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All correspondence should be addressed to The General Secretary, The Asiatic Society of Bangladesh, 5 Old Secretariat Road (Nimtali), Ramna, Dhaka-1000, Bangladesh.
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Helyar, K.R. and W.M. Porter. 1989. Soil acidification, its measurement and processes involved. *In:* Robson, A.D. (ed.) 'Soil Acidity and Plant Growth', Academic press, pp. 61-101.

Kabir, S.M. 2005. Acid sulfate ecosystem and their sustainable management. Unpublished Ph.D. thesis. Department of Soil, Water and Environment. Univ. of Dhaka, Bangladesh.

Khan, H.R., S.M. Kabir, M.M.A. Bhuiyan, F. Ahmed, S.M.A. Syeed and H.-P. Blume, 2008. Response of Mustard to Basic Slag and Aggregate Size Treatments under Modified-Plain-Ridge-Ditch Techniques Used for the Reclamation and Improvement of Cheringa Acid Sulfate Soil. *Soil and Environ*. **27**(1): 1-10.

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BREEDING BIRDS AT THE CHITTAGONG UNIVERSITY CAMPUS OF CHITTAGONG IN BANGLADESH

M. FARID AHSAN* AND M. MANIRUL ISLAM
Department of Zoology, University of Chittagong, Chittagong, Bangladesh

Abstract

A study on the breeding birds in the Chittagong University Campus (CUC) of Chittagong, Bangladesh was carried out, through direct field observations during January to June 2011**.** Fifty-five species of birds belonging to 27 families under 11 orders were observed to breed in the CUC. A total of 819 breeding pairs of birds were recorded, of which 25 (45.45%) species were passerines and 30 (54.55%) non-passerines. Among the breeding birds, the Asian pied starling (*Gracupica contra*) was the highest in number/frequency, comprised 128 (15.63% of the total) pairs and yellow footed green pigeon (*Treron phoenicopterus*) was the lowest, 1 (0.12% of the total) pair. Among the 27 families, Family Corvidae comprised the highest number of breeding species (7, 12.73%); Family Sturnidae and Passeridae had 4 species each (7.27%); while 4 families included 3 (5.46%), 7 families had 2 (3.64%) and 14 families had only 1 (1.82%) breeding species each. The maximum nest building was recorded in April 276 (33.70%) and minimum in January 31 (3.78%). The highest number of nests were built in plants 370 (45.18%) and among the rest 279 (34.06%) in buildings, 116 (14.16%) in hill slopes, 46 (5.62%) in lampposts and 8 (0.98%) in the ground. The birds were recorded to use 32 species of plants under 20 families, of which 21 (65.63%) were indigenous and 11 (34.37%) were exotic species for breeding purpose only. Mango (*Mangifera indica*) supported the highest number of bird species for nesting about 59 (15.94%) while the second highest was coconut (*Cocos nucifera*) 52 (14.05%), and plant species like Bhadi (*Garuga pinnata*) and Pitraj (*Aphanamixis polystachya*) was the lowest species of only 1 (0.27%). Among the 370 nests, 295 (79.73%) were recorded in the indigenous plants and the rest 75 (20.27%) were in the exotic species. Habitat degradation and destruction, pollution in and around CUC, planting exotic species, human settlements, collection of litters and firewood, and occasional fires are hampering breeding activities of birds in the CUC. Necessary steps are to be taken to overcome the problems and protect their breeding and feeding habitats, and further study is needed to know detail of their breeding behaviour.

Key words: Breeding birds, Nesting plants, Nesting substrates, Chittagong University Campus

Introduction

Breeding is the natural process of reproduction in the animal kingdom that is, producing of offspring for the perpetuation of the race or species. Birds breed through laying eggs by the females after mating with males and through incubating. Birds' show breeding

*Author for correspondence: <faridahsan55@yahoo.com>.

activities in different means such as, calling or singing, counter-calling, territoriality, agile movements, exhibiting breeding plumage, etc. to the opposite sex and/or rivals. Breeding of birds in an area reflects the quality of that habitat. The Chittagong University Campus (CUC) is a unique place for many species of bird to live and breed. More than 150 species of birds have been recorded from the CUC (M. F. Ahsan pers. obs.), although Asmat *et al.* (1985) reported 79 species, Ahsan and Khanom (2005) recorded 92 species from the campus and Kamruzzaman *et al.* (2007) added 34 species more to the list. Recently Kabir *et al.* (2017) reported 215 species from the campus excluding 39 species which were mentioned by early authors, although these were not seen between 2007 and 2014, but the total number of breeding species has not yet been recognized. That is why, one of the author (MFA) became interested to know the number of bird species breed in the CUC area. Therefore, an attempt was taken to study the breeding birds, breeding habitats and breeding season of the birds in the CUC.

Materials and Methods

The Chittagong University Campus is situated at Fatehpur, a village under Hathazari upazila of Chittagong district in Bangladesh (22°27′30″ to 22°29′0″ N and 91°46′30″ to 91°47′45″ E). It is about 23 km north of the Chittagong city area and 3 km south-west of Hathazari upazila headquarter and the campus is quite big, consists of about 709.78 ha (1,753.88 acres) of land decked with about 72% hills, lakes, ponds and plain land with stunningly green tall trees. The CUC is one of the floristically rich areas in Chittagong. It is situated in such an ideal place where hills, valleys and plain land are interwoven which is ideal representative place for plant exploration in Chittagong district. A total of 665 plant species (550 species dicotyledons and 115 monocotyledons) under 404 genera and 126 families are found in the CUC (Alam and Pasha 1999).

The breeding birds of CUC were studied during January to June, 2011. The total CUC area was divided into four sites (S-A, S-B, S-C and S-D) for the convenience of the study (Fig. 1). S-A included the University Railway Station to Shaheed Minar through right side of the Katapahar road and from No. 1 to No. 2 gates including the surrounding areas; S-B covered the area from Shaheed Minar to Institute of Marine Sciences and Fisheries, and from Shaheed Minar to Central Field and its adjacent areas including Shaheed Abdur Rab Hall; S-C comprised of the area from Biological Faculty to Botanic Garden and its adjacent areas; and S-D encompassed Botanic Garden to Institute of Forestry and Environmental Sciences, and the University Railway Station to Shaheed Minar through the left side of Katapahar road and its adjacent areas.

