were analyzed and the mean values for different parameters are given in Table 1.

The highest survival and height of *H. fomes* were 67% and 8.75 m respectively in 21 years old plantation at Char Keshem (P), and the highest diameter was 7.82 cm in 16 years old stand at Madarbunia. The mean annual height increment (MAI) of this species varied from 0.24-0.42 m and diameter increment from 0.21- 0.49 cm. The maximum survival of *E. agallocha* was 75% in 18 years old stand at Soner Char, the highest height was 13.0 m and the highest diameter was 11.62 cm in 21 years old trees at Char Kashem (P). The MAI in height and diameter of *E. agallocha* was 0.37-0.62 m and 0.40-0.61 cm respectively. The growth performance of this species was found higher than other species in almost all planting sites. The highest survival of *X. mekongensis* was 50% in 17 years old stand at Soner Char, the maximum height was 9.18 m in 21 years trees at Char Kashem (P) and the maximum diameter was 8.91 cm in 21 years trees at Char Kashem (N). The MAI in height and diameter of this species was 0.27-0.47 m and 0.32-0.50 cm respectively. The survival of *X. granatum* ranged from 11-50% in 16-18 years old plantations. The highest height and diameter of this species were 5.37 m and 6.03 cm in 16 years old stand at Madarbunia. The highest survival of *B. sexangula* was 16% in 21 years old stand of Char Kashem (N), the maximum height and diameter were 5.85 m and 6.51 cm respectively in 21 years old stand at Char Kashem (P) shown in Table 1.

The survival of *A. corniculatum* was 46-67% in 16-21 years old stands. The highest height and diameter were 8.14 m and 7.97 cm in 21 years old plantation at Char Kashem (P). The MAI in height and diameter of *A. corniculatum* was 0.26-0.39 m and 0.27-0.44 cm. The species showed promising survival and growth performance in all sites. The maximum survival of *C. ramiflora* was 42%, height was 7.21 m and diameter was 5.75 cm in 21 years old stand at Char Kashem (N). The mean annual height and diameter increment of this species were 0.24-0.34 m and 0.20-0.27 cm respectively. The survival of *C. decandra* was 12-41%, the highest height and diameter were 5.45 m and 5.83 cm. The survival of *L. racemosa* varied from 9-44% in 16-18 years old plantations and the highest height and diameter were 5.42 m and 8.76 cm (Table 1).

Table 1. Growth performance of eleven mangrove species planted at different locations of Rangabali and Char Kukri-Mukri islands.

Species (Local name)	Location	Age of trees (yrs)	Mean survival (%)	Mean height (m) ± SE	Mean annual height increment (m)	Mean DBH (cm) ± SE	Mean annual diameter increment (cm)
Heritiera fomes (Sundri)	Char Kashem(N)	21	30	6.69 ± 0.38	0.32	5.98 ± 0.28	0.28
	Char Kashem (P)	21	67	8.75 ± 0.34	0.42	7.03 ± 0.22	0.33
	Soner Char	18	58	4.98 ± 0.12	0.28	4.91 ± 0.12	0.27
	Soner Char	17	47	5.21 ± 0.17	0.31	3.59 ± 0.09	0.21
	Madarbunia	16	55	5.34 ± 0.09	0.33	7.82 ± 0.11	0.49
	Zylar Khal	21	30	7.28 ± 0.39	0.35	5.01 ± 0. 23	0.24
	Char Zamir	18	34	4.24 ± 0.12	0.24	5.73 ± 0.18	0.32
	Char Shafi	17	53	5.43 ± 0.28	0.32	5.29 ± 0.22	0.31
Excoecaria agallocha (Gewa)	Char Kashem(N)	21	66	10.45 ± 0.53	0.50	9.89 ± 0.48	0.47
	Char Kashem (P)	21	42	13.00± 0.28	0.62	11.62 ± 0.51	0.55

	Soner Char	18	75	8.05 ± 0.80	0.45	8.41 ± 0.23	0.47
	Soner Char	17	54	9.10 ± 0.33	0.53	10.22 ± 0.28	0.60
	Madarbunia	16	72	5.97 ± 0.09	0.37	9.01 ± 0.21	0.56
	Zylar Khal	21	70	10.04 ± 0.33	0.48	8.51 ± 0.33	0.40
	Char Zamir	18	54	8.49 ± 0.25	0.47	9.55 ± 0.28	0.53
	Char Shafi	17	52	9.33 ± 0.31	0.55	10.42 ± 0.31	0.61
Xylocarpus mekongensis (Passur)	Char Kashem(N)	21	52	7.14 ± 0.28	0.34	8.91 ± 0.21	0.42
	Char Kashem (P)	21	44	9.18 ± 0.31	0.44	8.66 ± 0.17	0.41
	Soner Char	18	42	4.95 ± 0.19	0.27	5.83 ± 0.15	0.32
	Soner Char	17	50	7.99 ± 0.15	0.47	8.50 ± 0.16	0.50
	Madarbunia	16	50	4.94 ± 0.08	0.31	7.93 ± 0.14	0.49
	Char Shafi	17	26	6.84 ± 0.27	0.40	7.34 ± 0.25	0.43
Xylocarpus granatum (Dhundul)	Soner Char	18	30	4.40 ± 0.26	0.24	4.91 ± 0.33	0.27
	Soner Char	17	11	4.34 ± 0.27	0.25	4.78 ± 0.18	0.28
	Madarbunia	16	50	5.37 ± 0.12	0.33	6.03 ± 0.12	0.38
Bruguiera sexangula (Kankra)	Char Kashem(N)	21	16	5.16 ± 0. 44	0.25	5.36 ± 0.26	0.26
	Char Kashem (P)	21	16	5.85 ± 0.15	0.28	6.51 ± 0.14	0.31
	Soner Char	18	10	4.10 ± 0.14	0.23	4.52 ± 0.26	0.25
Aegiceras corniculatum (Khalshi)	Char Kashem(N)	21	61	6.06 ± 0.15	0.29	6.09 ± 0.09	0.29
	Char Kashem (P)	21	64	8.14 ± 0.24	0.39	7.97 ± 0.16	0.38
	Soner Char	18	64	4.72 ± 0.16	0.26	4.91 ± 0.13	0.27
	Soner Char	17	58	5.43 ± 0.11	0.32	5.01 ± 0.12	0.29
	Madarbunia	16	67	5.13 ± 0.09	0.32	6.66 ± 0.13	0.42
	Char Zamir	18	46	6.61 ± 0.12	0.37	7.96 ± 0.18	0.44
Cynometra ramiflora (Shingra)	Char Kashem(N)	21	42	7.21 ± 0.37	0.34	5.75 ± 0.14	0.27
	Char Kashem (P)	21	30	5.86 ± 0.27	0.28	4.73 ± 0.39	0.22
	Zylar Khal	21	18	4.96 ± 0.15	0.24	4.27 ± 0.16	0.20
Ceriops decandra (Goran)	Char Kashem(N)	21	41	4.78 ± 0.11	0.23	5.18 ± 0.10	0.25
	Char Kashem (P)	21	16	5.45 ± 0.21	0.26	5.83 ± 0.21	0.28
	Soner Char	18	12	4.71 ± 0.21	0.26	4.12 ± 0.21	0.23
Lumnitzera racemosa (Kirpa)	Madarbunia	16	44	5.24 ± 0.10	0.33	6.31 ± 0.11	0.39
	Char Zamir	18	9	5.42 ± 0.50	0.30	8.76 ± 0.43	0.49
	Char Shafi	17	15	5.17 ± 0.26	0.30	6.26 ± 0.36	0.37
Phœnix paludosa (Hantal)	Char Kashem(N)	21	52	7.02 ± 0.28	0.33	5.80 ± 0.09	0.28
	Char Kashem (P)	21	58	6.40 ± 0.17	0.30	6.81 ± 0.18	0.32
	Soner Char	18	65	5.76 ± 0.09	0.32	5.48 ± 0.09	0.30
	Zylar Khal	21	59	4.92 ± 0.11	0.23	4.85 ± 0.09	0.23
	Char Zamir	18	89	5.14 ± 0.08	0.29	7.01 ± 0.09	0.39
	Char Shafi	17	66	5.68± 0.15	0.33	6.48 ± 0.10	0.38
Nypa fruticans (Golpata)	Madarbunia	16	37	3.55 ± 0.09	-	-	
	Baher Char	16	43	5.63 ± 0.07	-	-	-
	Nursery Khal	18	56	3.43 ± 0.04	-	-	-

N= Nursery Khal, P= Pashar Khal

The highest survival of *P. paludosa* was 89% in 18 years old stand at Char Zamir and the highest height was 7.02 m in 21 years old plantation at Char Kashem (N). The survival of *N. fruticans* ranged from 37-53% in 16-18 years old plantations.

Latif *et al.* (1992) found the mean diameter increment ranged from 0.062- 0.151 cm for *H. fomes*, 0.049-0.189 cm for *E. agallocha* in the Sundarbans. Siddiqi and Khan (1990) mentioned that the height and diameter increment varied between 0.27-0.70 m and 0.50-0.90 cm for 11-14 years old *E. agallocha* plantations in the coastal belt. The height and diameter increment of *X. mekongensis* in 14 years old trees were 0.34 m and 0.30 cm respectively in the coastal belt. The annual height increment in this genus varied from 0.23-0.38 m for the plantation of age 10-13 years (Siddiqi and Khan 1996).

The average survival percentage, height and diameter at breast height (DBH) from 16-21 years old stands of eleven mangrove species were analyzed separately for Rangabali and Char Kukri-Mukri locations. The result showed that the highest survival was recorded for *A. corniculatum* (63%) followed by *E. agallocha* (62%), *P. paludosa* (58%), *H. fomes* (51%) and *X. mekongensis* (48%) at Rangabali. The maximum survival was found for *P. paludosa* (71%), followed by *E. agallocha* (59%), *N. fruticans* (56%) *A. corniculatum* (46%) *H. fomes* (39%) and *X. mekongensis* (26%) at Char Kukri-Mukri island (Fig. 1). Siddiqi *et al.* (1992) reported very initial information on survival and height growth performance of mangrove species based on only 1990 plantations (4 places) at Rangabali and Char Kukri-Mukri. They found more than 90% survival for *E. agallocha, P. paludosa* and *H. fomes* at Rangabali and Char Kukri-Mukri. Siddiqi and Khan (1996) reported growth performance of 4 years old stands from the same experiment and they found higher survival for *E. agallocha* (97%) followed by *H. fomes* (93%), *P. paludosa* (92%) and *A. corniculatum* (68%). Siddiqi (2001 and 2002) prepared a partial and interim report on survival, height and diameter growth of 11 mangrove species at the age of 8 years at Char Kukri-Mukri. He found higher survival for *N. fruticans* (97.3%), followed by *E. agallocha* (90.3%), *H. fomes* (84.7%), *P. paludosa* (84.7%), *B. sexangula* (61.3%) and *X. mekongensis* (58.3%).

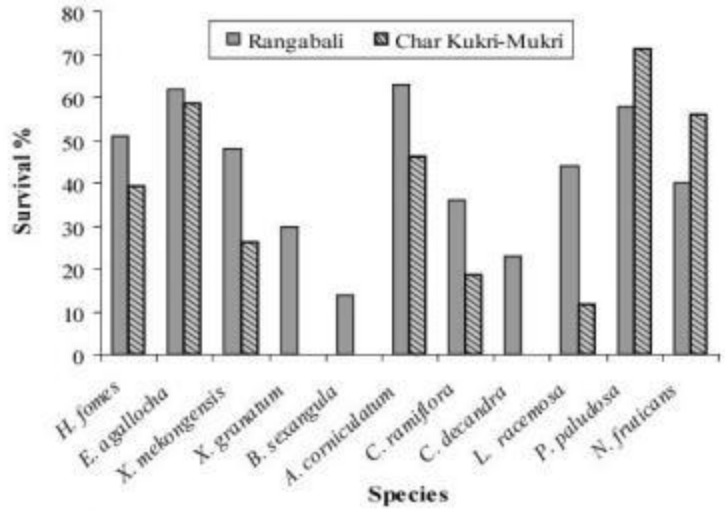


Figure 1. Mean survival percentage of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

In the present study, the highest mean height was recorded for *E. agallocha* (9.31 m) followed by *X. mekongensis* (6.84 m), *C. ramiflora* (6.54 m), *P. paludosa* (6.39 m), *H. fomes* (6.19 m) and *A. corniculatum* (5.90 m) at Rangabali. The highest mean height was also recorded for *E. agallocha* (9.29 m) followed by *X. mekongensis* (6.84 m), *A. corniculatum* (6.61 m) and *H. fomes* (5.65 m) at Char Kukri-Mukri island (Fig. 2). The highest mean DBH was recorded for *E. agallocha* (9.83 cm) followed by *X. mekongensis* (7.97 cm), *L. racemosa* (6.31 cm), *A. corniculatum* (6.13 cm), *P. paludosa* (6.03 cm) and *H. fomes* (5.87 cm) at Rangabali. The highest mean DBH was also recorded for *E. agallocha* (9.49 cm) followed by *A. corniculatum* (7.96 cm), *L. racemosa* (7.51 cm), *X. mekongensis* (7.34 cm), *P. paludosa* (6.11 cm) and *H. fomes* (5.34 cm) at Char Kukri-Mukri (Fig. 3). Siddiqi and Khan (1996) found higher height growth for *E. agallocha* (6.20 m) followed by *H. fomes* (2.60 m) and *X. mekongensis* (2.40 m) in four years old stands. Siddiqi (2001, 2002) recorded highest height for *E. agallocha* (9.23 m), followed by *H. fomes* (5.33 m) and *P. paludosa* (2.93 m) in 8 years old stands. He also found maximum DBH for *E. agallocha* (7.33 cm), followed by *P. paludosa* (5.06 cm) and *H. fomes* (3.13 cm) in the same experiment. Siddiqi and Khan (1990) found a height and diameter growth was 7.4 m and 11.14 cm for *E. agallocha* in 12 years old trees at Char Kukri; 3.75 m and 3.32 cm for *E. agallocha* in 11 years old trees at Char Kashem, and 3.5 m and 5.05 cm for *H. fomes* in 14 years old trees at Char Kukri-Mukri in other plantations.

The results of survival, height and diameter growth data revealed that *E. agallocha* are the most promising species both in Rangabali and Char Kukri-Mukri areas followed by *A. corniculatum*, *H. fomes* and *X. mekongensis* among the tree species. Among the shrubs and palms species, the most promising species was *P. paludosa* followed by *N. fruticans* both in Rangabali and Char Kukri-Mukri. In Rangabali area, *C. ramiflora* and *L. racemosa* showed better performance but very poor survival at Char Kukri-Mukri areas. Out of 11 species tried, all species were successful at Rangabali area but 8 species were successful and remaining 3 species fail

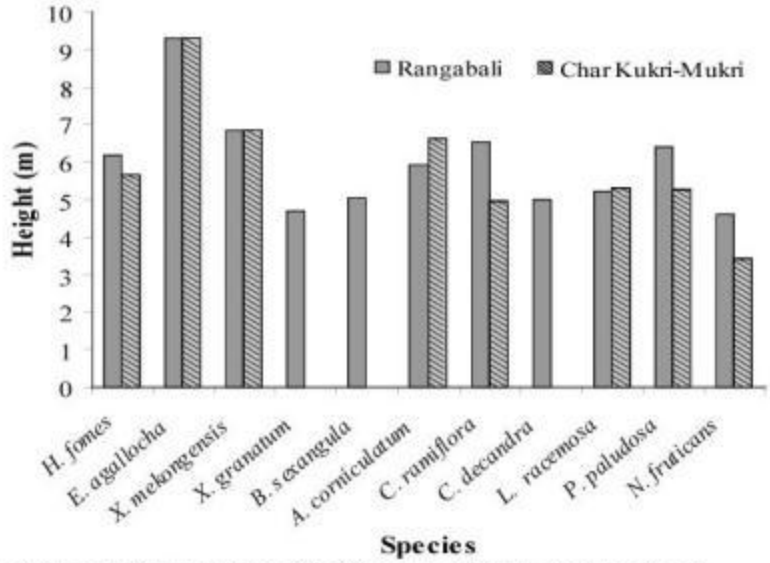


Figure 2. Mean height growth of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

to survive at Char Kukri-Mukri areas (Fig. 1). Grazing of domestic animal like cattles and buffalos has a highly detrimental impact on the successful establishment of mangrove plantations. Moreover, the introduced deer (*Axis axis*) in the Char Kukri-Mukri island browsed seedlings of some palatable species like *X. granatum* and *B. sexangula* which ultimately affect the growth and survival of the species. Therefore, survival of most of the species was found lower in Char Kukri-Mukri than in Rangabali. On the other hand, human interference and illicit felling of superior trees in the established experimental plots were very common in the coastal belts. Therefore, the survival was decreased for *H. fomes* and *X. mekongensis* in some places.

Natural regeneration mainly of *E. agallocha, H. fomes* and *P. paludosa* were observed in and around trial plots both at Rangabali and Char Kukri-Mukri areas. Flowering and fruiting of these species were started in 8-10 years old stands. Huge seedlings of the species were appeared in the areas. As these trial plantations have also been serving as the mangrove seed sources in the western coastal belt and thus it may become an opportunity to develop naturally second rotation vegetation inside *S. apetala* forests. Pictorial status of *E. agallocha, H. fomes, X. mekongensis, A. corniculatum, N. fruticans* and *P. paludosa* as underplanting is shown in Figure 4–9.

Bangladesh is a pioneer country in raising successful plantations with *S. apetala* in the newly accreted char lands along the coastline. But the existence of these plantations is under tremendous pressure due to geomorphic changes in the plantation sites and human interferences. Moreover, the life cycle of *S. apetala* is short (20 years rotation) and after harvesting this pioneer species, there will be no forests in absence of natural regeneration. Therefore, in order to maintain continuous forest vegetations, raising of second rotation forests under the canopy of existing plantations are immense important before harvesting. In the western coastline, the mangrove species like *E. agallocha, H. fomes, X. mekongensis, A. corniculatum* and *P. paludosa* were found promising as underplanting at the age of 4 and 8 years (Siddiqi and Khan 1996, Siddiqi 2001). On the basis of survival and growth performance of mature experimental stands of this study, *E. agallocha, H. fomes, X. mekongensis,*

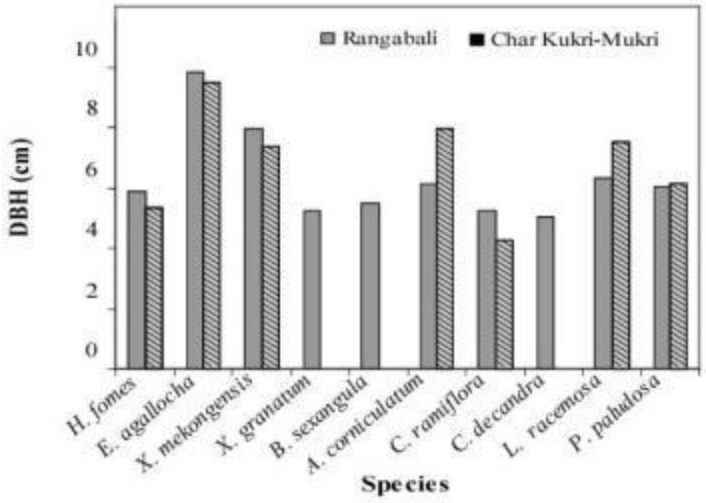


Figure 3. Mean diameter at breast height (DBH) of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

Figure 4. *E. agalloclu* underplanting plot at Zylar Khal of Char Kukri-Mukri.

Figure 5 *H. fomes* underplanting plot at Soner Char of Rangabali.

Figure 6. *X. mekongensis* underplanting plot at Char Keshem of Rangabali.

Figure 7. *A. corniculatum* underplanting plot at Char Kashem of Rangabali.

Figure 8. *N. fruticans* underplanting plot at Zylar Khal of Char Kukri-Mukri.

Figure 9. *P. paludosa* underplanting plot at Char Kashem of Rangabali.

A. corniculatum, *P. paludosa* and *N. fruticans* are also appeared promising at the age of 16-21 years. Thus these species can be recommended for afforstation inside *S. apetala* plantation for sustainable management of coastal forests. In many places, the coastal forests have been destroyed due to illegal occupation by erosion victim people. The influential persons behind the homeless people using them to grab government land. In the last few years, about 6,045 ha coastal forest land has been encroached and destroyed forest resources in only Noakhali coastal area (Sajjaduzzaman *et al.* 2005). So, participatory approach of forest management may also be considered for the development and conservation of mangrove forests. In addition, Forest Department must take intiative to declare the areas as reserve forests for protection of the existing coastal plantations.

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In Vitro Efficacy of Some Plant Extracts and Fungicides Against the Wilting of *Dalbergia sissoo* Caused by *Fusarium Solani* f. *dalbergiae*

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Abstract

Seven plant extracts and seven fungicides were tested to control the wilting disease of *Dalbergia sissoo* caused by *Fusarium solani* f. *dalbergiae*. Plant extracts of *Vitex negundo* (Nishinda), *Azadirachta indica* (Neem), *Ocimum basilicum* (Tulsi), *Tagetes patula* (Gandha), *Polygonum hydropiper* (Bishkantali), *Adhatoda vasica* (Basok) and *Centella asitica* (Thankuni) were tested in 100%, 50% and 25% concentration in controlling the vegetative growth of the fungus. Basilieum inhibited the highest amount, about 56% growth of the culture. *A. vasica* and *V. negundo* were the second and third in controlling about 43% and about 42% of the vegetative growth. *C. asiatica* controled 40% while *A. indica* and *T. patula* controled 39% and 37%. *P. hydropiper* was the least effective antifungal that inhibited about 32% growth of the tested fungus.

Synthetic fungicides namely Ridomil Gold (Metalaxyl-M & Mancozeb), Thiovit (Sulphur), Sunvit (Copper Oxychloride), Dithane M-45 (Mancozeb), Avistin (Carbendazim), Bavistin (Carbendazim) and Forastin (Carbendazim) were screened out to test their efficacies in 500 ppm, 250 ppm and 125 ppm concentrations. Bavistin was the most effective of all in digesting the growth of the culture by 73%, 65% and 64% in three concentrations respectively. Forastin was the second in destroying about 66%, 63% and 58% while Avistin ranked the third in digesting 59%, 52% and 41% mycelial growth in three fugicidal concentrations. Diathene M-45, Ridomil Gold, Sunvit and Thiovit inhibited 30%, 28%, 27% and 24% respectively.

সারসংক্ষেপ

শিশু গাছের উইল্টিং রোগের জন্য দায়ী ফিউজেরিয়াম সোলানী নামক ছত্রাক দমনের উদ্দেশ্যে সাতটি গাছের নির্যাস ও রাসায়নিক ছত্রাকনাশকের কার্যকারীতা পরীক্ষা করা হয়। *Vitex negundo* (নিশিন্দা), *Azadirachta indica* (নিম), *Ocimum basilicum* (তুলসী), *Tagetes patula* (গাঁদা), *Polygonum hydropiper* (বিষকাঁঠালী), *Adhatoda vasica* (বাসক) এবং *Centella asiatica* (থানকুনি) গাছের ১০০%, ৫০% ও ২৫% গাঢ়ত্বে এসব ভেষজ নির্যাসের ছত্রাক-বিধ্বংসী ক্ষমতার মূল্যায়ণ করা হয়। পরীক্ষাধীন ছত্রাকের ৫৬% দৈহিক বৃদ্ধি বন্ধ করে তুলসী সর্বাপেক্ষা বেশি কার্যকরী প্রাকৃতিক ছত্রাকনাশক হিসেবে প্রমাণিত হয়েছে। এ কাজে ছত্রাকের প্রায় ৪৩% ও প্রায় ৪২% বৃদ্ধি ধ্বংস করে বাসক ও নিশিন্দার কার্যকারীতার অবস্থান ছিল যথাক্রমে দ্বিতীয় ও তৃতীয়। থানকুনির নির্যাস ছত্রাকের ৪০% এবং নিম ও গাঁদা যথাক্রমে ৩৯% ও ৩৭% বৃদ্ধি ধ্বংস করেছে। ছত্রাক ধ্বংসের কাজে বিষকাঁঠালীর কার্যক্ষমতা ছিল সর্বনিম্ন; এটি ছত্রাকের প্রায় ৩২% দৈহিক বৃদ্ধি বন্ধ করতে সক্ষম হয়েছে।

রিভোমিল গোল্ড (মেটালেক্সিল-এম এন্ড ম্যালকোজেব), থিওভিট (সালফার), সালভিট (কপার অক্সিক্লোরাইড), ডায়থেন এম-৪৫ (ম্যালকোজেব), এভিস্টিন (কার্বানডেজিম), ব্যাভিস্টিন (কার্বানডেজিম) ও ফোরাসটিল (কার্বানডেজিম) নামক সংশ্লেষীয় ছত্রাকনাশকের ৫০০ পিপিএম, ২৫০ পিপিএম ও ১২৫ পিপিএম ঘনত্বে এদের কার্যকারীতা পরীক্ষা করা হয়। উক্ত তিনটি ঘনত্বে ছত্রাকের প্রায় ৭৩%, ৬৫% ও ৬৪% দৈহিক বৃদ্ধি ধ্বংস করে তিনটি ভিন্ন গাঢ়ত্বে ব্যাভিস্টিন সর্বাধিক সফলতা দেখিয়েছে। এ কাজে দ্বিতীয় স্থানে থাকা ফোরাসটিন-এর পারঙ্গমতা ছিল প্রায় ৬৬%, ৬৩% ও ৫৮% এবং এভিস্টিলের স্থান ছিল তৃতীয় যা ছত্রাকের প্রায় ৫৯%, ৫২% ও ৪১% দৈহিক বৃদ্ধি ধ্বংস করেছে। ডায়থেন এম-৪৫, রিভোমিল গোল্ড, সালভিট ও থিওভিট ছত্রাকের বৃদ্ধি রোধে যথাক্রমে ৩০%, ২৮%, ২৭% ও ২৪% কার্যকরী।

Keywords : Antifungal, *Dalbergia sissoo,* fungicides, *Fusarium solani,* f. *dalbergiae,* mycelial growths

Introduction

During 1990s, a serious disease threatening the survival of *Dalbergia sissoo* Roxb. was observed in several SAARC countries including Bangladesh. The plant was widely used for growing plantations of community and agro-forestry in Bangladesh. The disease was studied critically in the Bangladesh Forest Research Institute (BFRI), Chittagong. The causal fungus was identified as *Fusarium solani* f. *dalbergiae*, and some management practices for the disease were suggested (Basak 1994, Basak *et al.* 2003, Basak 2006, Basak and Basak 2011). The objective of the research was to develop ways of prevention or curation of the disease.

Integrated Pest Management (IPM) that utilizes all suitable techniques and methods in a compatible manner and maintains the population at levels below causing economic injury, was tried. Among the several components of IPM e.g., appropriate silvicultural practices, crop rotation, quarantine, biological control, biotechnology of developing host-plant resistance and use of pesticides, use of plant extracts, biological agents and fungicides, were applied.

Green plants possess a vast reservoir of chemicals which are effective against different diseases. Only 10% of these have been tested against human diseases but less against diseases of plants (Nityananda 1977). The earliest mention of poisonous plants is found in Wrik Veda during second millennium B.C. (Hoddy 1991). Recently, search for antifungal natural compounds has become intense due to increasing concern about pollutive effects of synthetic fungicides on environment (Alice and Rao 1987). Many pathogens are becoming resistant against those chemicals due to their consistent usages. Due to low phytotoxicity, cost-effectiveness, systemicity, biodegradability and capacity to stimulate host metabolism, antifungal compounds of plants are advantageous over synthetic fungicides (Beye 1978). Tewari (1998) listed some promising plant extracts which have proved antifungal toxicities. Anwar *et al.* (1994) reported antifungal activity of 23 plant extracts. There are works on antimicrobial studies of essential oils from plants (Chowdhury *et al.* 2003). Bhowmik and Chowdhury (1982) reported that leaf extract of *Azadirachta indica* had the highest inhibition of mycelial growth of *Alternaria alternata*. In Bangladesh, some plant extracts showed effective in controlling selected fungal pathogens of jute, rice and chickpea (Miah *et al.* 1990, Basher and Rai 1991).

Chemical pesticides are poisons and can control many plant diseases, though their misuse is destroying our environment. With the application of first commercial pesticide in 1867 that contained arsenical compound followed by Bordeaux mixture in 1885, lime

sulphur in 1880, lead arsenate in 1892, Thiram in 1931, DDT in 1939 and 2, 4-D in 1942, much reliance was placed on chemicals to control pests and diseases from 1940s by replacing all other control practices. This led to the misuse of pesticides and the emergence of environmental, health, economic and new pest and disease problems. Consequently, Integrated Pest Management (IPM) was developed to reduce the usages of pesticides. There is no extensive work on the antifungal activity of plant extracts and fungicides against the wilt fungus of *D. sissoo*. So, the present work was conducted to find out the procedures and impacts of the evaluated herbicides and fungicides on inhibiting the growth the fungal mycelium.

Materials and Methods

The mycelial growth inhibition test of the fungus, *Fusarium solani* f. *dalbergiæ* was conducted in 2004-05 in the Silviculture Genetics Division of Bangladesh Forest Research Institute, Chittagong. Fresh leaves of *Azadirachta indica, Vitex negundo, Adhatoda vasica, Ocimum basilicum, Centella asiatica, Polygonum hydropiper* and *Tagetes patula* were collected, cleaned, washed with water, dried over tissue paper and cut into 1-2 cm long pieces. Twenty-five grams of each sample was kept for 24 hours, inside separate conical flasks containing 50 ml sterile water maintaining a materials-water ratio of 1:2 (W/V). Then, they were crushed in a mortar and pastle. Extracts were first sieved through several layers of cheese cloth and finally through filter papers. Filtrates were sterilized for 15 minutes at 121°C under 15 PSI. Potato Dextrose Agar (PDA) medium was prepared, sterilized for 20 minutes at 40-45°C, and poured into Petridishes. Concentrated extracts of 10 ml having 100% concentration, were poured into 50, 55 and 57.5 ml PDA medium. Thus, 60 ml poisoned PDA for each concentration of each extract was prepared. The poisoned-foods were plated aseptically into 90 mm Petridishes at the rate of 20 ml in each for three replications of each concentration. Against each concentration, three replications of control Petridishes contained PDA and sterile water only. From seven days old culture, 9 mm diameter mycelial disc was cut by an agar cutter; excess agar was removed by a sterile scalpel, and the disc was placed inverted onto a food medium for helping the fungus to grow without delay. The plates were left at 27-30°C. Data on average diameter of inhibited as well as control growth, were recorded after 5 days of incubation.

The synthetic fungicides, namely Ridomil Gold, Thiovit, Sunvit, Dithane M-45, Avistin, Bavistin and Forastin were diluted into 500, 250 and 125 ppm and marked properly [The preparation of three concentration profiles for each of the fungicides: l g Bavistin + 100 ml water = 1% solution, i.e., 10,000 ppm. 1 ml solution from 10,000 ppm plus 9 ml water=1000 ppm. 10 ml from 1000 ppm solution+10 ml water=500 ppm. 10 ml from 500 ppm solution+10 ml water = 250 ppm. 10 ml from 250 ppm solution+10 ml water = 125 ppm]. One millilitre of the prepared solution of any strength was placed at the centre of a sterile Petridish and 15 ml hot PDA was added to that. By agitating the plates for mixing up of the fungicidal solution and PDA gel, the plates were left to solidification. Control plates contained three replications of PDA and sterile water against each concentration. The remaining procedures were similar to those used in case of the plant extracts. The inhibition percentage was calculated.

Results

The results of the percent inhibition of mycelial growth of *F. solani* f. *dalbergiæ* due to antifungal effect of plant extracts were presented in the Table 1. The findings differed greatly depending on the materials

and doses of the plant extracts. *O. basilicum* inhibited the highest amount of 56.36, 45.45 and 35.76% growth in 100, 50 and 25% concentrations respectively. *A. vasica* was the second in case of destruction of 43.04, 41.82 and 29.71% mycelia at 100, 50 and 25% concentrations respectively. *P. hydropiper* was less efficient in inhibiting the fungus, nearly 32% in every concentration. The antifungal performances of *V. negundo* ranked the third and *C. asiatica* the fourth. *A. indica* and *T. patula* were similar in their capabilities.

The result of efficacies of the synthetic fungicides is given in the Table 2. Bavistin proved superior to others in inhibiting the test fungus by 72.73, 64.85 and 64.25% in three concentrations followed by Forastin (66.0, 62.8 and 57.69%). In controlling the fungus, *F. solani* f. *dalbergiæ*, Avistin ranked the third (59.4%, 51.53% and 41.22%). The range of inhibition of fungal growth by the remaining synthetic fungicides was recorded much lower, 24-30% than those of the Bavistin, Forastin and Avistin (about 41-73%).

Discussion

Among the plant extracts, *O. basilicum, A. vasica, V. negundo and C. asiatica* showed a very promising result by digesting about 50% vegetative growth of the test fungus within

Table 1. *In vitro* efficacy of herbicides in controlling growth of *Fusarium solani* f. *dalbergiæ*

Names of the plant extracts	Mean inhibition of mycelial growth (%)		
	100% conc.	50% conc.	25% conc.
Vitex negundo (Nishinda)	41.82	40.00	37.58
Azadirachta indica (Neem)	38.80	36.98	25.45
Ocimum basilicum (Tulsi)	56.36	45.45	35.76
Tagetes patula (Gandha)	36.76	35.16	29.09
Polygonum hydropiper (Bishkantali)	32.12	32.13	31.53
Adhatoda vasica (Basok)	43.04	41.82	29.71
Centella asiatica (Thankuni)	40.00	35.76	34.55

Table 2. *In vitro* efficacy of synthetic fungicides in controlling *Fusarium solani* f. *dalbergiae*

Fungicides	Mean inhibition of mycelial growth (%)		
	500 ppm	250 ppm	125 ppm
Ridomil Gold (Metalaxyl-M & Mancozeb)	27.89	23.04	19.40
Thiovit (Sulpher)	23.73	21.81	16.04
Forastin (Carbendazim)	66.04	62.83	57.69
Bavistin (Carbendazim)	72.73	64.85	64.25
Dithane M-45 (Mancozeb)	30.31	18.18	13.95
Sunvit (Copper Oxychloride)	26.67	16.98	09.09
Avistin (Carbendazim)	59.40	51.53	41.22

five days. The above plant extracts contained antimicrobial substances like unsaturated lactones, cyanogenic glycosides, sulphur compounds, phenols, phenolic glycosides and saponins (Singh 1984). Plant extracts of *O. basilicum* inhibited 22 fungi (Dube *et al.* 1989). Plant extracts of *Vitex negundo* was found phytotoxic against *Helminthosporium oryzae* (Grainage *et al.* 1985) and in the present study, it ihhibited 38-42% mycelial growth of the test fungi. The leaf extracts of *Polygonum hydropiper* and *Azadirachta indica* showed 60% and 58% inhibition of mycelial growth of *F. solani* (Basak and Paul 1999). The results indicated that the doses of the plant extracts should be higher than those applied. Autoclaving might have destroyed the antifungal properties of the essential oils of the extracts to some extents and perhaps not by heating alone and storage for a few days. Pesticides of microbes and plants are compatible with IPM programme, and Neem products, at present are being applied as a pesticide.

Due to systemic in nature Bavistin, Forastin and Avistin showed higher results over the others for three concentrations in killing a substantative quantity of the mycelial growth of *F. solani* f. *dalbergiae* within five days. Bavistin inhibited both mycelial growth and spore germination in *in vitro* conditions. It is worthwhile to note that fungicides could be used prior to sowing of seeds, in the seedling stage and also in the plantations after the onset of symptoms of diseases. Harsh (1993) treated seeds of *D. sissoo* with Topsin-M (Thiophanate methyl) and Bavistin (Carbendazim) which provided an adequate control of damping-off in seedlings caused by *Fusarium* spp. Sinha (1975) observed reduction of wilt disease by Bavistin when applied as soil drench at 2000 ppm, 10 days before inoculation of pigeonpea with *F. udum*. Solarization alone or in combination with Bavistin and Captan proved very effective (Kaushik *et al.* 2002). Chakravarty and Misra (1986) found positive results of using VAM in decreasing wilting of *D. sissoo*. In a greenhouse trial, pre-inoculation of VAM fungi and *Ganoderma tenuis* against *F. solani* and *F. oxysporum*, increased growth of the plant and reduced serverity of wilting of *D. sissoo*. Organic substrates with high C/N ratio, suppressed *F. solani* when soil was amended with bean straw and saw dust; casualty was minimum (Kaushik *et al.* 1993). Further work may be conducted on application of potassium fertilizer in extra doses, solarization and host-plant resistance.