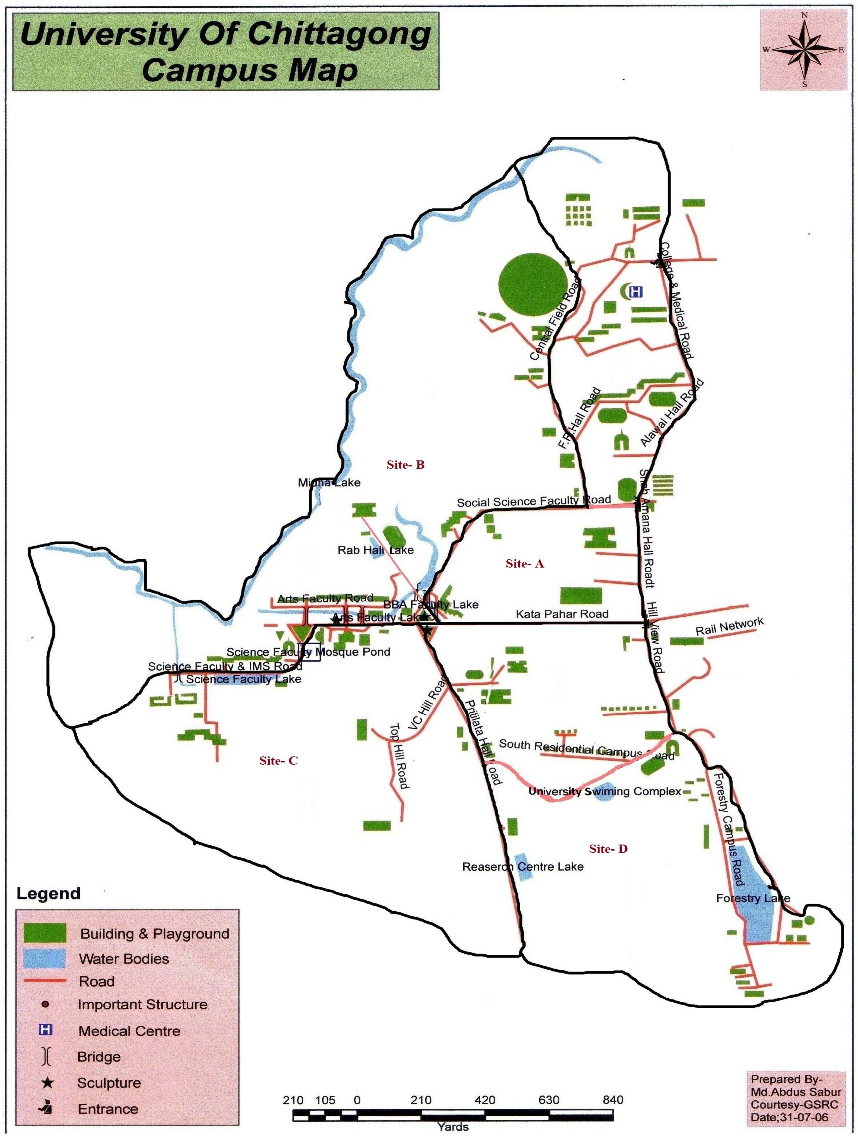

Fig. 1. Map of the CUC area with marked study sites.

Fortnight field observations were made for collecting data during the study period. Singing and calling sounds, breeding plumage, carrying nest materials and/or food for nestlings, seeing the eggs and/or nestlings, birds sitting on/in nests were considered for confirming the breeding birds in the CUC (Table 1). Besides enlisting breeding species of birds, nest, nesting site, nesting tree and nest height from the ground were also recorded (Table 2). The birds were observed either by naked eyes and/or with the help of a pair of binoculars (Bushnell 10 × 40). A field guide book (e.g., Grimmett *et al.* 2006) was used (when necessary) for the identification of species and a digital camera (Sony Cyber shot 10.1 Mega pixels, Model no. DSC-H20) was also used for documenting photographs.

Results

Fifty-five species of birds belonging to 27 families under 11 orders were observed to breed in the CUC during January to June, 2011 (Table 1). A total of 819 breeding pair of birds (Table 3) was recorded of which 25 (45.45%) species were passerines and 30 (54.55%) non-passerines (Table 1). Among the breeding pairs, 289 (35.3% of the total) belonged to 20 species in S-A; 143 (17.45% of the total) comprised of 23 species in S-B; 161 (19.65% of the total) included 29 species in S-C and 226 (27.6% of the total) contained 21 species in S-D (Table 2). Among the breeding species of birds, the Asian pied starling (*Gracupica contra*) was the highest in frequency, which comprised of 128 (15.63% of the total) pairs and yellow-footed green pigeon (*Treron phoenicopterus*) was the lowest, 1 (0.12% of the total) pair (Table 2).

Table 1. Breeding bird species in the Chittagong University Campus.

Sl. No.	Family	Scientific name	Common name	Vernacular name
	Non-passerine			
1	Phasianidae	*Gallus gallus*	Red jungle fowl	Lal Bonmurgi
2	Picidae	*Dendrocopos macei*	Fulvous breasted woodpecker	Batabi Kathkurali
3		*Dinopium benghalense*	Lesser golden back woodpecker	Bangla Kaththokra
4	Capitonidae	*Megalaima lineata*	Lineated barbet	Dagi Boshonta
5	Coraciidae	*Coracias benghalensis*	Indian roller	Neelkanta
6	Alcedinidae	*Alcedo atthis*	Common kingfisher	Pati Machranga
7	Dalcelonidae	*Halcyon smyrnensis*	White-throated kingfisher	Dholagola Machranga
8	Cerylidae	*Ceryle rudis*	Pied kingfisher	Pakra Machranga
9	Meropidae	*Merops leschenaultia*	Chestnut-headed bee-eater	Khoiramatha Shuichora
10		*Merops orientalis*	Green bee-eater	Banaspati
11		*Merops philippinus*	Blue-tailed bee-eater	Neel-lej Shuichora
12	Cuculidae	*Hierococcyx varius*	Common hawk-cuckoo	Pati Chokhgelo
13		*Eudynamys scolopaceus*	Asian koel	Kokil
14		*Phaenicophacus tristis*	Green-billed malkoha	Shobuj Thot Malkoa
15	Centropodidae	*Centropus bengalensis*	Lesser coucal	Kukka

(Contd.)