Acknowledgement

The authors are indebted to Saurov, the dearest son of the first author who left this world untimely. His assistance and inspiration during the study will be remembered always. The authors are grateful to Mr S.A.M. Nurul Islam, a veteran Biotechnologist and a big-hearted scientist of BFRI for his generocity of allowing us to use his working place in conducting the work.

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Rubber Seed Oil- A Non-traditional By-product of Rubber Tree and Its Commercial Prospect in Bangladesh

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Abstract

Rubber seed oil is a promising by-product of rubber plant (*Hevea brasiliensis* Muell. Arg.), has so far been unknown to the rubber growers of Bangladesh. A Laboratory-based research was made on different aspects of rubber seed oil of four selected clones (RRIM-600, RRIM-605, PB-255 and GT-1) grown in the country. Results show that rubber seeds of the clones contain 28-44% edible oil which is will be cheaper than soybean and palm oil. Gas Liquid Chromatography (GLC) analysis shows that the seed oil contains 83-89% essential unsaturated fatty acids and 17-22% saturated fatty acid. On the other hand, the seed-cakes contain 29-39% proteins which is determined by the Macro Kjeldahl Procedure can be used as animal feed.

Besides, the seed-cakes contain six minerals (N, P, K, Na, Ca and Fe), where percentages of N, P and K have been found to be 5.5%, 2.8%, and 1.4% compared to those in ground nut (7.1%, 1.3%, and 1.2%) and cotton seed (3.8, 1.1% and 1.4%). It has also been estimated that if proper initiatives are taken, at least Tk. 49.32 crore could be earned per annum from the seed oil of the existing 37,646 ha plantations of the country. The seed oil and the de-oiled seed-cakes will not only create employment opportunity and flow of economic activities, but will also save substantial amount of foreign exchange from importing other edible oils and the essential ingredients of animal feed.

সারসংক্ষেপ

রাবার বৃক্ষের (*Hevea brasiliensis* Muell. Arg.) একটি সম্ভাবনাময় উপজাত হিসাবে রাবার বীজ-তেল এতদিন বাংলাদেশের রাবার চাষীদের নিকট অজানাই ছিল। বিগত ২০০৫ সালে দেশে উৎপাদিত চারটি জাতের রাবার (আরআরআইএম-৬০০, আরআরআইএম-৬০৫, পিবি-২৫৫ ও জিটি-১) বীজ-তেলের বিভিন্ন বিষয়ের উপর গবেষনাগারে এক বিশ্লেষন-ধর্মী গবেষনা পরিচালিত হয়। ফলাফলে দেখা যায় যে, উক্ত চারটি জাত ২৮-৪৪% তেল সম্বৃদ্ধ, যা সয়াবিন ও পামওয়েলের তুলনায় সস্তা। গ্যাস লিক্যুইড ক্রোমাটোগ্রাফী (জিএলসি) বিশ্লেষনে দেখা যায় যে, এ বীজ-তেলে ৮৩-৮৯% আন-স্যাচুরেটেড ও ১৭-২২% স্যাচুরেটেড ফ্যাটি-এসিড রয়েছে। অপরপক্ষে, রাবার বীজ-কেক-এ ২৯-৩৯% প্রোটিন পাওয়া যায়, যা ম্যাক্রোজেলডাল পদ্ধতিতে নির্ণয় করা হয়েছে এবং এটি প্রানীজ খাবার হিসাবে ব্যবহার করা যেতে পারে।

এছাড়াও বীজ-কেক-এ রয়েছে ছয়টি মিনারেল (নাট্রোজেন, ফসফরাস, পটাশ, সোডিয়াম, ক্যালসিয়াম ও আয়রন) যেখানে সার হিসাবে ব্যবহৃত নাট্রোজেন, ফসফরাস ও পটাশের পরিমান যথাক্রমে ৫.৫%, ২.৮% ও ১.৪% যা বাদাম ও তুলাবীজে রয়েছে যথাক্রমে ৭.১%, ১.৩% ও ১.২% এবং ৩.৮%, ১.১% ও ১.৪%। হিসাব করে দেখা গেছে, যথাযথ ব্যবস্থা গৃহীত হলে দেশের বিদ্যমান ৩৭,৬৪৬ হেক্টর বাগান থেকে বছরে ৪৯.৩২ কোটি টাকার রাবার বীজ-তেল সংগ্রহ করা সম্ভব। উক্ত বীজ-তেল ও বীজ-কেক দেশে কেবলমাত্র নূতন কর্ম-সংস্থান ও অর্থনৈতিক কর্মকান্ডই বৃদ্ধি করবে না বরং এতে অন্যান্য ভোজ্য-তেল আমদানীসহ প্রাণীজ খাবারের প্রয়োজনীয় উপাদান আমদানীর ক্ষেত্রেও প্রচুর বৈদেশিক মুদ্রার সাশ্রয় হবে।

Keywords: Clones, cultivars, *Hevea brasiliensis*, kernel, latex

Introduction

Rubber (***Hevea brasiliensis***) is indigenous to the Amazon valley of Brazil, Venezuela, Peru, Ecuador and Colombia. Among the nine species and four varieties of the Amazon basin, *H. brasiliensis* was found the most outstanding owing to its high latex yield and superior quality rubber (Anon. 1959). Now-a-days, Malaysia, Indonesia, India, Sri Lanka and Nigeria are the leading rubber growing countries of the world. The concentration of rubber industry in South-east Asia is due to its congenial environmental conditions as well as availability of cheaper labour force (Lim 1985).

In Bangladesh, rubber plantations were first introduced in 1952 by the Forest Department and later extended by Bangladesh Forest Industries Development Corporation (BFIDC) and other private and public bodies. It is now grown in major areas of Chittagong, Chittagong Hill Tracts, Cox'sbazar, Srimangal, Modhupur and Dinajpur under different Rubber Estates of BFIDC, Private Estates, Chittagong Hill Tracts Development Board (CHTDB), Tea Estates and Private Small Holders. Emdad Hossain (2001) mentioned that there are a number of clones being cultivated in Bangladesh some of which are: (i) RRIM-600, 605, 617, 627 & 612, (ii) PB-235 & PB-255, (iii) PR-255 and (iv) GT-1. According to Nandy (1990), the average number of rubber trees planted in the country is about 400-450 per hectare. Unfortunately, Bangladesh has been commercially cultivating the 50-year old RRIM-600 clone of Malaysia. Though this country has developed number of improved clone from RRIM-600 series.

It is evident that both latex and rubber wood are, now-days, the two most important commercial commodities of rubber plants established throughout the world including Bangladesh. But, rubber seed oil (RBSO) did not so far appear into scenario as a non-traditional commodity in this country. According to Islam (2010) there are 37,646 ha of rubber plantations in the country under the Rubber Estates of BFIDC, Private Estates, CHT Development Board, Duncan Brothers, James Finley, Naptune Tea and Private Small Holders where the estimated number of matured rubber trees are 61,64,987. The total quantity of rubber seeds in the country has been estimated to be 7,000 metric tons. It means, only 1.14 kg seeds/tree could be produced from the existing rubber plantations of the country. On the contrary, Mannan (1999) mentioned that about 5-7 kg seeds/tree were found to be produced in the rubber gardens of Bangladesh which shows a big difference with the BFIDC estimates.

Ukhun *et al.* (1988) cited that rubber seed and Rubber Seed Oil (RBSO) are being used for edible purpose in Malaysia and Indonesia as it contains protein, fats and minerals. Rubber seeds of Karnataka, India contain the highest oil content of 44% and the lowest 28% (Jayappa *et al.*); and 45-50% in Bogor, Indonesia (Hardjosuwitu *et al.* 1976). It is also used in manufacturing resins and soaps (Aigbodion 1991). Njoku *et al.* (1996) reported that RBSO has large amounts of C18 fatty acids as well as traces of other fatty acids. So, there is no valid reason to consider it as a non-edible oil.

Rubber seed oil (RBSO) may, therefore, be considered as an important by-product to the rubber growers of Bangladesh as well. It has so far been overlooked and neglected as an unimportant produce. But, with the advancement of technical know-how, it is the time to consider RBSO also as a valuable commodity. Traditionally, rubber seeds had been used only for production of seedlings in the country. The huge seed-lots have been left unutilized and damaged without proper

utilization and fruitful use. The present study was, therefore, undertaken to determine the total oil content of the country, its chemical composition, mineral contents and also to establish a base line information on the rubber seed oil and the commercial prospect of rubber seed-based industry in the country.

Materials and Methods

Out of the 9-10 high yielding clones or varieties of rubber cultivated in Bangladesh, four were used for this study. These are RRIM-600, RRIM-605, PB-255 and GT-1. The seeds were collected from some old plantations of Datmara Rubber Estate, BFIDC, Hyanko, Chittagong during the month of December, 2004. Seed oils were extracted through solvent extraction method using soxhlet apparatus and purified standard method (Laurence and Christopher 1989). Oil contents were then determined. Composition of fatty acids (unsaturated and saturated) was determined through Gas Liquid Chromatography. Protein and mineral (N, P, K, etc.) contents of the de-oiled seed cakes for each clone were also determined.

To estimate the total RBSO in the country and the derived income to be generated from the rubber seed, the production of rubber seed/tree has to be ascertained first. A total of 7,000 metric tons of rubber seeds may be produced in the country from BFIDC rubber garden (Islam 2010). That is, only 1.14 kg seeds/tree may be procured from the existing 37,646 ha of rubber plantations while Mannan (1999) mentioned that about 5-7 kg seeds/tree were found to be produced in the rubber gardens of Bangladesh. These two estimates show a big gap. So, to be in safe side, if an average of 04 kg seeds/tree (which is less than the lowest quantity cited by Mannan) is taken into consideration, the following results will appear.

A. Total number of matured rubber trees: 61,64,987

B. Number of rubber seeds/tree: 4 kg

C. Total quantity of rubber seeds in the country (A x B): 2,46,59,948 kg = 24,660 metric tons.

D. Quantity of rubber seed oil (C x 20%): 4,93,1989 kg = 4,932 metric tons.

E. Value of the total RBSO produced in the country = D x Tk.100/- = Tk. 49,31,98,900/-

= Tk. 49.32 crore.

(Assuming that the price of RBSO is Tk.100/kg compared to soybean @Tk. 130/- and palm oil Tk. 120/- per kg.)

Results and Discussion

The oil contents of the four seed clones of *Hevea brasiliensis* were determined gravimetrically from the oil extracts of the crushed seeds on air-dry basis and found to be 31.4% (RRIM-600), 28.7% (RRIM-605), 32.2% (PB-255) and 44.0% (GT-1) shown in Table-1. ANOVA shows that GT-1 seeds contain the highest amount of oil (44.0%) while RRIM-605 the lowest (28.7%). On the other hand, PB-255 and RRIM-600 contains the second highest oil with no significant difference. It reveals that the average oil contents (28-44%) of the four rubber clones of Bangladesh seem to be reasonable compared to those in India (28-44.2%) and Indonesia (45-50%).

It has been observed and established that the oil contents of the rubber seeds decrease with the increase of storage time after harvest. So, the highest quantity of oil may be obtained if oils are extracted immediate after the harvest in July-August (Mannan 1999). The similar results of India and Bangladesh seem to be reasonable, may be because of near similarity in soil and climate conditions, although the yield of Indonesia is quite higher than these two countries. The oil contents (%) found in the

Table 1. Percent of oil content of rubber seeds of four rubber clones.

Replication	Oil content (%)			
	RRIM-600	RRIM-605	PB-255	GT-1
1	29.7	25.6	33.8	44.9
2	34.3	31.5	30.3	42.8
3	30.2	28.9	32.5	44.2
Mean	31.4	28.7	32.2	44.0
S.E.	1.5	1.7	1.0	0.6
F-ratio (P-value)	32.6*** (7.8E-5)			
LSD-value at 5%	1.9			

Note: SE- Standard Error, F-ratio- Variance ratio, LSD- Least Sig. Difference

present study could be higher (may be nearer to those of Indonesia) if the seeds were collected in July-August instead of December.

The Protein contents (Pearson 1976) of the seed-cakes of the four clones were found to be 39% (RRIM-600), 33% (RRIM-605), 36% (GT-1) and 29% (PB-255) by Macro Kjeldahl Procedure while the Soybean and Cotton seed contain 49% and 22% protein (Duffus and Slaughter 1987). It indicates that the rubber seed-cakes of the four clones have high protein contents and can safely be used as animal feed (Table 2). GLC analysis also shows that the RBSO contains eight fatty acids, viz., Lauric, Myristic, Palmitic, Stearic, Oleic, Linoleic, Linolenic and Arachidic.

It also reveals that all the four clones contain substantial amounts of unsaturated fatty acids (83-89%), i.e., RRIM-600 (88.6%), RRIM-605 (82.9%), GT-1(83%) and PB-255 (84.2%) which are presented in Figure-1. It indicates that RBSO may be edible due to high unsaturated fatty acids but it needs further detailed investigation. It has been proved by a recent study that the unsaturated fatty acids reduce cardiovascular problems.

Figure 1 also shows that RBSO contains 17-22%, of saturated fatty acids which can be used for industrial purposes. It is noteworthy that palmitic and stearic acids are important ingredients for good soaps. Stearic acid in the form of zinc, calcium, and magnesium and aluminium stearate is much used in manufacturing different cosmetics, like bath soaps and talcum powder, etc. Stearine (mixture of palmitic and stearic acids) is used in manufacturing candles, saving soaps and emulsifying agents, etc.

The percentages of six minerals (N, P, K, Na, Ca and Fe) of de-oiled seed-cakes of the four clones found by Quantitative Analysis (Pearson 1976; Allen 1986; Vogel 1971) are

Table 2. Percentage of protein and other constants of de-oiled rubber seed-cake

Parameter	% of rubber seed-cake			
	RRIM-600	RRIM-605	GT-1	PB-255
Moisture content	0.22	0.26	0.29	0.52
Ash content	1.97	1.66	1.78	1.95
Protein	38.99	32.60	35.95	29.11

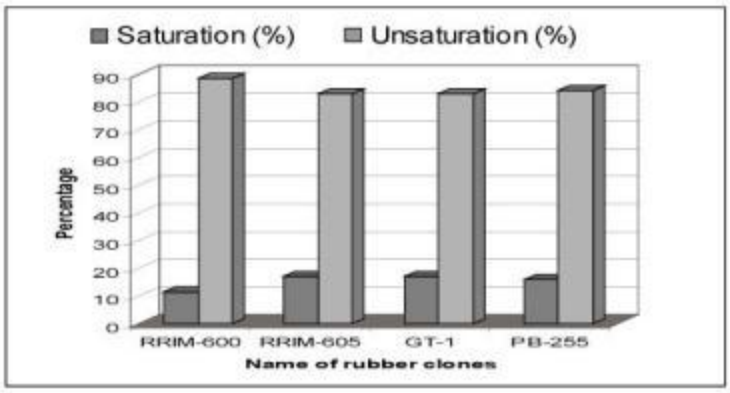

Figure 1. Percentages of saturated and unsaturated fatty acids found in seed oils of four rubber clones.

presented in Table 3. The average N, P & K contents were found to be 4.7-6.2%, 0.26-0.31% and 1.1-1.6% which are comparable to those in ground nut (7.1%, 1.3%, and 1.2%) and cotton seed (3.8%, 1.1% and 1.4%), (Kaul and Das 1986). It is evident that N, P & K are used as fertilizer to the soil. Other three minerals sodium, calcium and iron were found to be 0.38-0.58%, 2.7-3.1% and 0.01-0.02% respectively.

Prospect of Rubber Seed Oil (RBSO) in Bangladesh

Although rubber plantations were started in the nineteen sixties and not a very recent practice in Bangladesh, it has little studies on oil from rubber seed and other diversified uses. Knowing the total acreage of rubber plantations and the seed oil production per unit area, the country can estimate the value of the total produce and can assess its prospect as well. Accordingly, future plans and programmes may be undertaken for necessary seed production and also for proper utilization of the seed oil. It has been reported by Nandy (1990) that depending on the clones and the plantations raised in different dendro-ecological zones, about 400-450-rubber trees/ha were planted in the country. Mannan (1999) reported 5-7

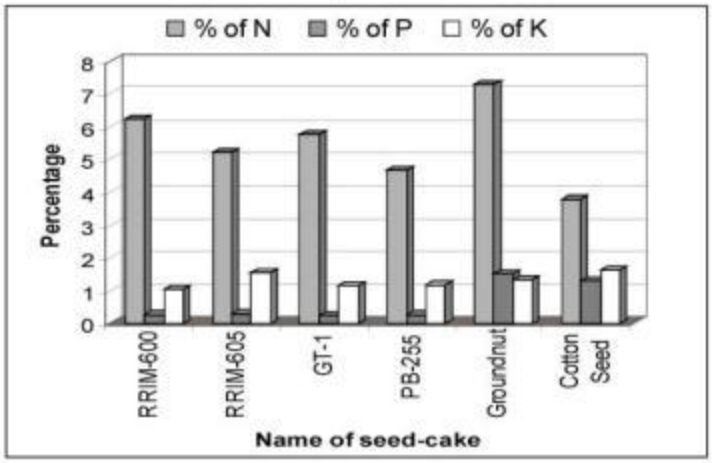

Figure 2. Percentages of N, P & K found in seed cakes of the four clones compared to groundnut and cottonseed.

Table 3. Percentage of different minerals of de-oiled rubber seed-cakes.

Minerals	Four different rubber clones of Bangladesh			
	RRIM-600	RRIM-605	GT-1	PB-255
Nitrogen	6.24	5.22	5.75	4.66
Sodium	0.48	0.39	0.38	0.58
Potassium	1.06	1.57	1.16	1.18
Calcium	2.78	2.66	3.11	2.84
Iron	0.02	0.01	0.01	0.01
Phosphorous	0.27	0.31	0.26	0.27

kg seeds are produced per tree, then about 2,000-3,000kg seeds may be obtained from one hectare of plantation.

About 37,646 hectares of rubber plantations have so far been raised under BFIDC Rubber Estates, CHT Development Board, Duncan Brothers, James Finley, Naptune Tea and Private Small Holders (Islam 2010). If only 25,000 hectares (two-third of the total) are considered mature for seed production, then about 50,000 tons of seeds can be obtained from the existing plantations, assuming an average of 2,000 kg seeds/ha. Then these seeds can produce at least 7,500-10,000 tons of oil, if only 15-20% oil/kg-seed (or 28-44% oil/kg-kernel) are taken into consideration. It shows that at least 40,000 tons of rubber seeds and 8,000 tones of RBSO could be produced per year in the country. This 8,000 tons of RBSO worth of Tk. 80.00 crore (@Tk.100/kg) could save the valuable foreign exchange of Tk.104.00 crore for importing same quantity of soybean oil (@ Tk. 130/- per kg) or palm oil of Tk. 96.00 crore (@ Tk. 120/- per kg).

As per the present study, about 58% of the seeds are the kernels. It means an estimated quantity of 23,200 tones of kernels/year may be produced from the existing plantations. If this entire amount of seed-kernels (or oil-cakes) could be utilized as alternative animal feed, it will be of great benefit. Since the seeds are easily available, the per-unit cost of the feed will substantially be reduced and hence the poultry/animal meat. Moreover, it will save the valuable foreign exchange for importing the essential ingredients of the poultry/animal feed.

Each rubber garden can easily make a separate processing plant/unit within the garden. They can also utilize the existing working force of the gardens with some extra payment. If the workers are allowed to collect and process the seed separately it will also be a source of another income for them. Certainly, this will create new flow of economic activity toward employment generation and poverty alleviation of the country.

Recommendation

It may be recommended that proper initiatives in production, collection and preservation of rubber seed can ensure raw materials supply. Extraction of lipid, utilization of oils for edible purpose, use of seed cakes as animal seed would play a significant role in the national economy of Bangladesh. A further detailed study may be undertaken for quality improvement of seed oil and seed cakes of the product for sustainable management.

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Composition and Diversity of Tree Species in Moulvibazar Natural Forests of Sylhet Forest Division, Bangladesh

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Abstract

The composition and diversity of native tree species of Moulvibazar natural forests of Sylhet Forest Division were investigated. A total of 1,051 individual stems having dbh of ≥ 5 cm were recorded from 1.44 ha sampled area. These comprise 81 native tree species belonging to 59 genera under 33 families. Moraceae and Euphorbiaceae dominated in the study area containing 9 and 8 species respectively followed by Rubiaceae (7), Myrtaceae and Verbenaceae (6 species each). Average species diversity was 3.40 and ranged from 3.21-3.61 in the study area. Species similarity index was highest (69.72%) between Lawachara and Adampur followed by Adampur and Gobindapur (65.4%) and lowest (62.7%) between Lawachara and Gobindpur. Tree density was found 573 stems ha^{-1} in Lawachara, 860 stem ha^{-1} in Adampur (Kalengi) and 756 stems ha^{-1} in Gobindapur. *Artocarpus chama* showed the highest (32.63 m^2) basal area in Lawachara followed by *Lagerstroemia parviflora* (6.98 m^2) and *Chukrasia velutina* (5.74 m^2), but in Adampur maximum basal area showed by *Syzygium firmum* (2.39 m^2) followed by *Artocarpus chama* (2.04 m^2), *Castanopsis tribuloides* (1.24 m^2), while in Gobindapur, meximam basal area recorded for *Elaeocarpus varunna* (1.31m^2) followed by *Artocarpus chama* (1.04 m^2) and *Vitex pubescens* (0.82 m^2). Highest Importance Value Index (IVI) in Lawachara natural forests was 86.92 for *Artocarpus chama* followed by *Lagerstroemia parviflora* (29.53), *Chukrasia velutina* (15.11), but in Adampur *Syzygium firmum* attains the highest IVI (39.92) followed by *Castanopsis tribuloides* (17.62), *Artocarpus chama* (17.46), *Lagerstroemia parviflora* (15.62) and *Elaeocarpus varunna* (15.41), while, in Gobindapur, the highest IVI was recorded for *Elaeocarpus varunna* (22.32) followed by *Vitex pubescens* (15.06) and *Syzygium formosum* (14.71).

সারসংক্ষেপ

সিলেট বন বিভাগের মৌলভীবাজার জেলার প্রাকৃতিক বনের তিনটি স্থানে দেশীয় বৃক্ষ প্রজাতির সংমিশ্রণ ও বৈচিত্র্য অনুসন্ধান করা হয়েছে। মৌলভীবাজার জেলার প্রাকৃতিক বনের ১.৪৪ হেক্টর প্লটে বুক সমান উচ্চতায় ৫ সে.মি. বা এর বেশী ব্যাসের ১,০৫১টি গাছের মধ্যে ৩৩ পরিবার ও ৫৯ গনের অর্ন্তগত ৮১টি দেশীয় প্রজাতির বৃক্ষ পাওয়া যায়। মোরেসি এবং ইউফরবিয়েসি পরিবার যথাক্রমে সর্বোচ্চ ৯টি ও ৮টি, রুবিয়েসি পরিবারে ৭টি, মাইটেসি ও ভারবেনেসি পরিবারে ৬টি করে প্রজাতি পাওয়া যায়। পরীক্ষণ নমুনা এলকায় প্রজাতির বৈচিত্রতা পাওয়া যায় গড়ে ৩.৪০, যাহার বিস্তৃতি ৩.২১-৩.৬১। প্রজাতির সাদৃশ্যতা নির্দেশক মান সর্বোচ্চ পাওয়া যায় লাউয়াছড়া ও আদমপুরের মধ্যে (৬৯.৭২%), এর পরেই রয়েছে আদমপুর ও গোবিন্দপুর (৬৫.৪%) এবং সর্বনিম্ন লাউয়াছড়া এবং গোবিন্দপুর (৬২.৭%) এর মধ্যে। বুক সমান উচ্চতায় ৫ সে.মি. বা তার বেশী ব্যাসের প্রতি হেক্টরে বৃক্ষের সংখ্যা লাওয়াছড়ায় ৫৭৩টি, আদমপুরে ৮৬০টি এবং গৌবিন্দপুরে ৭৫৬টি। পরীক্ষণ নমুনা এলাকার মধ্যে লাওয়াছড়ায় চাপালিশের (*Artocarpus chama*) বেসাল এরিয়া প্রতি হেক্টরে সর্বোচ্চ (৩২.৬৩) বর্গ মি., এর পরেই রয়েছে সিদাজারুল (*Lagerstroemia parviflora*) ৬.৯৮ বর্গ মি. এবং চিকরাশি (*Chukrasia velutina*) ৫.৭৪ বর্গ মি.। আদমপুরে (কালিঞ্জি) ঢাকিজামের (*Syzygium firmum*) বেসাল এরিয়া সর্বোচ্চ ২.৩৯ বর্গ মি., এর পরেই

রয়েছে চাপালিশ (*Artocarpus chama*) ২.০৪ বর্গ মি., খামিবাটনা (*Castanopsis tribuloides*) ১.২৪ বর্গ মি.। অন্যদিকে গৌবিন্দপুরে সর্বোচ্চ বেসাল এরিয়া পাওয়া যায় বন জলপাইয়ে (*Elaeocarpus varunna*) ১.৩১ বর্গ মি., এর পরেই রয়েছে চাপালিশ (*Artocarpus chama*) ১.০৪ বর্গ মি., আউয়াল (*Vitex pubescens*) ০.৮২ বর্গ মিটার। গুরুত্ব নির্দেশক মানে (IVI) লাওয়াছড়ায় চাপালিশ (*Artocarpus chama*) সর্বোচ্চ ৮৬.৯২, এর পরেই রয়েছে সিদাজারুল (*Lagerstroemia parviflora*) ২৯.৫৩, চিকরাশি (*Chukrasia velutina*) ১৫.১১। কিন্তু আদমপুরে ঢাকিজাম (*Syzygium firmum*) সর্বোচ্চ ৩৯.৯২, এর পরেই রয়েছে খামিবাটনা (*Castanopsis tribuloides*) ১৭.৬২, চাপালিশ (*Arotocarpus chama*) ১৭.৪৬, সিদাজারুল (*Lagerstroemia parviflora*) ১৫.৬২ এবং বনজলপাই (*Elaeocarpus varunna*) ১৫.৪১। অন্যদিকে গেবিন্দপুরে গুরুত্ব নির্দেশক মান সর্বোচ্চ পাওয়া যায় বন জলপাইয়ের (*Elaeocarpus varunna*) ২২.৩২, এর পরেই রয়েছে আউয়াল (*Vitex pubescens*) ১৫.০৬ এবং পুতিজাম (*Syzygium formosum*) ১৪.৭১।

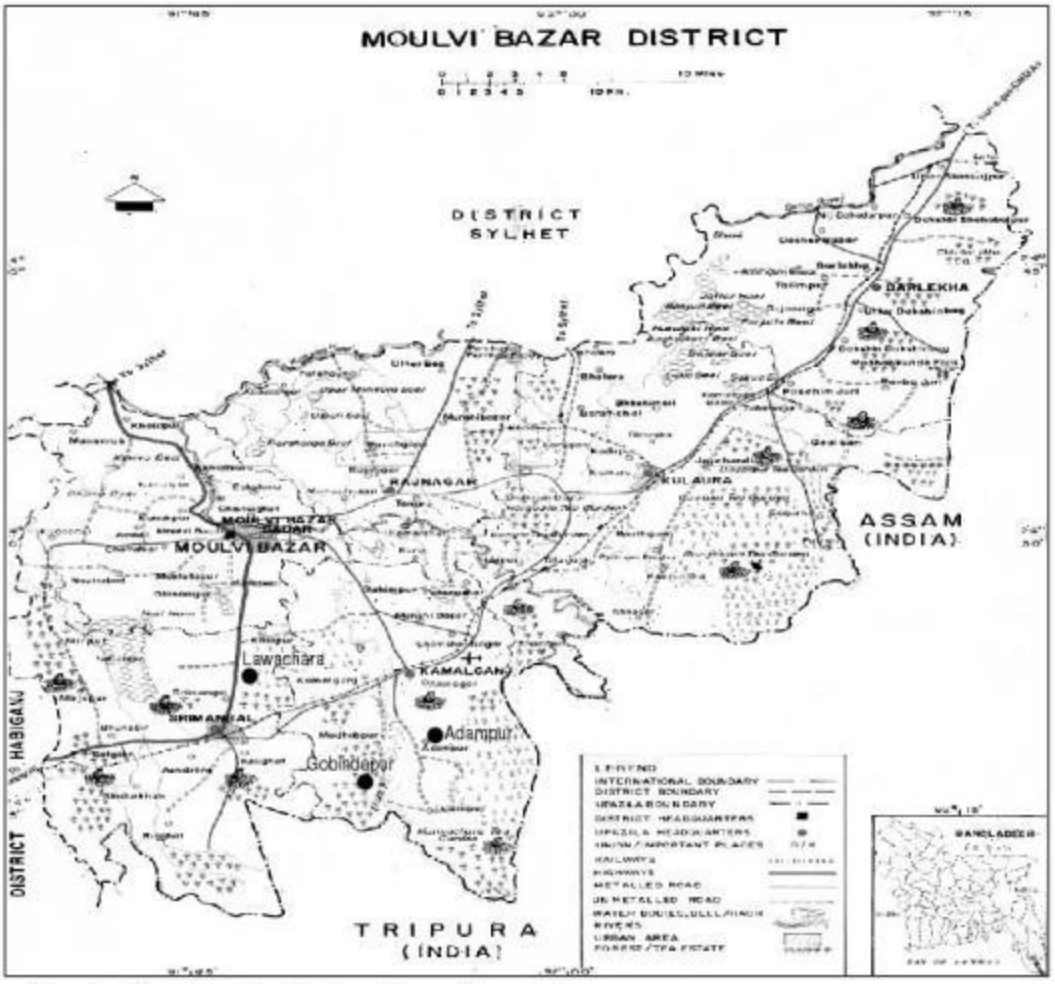
Keywords : Basal area, composition, diversity, importance value index, tree density, natural forests

Introduction

Bangladesh possesses 2.57 million hectares of forest land that covers 17.5 percent of its total land areas (Altrell *et al.* 2007, BBS 2010). Sylhet Forest Division falls under moist tropical evergreen and semi-evergreen forest which is situated in between 23°55' and 25°02' North latitude and between 90°55' and 92°30' East longitude. Sylhet Forest Division has an area of 74,823 ha of forest land which is almost 11.2 percent of total hill forests. It is extended over four districts, namely Sylhet, Sunamgonj, Moulovibazar, and Hobiganj. The division is bounded by the Khasia and Jainta Hills of India on the North; Patharia Hills, Tripura and Assam in the East; the international boundary with Tripura State of India and Brahmanbaria District in the West (Chowdhuri 2006).

Ecologically, these forests constitute a transition between the Indian subcontinent floristic region and the Indo-China floristic region. The inventory of the Sylhet forests was completed in 1988 under FMP Project (FRA 2000) which indicates that closed forest have roughly remained the same at about 2,749 ha in 1988 and 2,782 ha in 1996. However, area under scattered trees has decreased from 23,239 ha in 1988 to 20,911 ha in 1996 and the total volume has gone down to 1.26 million m^3 in 1996. In Sylhet the bamboo (muli) resources have decreased from about 17,000 stems to 11,000 stems ha^{-1} over the last eight to ten years (FRA 2000). Forest resources of Sylhet Forest Division depleted like other parts of the country at an alarming rate due to over exploitation. Rapid loss and degradation of forest resources in the country has created an alarming rate of forest biodiversity depletion (Rahman *et al.* 2000, Hossain 2001). Status of species composition and their distribution and regeneration potentials of a forest are necessary for better management and economic value.

Moulovibazar is the widely hilly district in the country next to the Chittagong Hill Tracts. Moulvibazar natural forests are composed of diverse species composition with rich floristic diversity (Nishat *et al.* 2002). There is no comprehensive base line information about the tree species of Moulvibazar natural forests. Present study is an attempt to assess the species composition and quantitative distribution of indigenous tree species in natural forests of Moulvibazar district under Sylhet Forest Division.



Map 1 : Map showing the locations of the study area

Materials and Methods

The study was conducted in Lawachara, Adampur (Kalengi) and Sree-Gobindapur natural forests of Moulvibazar district (Map 1). Lawachara is under Lawachara National Park (LNP) a well known protected area (1250 ha) of West Banugach reserved Forests of Moulvibazar Range. Adampur (Kalengi) reserve is under Adampur beat (5520 ha) of Rajkandi range, and Sree-Gobindapur was a reserve forests under Moulvibazar range. Sree-Gobindapur reserve was handed over to private ownership in 1980's through lease and now is under the control of Sree-Gobindapur tea estate and gradually converted the forest into tea garden except the remaining of 300 ha forest area. The typical vegetation of the study area is tropical wet semi evergreen type; topography is undulating with slope and hillocks. The hillocks are scattered throughout the forests and generally ranging from 10-20 m in height and rarely exceeds 60-80 m. The soils of the study area are dark brown, sandy clay loam of Pliocene origin (Hossain *et al.* 1989). Rainfall varies from 2400-5400 mm and maximum rainfall occurs during May-September.

The floristic composition of tree species in the study area was enumerated through random sampling method during November 2010 – January 2011. We selected 36 sample plots of 20 m x 20 m and plot size was determined by applying species area curve (Williams 1991). Trees number having dbh ≥5 cm and above (over bark) measured and recorded. Basal area, relative frequency, relative dominance, relative abundance and finally Importance Value Index (IVI) were calculated following Shukla and Chandel (1980). Species similarity and Shannon's index were calculated according to Muller-Dombois and Ellenberg (1974). The collected specimen was identified following Kanjilal *et al*. (1940) and Rahman *et al*. (2000). For authentic identification the collected samples were compared with voucher specimens preserved in the Herbarium of Bangladesh Forest Research Institute, Chittagong and National Herbarium, Dhaka.

Results and Discussion

A total of 81 indigenous tree species were documented having dbh ≥5 cm and above from 1.44 ha sampled area only. These species belongs to 59 genera and 33 families. Species richness was 52 for Lawachara, 57 for Adampur and 50 for Sree-Gobindapur and there was very little difference among the locations (Table 1). The mean density of three locations was 730 stem ha^{-1} and the basal area was 58.04 m^2 ha^{-1}. Mean Shannon's index (H') was 3.40, but it varies in different locations (3.21, 3.37 and 3.61). Simpson's value ranges from 0.03-0.07. Among the locations highest species similarity index was 69.72% between Lawachara and Adampur. The lowest value was 62.7% between Lawachara and Gobindapur (Table 1).

The number of species varies from 1-9 within the family. Moraceae and Euphorbiaceae dominated with 9 and 8 species followed by Rubiaceae (7), Myrtaceae and Verbenaceae (6 species each). One family posses 5 species, 4 families possess 3 species, 5 families with 2 species and the remaining 18 families possesses only 1 species (Table 2).

In the studied area the species richness value was 81 which is almost similar to earlier findings of similar natural forests of Bangladesh. 85 tree species recorded in Bamu reserve forests (Hossain *et al*. 1997) and 85

Table 1. Tree species inventory in three locations (0.48 ha plots/location) of Moulvibazar natural forests.

Description	Lawachara	Adampur	Gobindapur	Total for 1.44 ha/ mean
No. of tree species	52	57	50	81
No. of genera	-	-	-	59
No. of family	-	-	-	33
Density (stems ha^{-1})	573	860	756	1051/730 (mean)
Species diversity	3.21	3.37	3.61	3.40 (mean)
Simpson's index	0.07	0.06	0.03	0.05 (mean)
Basal area(m^2 ha^{-1})	113.58	33.46	27.08	58.04 (mean)
Similarity index				
Lawachara	00	69.72	62.7	
Adampur		00	65.4	
Gobindapur			00	

Table 2. Scientific name, local name and family of tree species collected from three locations of the Moulvibazar natural forests.