16		*Centropus sinensis*	Greater coucal	Kana-Kua
17	Psittacidae	*Psittacula alexandri*	Red-breasted parakeet	Modna Tia
18		*Psittacula krameri*	Rose-ringed parakeet	Shobuj Tia
19	Apodidae	*Cypsiurus balasiensis*	Asian palm swift	Nakkati
20		*Apus nipalensis*	Little /House swift	Ghor Batashi
21	Tytonidae	*Tyto alba*	Barn owl	Laksmi Pecha
22	Strigidae	*Athene brama*	Spotted owlet	Kutare Pencha
23	Columbidae	*Columba livia*	Rock pigeon	Jalali Kobutor
24		*Streptopelia chinensis*	Spotted dove	Tila Ghughu
25		*Treron phoenicopterus*	Yellow-footed green pigeon	Holdepa Horial
26	Rallidae	*Amaurornis phoenicurus*	White-breasted waterhen	Dahuk
27	Jacanidae	*Metopidius indicus*	Bronze-winged jacana	Dol Pipi
28	Charadriidae	*Vanellus indicus*	Red-wattled lapwing	Lal Lotika Hot-ti-ti
29	Ardeidae	*Bubulcus ibis*	Cattle egret	Go-Bok
30		*Ardeola grayii*	Indian pond heron	Kani Bok
	Passerine			
31	Laniidae	*Lanius schach*	Long-tailed shrike	Lenja Latora
32	Corvidae	*Dendrocitta vagabunda*	Rufous treepie	Hari Chacha
33		*Corvus splendens*	House crow	Pati Kak
34		*Corvus macrorhynchos*	Large-billed crow	Danr Kak
35		*Artamus fuscus*	Ashy woodswallow	Metey Bonababil
36		*Oriolus xanthornus*	Black hooded oriole	Halde Pakhi
37		*Dicrurus macrocercus*	Black drongo	Kala Fingey
38		*Aegithina tiphia*	Common iora	Fatik Jal
39	Muscicapidae	*Copsychus saularis*	Oriental magpie robin	Doel
40	Sturnidae	*Gracupica contra*	Asian pied starling	Gobrey Shalik
41		*Sturnus malabarica*	Chestnut-tailed starling	Kath Shalik
42		*Acridotheres tristis*	Common myna	Bhat Shalik
43		*Acridotheres fuscus*	Jungle myna	Jhuti Shalik
44	Paridae	*Parus major*	Great tit	Tit Pankhi
45	Pycnonotidae	*Pycnonotus cafer*	Red-vented bulbul	Bulbul
46		*Pycnonotus jocosus*	Red-whiskered bulbul	Sipahi Bulbul
47	Silvidae	*Orthotomus sutorius*	Common tailorbird	Pati Tuntuni
48		*Garrulax ruficollis*	Rufous necked laughing-thrush	Lalghar Penga
49	Nectariniidae	*Dicaeum cruentatum*	Scarlet backed flowerpecker	Lalpith Fuljhuri
50		*Leptocoma zeylonica*	Purple-rumped sunbird	Begunikomor Moutushi
51		*Cinnyris asiaticus*	Purple sunbird	Beguni Moutushi
52	Passeridae	*Passer domesticus*	House sparrow	Pati Chorui
53		*Ploceus philippinus*	Baya weaver	Deshi Babui
54		*Lonchura malacca*	Black-headed munia	Kalamatha Munia
55		*Lonchura punctulata*	Scally-breasted munia	Tila Munia

Table 2. Breeding birds used different substrates and sites in the CUC.

Sl. No.	Breeding species	Breeding sites, trees and substrate used	No. of nests/breeding pair in four sites				Total pair
			S-A	S-B	S-C	S-D	
1	Red jungle fowl	Ground in the botanic garden and chicks in the north-western part of Biological faculty & Forestry area	-	-	3	1	**4**
2	Fulvous-breasted woodpecker	Tree holes in *VC hill & Shaheed Minar	-	-	2	-	**2**
3	Lesser golden-back woodpecker	Shilkoroi and coconut tree	-	-	2	-	**2**
4	Lineated barbet	Mango and shilkoroi tree holes	-	-	-	2	**2**
5	Indian roller	Jackfruit and rice straw heap	-	2	-	-	**2**
6	Common kingfisher	RCMPS area and Katapahar	-	-	-	2	**2**
7	White-throated kingfisher	Hill slopes in Katapahar and adjacent to Shah Amanat hall	2	1	-	-	**3**
8	Pied kingfisher	Earth bank near central field	-	1	1	-	**2**
9	Chestnut-headed bee-eater	Hill slopes in Katapahar & beside the VC hill near the pond	6	-	11	17	**34**
10	Green bee-eater	Hill slopes in Katapahar & beside the VC hill near the pond	2	-	7	3	**12**
11	Blue tailed bee-eater	Hill slopes in Katapahar & beside the VC hill near the pond	11	-	23	27	**61**
12	Common hawk-cuckoo	Breeding call confirms breeding site	-	-	-	-	**-**
13	Asian koel	Breeding call confirms breeding site	-	-	-	-	**-**
14	Green-billed malkoha	Seen juvenile as breeding record	2	-	2	-	**4**
15	Lesser coucal	Botanic garden and Dolasarani area	-	-	1	1	**2**
16	Greater coucal	Forestry pond side	-	-	-	2	**2**
17	Red-breasted parakeet	Shilkoroi tree in VC hill	-	-	2	-	**2**
18	Rose-ringed parakeet	Shilkoroi tree in VC hill	-	-	2	-	**2**
19	Asian palm swift	BBA faculty roof	7	-	-	-	**7**
20	Little/House swift	BBA faculty roof	9	-	-	-	**9**
21	Barn owl	SAR hall	1	1	-	-	**2**
22	Spotted owlet	SA and SAR halls and Science faculty.	1	2	1	-	**4**
23	Rock pigeon	Buildings (cornice and ventilator)	4	7	3	4	**18**
24	Spotted dove	Forestry pond side, gamari tree	-	-	-	3	**3**
25	Yellow-footed green pigeon	Shimul tree in VC hill	-	-	1	-	**1**
26	White-breasted waterhen	Streamline and lake adj. to SAR hall, Botanic garden, RCMPS and forestry lake	-	7	3	2	**12**
27	Bronze-winged jacana	Forestry pond	-	-	-	2	**2**
28	Red-wattled lapwing	Central field and roof of Science faculty	-	2	1	-	**3**
29	Cattle egret	Bamboo clump	-	7	-	7	**14**

(Contd.)

30	Indian pond heron	Streamline and lake adj. to SAR hall, Botanic garden, RCMPS and forestry lake	-	4	2	1	**7**
31	Long-tailed shrike	Small trees and bushes	-	-	2	-	**2**
32	Rufous treepie	Forestry pond side and juvenile in the Dolasarani area	-	-	-	3	**3**
33	House crow	Mango, Jackfruit, Coconut, Mahagani, Jam, Kul, Jhao trees	67	13	4	13	**97**
34	Large billed crow	Akashmoni	1	-	1	-	**2**
35	Ashy wood-swallow	Thatched roof of forestry academic building	-	-	-	6	**6**
36	Black hooded oriole	Juvenile	2	-	2	-	**4**
37	Black drongo	Shimul, kalokoroi	-	-	3	9	**12**
38	Common iora	Juvenile	-	-	2	-	**2**
39	Oriental magpie robin	Holes of building, trees and electric lamp post	1	1	2		**4**
40	Asian pied starling	Mango, jackfruit, mahagani, coconut, kalokoroi, segun, gamari, jarul, kul, jhao, carenga chikrassia trees & electric lamp post.	49	18	21	40	**128**
41	Chestnut-tailed starling	Holes of building and electric lamp post	7	6	14	8	**35**
42	Common myna	Cornices of building & holes of mango, jackfruit and jam tree	13	11	4	11	**39**
43	Jungle myna	Holes of building	34	17	21	11	**83**
44	Great tit	Holes of kul and mango tree		2	2	2	**6**
45	Red-vented bulbul	Bushes in the north-western part of biological faculty near streamline and adjacent to SA Hall	1	-	1	-	**2**
46	Red-whiskered bulbul	Small trees of SAR hall flower garden & Botanic garden	-	1	1	-	**2**
47	Common tailorbird	Small tree of SA and SAR Hall	1	2	-	-	**3**
48	Rufous necked laughing-thrush	Reed and bushes in the north-western part of Biological faculty near streamline	-	-	3	-	**3**
49	Scarlet backed flower-pecker	Small tree of SA and SAR Hall	1	1	-	-	**2**
50	Purple rumped sunbird	Small tree of SA ad SAR Hall	1	2	-	-	**3**
51	Purple sunbird	Small tree of SA and SAR Hall	1	2	-	-	**3**
52	House sparrow	Building cornices and electric lamp post	64	23	11	17	**115**
53	Baya weaver	Coconut trees at Botanic garden area	-	-	-	33	**33**
54	Black headed munia	Juvenile, holes of electric lamp post and collecting nesting material	-	4	-	-	**4**
55	Scally breasted munia	Debdaru, holes of electric lamp post, Cornices of building and nesting material	-	6	-	-	**6**
	Total		**289**	**143**	**161**	**226**	**819**

*VC hill - Vice - Chancellor's hill; SA - Shah Amanat Hall; SAR - Shaheed Abdur Rab Hall; RCMPS - Research Centre for Mathematical & Physical Sciences.

Table 3. Month-wise recorded breeding pairs at 4-site in the CUC.

Month	Site-A	Site-B	Site-C	Site-D	Sub-total
January	16	7	4	4	31
February	23	13	9	14	59
March	57	28	39	47	171
April	91	41	65	79	276
May	53	29	40	47	169
June	27	21	29	36	113
Total	**267**	**139**	**186**	**227**	**819**

Breeding habitat analysis: The breeding birds in the CUC used nesting in trees, building hollows or holes and cornices, ground holes, ground, tree holes, electric lamp posts and roof of thatched houses. The present data (Table 4) reveal that the highest number of nests 370 (45.18%) were found in plants, the second highest was 279 (34.06%) nests in buildings, and the lowest number of nests 8 (0.98%) were located on the ground.

Table 4. Recorded substrates of the breeding pairs in the CUC.

Breeding substrates	Total no. of pairs	% of total pairs
Plant species	370	45.18
Buildings and walls	279	34.06
Hill slopes	116	14.16
Lamp post	46	5.62
Ground and earth bank	8	0.98
Total	**819**	**100.00**

The recorded nesting habitats of breeding substrates of all 55 breeding species in four sites of the CUC were located (Table 2). Seven species of birds (rock pigeon, house crow, Asian pied starling, chestnut-tailed starling, common myna, jungle myna and house sparrow) nested in all four sites in the CUC, of which the highest number of nests (128) was built by Asian pied starling and the lowest number of nests (35) was constructed by common myna (Table 2). Three sites were used for nesting by eight species of birds, two sites by 17 species and single site by 21 species. Two species of parasitic birds (common hawk cuckoo and Asian koel) were found to lay eggs in the nests of other birds.

Similar groups of species selected same site(s) for nesting, for instance, bee-eaters (chestnut-headed, green and blue-tailed) nested in sites A, C and D; Asian palm swift and house swift chosen site A. Site C was chosen by the maximum number of species (34) of birds followed by site B preferred by 25 species, and both sites A and D were selected for nesting by 24 species of birds. Among the single site nesting birds eight species selected site C, seven species preferred site D, four species chosen site B and two species opted for site A. The maximum number of nests (289) were spotted in site A followed by 226 nests in site D, 161 nests in site C and 143 nests in site B.

House sparrow (*Passer domesticus*), jungle myna (*Acridotheres fuscus*), rock pigeon (*Columba livia*), etc. used the building hollows and cornices for constructing nests (Table 2). Bee-eaters (*Merops* spp.) and kingfishers (common kingfisher [*Alcedo atthis*], white-throated kingfisher [*Halcyon smyrnensis*] and pied kingfisher [*Ceryle rudis*]) used the self-made holes in the hill slopes, while Asian pied starling (*Gracupica contra*), house crow (*Corvus splendens*) and others used various trees like shil koroi (*Albizia lebbek*), coconut (*Coccos nucifera*), jackfruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*), shimul (*Salmalia malabaricum*), jarul (*Lagerstroemia speciosa*), gamari (*Gmelina arborea*) and other large trees (Table 2). The chestnut-tailed starling (*Sturnus malabarica*) utilized mainly the electric lamp posts and building holes; while ashy wood swallow (*Artamus fuscus*), Asian palm swift (*Cypsiurus balasiensis*) and little/house swift (*Apus nipalensis*) used the thatched roofs and cornices of the buildings (Table 2). The nesting heights were from ground to several meters high and it varied even within the species.

During the study period, 370 nests of 55 species of birds were spotted in 22 plant species in the CUC, of which 295 nests were built in indigenous plant species (Table 5). The maximum number of nests (59) were found in Aam trees (*Mangifera indica*) followed by 52 on Dab/Narikel palm (*Coccus nucifera*), 52 on Kanthal trees (*Artocarpus heterophyllus*), and the lowest number of nest (1) was found in Bhadi (*Garuga pinnata*) and Pitraj (*Aphanamixis polystachya*) trees (Table 5). On the other hand, 75 nests were located in 11 exotic plant species, of which the highest number (23) of nests came across in Jhau (*Casuarina littorea*) followed by Jarul (15) trees (*Lagerstroemia speciosa*), and the lowest number (2) of nests were seen in each Akashmoni (*Acacia moniliformis*) and Christmas (*Araucaria columnaris*) trees (Table 5).