Sl. No.	Scientific Name	Local Name (in Bangla)	Family
1.	*Holigarna caustica* (Dennst.) Oken.	Jawa	Anacardiaceae
2	*Lannea coromandelica* (Houtt.) Merr.	Jigabadi	Anacardiaceae
3	*Mangifera sylvatica* Roxb.	Uriam	Anacardiaceae
4	*Polyalthia longifolia* (Sonn.) Thw.	Debdaru	Annonaceae
5	*Alstonia scholaris* (L.) R. Br.	Chatim	Apocynaceae
6	*Ilex godajam* Coleb.	Ludh	Aquifoliaceae
7	*Trevesia palmata* Vis.	Bonpapaya	Araliaceae
8	*Caryota urens* L.	Bonsupari	Arecaceae
9	*Oroxylum indicum* (L.) Vent.	Kanaidinga	Bignoniaceae
10	*Stereospermum colais* (Buch.-Ham ex Dillw) Mabberley	Dharmara	Bignoniaceae
11	*Bombax insigne* Wall.	Bonsimul	Bombacaceae
12	*Protium serratum* (Wall. Ex Colebr.) Engl.	Gutguttya	Burseraceae
13	*Garcinia xanthochymus* Hook. F.	Demgola	Clausiaceae
14	*G. cowa* Roxb.	Kao	Clausiaceae
15	*Terminalia catappa* L.	Katbadam	Combretaceae
16	*T. chebula* (Gaertn.) Retz.	Haritaki	Combretaceae
17	*T. bellirica* (Gaertn.) Roxb.	Bahera	Combretaceae
18	*Dillenia pentagyna* Roxb.	Hargaja	Dilleniaceae
19	*Dipterocarpus turbinatus* Gaertn.	Teligarjan	Dipterocarpaceae
20	*Elaeocarpus varunna* Ham.	Bonjalpai	Elaeocarpaceae
21	*Aporosa dioica* (Roxb.) Muell.Arg.	Kakra	Euphorbiaceae
22	*Baccaurea ramiflora* Lour.	Lotkon	Euphorbiaceae
23	*Mallotus albus* Muell. Arg.	Banmali	Euphorbiaceae
24	*M. philippensis* Muell. Arg.	Kamila	Euphorbiaceae
25	*Macaranga denticulata* (Bl.) Muell. Arg.	Bongulli	Euphorbiaceae
26	*Phyllanthus emblica* L.	Amloki	Euphorbiaceae
27	*Sapium baccatum* Roxb.	Bolos	Euphorbiaceae
28	*Trewia nudiflora* L.	Pitali	Euphorbiaceae
29	*Castanopsis lancifolia* (Kurz) Hickel & A. Camus	Jatbatna	Fagaceae
30	*C. tribuloides* A.DC.	Khamibatna	Fagaceae
31	*C. indica* (Roxb.) A.DC.	Silbatna	Fagaceae
32	*Cinnamomum cecidodaphne* Meissn.	Tezbohal	Lauraceae
33	*Litsea monopetala* (Roxb.) Pers.	Kukurchita	Lauraceae
34	*L. glutinosa* (Lour) C. B. Rob.	Menda	Lauraceae
35	*Careya arborea* Roxb.	Kumbi	Lecythidaceae
36	*Lagerstroemia parviflora* Roxb.	Sidajarul	Lythraceae
37	*L. speciosa* (L.) Pers.	Jarul	Lythraceae
38	*Amoora wallichii* King	Lalipitraj	Meliaceae
39	*Aphanamixis polystachya* (Wall.) Parker	Pitraj	Meliaceae
40	*Chukrasia velutina* W & A	Chickrassi	Meliaceae

Sl. No.	Scientific Name	Local Name (in Bangla)	Family
41	*Dysoxylum binectariferum* Hook. F. Ex Bedd.	Bararata	Meliaceae
42	*Toona ciliata* M. J. Roem	Toon	Meliaceae
43	*Albizia procera* (Roxb.) Benth.	Sadakoroi	Mimosaceae
44	*Xylia kerrii* Craib & Hutch (planted)	Lohakat	Mimosaceae
45	*Artocarpus heterophyllus* Lamk.	Kanthal	Moraceae
46	*A. lacucha* Buch.-Ham.	Borta	Moraceae
47	*A. chama* Hamilton	Chapalish	Moraceae
48	*Ficus clavata* Wallich	Panidumur	Moraceae
49	*F. hispida* L.	Kakdumur	Moraceae
50	*F. lepidosa* Wallich	Putidumur	Moraceae
51	*F. racemosa* L.	Jogdumur	Moraceae
52	*F. auriculata* Lour.	Laldumur	Moraceae
53	*Streblus asper* Lour.	Herba	Moraceae
54	*Ardisia khasiana* Clarke var. thomsoni Clarke	Bonkola	Myrsinaceae
55	*Syzygium cumini* (L.) Skeel	Kalojam	Myrtaceae
56	*S. fruticosum* (Roxb.) DC.	Putijam	Myrtaceae
57	*S. firmum* Thw.	Dhakijam	Myrtaceae
58	*S. macrocarpum* (Roxb.) Balak.	Bonjam	Myrtaceae
59	*S. syzygoides* (Miq.) Merr. & Parry.	Khudijam	Myrtaceae
60	*S. formosum* (Wall.) Masamune	Pannyajam	Myrtaceae
61	*Xanthophyllum flavescens* Roxb.	Gandi	Polygalaceae
62	*Neolamarckia cadamba* (Roxb.) Bosser	Kadam	Rubiaceae
63	*Gardenia coronaria* Ham.	Kannyari	Rubiaceae
64	*Hymenodictyon orixensis* (Roxb.) Mabberley	Bhui kadam	Rubiaceae
65	*Mitragyna rotundifolia* (Roxb.) O.Ktze.	Bonchampa	Rubiaceae
66	*M. parviflora* (Roxb.) Korth.	Dakrom	Rubiaceae
67	*Randia dumetorum* Lamk.	Monkanta	Rubiaceae
68	*Wendlandia glabrata* DC.	Parba	Rubiaceae
69	*Acronychia pedunculata* (L.) Miq.	Bonjamir	Rutaceae
70	*Sterculia. foetida* L.	Jorabadam	Sterculiaceae
71	*Eurya acuminata* DC.	Jharu	Ternstroemiaceae
72	*Schima wallichii* (DC.) Korth.	Kanak	Ternstroemiaceae
73	*Microcos paniculata* L. *ex* W&A	Assar	Tiliaceae
74	*Trema orientalis* (L.) Bl.	Bonpatua/Jigni	Ulmaceae
75	*Villebrunea integrifolia* Gaud.	Bonria	Urticaceae
76	*Callicarpa macrophylla* Vahl.	Bongamar	Verbenaceae
77	*C. tomentosa* (L.) Murr.	Barmala	Verbenaceae
78	*Gmelina arborea* Roxb.	Gamar	Verbenaceae
79	*Tectona grandis* L.	Shegun	Verbenaceae
80	*Vitex pubescens* Vahl.	Awal	Verbenaceae
81	*V. peduncularis* Wallich	Horinagoda	Verbenaceae

tree species in Sitapahar reserve forest of Chittagong Hill Tracts (Nath *et al.* 1998). Rahman and Hossain (2002) reported 77 tree species in Baraitali reserve forest of Chittagong (South) Forest Division and 73 tree species in Satchari reserve forest of Hobigonj by Arefin *et al.* (2011). Species diversity of the present study ranged from 3.21–3.61 which is similar to Nath *et al.* (2000) in Sitapahar Reserve Forests of Chittagong South Forest Division (2.63-3.64). Knight (1975) reported higher value 5.06-5.40 for tropical forest and Reddy *et al.* (2011) reported 5.68 in Eastern Ghats of Andra Pradesh. It is mentionable that structural complexity, climatic condition and human interference affect the diversity and richness of natural forests (Diamond 1988). Present findings also indicate the decrease of species diversity may be due to biotic interference in the study area.

Basal area is used to determine the forest stand density and dominance. It is also important for forest management plan. The basal area of sampled trees of the three locations is given in Table 3. The total basal area was 54.52 m^2 for 0.48 ha in Lawachara. The highest basal area recorded for *Artocarpus chama* 32.63 m^2 followed by *Lagerstroemia parviflora* (6.98 m^2), *Chukrassia velutina* (5.74 m^2), and *Castanopsis tribuloides* (1.47 m^2). These four species together represents about 85.88% of the total basal area of Lawachara. In Adampur, the basal area for all trees was 16.06 m^2. Maximum basal area recorded for *Syzygium firmum* 2.39 m^2 followed by *A. chama* (2.04 m^2), *C. tribuloides* (1.24 m^2) and *Elaeocarpus varunna* (1.15 m^2). These four species represents about 42.47 % of the total basal area of Adampur. In Gobindapur, total basal area for all trees was 13.00 m^2 where maximum basal area was recorded for *E. varunna* (1.31 m^2) followed by *A. chama* (1.04 m^2), *Vitex pubescens* (0.82 m^2) and *Bombax insigne* (0.65 m^2). Rahman *et al.* (2000) also found total basal area for all species with ≥ 10 cm dbh was 33.77m^2 ha^{-1} in Chunati Wildlife Sanctuary of Chittagong (South) Forest Division. Nath *et al.* (1998) recorded 53.5 m^2 ha^{-1} basal area in Sitapahar forest reserve of CHTs (South) Forest Division. Sha (1990) recorded basal area 30.87 m^2 ha^{-1} in a tropical rain forest of Western Ghats, India. Ferreira and Rankin-de-Merona (1998) reported the total basal area of 25.4 m^2 ha^{-1} in Terra Firme Forest in Central Amazonia. Lawachara natural forest showed higher basal area (54.52 m^2) in comparison to the above mentioned study sites. It may be due to presence of some old large trees of *A. chama, L. parviflora* and *C. velutina* in the area.

Importance Value Index (IVI) indicates the ecological dominance of a species in the natural forest community and IVI of tree species in the study area were given in Table 3. In Lawachara, highest IVI was 86.92 for *A. chama* followed by *L. parviflora (29.53), C. velutina* (15.11), *Macaranga denticulata* (13.64), *Trevesia palmata* (12.62), *Callicarpa macrophylla* (10.14) and *Castanopsis indica* (7.44). But, in Adampur, *S. firmum* attains the highest IVI of 39.92 followed by *C. tribuloides* (17.62), *A. chama* (17.46), *L. parviflora* (15.62), *E. varunna* (15.41), *Tectona grandis* (14.05) and *Dipterocarpus turbinatus* (11.49). In Gobindapur, the highest IVI was recorded for *E. varunna* (22.32) followed by *V. pubescens* (15.06), *S. fruticosum* (14.71), *Ficus racemosa* (13.20), *A. chama* (12.81), *Garcinia cowa* (11.34), and *S. firmum* (10.61). It is evident that in Lawachara *A. chama* and *L. parviflora* are the dominant and co-dominant species respectively. In Adampur, *S. firmum* is the dominant species followed by *C. tribuloides, A. chama, L. parviflora* and *E. varunna* are the co-dominant species. While in Gobindapur, *E. varunna* is the dominant species followed by *V. pubescens; S. fruticosum, F. racemosa* and *A. chama* are co-dominant species. The findings uphold the statement that the IVI

indicates the ecological dominancy of species in a heterogeneous plant community (Shukla and Chandel 1980). Species with high IVI values are considered comparatively more important than those with low IVI value. The IVI value can also be utilized to prioritize species for conservation, and species with comparatively high IVI value need less conservation efforts, whereas, those having comparatively low IVI need high conservation effort (Shibru 2002). The results suggest that the species having comparatively low IVI value should be prioritize for conservation programs.

Tree density of the study area is also presented in Table 3. In Lawachara, tree density was 573 stems ha^{-1}. Highest density was recorded for *A. chama* (113), followed by *L. parviflora* (69), *T. palmata* (44) and *M. denticulata* (42). In Adampur (Kalengi), individual tree stems was recorded 860 ha^{-1} and maximum recorded for *S. firmum* (154), followed by *L. parviflora* (81), *T. grandis* (52), *D. turbinatus* (50). In Gobindapur, individual tree stems was 756 ha^{-1} and *E. varunna* (58) showed the highest, followed by *F. racemosa* (48), *S. fruticosum* (44), and *V. pubescens* (35).

The mean stand density in three locations of Moulvibazar natural forests was 730 stem ha^{-1} and it varies from 573-860 stem ha^{-1}. Nath *et al.* (1998) reported 381 stems ha^{-1} in 2.0 ha sample area of Sitapahar Reserve Forest in Chittagong Hill Tracts. Rahman *et al.* (2000) reported average density of

Table 3. Number of stems, Importance Value Index (IVI) and Basal Area (BA) of tree species in Lawachara, Adampur and Gobindapur natural forests (0.48 ha sampled area in each location).

SL No.	Scientific Name	No. of Stems			Importance Value Index (%)			Basal Area (m^2)		
		Law.	Adm.	Gob.	Law.	Adm.	Gob.	Law.	Adm.	Gob.
1	*Artocarpus chama*	54	10	10	86.92	17.46	12.81	32.63	2.04	1.04
2	*Lagerstroemia parviflora*	33	39	1	29.53	15.62	0.87	6.98	0.61	0.02
3	*Trevesia palmata*	21	6	1	12.62	4.06	0.74	0.14	0.04	0.01
4	*Castanopsis indica*	8	8	3	7.44	6.96	2.44	0.63	0.52	0.05
5	*Aphanamixis polystachya*	7	5	11	6.66	3.46	7.15	0.03	0.17	0.32
6	*Castanopsis tribuloides*	6	19	1	6.49	17.62	1.13	0.87	1.24	0.06
7	*Elaeocarpus varunna*	6	17	28	6.47	15.41	22.32	0.86	1.15	1.31
8	*Sterculia foetida*	6	10	3	4.97	6.79	2.21	0.05	0.23	0.02
9	*Syzygium macrocarpum*	6	9	10	6.7	8.29	8.13	0.62	0.51	0.38
10	*Vitex pubescens*	4	3	17	6.18	2.37	15.06	1.47	0.07	0.82
11	*Toona ciliata*	4	2	8	3.51	1.82	8.34	0.02	0.02	0.42
12	*Syzygium firmum*	3	74	12	3.14	39.92	10.61	0.01	2.39	0.63
13	*Garcinia cowa*	3	12	15	3.16	5.76	11.34	0.02	0.08	0.46
14	*Holigarna caustica*	3	8	9	2.48	5.88	7.79	0.02	0.25	0.37
15	*Stereospermum colais*	3	3	9	3.42	1.36	7.97	0.16	0.01	0.45
16	*Ficus clavata*	2	8	14	2.09	3.64	9.57	0.01	0.08	0.16
17	*Litsea glutinosa*	2	5	9	2.12	3.05	6.09	0.02	0.11	0.15

SL No.	Scientific Name	No. of Stems			Importance Value Index (%)			Basal Area (m^2)		
		Law.	Adm.	Gob.	Law.	Adm.	Gob.	Law.	Adm.	Gob.
18	*Garcinia xanthochymus*	2	4	2	2.10	4.10	2.33	0.01	0.22	0.13
19	*Ficus racemosa*	1	13	23	1.06	9.00	13.20	0.01	0.18	0.25
20	*Schima wallichii*	1	4	5	1.41	3.35	5.88	0.20	0.19	0.32
21	*Ficus hispida*	1	2	14	1.06	1.63	9.56	0.01	0.09	0.26
22	*Microcos paniculata*	1	2	10	1.05	1.37	6.65	0.01	0.05	0.13
23	*Syzygium cumini*	1	1	2	1.07	1.06	2.56	0.01	0.04	0.16
24	*Mallotus albus*	3	1	3	3.17	0.85	3.03	0.03	-	0.13
25	*Eurya acuminata*	1	5	11	1.05	4.05	7.61	-	0.08	0.17
26	*Syzygium formosum*	1	2	21	1.05	1.19	14.71	-	0.02	0.57
27	*Dysoxylum binectariferum*	1	1	2	1.05	0.85	1.84	-	-	0.06
28	*Syzygium fruticosum*	8	7	-	7.32	5.51	-	0.19	0.23	-
29	*Terminalia catappa*	7	1	-	5.2	1.55	-	0.34	0.11	-
30	*Aporosa dioica*	6	12	-	5.65	8.75	-	0.05	0.18	-
31	*Acronychia pedunculata*	4	4	-	4.21	2.98	-	0.03	0.04	-
32	*Neolamarckia cadamba*	4	2	-	5.3	3.38	-	1.36	0.28	-
33	*Dillenia pentagyna*	3	3	-	3.15	3.85	-	0.02	0.22	-
34	*Gmelina arborea*	3	1	-	3.09	1.15	-	0.72	0.05	-
35	*Dipterocarpus turbinatus*	2	24	-	2.1	11.49	-	0.01	0.63	-
36	*Castanopsis lancifolia*	2	3	-	2.11	2.44	-	0.02	0.09	-
37	*Lagerstroemia speciosa*	1	3	-	1.22	2.06	-	0.1	0.02	-
38	*Baccaurea ramiflora*	1	2	-	1.06	1.70	-	0.01	0.01	-
39	*Lannea coromandelica*	1	-	11	1.06	-	9.28	0.01	-	0.33
40	*Mitragyna parvifolia*	1	-	7	1.72	-	5.56	0.37	-	0.21
41	*Litsea monopetala*	1	-	5	1.06	-	3.98	0.01	-	0.07
42	*Randia dumetorum*	1	-	2	1.11	-	1.10	0.04	-	0.02
43	*Callicarpa macrophylla*	-	12	7	-	8.18	6.96	-	0.28	0.33
44	*Sapium baccatum*	-	8	3	-	9.85	2.78	-	0.99	0.09
45	*Artocarpus lacucha*	-	3	9	-	3.57	8.18	-	0.17	0.42
46	*Acronychia pedunculata*	-	3	4	-	2.64	2.86	-	0.02	0.02
47	*Mitragyna rotundifolia*	-	1	7	-	1.35	6.74	-	0.08	0.41
48	*Ilex godajam*	-	1	3	-	1.81	2.90	-	0.16	0.16
49	*Ardisia khasiana*	-	1	1	-	1.02	1.23	-	0.03	0.07
50	*Pterospermum acerifolium*	1		9	1.05		8.16	-		0.42
51	*Alstonia scholaris*	-	1	2	-	0.86	2.61	-	-	0.16