Breeding season: The breeding season of birds at the CUC spreads over January to June. The highest number of breeding pairs, 276 (33.70%) were recorded in April and minimum, 31 (3.78%) in January (Table 3). The breeding season of the recorded bird species varied between and even within species. It depends on the physical, physiological, environmental conditions and also food resources.

Table 5. Plant species used for nesting by breeding species of birds in the CUC.

Sl. No.	Family	Scientific name	Local name	Type	Status*	No. of nests	Nesting (%)
01	Acoraceae	*Calamus* spp.	Cane cluster	Grass	I	7	1.89
02	Anacardiaceae	*Mangifera indica* L.	Aam	Tree	"	59	15.94
03	Annonaceae	*Polyalthia longifolia* Sonn.	Debdaru	"	"	3	0.81
04	Araucariaceae	*Araucaria columnaris* (Forst.) Hook.	Christmas tree	"	E	2	0.54
05	Arecaceae	*Cocos nucifera* L.	Narikel, Dab	Palm	I	52	14.05
06	Arecaceae	*Oreodoxa regia* Kunth	Bottle palm	"	E	3	0.81
07	Arecaceae	*Phoenix sylvestris* (L.) Roxb.	Khejur	"	I	2	0.54
08	Burseraceae	*Garuga pinnata* Roxb.	Bhadi	Tree	"	1	0.27
09	Casuarinaceae	*Casuarina littorea* L.	Jhau	"	E	23	6.21
10	Euphorbiaceae	*Acalypha wilkesiana* (Muell. Arg.) Fosberg	Patabahar	"	I	3	0.81
11	Fabaceae	*Acacia moniliformis* Hook. & Arn.	Akashmoni	"	E	2	0.54
12	Fabaceae	*Albizzia lebbeck* (L.) Benth.	Kalokoroi	"	I	13	3.51
13	Fabaceae	*Albizzia procera* (Roxb.) Benth.	Shilkoroi	"	"	9	2.43
14	Fabaceae	*Caesalpinia pulcherrima* (L.) Sw.	Radhachura	"	"	3	0.81
15	Fabaceae	*Pongamia pinnata* (L.) Pierre	Karenza	Shrub	"	4	1.08
16	Lamiaceae	*Bombax ceiba* L.	Shimul tula	Tree	"	14	3.79
17	Lamiaceae	*Gmelina arborea* Roxb.	Gamari	"	"	26	7.03
18	Lamiaceae	*Tectona grandis* L.	Shegun	"	E	3	0.81
19	Lythraceae	*Lagerstroemia speciosa* (L.) Pers.	Jarul	"	"	15	4.05
20	Malvaceae	*Hibiscus rosa-sinensis* L.	Jaba	Shrub	"	5	1.35
21	Marantaceae	*Schumannianthus dichotomus* (Roxb) Gagnep.	Mestag	"	I	3	0.81
22	Meliaceae	*Aphanamixis polystachya* (Wall.) R.N. Parker	Pitraj	Tree	"	1	0.27
23	Meliaceae	*Chukrasia tabularis* A. Juss.	Chikrasi	"	I	15	4.05
24	Meliaceae	*Swietenia mahagani* (L.) Jacq.	Mehagini	"	E	5	1.35
25	Moraceae	*Artocarpus heterophyllus* Lam.	Kanthal	"	I	33	8.92
26	Myrtaceae	*Melaleuca leucadendra* (L.) L.	Mallalucha	"	E	5	1.35
27	Myrtaceae	*Syzygium cumini* (L.) Skeels	Jam	"	I	12	3.24
28	Poaceae	*Melocanna baccifera* (Roxb.) Kurz	Muli Bansh	Grass	"	18	4.86
29	Poaceae	*Thysanolaene maxima* (Roxb.) Kuntze	Reed	"	I	6	1.62
30	Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	Kachuri Pana	Hydrophyte	E	6	1.62
31	Rhamnaceae	*Zyziphus mauritiana* Lam.	Kul	Tree	I	7	1.89
32	Rubiaceae	*Ixora coccinea* L.	Rangan	Shrub	E	6	1.62
33	…………	Unidentified	Undergrowth veg.	"	I	4	1.08
Total						370	100

* E = Exotic, I = Indigenous.

Discussion

Out of 650 species of birds in Bangladesh (Siddiqui *et al*. 2008), 188 species breed and a further 59 are likely to breed (Harvey 1990) in the country. The present study confirms that 55 species of birds breed in the CUC, which is nearly 30% of the country's breeding species, and the number is likely to be increased, so, that will be the areas of future studies.

Among the breeding birds, house crow (*Corvus splendens*) and Asian pied starling (*Gacupica contra*) play a vital role in keeping healthy environment through scavenging. Huge amount of waste materials are being produced everyday at the CUC area, which are being reduced through consumption mainly by these two species among the birds. Some other bird species also play important role in pollinating, pest controlling, seed dispersing, etc. and thus birds are helping in maintaining ecological balance.

The main threats of these breeding birds at CUC are the unplanned settlements and agricultural practices, and recently introduce fish culture in the derelict ponds through cleaning and re-excavating. These directly affect breeding and feeding habitats of the birds. Cultivation of agricultural crops and burning herbs, bushes and shrubs in the hills, collecting firewood, litter-fall, etc. have negative effects on the natural activities of birds. Another threat for breeding birds is the shortage of suitable breeding habitats like indigenous tree species and presence of huge exotic species. Planted exotic species of trees play harmful effects on the environment and virtually birds avoid building nests in exotic species. Only 75 pairs (9.16% of the total recorded pairs) of bird out of 819 pairs observed to build nests in exotic species during the study period. Among the 55 species Asian pied starling (*Gracupica contra*), common myna (*Acridotheres tristis*), house crow (*Corvus splendens),* large-billed crow (*Corvus macrorhynchos*), white-breasted waterhen (*Amaurornis phoenicurus*) and bronze-winged jacana (*Metopidius indicus*) were noticed to nest in the exotic plants. The breeding pairs used exotic plant species for nesting most probably due to the shortage of suitable indigenous nesting trees nearby because in the CUC area huge number of exotic plant species were planted by the authority and these birds are trying to adapt themselves with the new environment. But, planting native fruiting trees is essential through eradicating exotic tree species for birds for keeping healthy environment and balanced ecosystems for humans also in the CUC.

The breeding season and clutch size of breeding species of birds in the CUC have been compared (Table 6) with the records of Ali and Ripley (1983) including two-year-round breeder species (Asian palm swift and rock pigeon). The available data (Table 6) reveal that the breeding season of birds in the CUC is mostly same with that of the Ali and Ripley (1983). A few additions to the report of Ali and Ripley (1983) are: in CUC barn owl breeds during April - July, red-wattled lapwing during March - July and the breeding call of common hawk cuckoo recorded during March - June. Breeding season of the birds

Table 6. Comparison of breeding records of birds between the present study and Ali and Ripley (1983).

Sl. No.	Breeding species	Present study		Ali and Ripley (1983)	
		Breeding season	Clutch size/ juvenile	Breeding season	Clutch size
01	Red jungle fowl	March - May	5 - 6	March-May, odd clutch January - October	5 or 6
02	Fulvous-breasted woodpecker	April - May	3	April - May	Normally 3, sometimes 4 or 5
03	Lesser golden-back woodpecker	February - July	3	February - July	3
04	Lineated barbet	March - June	2	March - June	2 - 4
05	Indian roller	April - May	3	March - June	3, sometimes 4, rarely 5
06	Common kingfisher	March - June	4 - 6	March - June	5 - 7
07	White-throated kingfisher	March - June	4 - 7	March -July	4 - 7
08	Pied kingfisher	March - June	5 - 6	Throughout the year	5 - 6
09	Chestnut-headed bee-eater	February - June	5 - 6	February - June	5 - 6
10	Green bee-eater	February - June	4 - 7	February - June	4 - 7
11	Blue tailed bee-eater	March - June	5 - 7, normally 7	March - June	5 - 7
12	Common hawk-cuckoo	March - June	Breeding call	-	-
13	Asian Koel	March - July	1	March - August, chiefly May - July	1
14	Green-billed malkoha	April - August	2	April - August	2 - 4, most commonly 3
15	Lesser coucal	March - October	3	March - October	3or 4
16	Greater coucal	June - August	3 or 4	June - August	3 or 4, exceptionally 5
17	Red-breasted parakeet	January - April	3 - 4	January - April	3 - 4
18	Rose-ringed parakeet	January - July	3 or 4	January - July	3 or 4, sometimes 5, rarely 6
19	Asian palm swift	Throughout the year	2 - 3	Throughout the year	2 - 3
20	Little/House swift	April - July	2 or 3	April - July	2 or 3, rarely 4
21	Barn owl	April - July	4 - 7	Undefined	4 - 7
22	Spotted owlet	February - April	3 - 4	February - April	3 - 4
23	Rock pigeon	Throughout the year, (mainly May - July)	2	Throughout the year,	2
24	Spotted dove	April - July	2	April - July	2

(Contd.)

25	Yellow-footed green pigeon	March - June	2	March - June	2
26	White-breasted waterhen	March - October	6 or 7	March - October	6 or 7
27	Bronze-winged jacana	June - September	4	June - September	4
28	Red-wattled lapwing	March - September	3 - 4	-	-
29	Cattle egret	June - August	3 or 4, sometimes 5	June - August	3 or 4, sometimes 5
30	Indian pond heron	May - August	3 or 5	May - August	3 or 5
31	Long-tailed shrike	January - July	-	March - July	-
32	Rufous treepie	March - July	4 or 5	March - July	4 or 5
33	House crow	January - June	4 - 5	January - June	4 - 5
34	Large billed crow	February - June	3 - 5	February - June	3 - 5
35	Ashy wood-swallow	March - June	2 - 3	March - June	2- 3
36	Black hooded oriole	March - August	2	March - August	2 - 4, usually 3
37	Black drongo	February - August	3 - 4	February - August	3 - 4, rarely 5
38	Common iora	January - September	2	January - September	2 or 3, exceptionally 4
39	Oriental magpie robin	March - July	-	March - July	-
40	Asian pied starling	March - September	4 - 6	March - September	4 - 6, commonly 5
41	Chestnut-tailed starling	April - July	3 - 5	April - July	3 - 5
42	Common myna	March - September	4 - 5	March - September	4 - 5
43	Jungle myna	February - July	3 - 6	February – July	3 - 6
44	Great tit	March - June	4 - 6	March - June	4 - 6, occasionally 9
45	Red-vented bulbul	April - August	3	April - August	2 or 3
46	Red-whiskered bulbul	March - September	3	March - September	3
47	Common tailorbird	May - July	3 - 5	May - July	3 - 5, usually 2
48	Rufous necked laughing-thrush	March - August	3	March - August	3, sometimes 2 or 4
49	Scarlet backed flower-pecker	April - August	2 - 3	April - August	2 - 3
50	Purple rumped sunbird	February - June	2	February - June	2, exceptionally 3
51	Purple sunbird	April - June	2	April - June	2, sometimes 1 or 3
52	House sparrow	March - June	3 - 6	March - June	3 - 6, usually 4
53	Baya weaver	May - August	-	May - August	2 - 4, usually 3
54	Black headed munia	May - November	5	May - November	5, sometimes 6
55	Scally breasted munia	May - September	4 - 6	May - September	4 - 10, usually 5 - 7

in the CUC starts in January but the majority (24 species) starts in March and the maximum (16 species) complete by June.

The clutch size of birds varied from 2 to 7 in the CUC, which are mostly similar with Ali and Ripley (1983) with slightly different in a few cases (Table 6). Two eggs were laid by lineated barbet, green-billed malkoha, rock pigeon, spotted dove, yellow-footed pigeon, black-hooded oriole, common iora, purple-rumped sun bird and purple sun bird; while seven or up to seven eggs laid by white-throated kingfisher, green bee-eater, blue-tailed bee-eater, barn owl and white-breasted waterhen (Table 6).

Conclusion

The population of some bird species is decreasing but the diversity is increasing in the Chittagong University Campus (CUC) day by day (M. F. Ahsan pers. obs. since 1982). Habitat degradation and destruction, pollution in and around CUC, planting exotic species, human settlements, collection of litters and firewood, cutting undergrowth and bushes for sealing litters in the sacs, and occasional fire hampering breeding activities of birds in the CUC. For conserving bird species in the CUC, it is necessary to take steps to overcome the mentioned problems.