SL No.	Scientific Name	No. of Stems			Importance Value Index (%)			Basal Area (m^2)		
		Law.	Adm.	Gob.	Law.	Adm.	Gob.	Law.	Adm.	Gob.
52	*Macaranga denticulata*	20	-	-	13.64	-	-	0.16	-	-
53	*Caryota urens*	11	-	-	10.17	-	-	0.42	-	-
54	*Chukrasia velutina*	7	-	-	15.11	-	-	5.74	-	-
55	*Trewia nudiflora*	2	-	-	1.46	-	-	0.03	-	-
56	*Ficus lepidosa*	1	-	-	1.05	-	-	0.01	-	-
57	*Streblus asper*	1	-	-	1.05	-	-	0.01	-	-
58	*Amoora wallichii*	1	-	-	1.05	-	-	0.01	-	-
59	*Tectona grandis*	-	25	-	-	14.05	-	-	0.43	-
60	*Protium serratum*	-	5	-	-	2.83	-	-	0.07	-
61	*Amoora wallichii*	-	4	-	-	4.70	-	-	0.31	-
62	*Litsea monopetala*	-	4	-	-	2.56	-	-	0.07	-
63	*Cinnamomum cecidodaphne*	-	2	-	-	1.27	-	-	0.03	-
64	*Gardenia coronaria*	-	2	-	-	1.72	-	-	0.01	-
65	*Vitex peduncularis*	-	2	-	-	1.15	-	-	0.01	-
66	*Albizia procera*	-	1	-	-	1.92	-	-	0.17	-
67	*Syzygium syzygoides*	-	1	-	-	7.05	-	-	1.00	-
68	*Bombax insigne*	-	-	8	-	-	9.24	-	-	0.65
69	*Artocarpus heterophyllus*	-	-	6	-	-	4.54	-	-	0.11
70	*Ficus auriculata*	-	-	6	-	-	5.45	-	-	0.17
71	*Hymenodictyon orixensis*	-	-	5	-	-	3.55	-	-	0.07
72	*Careya arborea*	-	-	3	-	-	2.86	-	-	0.10
73	*Oroxylum indicum*	-	-	3	-	-	2.42	-	-	0.05
74	*Mallotus philippensis*	-	-	2	-	-	2.69	-	-	0.17
75	*Phyllanthus emblica*	-	-	2	-	-	1.72	-	-	0.05
76	*T. bellirica*	-	-	2	-	-	1.73	-	-	0.05
77	*Xanthophyllum flavescens*	-	-	2	-	-	1.51	-	-	0.02
78	*Polyalthia longifolia*	1	-	-	1.05	-	-	-	-	-
79	*Xylia kerrii*	1	-	-	1.05	-	-	-	-	-
80	*Callicarpa tomentosa*		1	-		0.86	-	-	-	-
81	*Villebrunea integrifolia*		1	-		0.85	-	-	-	-
	Total	**275**	**413**	**363**	**300**	**300**	**300**	**54.52**	**16.06**	**13.00**
	No. of stems/ ha	**563**	**860**	**756**						

Law. = Lawachara, Adm. = Adampur and Gob. = Gobindapur

individual stems of dbh ≥10 in Chunati Wildlife Sanctuary was 459 ha^{-1}. Horkar and Totey (2001) reported density of trees varies 730-915 ha^{-1} in Navegoan National Park of India. Low stand density was observed in Costa Rica from 448-617 stems ha^{-1} (Heaney and Proctor 1990), in Brazil from 420-777 stem ha^{-1} (Campbell *et al*. 1992), and in Malaysia 200-500 stem ha^{-1} (Primack and Hall 1992). The present findings indicate that natural forests of Moulvibazar have higher density (573-860) of stems ha^{-1}.

Conclusion

Natural forests of Moulvibazar districts are heterogeneous in composition and diversity. Information on occurrence and composition of trees species in this forest is inadequate. The present findings provide valuable information on tree species distribution and their relative dominance which will helpful for the future conservation and management plan of that area.

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Strength Properties and Dimensional Stability of Particleboard made from Furniture Wastage

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Abstract

An experiment was conducted to find out the strength properties and dimensional stability of particleboard using waste wood and planer shavings collected from Bangladesh Forest Industries Development Corporation (BFIDC). Waste wood were converted into chips. Particleboards were fabricated at five different ratios of wood chips and planer shaving such as 100:0, 75:25, 50:50, 25:75, and 0:100. Results show that particleboards made from 100% planer shavings have good static bending properties (143 kg/cm^2) and excellent tensile strength (13 kg/cm^2). Both the values satisfy the Indian and British standard. The percentage of thickness swelling and water absorption were measured after 2 and 24 hours soaking in water. Lowest thickness swelling and water absorption were found in the board made of 100% planer shavings. Particleboards made from 75% and 50% planer shavings also satisfy the Indian standard. It is concluded that planer shavings from different wood based industries can be used for making conventional particleboard of high strength properties.

সারসংক্ষেপ

বাংলাদেশ বন শিল্প উন্নয়ন কর্পোরেশন (বি এফ আই ডি সি) হতে সংগৃহীত ফেলনা কাঠ ও রাঁন্দার পাতলা ফালি ব্যবহার করে পার্টিকেল বোর্ড তৈরির উপযুক্ততা যাচাইয়ের পরীক্ষা চালানো হয়। ফেলনা কাঠগুলোকে কুঁচিতে রূপান্তরিত করা হয়। কাঠের কুঁচি বা রাঁদার পাতলা ফালি দিয়ে পাঁচটি বিভিন্ন অনুপাতের পার্টিকেল বোর্ড তৈরী করা হয়। অনুপাতগুলো হল ১০০ঃ০, ৭৫ঃ২৫ ৫০ঃ৫০, ২৫ঃ৭৫ এবং ০ঃ১০০। ফলাফল বিশ্লেষনে দেখা যায় যে, ১০০% রাঁদার পাতলা ফালি দিয়ে তৈরীকৃত পার্টিকেল বোর্ডের static bending (143 kg/cm^2) এর মান ভাল এবং আভ্যন্তরীন বন্ধন শক্তির (13 kg/cm^2) মান উত্তম। উক্ত উভয় শক্তির মানই ইন্ডিয়ান ও বৃটিশ স্টান্ডার্ড এর শর্ত পুরন করে। সব ধরনের বোর্ড ২ ও ২৪ ঘন্টা ব্যাপি পানিতে চুবিয়ে শতকরা পুরুত্বের স্ফিতি ও পানি শোষন পরিমাপ নির্ণয় করা হয়। ১০০% রাঁন্দার পাতলা ফালি দিয়ে তৈরী কৃত বোর্ডে সবচেয়ে কম পুরুত্ব স্ফিতি এবং পানি শোষন পাওয়া যায়। ৭৫% ও ৫০% রাঁন্দার পাতলা ফালি দিয়ে তৈরীকৃত পার্টিকেল বোর্ডের শক্তিকৃত মান ইন্ডিয়ান স্টান্ডার্ড এর সমমান। অতএব, বিভিন্ন কাঠ ভিত্তিক শিল্প প্রতিষ্ঠান হতে প্রাপ্ত রাঁন্দার পাতলা ফালি ব্যবহার করে উল্লেখযোগ্য শক্তি সম্পন্ন প্রচলিত পার্টিকেল বোর্ড তৈরি করা যায়।

Keywords: Internal bond strength, modulus of rupture, planer shavings, thickness swelling, urea formaldehyde glue, water absorption

Introduction

Bangladesh has only 17% forest areas which are very limited compared to its demand (BSS 2011). It is therefore imperative to develop and maintain effective economical basis of utilization of forest resources especially wood and wood products. A large

amount of wood conversion is done everyday in 4,800 sawmills and wood based industries located in the different parts of the country. It has been estimated that these sawmills produce about 3.34 million tons of wood waste per year during conversion of log wood (Islam *et al*. 2004). The authors noted that sawmilling residues amount to about 40.5% of the total consumption of logs in sawmills in which edging/trimmings are 20.75%. These furniture wastage are found in different size. During processing, saw dust and planer shavings come out as wastage. Much of these waste products create problems, but efficient use of these can solve the disposal difficulties. Effective utilization of sawmill residue and wastage can lessen the problem and at the same time add to the economy of the country.

Five species namely civit (*Swintonia floribunda*), garjan (*Dipterocarpus* sp.) chapalish (*Artocarpus chaplasha*), narikeli (*Pterigota alata*) and pitali (*Trewia nudiflora*) are widely used for making particleboard in Bangladesh (Anon. 1981). Most particleboard industries use wastage of green and clipping of veneer, defaulted match sticks and round wood left after peeling veneer. But they do not use wastage of furniture industries and sawmill residue as these are of different size of shapes. Size and shape of the wood particles influence the processes and final board products (Moslemi 1974). Admixture of small particle with larger particles results in panel imbalance and thus causing strength reduction. Fine particles absorb high amount of resin for equivalent board. Oversize particles, when placed on the surface layer, produce rough surfaces. Thus uniformity of chips size is important for production of good quality board (Maloney 1977). Therefore an experiment was conducted to find out the strength properties and dimensional stability of particleboards made from furniture wastage.

Materials and Methods

Furniture wastage and planer shavings were collected from the furniture unit of Bangladesh Forest Industries Development Corporation. Garjan (*Diptrerocarpus* sp.) waste comprised 80% and the rest were teak (*Tectona grandis*) and telsur (*Hopea odorata*). The specific gravity of garjan, teak and telsur are 0.71, 0.61 and 0.64 respectively (Sattar *et al*. 1999).

The waste woods were cut into small pieces. These were hammer milled to chips using screen of 0.63 cm diameter. The chips were then sieved through 20 mesh screen to remove dust and fines. The length and thickness of chips were larger than those of planer shavings. The planer shavings were wider than the chips. The chips and planer shavings were dried in the batch oven at 70°C temperatures to 4–5% moisture content.

Fifteen single layer particleboards were prepared using the screened chips and planer shavings in the laboratory hot press. Dimension of the particleboards were 50 cm x 50 cm x 1.25 cm having a target density of 750 kg/m^3. The temperature of the platens of the hot press was maintained at 140°C. Particles of different sizes were mixed in five different ratios of wood chips and planer shaving such as 0:100, 25:75, 50:50, 75:25, and 100:0. Liquid urea formaldehyde glue having 10% solid content based on oven dry chips was used. The glue was catalyzed with 2% hardener (ammonium chloride). The mats of the board were formed manually in wooden fabricated bordered frame. The formed mats of the particleboard were pressed initially at 35 kg/cm^2 for 6 minutes. The pressure were then lowered firstly to 10.5 kg/cm^2 for 4 minutes and then 3.5 kg/cm^2 for 2 minutes and then conditioned at 65±5% relative humidity and 20±2°C temperature.

The prepared particleboards were cut into tests specimens. The static bending tests

(modulus of rupture in bending) and the tensile strength perpendicular to the surface were carried out as per IS:2380 (Anon. 1977). Thickness swelling and water absorption due to general absorption of water were done. Three specimens of size 100 mm x 100 mm were taken from each board. The thickness of the specimens was measured with the platform type thickness gauze with an accuracy of 0.01 mm and immersed in 25 mm depth of cold water at room temperature. At the end of 2 and 24 hours, the test specimens were withdrawn from water, wiped with a damp cloth, reweighed and remeasured the thickness as before. The percentage of water absorption and thickness swelling were then calculated.

Results and Discussion

Static bending and tensile strength

Results of modulus of rupture in static bending and the tensile strength perpendicular to face (IB) are presented in Table 1. The values are compared with Indian Standard IS:3087 (Anon. 1985), German Standard. Din:68761 (Verkor and Ledune 1975) and British Standard BS 5669 (Anon. 1979). It was found that the values of modulus of rupture of particle board are different for different ratios of chips and planer shavings. Particle board containing 100% planer shavings have the highest values of modulus of rupture than all other boards. The value is 143 kg/cm^2 which satisfies the Indian standard (112 kg/cm^2) and British standard (140 kg/cm^2).

High density woods are difficult to bond due to thicker cell wall, less lumen volume and higher percentage of resinous material which result less penetration of adhesive at the time of board making. In the present study, the particleboard made from only wood chips shows low modulus of rupture value compared to the standard values. This poor bonding might be due to resinous material present in the wood and low press pressure required for high density wood. Scientist pointed out that much greater pressure is required for high density wood to bring contact between wood surface and adhesive (Vick and Rowell 1990).

Table 1. Static bending strength and tensile strength of particleboard

Type of particleboard	Composition (%)		Modulus of rupture (MOR) (kg/cm^2)	Internal bond strength (IB) (kg/cm^2)
	Wood Chips	Planer Shavings		
Single layer	100	0	68	10
Single layer mixed	75	25	108	12
Single layer mixed	50	50	130	11
Single layer mixed	25	75	128	13
Single layer	0	100	143	13
IS : 3087	-	-	112	8
German Standard Din 68761	-	-	180	3.50
BS : 5669	-	-	140	3.47

The values of internal bond strength of different types of particle board are different for different ratios of chips and planer shavings. The particleboard containing 100% and 75% planer shavings shows maximum values (13 kg/cm^2) and these are higher than the standards (Anon. 1985, 1979; Verkor and Ledune 1975).

Thickness swelling and water absorption

The values of thickness swelling after 2 and 24 hours are shown in Table 2. The observed thickness swellings of the different types of boards were 5-12% after 2 hours soaking and 10-31% after 24 hours soaking. It was found that the thickness swelling of the three types of board containg 50, 75 and 100% wood chips were 11, 10 and 12% thickness swelling respectively after 2 hours soaking. These values however, do not satisfy the value specified in both Indian and German standard. The thickness swelling of the boards made of 100 and 75% planer shavings were 5 and 6% respectively after 2 hours soaking. The values satisfy in Indian and German standards. Kollman *et al.* (1975) also reported that the highest thickness swelling after two hours immersion in water should not exceed 6-10% of the original thickness.

The extent of water absorption after 2 and 24 hours soaking are given in Table 2. The observed water absorption of the different types of board was 6-17% after 2 hours soaking and 16-35% after 24 hours soaking. It was found that the water absorption after 2 and 24 hours of boards made from wood chips and planer shavings alone and in mixture satisfy the value specified in Indian standard.

Conclusion

The strength properties and the dimensional stability of particleboard made from planer shavings are found suitable and can be used as furniture components and other purposes. The increase of wood chips in mixture decreases the strength properties

Table 2. Thickness swelling and water absorption of particleboard made from furniture wastage

Type of particleboard	Composition (%)		Thickness swelling (%)		Water absorption (%)	
	Wood chips	Planner Shaving	2 hrs	24 hrs	2 hrs	24 hrs
Single layer	100	0	12	31	17	35
Single layer (mixed)	75	25	10	23	13	32
Single layer (mixed)	50	50	11	18	14	29
Single layer (mixed)	25	75	6	13	9	27
Single layer	0	100	5	10	6	16
IS : 3087			10	-	25	50
German Standard Din 68761	-	-	max -6	-	-	-
BS : 5669	-	-	2 (1hr, soaking)	-	-	-

of the board. The tensile strength perpendicular to surface was high which indicated stronger bonding for all types of board. The water absorption satisfies the different standards but the percentage of thickness swelling of some boards are high. Addition of wax emulsion with urea formaldehyde glue may improve the thickness swelling properties of the particleboards.

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Carbon Stock in 18-year old *Acacia auriculiformis* Cunn., *Anthocephalus chinensis* Lamk. and *Tectona grandis* L. of Tankawati Forest Area in Chittagong, Bangladesh

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Abstract

The aim of the study was to estimate carbon stock of 18-year old three plantations species namely *Acacia auriculiformis* Cunn., *Anthocephalus chinensis* Lamk. and *Tectona grandis* L. Systematic sampling method was used to identify each sampling point through the Global Positioning System (GPS). Tree biomass estimated by Loss on Ignition method and soil carbon stock was dertermined by Walkley-Black oxidation method. Results showed that the total carbon stock was highest 211.09 ton·ha^{-1} in *Acacia auriculiformis* plantation. The maximum litter carbon was 2.46 ton·ha^{-1} in *Tectona grandis* plantation followed by 1.89 ton·ha-1 in *Anthocephalus chinensis*. Selection of plantation tree species according to highest carbon stock capacity may help the developing countries to earn more carbon credits, and in the long run, to tackle the climate change.