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DIVERSITY AND ABUNDANCE OF PTEROPODS ALONG THE SAINT MARTIN'S ISLAND AND ITS EFFECTS ON ECOLOGY OF BAY OF BENGAL, BANGLADESH

S.K. SAHA*, NAHID IBN MUZIB AND MAHMUD AL NOOR TUSHAR
Department of Geology, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

The study deals with pteropods which is an important group of Holoplanktonic mollusks belonging to the class Gastropod. The study attempted to disclose the available pteropods in this region and to attain a clear concept of their abundance and diversity in and around Saint Martin's Island. The study also attempted to establish pteropods as another significant environmental indicator along with other microfossils in this region. Among the 41 identified species included both Thecosomata and Gymnosomata orders with having a total of 17 families and 19 genera were described. The study was conducted from the ferry ghat to Uttar para and Dakkshin para and covering to the southernmost part of Chera Dwip of the Saint Martin's island. The study also reveals the diversity and variation of the species with the gradual distance and water depth from land to ocean area. The study identified both the freshwater and Pelagic pteropods. Abundance of Thecosomes was a significant finding which can boost in further studies on ocean acidification in Saint Martin's island of Bay of Bengal.

Key words: Pteropods, Ocean acidification, Bay of Bengal, Saint Martin's Island

Introduction

St. Martin's Island is a small coral island in the north-eastern part of the Bay of Bengal, about 9 km south of Cox's Bazar-Teknaf Peninsular tip and forms the southernmost tip of Bangladesh (Afrin *et al.* 2013). The area of the island is about 5.9 km^2 whereas with the rocky platforms extending into the sea. The total area of the island is about 12 km^2. It was connected to the mainland of the Teknaf Peninsula as recently as 6,000-7,000 years ago (Warrick *et al.* 1993, Chowdhury 2012).

The coral community in St. Martin's Island supports associated fish and invertebrate fauna characteristics of coral reef environment. The most abundant group of invertebrate found in the coral bed are mollusks. About 61 species of them have been identified so far. Besides 9 species of Echinoderms, 4 species of Zonathids and 4 species of Bryzoans are also present here (Tomascik 1997, DoZ 1997).

*Author for correspondence: <sks@du.ac.bd>.

Pteropods were first described as a group in 1804 by Georges Cuvier. Pteropods are a group of heterobranch gastropods - a superorder comprised of the orders Thecosomata, also referred to as ‘‘sea butterflies”, and Gymnosomata, or ‘‘sea angels” that play an important role in marine food webs (Lalli and Gilmer 1989). Pteropods are found throughout the world’s ocean and are holoplanktonic that means they spend their entire life cycle in the open water column. Pteropod tests are limited to shallow tropical and subtropical oceanic regimes such as the Arabian Sea (e.g. Herman and Rosenberg 1969, Singh and Rajarama 1997, Singh *et al.*2001) and to marginal seas such as the Red Sea and the Mediterranean Sea (Reiss *et al.* 1980, Almogi-Labin 1982, Almogi-Labin *et al.*1991, Wang *et al.* 1995). They represent an extraordinary diversity in morphological forms and can be numerically and functionally important components of marine food webs (Lalli and Gilmer 1989). Shelled pteropods affect the ocean carbon cycle by producing aragonite shells that can accelerate the export of organic matter from the surface into the deep ocean. Because of their delicate aragonite shells, pteropods have been identified as extremely vulnerable to the effects of ocean acidification (Feely *et al.* 2009).

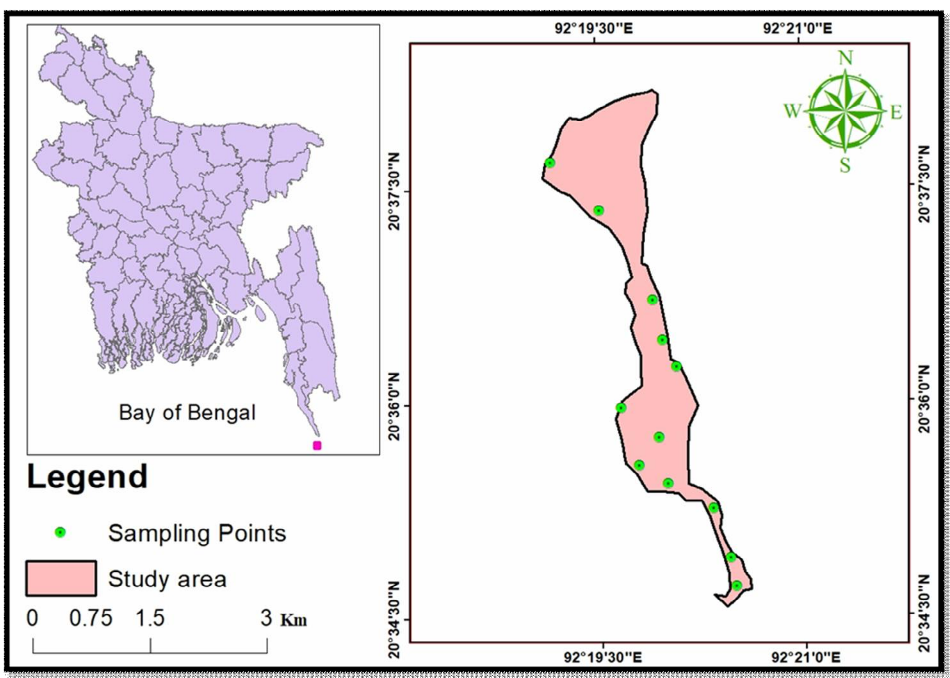
The distribution of pteropods is mainly influenced by the depth of the ocean (van Straten 1972). The abundance of pteropods within different water masses depend upon specific physico-chemical properties and by the adaptive potential of different individual species. Thecosome pteropods depend on the process of calcification to grow their shells which consist of aragonite and calcium carbonate. Hence the saturation of carbonate ions in the water is vital to their survival. Their body is made up of an aragonite and calcium carbonate shell; they are very sensitive to ocean acidification driven by the increase of anthropogenic CO_2 emissions and other oceanic processes (Comeau *et al*. 2009) and also play a key role in the cycling of carbon and carbonate. The recent research on pteropods mainly focuses on their susceptibility to ocean acidification (Fabry *et al*. 2008).

The studies of pelagic pteropods from the Arabian Sea and Bay of Bengal were very meagre and most of the studies concentrated on ecological or fossil studies not in a taxonomic point of view. Most of the fossil studies of pteropods are from the Arabian Sea or from the Andaman Sea within the EEZ of India (Berner 1977). In the Bay of Bengal, the pelagic studies were done by Aiyar *et al.* (1936) from Madras, Arabian Sea (Sakthivel 1976), Eastern Bay of Bengal, around Tillachang Island and the paleontological studies from the Andaman Sea (Bhattacharjee *et al.* 2002 and Bhattacharjee 2005).