সারসংক্ষেপ

বাংলাদেশে বনায়নকৃত ১৮-বছর বয়সী, আকাশমনি, কদম এবং সেগুন প্রজাতি বৃক্ষে কার্বনের পরিমাপ করা হয়েছে। নিয়মতান্ত্রিক পদ্ধতির মাধ্যমে গোবাল পজিশনিং সিস্টেমের (GPS) সাহায্যে প্রত্যেক নমুনা বিন্দু সনাক্ত করা হয়েছে। গাছের জৈববস্তুপুঞ্জ এবং মাটির কার্বন নির্ণয়ে যথাক্রমে ইগনিশন (Ignition) এবং ওয়াল্কি-বেক (Walky-Black) জারণ পদ্ধতি ব্যবহার করে করা হয়। ফলাফলে দেখা যায় মোট কার্বনের সর্বোচ্চ ছিল আগত আকাশমনি আবাদে (২১১.০৯ টন/হেক্টর)। এছাড়াও গাছের পাতায় সর্বোচ্চ কার্বন পাওয়া যায় সেগুন আবাদে (২.৪৬ টন/হেক্টর) এর পরে রয়েছে দেশীয় কদম আবাদে (১.৮৯ টন/হেক্টর)। কার্বন মজুদের ক্ষমতানুসারে আবাদযোগ্য প্রজাতি সনাক্ত করা গেলে উন্নয়নশীল দেশগুলো অনেক বেশী মুনাফা অর্জন এবং অদূর ভবিষ্যতে জলবায়ু মোকাবেলায় সক্ষম হবে।

Keywords : Carbon stock, plantations, loss on ignition, Walkley-Black method

Introduction

The response of forests to rise atmospheric CO_2 concentrations is crucial for the global carbon cycle since forest ecosystems contain from 62% to 78% of the total terrestrial carbon (Hagedorn *et al*. 2002). Moreover, creation and maintenance of carbon stocks in the tropical forests is an important response option for global warming in tropical developing countries such as Bangladesh (Moura-Costa 1996, Myers 1996). Under the greenhouse gas reduction regime through the CDM concept, carbon credits can be gained from natural and plantation forests in developing

countries (UNFCCC 2004), so forests play an important role in the sequestration of carbon globally (Rawat *et al.* 2003). Plantations have high annual carbon sequestration rates (Bass *et al.* 2000) and establishing plantations on degraded land has been proposed as an effective carbon management approach (Montagnini and Porras 1998). Through the Clean Development Mechanism (CDM), carbon management approach can be achieved by plantation programme in developing countries such as Bangladesh (UNFCCC 2004). Developing countries are mostly affected by the consequences of the global warming (Anon. 1998). The large portions of natural forests in Bangladesh have already been significantly degraded and fragmented (Mollah and Kundu 2004), leaving the country with only a small percentage of forest cover (Alamgir and Al-Amin 2007). The total plantation area of Bangladesh under reforestation activities are 0.257 million ha, among which hill forest, bamboo forest, long rotation, short rotation and mangrove plantations are 0.023, 0.004, 0.131, 0.054 and 0.045 million ha, respectively (FAO 2007).

A realistic estimate of the carbon stock is crucial for two reasons: the first one indicates the potentiality of vegetation to release or absorb carbon and the second one indicates that a time series of the carbon stock in vegetation may be used to strain methods, i.e., inverse modeling, in estimating the net carbon flux to or from the global soils (Goodale *et al.* 2002). Poverty and lack of appropriate technology are two major barriers in Bangladesh for estimating the carbon sinks in the forests through plantation programmes under the CDM. Bangladesh can effectively participate in the carbon trading, but the country is lacking research on the quantification of carbon credits by reforestation and afforestation.

Quantification of net carbon sequestration by plantation species is a primary research in deducting the carbon credit of reforested plantations. Bangladesh has a very long history of plantation forestry starting from 1871 with *Tectona grandis* in Chittagong hill forest, along with indigenous species. Many plantations were established successfully and the area is now viewed as an important example for carbon sequestration in Bangladesh. Hence, determination of carbon stocks at different geo-positions of 18-year old plantations of *Acacia auriculiformis, Anthocephalus chinensis* and *Tectona grandis* is the prime objective.

Materials and Methods

The study was conducted in the mono plantation area of Tankawati forest (21°56'–21°59'N and 92°06'–92°13'E) of Chittagong South Forest Division, Bangladesh. The study area was situated on the western aspect of mid hill. The plantation area was 28.4 ha for Teak (*Tectona grandis*), 6.3 ha for Akashmoni (*Acacia auriculiformis*) and 6.3 ha for Kadam (*Anthocephalus chinensis*). The elevation of the study area ranged between 14 m and 87 m above mean sea level (Islam *et al.* 1999). The study area has a moist tropical maritime climate, with high rainfall concentrated during monsoon period from June to September, high temperature (only small seasonal differences) and high humidity (70% to 85%) (Motaleb and Hossain 2007). The mean monthly temperature in the study area ranges from 21.20°C in November to 28.44°C in April with a mean annual temperature of 26.44°C. The mean monthly maximum temperature ranges from 26.37°C in November to 32.72°C in April and the mean monthly minimum temperature from 16.03°C in November to 25°C in April. The mean minimum and maximum temperatures are 21.97°C and 30.51°C respectively. The mean annual

fluctuation in temperature is about 6.4°C during the rainy season of May to September and 10.08°C during the dry season. The highest concentration of precipitation is found from May to September, pre- and post-monsoon periods of rain during April, May and October, November to March constitute the dry season. The mean monthly relative humidity of the study area is high throughout the year, which is very high (87%) in July and low (69%) in February (Motaleb and Hossain 2007). Soils are brown sandy loams, somewhat excessively drained, Barkal soil series and classified according to the USDA Taxonomy by Alam *et al*. (1993) as Udic Ustochrept.

Sampling procedure

The study was conducted from January to December in 2009. Data on diameter and tree height were collected from standing trees; soil samples were collected from the field and were analyzed in laboratory. The three mono plantations of *Acacia auriculiformis, Anthocephalus chinensis* and *Tectona grandis* were raised in 1991 in the deforested areas of Tankawati forest. Each intersection point was determined using systematic sampling method. The geo-position of the plantation area was determined by using GPS at first, after that one-minute interval was inserted in the map from 21°56'–21°59'N latitude and 92°08'–92°12'E longitude of the study area (Map 1). A total of 27 sample plots were selected for three species of 18 years old plantation and sample plots size were 10 m x 10 m.

Primarily, the land use of each intersection point was identified in the field. In the fixed grid lines, number of stems was counted, a Spiegel Relascope was used to measure height and a diameter tape was used to measure diameter. Samples were collected from all trees of the plot for laboratory analysis to estimate carbon stock and increment cores were collected by wood borer at breast height (1.3 m). We established

Map 1. Map showing the Tankawati Forest area in Chittagong

27 sample plots, each of 2 m x 2 m in size and nine plots from each plantation, in the crown-covered area to estimate the biomass of fallen litter in the plantations. Fallen litter was collected after six months and the average litter fall for six months was converted to annual litter fall per ha.

To estimate soil carbon stock in the selected geo-position, nine soil plots from each plantation were sampled at three depths, i.e., top (1 to 14 cm), middle (14 to 30 cm) and bottom (30 to 100 cm). The size of the sample plot was 2 m x 2 m. Each sample was a composite of three sub-samples. Thus for the three plantations, a total of 27 soil samples were studied. Soil samples were collected using an earth augur. The samples were carefully taken to the laboratory for chemical analysis through the Walkey-Black oxidation method.

Biomass estimation

Scientists developed different models for determining above ground biomass (Negi *et al*. 1988, Brown *et al*. 1989 and Luckman *et al*. 1997). We used models of Brown *et al*. (1989) to determine the above ground biomass as it is reported one of the most suitable methods for tropical forest (Alves *et al*. 1997, Brown 1997, Schroeder *et al*. 1997). The model is as follows:

$$Y = \text{Exp.}\{-2.4090 + 0.9522 \ln (D^2HS)\}$$

where, Y the above ground biomass (kg)

H the height of the trees (m),

D the diameter at breast height (cm)

S the wood density (ton·m^{-3}), for specific species Satter *et al*.(1999).

Below ground, biomass was calculated as 15% of the above ground biomass (MacDicken 1997). The above- and below-ground biomasses were added to get the total biomass of the plantation.

Carbon stock estimation

Loss on ignition method was used to estimate carbon stock of the tree species. The fresh weight of tree samples were taken using an electronic balance, then dried at 65ºC in an oven for 48 h to measure dry weight. Oven dried grind samples were taken (1 g) in pre-weighted crucibles, after that they were put in the furnace and followed by ignition for 1 h. After cooling, the crucibles with ash were weighted to calculate the percentage of biomass carbon as Allen *et al*. (1986):

$$\text{Ash } (\%) = (W_3-W_1)/(W_2-W_1)\text{x}100$$

$$C\ (\%) = (100-\text{Ash } \%) \text{ x } 0.58$$

where,

C the biomass carbon stock (%)

W_1 the weight of crucibles (g)

W_2 the weight of oven dried grind samples and crucible (g)

W_3 the weight of ash and crucibles (g). 58% carbon was considered in ash free litter material.

During field work, soil from each depth was collected to determine organic carbon, and soil core was used to calculate bulk density for different depths. Field's moist soil cores were dried in an oven at 105ºC for 8 h, and re-weighted to determine moisture content and dry bulk density. To estimate the percentage of organic carbon in the soil, samples were analyzed by the wet oxidation method (Huq and Alam 2005).

Results and Discussion

Among the three mono plantations established at the mid-hill positions, the highest tree biomass carbon and soil organic carbon were found in *Acacia auriculiformis* plantation, followed by *Tectona grandis* and *Anthocephalus chinensis* plantations (Fig. 1). The total (above- and

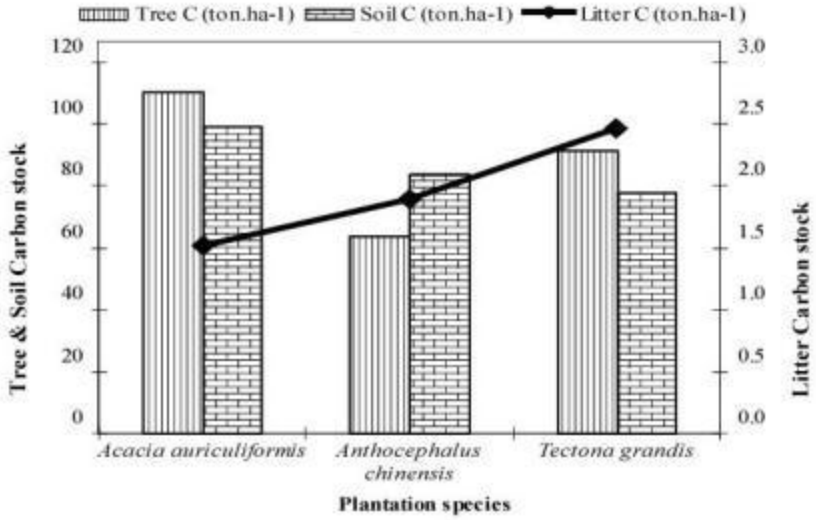

Figure 1. Carbon stocks (ton·ha^{-1}) of 18-year old plantations

below-ground) carbon stocks were found highest in *A. auriculiformis* (110.25 and 100.84 ton·ha^{-1} respectively), followed by *T. grandis* (91.28 and 80.33 ton·ha-1) and *A. chinensis* (63.70 and 85.26 ton·ha^{-1}) plantations. Highest litter carbon stock (2.46 ton·ha^{-1}) was found in the plantation of deciduous trees of *T. grandis* rather than other two plantations. Soil organic carbon was found highest in *A. auriculiformis* (99.32 ton·ha-1) and the lowest in *T. grandis* (77.87 ton·ha^{-1}).

A. auriculiformis is a fast growing species compare to *T. grandis* and *A. chinensis*. Moura-Costa (1996) found that fast growing species accumulate higher amounts of biomass than slow growers during the same time period. During the growth of trees, carbon was accumulated in their biomass, and thereby the amount of carbon stored in the tree plantation areas increase. Hossain (2003) found that *A. auriculiformis* plantation showed better survival and growth in different areas of Bangladesh with the yield of 15–20 m^3·ha^{-1}·yr^{-1} after rotation of 10–12 years, but it is less than 7–8 m^3·ha^{-1}·yr^{-1} in a *A. chinensis*. Sá *et al.* (1998) found that plantation of leguminous tree, *A. auriculiformis*, had 2–3 fold higher above-ground carbon stock capacity than a plantation of other species of the same age. Therefore, from Sá *et al.* (1998) and our studies, it was found that in similar hill position(s) and also from same-age plantations of different species, *A. auriculiformis* plantation might stock higher carbon than other stated species.

In this study, it was found that *T. grandis* plantation had the highest litter carbon because of large broad-leafed and deciduous tree (*A. auriculiformis* and *A. chinensis* both are evergreen) that shades its leaves during the dry season as litter fall including branches, twigs and bark resulting in larger amount of litter which generates higher carbon stock than other species. Consequently, it is evident that variation of litter carbon stock per ha was mainly affected by litter delivery and their total amount, which may different with species.

The distribution of soil carbon stock also varied among the three species. Osman *et al.*

(2001) concluded that soil organic matter increases with the age of the plantation until canopy closure, but is dependent on the ability of the species to produce litter. Among the three species *A. auriculiformis* produce more litter than the other two species and in turn, the decomposition of litter enrich the carbon stock in soil. Singh *et al.* (2004a) mentioned that the deposition and release of carbon through litter fall and its decomposition was highest in legume species, i.e., *A. auriculiformis, Albizia procera* and *A. lebbeck* plantations. *T. grandis* (non-legume) contributes poor carbon stock in the soil due to its deposition of less organic matter (Singh *et al.* 2004b).

Hossian (2005) mentioned that fast growing exotic species are mostly dominated in the natural hill forest ecosystems, crop fields, fallow and marginal lands. Moreover, their luxuriant growth suppressed the growth of other native species. However, carbon densities of tree plantation vary with age, species and site (Lasco and Pulhin 2009). The difference of carbon stocking was found among the three species of same-age group and same location (Fig. 1). It is may be due to differences in wood density. As a result the carbon stock of exotic species is higher than that of native species. *T. grandis* and *A. auriculiformis* are exotic species in Bangladesh but at present these two species become common species due to their higher growth and productivity compare to the native one *A. chinensis*.

Conclusion

The results clearly show the capacity of three 18-year old plantations of *Acacia auriculiformis, Anthocephalus chinensis* and *Tectona grandis* to sequester atmospheric carbon and that reforestation makes a significant contribution to carbon sequestration in Bangladesh. Both *A. auriculiformis* and *T. grandis* are exotic tree species in Bangladesh, but now become common species due to the most of the land coverage through plantation and their economic values. Hence, it is essential to conduct the study for estimating carbon stock. A continued increase in carbon stock and their accumulation rates for all plantation species along with plantation age indicated a progressive development of soil.

To overcome the problem of global warming and climate change, sustainable forest management is the best way to achieve optimum carbon sequestration; and more easy, applicable and fast scientific methods are required to estimate the carbon stock in plantation forest. In the present study, the estimation of carbon stock can be directed to researchers and administrators to analyze global carbon credit, which can be helpful to develop the forestry and environmental sectors, such as Bangladesh and other tropical countries with similar environments.

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Leaf Spot Disease of *Aloe indica* L. Caused by *Cochliobolus lunatus* Nelson & Haasis and its Management in Bangladesh

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Abstract

Aloe indica L. is an important commercial medicinal plant and commercially cultivated in the Northern part of Bangladesh. In 2004, a severe leaf spot disease was found in the four months' old plantations of *Aloe indica*. The symptom of the disease was recorded and the causal organisms were identified. Four types of fungi namely *Cochliobolus lunatus* Nelson & Haasis, *Penicillium* sp., *Aspergillus* sp. and *Fusairium* sp. were isolated from the infected leaves of *A. indica*. Only *C. lunatus* fungus was isolated from the healthy leaves. Out of these, *C. lunatus* was frequently found to be responsible for the disease. The pathogenicity test was conducted, and the association of the fungus with the disease was confirmed. Three types of fungicides *viz.*, Sunvit, Dithane M- 45 and Aimcozim each @ 2gm/l water was applied against the disease. Dithane M-45 gave the best result among three fungicides.

সারসংক্ষেপ

ঘৃত কাঞ্চন একটি বাণিজ্যিক গুরুত্বসম্পন্ন ঔষধি উদ্ভিদ। এ উদ্ভিদটি বাংলাদেশের উত্তরাঞ্চলে বাণিজ্যিকভাবে চাষাবাদ হচ্ছে। গত ২০০৪ সালে পাতায় দাগ রোগ নামে এক ধরণের মারাত্মক রোগ চার মাস বয়স্ক ঘৃত কাঞ্চনে দেখা যায়। রোগের লক্ষণ নির্ণয় ও দায়ী ছত্রাক সনাক্ত করা হয়। *Cochliobolus lunatus, Penicillium* sp., *Aspergillus* sp. ও *Fusarium* sp. নামক চার ধরণের ছত্রাক আক্রান্ত পাতা থেকে পৃথক করা হয়। কিন্তু *Cochliobolus lunatus* পৃথক করা হয় এক মাত্র সতেজ ও সুস্থ পাতা থেকে। এদের মধ্যে *C. lunatus* ছত্রাক কে এই রোগের জন্য দায়ী বলে সনাক্ত করা হয়। এই রোগের সাথে সম্পৃক্ত ছত্রাকের রোগাতাত্ত্বিক পরীক্ষা (pathogenicity test) সম্পন্ন করা হয়। রোগ নিয়ন্ত্রণের জন্য সানভিট, ডায়থেন এম-৪৫ ও এমকোজিম ছত্রাকনাশক প্রতি লিটার পানিতে ২ গ্রাম হারে প্রয়োগ করা হয়। এদের মধ্যে ডায়থেন এম-৪৫ নামক ছত্রাকনাশক সবচেয়ে বেশী কার্যকর ।

Keywords: Aimcozim, *Aloe indica*, *Cochliobolus lunatus*, Dithane M-45, leaf spot, Sunvit

Introduction

Ghrita kanchan (*Aloe indica* L.) belongs to the family Liliaceae, and it comprises about 300 species. It is indigenous to the East and the South Africa (Mukerji and Bashin 1968). It is also found in China, America, Egypt, India and Bangladesh (Raina 1982). *Aloe indica* and *Aloe vera* have been introduced in Bangladesh which grow in diverse climaties conditions and in different types of soils. The stem is about 25 cm long and 5 cm in diameter, with a rosette of about 10 to 15 leaves from 30 to 40 cm long and from 5 to 7 cm in diameter at the base (Edward 1961). *A. indica* is not a water-loving

plant. Propagation of aloes is done through root suckers. It can be cultivated in poor soils with minimum care (Baurke 2009). The plant is commercially important and very valuable. Dried and green leaves of *A. indica* are being used in the field of modern medicine, perfume, cosmetic and traditional treatment in Bangladesh. It is a popular remedy of intestinal worms for children (Raina 1982). The leaves are commonly used as an external application on inflamed painful parts of the body (Satyavati *et al*. 1976).

In Bangladesh, the plant is being cultivated commercially in the locally famous 'Medicinal Village' of Kholabaria, under Luxmipur union of Natore district. A severe incidence of leaf spot disease of *A. indica* was observed in the field. The disease occurs almost every year and prevails round the year becoming severe in winter. The farmers were worried about the cultivation of *A. indica* as they incurred losses due to low prices of the leaves caused by the disease. The leaf spot disease of *A. indica* was first reported from Bhagalpur, Bihar of India and causal organisms were *Alternaria alternata* and *Fusarium solani* (Raina 1982), *Colletorichum gloeosporioides* Penz., *Fusarium solani* and *Pestalotiopsis versicolar* (Roy 1976). The study was, therefore, undertaken with a view to identify the causal organism, its etiology, development of disease and control measures of leaf spot disease of *A. indica*.

Materials and Methods

Collection of sample

The leaf samples (both infected and healthy) were collected from the Medicinal Villages Kholabaria of Natore districts, Minor Forest Product Division (MFPD) and Forest Protection Division (FPD) nursery of Bangladesh Forest Research Institute (BFRI), Chittagong. The symptoms of leaf spot were recorded following the standard method (Anon. 1983).

Isolation

The desired samples were selected for isolation following the Commonwealth Mycological Institute (CMI) & other procedures (Anon. 1968, 1983, Booth 1971). Isolation was carried out within 12- 18 hours after collection to avoid contamination. Leaves were cleaned under running tap water for about 4-5 minutes and then selected portions of apparently healthy and infected leaves were sterilized by immersing them into 0.001% mercuric chloride solution for 30-60 seconds. The sterilized portions were dried by placing them within several folds of sterilized tissue paper. A few millimeters of these specimens were removed using a sterile sharp scalpel. Leaves were cut off into several pieces separately. Small pieces of inocula (approximately 1-2 mm size) were cut off and 8-10 inocula were placed separately onto Petridishes containing sterilized 2% Potato Dextrose Agar (PDA), 2% Malt Extract Agar (MA) and 2% Potato Sucrose Agar (PSA) media.

Pathogenicity test

The pathogenicity test was conducted on 4 months old plant leaves in the pathology laboratory of BFRI. 30 days old mycelia/conidia suspension was inoculated on Twenty (20) individual plants (Fig.1) The mycilial suspension was inoculated by means of scalpel and sterilized syringe and, then each plant was covered with a polythyne bag to maintain high relative humidity for three days. After fifteen days of inoculation, specific symptoms of spot appeared on the leaves. The leaves were re-cultured for the quest of responsible pathogen for the fulfillment of the famous Koch's postulates (Boyce 1961).

Control measure

Three fungicides, namely Sunvit (Copper oxychloride), Dithane M-45 (Mencozeb) and Aimcozim (Carbendazim)

were tested for controlling of the disease. The fungicides were sprayed on 35 leaves of *A. indica* @ 2 gm/l water. Five sprays were given after fifteen days interval. Fresh water (as control) was sprayed in the affected leaves of *A. indica*. Data were recorded for three consecutive months.

Results and Discussion

Leaf spots were observed on 90% of *A. indica* plantations in Kholabaria Medicinal Village of Luxmipur under Natore district and also in the nurseries of FPD and MFPD of BFRI. In most of the nurseries, symptoms appeared every year in winter season. During winter, the weather is dry and the plants get less water from soil that leads to the development of the disease. During this period, the farmers apply lime dust to prevent leaf spot disease of *A. indica*, but this method was found not effective.

Symptom

Numerous spots were found all over the leaf blades, mostly on the upper surface (Fig. 2). Initial color of the spot was light brown, but later it turned to blackish-brown. The spots were sunken, and the leaves dried up from the top. The spots were usually round or irregular in shape varying from 3 to 5 mm and each was encircled by blackish-brown color in the margin. All older leaves were found infected. In some leaves, the spots enlarged in concentric sizes and they dried up from top to bottom.

Four fungi were isolated from the infected leaves, e.g. *Cochliobolus lunatus* Nelson & Haasis, *Penicillium*, *Aspergillus* sp. and *Fusarium* sp. The number of colony of *C. lunatus* (Fig. 3) was the maximum in MA medium followed by PDA and PSA media (Table 1). *C. lunatus* was consistently isolated from the infected and the healthy leaves. The results revealed that *C. lunatus* was the consistently isolated fungus from the infected and healthy leaves. The results reveals that *C. lunatus* was the most consistent isolated fungus over the others. *C. lunatus* with the infected leaf was highly significant (P = 0.05) as compared with that of *Penicillium*, sp. *Aspergillus* sp. and *Fusarium* sp. Identification of the causal fungus was confirmed later on by artificially inoculation of mycelia/conidia of *C. lunatus* on the leaves of *A. indica*. *C. lunatus* was re-isolated from the leaves of *A. indica*, which suggested that the fungus, *C. lunatus* was responsible for causing the leaf spot disease of *A. indica*.

Characteristics of *Cochliobolus lunatus*

The fungus, *C. lunatus* developed effuse; growth along with white to dark sporodochia (Anon. 1968). Colonies of this fungus were effused, brown to blackish-brown, and black hairy or velvety on PDA, MA and PSA media. The mycelium was immersed mostly. Conidiophores were solitary or in small groups, simple or branched straight or flexuous, sometimes geniculate, pale to dark brown, septate, upto 650µ long, 5-9µ thick, often swollen at the base, 10-15µ. Conidia were acropleurogenous with three septate (Fig. 4). In all the cases, the condia are almost curved at the third cell from the base which is usually longer and often darker than the others, cell at each end was sub-hyaline or pale brown, intermediate cells mild to dark brown, smooth, size 20-32 x 9-15µ.

Out of the three fungicides applied (viz. Sunvit, Dithane M-45 and Aimcozim) for the management of the disease, it is evident that Dithane M-45 showed the maximum efficacy (94.23%) after observation for three months, followed by Aimcozim (62.86%) and Sunvit (51.83%). So, it is clear that Dithane M-45 could be the solutions for controlling the leaf spot disease of *A. indica* caused by *C. lunatus* (Fig. 5 and 6).

There was no report of the leaf spot of *A. indica* caused by *C. lunatus*. However, Roy

(1976) reported *Colletorichum glœosporioides*, *Fusarium solani* and *Pestalotiopsis versicolar* as the causes of leaf spots on *A. indica* in Bhagalpur of Bihar, India. *Alternaria alternata* and *Fusarium solani* were the causal agents of the leaf spot of *A. indica* in Bihar (Raina 1982). In the present study, none of these fungi was isolated. *Cochliobolus lunatus* which has been found to cause the leaf spot of *Aloe indica* in Natore district and MFPD, FPD nurseries, is a well established pathogen of various plants. According to the descriptions the fungus is associated in causing the following diseases namely; sugarcane leaf spot, gladiolus leaf spot, seedlings blight of sugar and seed blight of rice. Thus, the present finding about the close association of *C. lunatus* with leaf spot of *A. indica* appears to be a new record from Bangladesh.

Table 1. Frequency of isolation of fungi from infected and healthy leaves of *Aloe indica*

Status of leaves	Type of media	No. of leaves plated	No. of fungal growth	Types of fungi			
				Cochliobolus lunatus	*Penicillium* sp.	*Aspergillus* sp.	*Fusarium* sp.
Infected	PDA	78	109	79	12	8	10
	MA	89	125	95*	10	12	8
	PSA	65	88	64	13	6	5
Healthy	PDA	21	5	5	0	0	0
	MA	33	9	8*	1	0	0
	PSA	9	2	2	0	0	0

* Significant at 5% level, Critical difference 4.06 at the same level

Figure 1. Artificial inoculation of *Cochlibolus lunatus* on *Aloe indica* leaf

Figure 2. Leaf spot symptom of *Aloe indica*

Figure 3. Colony of *Cochliobolus lunatus*

Figure 4. Conidia of *Cochliobolus lunatus*

Figure 5. Status of leaves after application of Dithane M-45

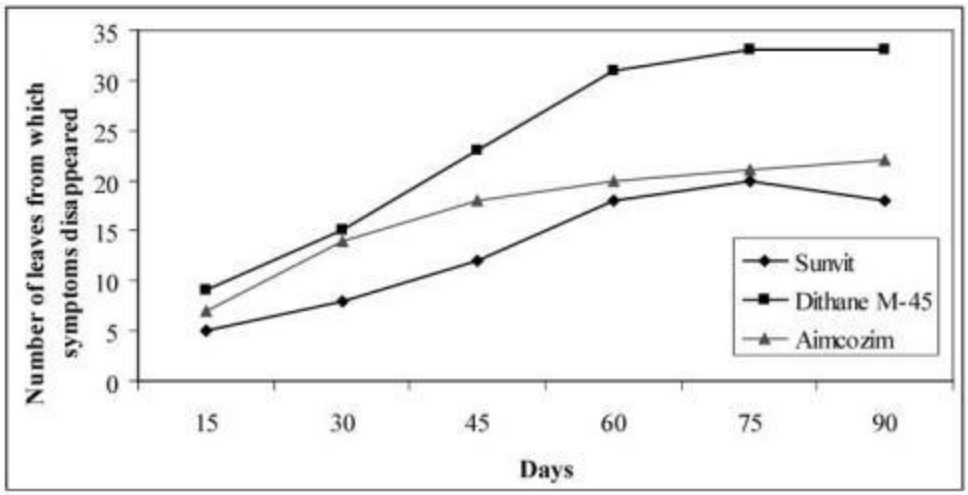

Figure 6. Efficacy of fungicidal application on the leaves of *Aloe indica*

Conclusion

The leaf spot disease is a major problem of *Aloe indica* L. in Bangladesh which is caused by *Cochliobolus lunatus* Nelson & Haasis. Incidence of the disease has been increasing day by day. As a result, the medicinal quality and as well as market value of the species are reducing. So, it is a grave concern to protect and conserve the species from the disease. In this regard, remedial measures have been highlighted for better management of this species. Follow up research is felt necessary for biological management of the disease.

Acknowledgements

Authors are grateful to the Director, BFRI for his kind cooperation to conduct this study. The auther pay their best thanks to Mr. Rafiqul Haider of Divisional Officer for his constructive criticism and correction for improving this paper. We convey our thanks to Md. Matiar Rahman, Md. Mofizul Islam Khan and Md. Shahadat Hossain and all the staffs of Forest Protection Division for their various help during the works. Last but not least authors are grateful to Dr. M. W. Baksha, Ex-Director, BFRI for his valuable comments and corrections.

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Short Communication

Growth Performance of Coastal Plantations and Land Stabilization in an Offshore Island of Hatiya in Noakhali, Bangladesh

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Keywords: Afforestation project, charland, land accretion, land stabilization, mangrove

The coastal environment of Bangladesh is highly unstable due to direct exposure of the wind and wave action of the Bay of Bengal. Moreover, the life and properties of the coastal area is always at risk (Saenger and Siddiqi 1993). The newly accreted coastal lands are not suitable for any land practices except afforestation because of a number of unpredictable geo-morphological changes, viz. rapid accretion, sand smoothening, sediment winnowing and rapid siltation or sand dune movements (Das and Siddiqi 1985). The pneumatophores of coastal plantation species spread up laterally and persist within the silt layer for a longer time which also hasten the procedure of depositing and fixing silts, and thus helps in stabilization of lands (Siddiqi 2001). Bangladesh is a pioneer country for coastal plantations (Siddiqi 2001). It is believed that a permanent green belt along the shoreline and near the shore and offshore islands of Bangladesh would considerably reduce the losses incurred from the frequent cyclones and tidal surges. It will also increase forest resources and provide ecological security to the whole coastal area.

Noakhali Coastal Afforestation Division was established in 1966-67 for raising plantations in the newly accreted char lands and the off-shore islands of Noakhali district. Hatiya is one of the off-shore island of Noakhali district and the Nolchira Range is situated at the northern side of Hatiya Upazilla. A total of 14,370.07 ha coastal plantations were raised in the Nolchira Range during 1967-2007. In addition, some non-mangrove species were also established in the embankment, highway and feeder roads of the island. The present study was carried out to assess the status of plantations both in the coastal and marginal lands of the island.

The study assessed the growth performance of coastal plantations, land accretion, erosion and stabilization at Nolchira Range of Hatiya Upa-zila of Noakhali district. The Range consists of 4 beats namely Ochkhali, Gashiar Char, Char Nurul Islam and Dalchar beat. Considering the limitations of time and accessibility, the present study was concentrated only in Ochkhali and Dalchar beats of the Range. Fifteen sample plots of 20 m x 20 m in size were taken for 27 years old Keora (*Sonneratia apetala*) and Baen (*Avicenia officinalis*) plantations by random sampling methods for determining the growth performance of the plantations. Ten plots of 50 m long strips were taken for each highway, embankment and feeder roads to assess the growth performance of non-mangrove species.

A total of 14,370.07 ha coastal plantations were raised during 1967 – 2007.

Among the raised plantations, 12,450.62 ha land became stabilized and the rest 1,920.11 ha was eroded by river and tidal waves. Moreover, 795.0 ha stabilized lands were converted to agricultural land for crop cultivation (Table 1).

Considering the growth performance, mean dbh of 27 years old *S. apetala* was 20 cm and 10 cm for *A. officinalis* respectively in Ochkhali beat, whereas, it was 24.5 cm and 12 cm respectively in Dalchar beat (Table 2). Mean height for keora plantations was 18.5 m

Table 1. Coastal plantations and land stabilization in Nolchira Range, Hatiya

Plantations established under the project	Plantation year	Area (ha)	Eroded land (ha)	Stabilized land (ha)	Stablized lands transferred to agri-land (ha)
Coastal Afforestation Project	1967-1980	1,280.81	451.94	828.87	100.0
Mangrove Afforestation Project	1980-1986	1,910.66	140.00	1,770.66	150.0
2nd Forestry Project	1986 -1992	1,379.26	130.97	1,248.29	80.0
Forest Resources Management Project	1992- 2000	7,250.00	790.00	6,460.00	45.0
Revenue budget	2002 – 2003	150.00	50.00	100.00	20.0
Forestry Sector Project	2003- 2007	2,400.00	357.20	2,042.80	400.0
Total		**14,370.73**	**1,920.11**	**12,450.62**	**795.0**

Table 2: Growth performance of mangrove and non- mangrove tree species in Nolchira Range, Hatiya

Sampling site and area surveyed	Age (year)	Plantation type	Species	Mean dbh (cm)	Mean ht (m)
Ochkhali (50 ha)	27	Coastal charland	*Sonneratia apetala*	21.0	16.5
			Avicenia officinalis	10.0	5.0
Dalchar (300 ha)	27	Coastal charland	*Sonneratia apetala*	24.5	18.5
			Avicenia officinalis	12.0	5.5
Ochkhali 50 m long plot	27	Highway	*Albizia saman*	54.0	30.5
			Acacia auriculiformis	37.0	26.5
			Casuarina equisetifolia	17.0	32.5
Ochkhali 50 m long plot	14	Embankment	*Albizia saman*	40.0	27.4
			Acacia auriculiformis	19.6	20.4
			Casuarina equisetifolia	13.5	20.0
			Leucaena leucocephala	10.5	14.5
Ochkhali 50 m long plot	12	Feeder road	*Albizia saman*	16.4	13.5
			Acacia auriculiformis	10.5	11.2
			Casuarina equisetifolia	12.5	15.5

in Dalchar beat, but it was 16.5 m in Ochkali beat (Table 2). Plantations in highway, embankment and feeder road showed that *Albizia saman, Acacia auriculiformis, Casuarina equisetifolia* and *Leucaena leucocephala* have promising growth performance (Table 2).

The successful growth and development of *S. apetala* and *A. officinalis* support the findings of Siddiqi and Khan (1990). However, there is a report on massive deforestation in the coastal plantations of this division (Iftekhar and Islam 2004). Influential land lords and local landless people are the main causes for the destruction of coastal plantations and raised stabilized lands are gradually encroached for habitation and agricultures. Some non-mangrove species, e.g. *A. saman* and *A. auriculiformis* are also successful in the highway, feeder road and embankments which also supports the results of Siddiqi *et al.* (1993).

Land accretion and erosion in the coastal areas was going on since time immemorial but due to the absence of successful practices the ultimate gain in landmass stabilization was not significant. The Ganges, the Brahmaputra and the Meghna are flowing through Bangladesh and on its way to the Bay of Bengal, these rivers carry 1.5 – 2.5 billion tons of sediments (Siddiqi 2002). These sediments are subjected to coastal dynamic processes generated mainly by river flow, tidal and wind action, leading accretion and erosion. Without the development of deep rooted vegetation, new formations remain unstable in costal areas. Surface erosion is a continuous phenomenon. Protection in certain new coastal formations has been attempted through coastal newly accreted land helps not only in the retention of deposited soil particle, but also hastens the process of raising the land above the tide level (Hassan 1987). Through afforestation, the incoming silt loads are intercepted by existing stems, twigs, roots and fallen leaves of the plantations. This accelerates the siltation process and in this way the site gets silted and raised in an accelerated manner. The pneumatophore of mangrove species spreads up laterally and persists within the silt layer for a longer time which also hastens the procedure of depositing and fixing up silts, and thus helps in reclamation and stabilization of land (Siddiqi 2001).

A large amount of landmass was settled to the south eastern part of Nolchira Range by the course of accretion. Stabilization of the accreted lands enhanced through afforestation and reforestation programs of the Forest Department. More stabilized lands may also be available for agriculture and habitation as the raised stabilized coastal lands does not suitable for keora/baen plantations anymore.

Coastal plantations play an important role in reducing the vulnerability of coastal people to natural disasters. The plantations act as a bio-shield to safe-guard the coastal people and in the long-term changes the topography through processes of sediment accretion and land stabilization. The well developed root systems of the keora/baen plantations acts as a coastal land stabilizer and binders of sediments. It prevents the soil erosion and gradually stabilize the newly accreted land that may contribute to the landmass development from the Bay of Bengal.

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Bangladesh Journal of Forest Science
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   Baksha, M. W. and Crawley, M. J. 1998b. Effect of defoliation on the growth of teak. *Journal of Tropical Forest Science* 10 (3): 312-317.

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ISSN 1021–3279

Bangladesh Journal of Forest Science

January - June 2012

Volume 32, Number 1

Contents

Vol. 32, No. 2 January - June 2013

Bangladesh Journal of Forest Science

Printed & Published by The Director, Bangladesh Forest Research Institute
Chittagong, Bangladesh from The-AD Communication, Chittagong