A micropaleontological investigation of the fossils present in Saint Martin’s Island can give some important information and ideas about the past paleo-climatic condition and its sequential changes from past to present. The main objectives of this research was to identify the systematic description of the pteropods as well as to infer the ecological consideration and distribution of the species.

Materials and Methods

Saint Martin's Island is a small island in the northeast of the Bay of Bengal. The island is 7.315 km long and is aligned NNW and SSE. For the purpose of conducting a micropalaeontological investigation and studying the microfossils and their relationships to the climatic change in the past and near future of Saint Martin's island it was necessary to explore the sediments of this area. About 32 samples of 12 locations from Saint Martin and Chera Dwip were collected with GPS location for analysis.



Source: Author's filed survey.
Fig. 1. Location map and sampling points of the study area.

Modern microfossil collection follows standard method (Palmer and Abbott 1986, Gehrels *et al.* 2002) which is also very familiar to foraminifer's collection. Standard sample volume (10 cm^2 by 1 cm thick) allows comparison with similar studies (e.g.

Horton *et al.* 2003). All materials were collected in low tide during a neap tidal cycle. The sampling interval was about 100 m. These samples were sieved retaining the fraction 60, 80, 120 µm and the time interval for all is 10 minute. The 60 and 80 µm samples were chosen for microscopic analysis.

The sediments may contain abundant microfauna that can be analyzed with a binocular microscope (Meiji techno EMT2) and photographs were taken by camera built in microscope (Leica EZ4E). The samples selected for microfaunal analysis were prepared by following the protocol justifying their grouping. All the specimens were photographed neatly with camera attached to a binocular microscope` for further detailed analysis.

Geology of the study area: Saint Martin’s Island is a dumb-bell shaped sedimentary continental island located on the Eastern flank of an anticline, which like Chittagong may be part of the Arakan-Yoma-Nagafolded system (Warrick *et al.* 1993). The land of the island is about 8 km^2 depending on the tidal level. The island is almost flat with an average height of 2.5 m above mean sea level (MSL), rising to a maximum of 6.5 m high cliffs along the eastern coast of Dakshin Para (Ahmed 1995).

The tectonic structure of the island is simple and is represented by an anticlinal uplift. A little of the axis of the anticline is traceable along the west coast of Dakshin para. The exposed portion of the axis runs NNW to SSE, approximately parallel to the island. There is a fault along the northwestern shoreline with a trend nearly parallel to the axis (Banglapedia 2015).

The fault seems to be reverse in nature with the eastern side as the up thrown block. The anticline is slightly asymmetrical with a monoclinal swing on the eastern flank. The bedrock on the eastern flank near the axis dips very gently at an angle of 3 to 5° towards the east, increasing eastwards to 10 to 12°. The monoclinal swing gives a high dip of 30° and above at Chheradia. Very little of the western flank is exposed above the sea which records a dip of 6° towards the west. The monoclinal swing gives the anticline a box-like shape. The birth of the island is related to the regional tectonics of southeast Asia. As a sequel to the most dynamic Himalayan orogeny during Middle Miocene (around 15 million years before) (Banglapedia 2015).

Systematic description: Pteropods (Thecosomata and Gymnosomata) are the groups of holoplanktonic molluscs belonging to the Class Gastropoda. They are commonly called sea butterflies and found in good numbers in zooplankton collections. Of the approximately 50,000 marine species of gastropods only 244 species are holoplanktonic (van der Spoel and Dadon 1997). They are wide spread in the surface waters of open oceans of the tropical, subtropical latitudes (Gilmer and Harbison 1991) Hunt and Hosie

2006). Their shells are thin, fragile and made up of aragonite and calcium carbonate (Janssen 2005). Empty shells of pteropods constitute a major portion of shallow marine sediments, especially in the tropical and subtropical regions (Herman 1968). During this field investigation, 32 species were finally selected to analyze and the description of the species are stated below.

Phylum: Mollusca

Class: Gastropoda

Subclass: Heterobranchia

Super order: Pteropoda

Order: Thecosomata

Suborder: Eucosomata

Super family: Limacinoidea

Family: Limacinidae

Genus: *Limacina*

Type species: *Limacina atypica* (Woodward 1854)

Plate 1, Figs 1, 2 (Uttar para 2 Lat. 20° 34' 33"; Lon. 92° 20' 13.4").

Remarks: Shell is small, sinistral with up to four convex whorls, 1.5 to 1.6 times wider than its height and has a flat apical side. The whorls are coiled in a plane spiral. The periphery is evenly rounded. The aperture is obliquely ovoid, slightly indented by the penultimate whorl. Type locality of the specimen is Pakaurangi Point, Kairapara, New Zealand.

Genus: *Limacina*

Type species: *Limacina inflate*

Plate 1, Figs 3, 4 (Uttar para 2 Lat. 20° 34' 33"; Lon. 92° 20' 13.4").

Remarks: Shell is small (maximum diameter is 1.5 mm), sinistral shell with up to three whorls coiled at one level. The last whorl is swollen. Aperture is heart-shaped with blunt tooth extending on the last whorl as faint keel or rib. Rostrum or aperture tooth is variable in shape. Umblicus is deep. The shell is embryonic with rough granulated surface both on proximal zone and the first whorl (Boltoveskoy 1978). Type locality of the specimen is known to be at Atlantic and Pacific Ocean.

Genus: *Limacina*

Type species: *Limacina heliconoides* (Jeffreys 1858)

Plate 1, Fig. 5 (Uttar para 4, Lat. 20° 36' 14.8"; Lon. 92° 19' 51.7").

Plate 1. Selected pteropods recovered from Saint Martin' Island.

Remarks: It has a large chest-nut shell (diameter is about 0.09 to 0.15 mm), some spiral lines of punctation are found on the first whorl and on the embryonic shell. Transverse growth lines are found on the last whorl. The shell is depressed with three to four whorls of which the last one is swollen and composes a major part of the shell. The narrow umbilicus is closed or absent. The aperture is oval, higher than its width.This is the only species of *Limacina*, in which a larval (secondary) shell is followed by a tertiary shell differing in sculpture (not gross rnorphology) and reflecting the time of hatching from the mantle cavity (van der Spoel 1978). This species is mainly found in Atlantic and Pacific Ocean.

Genus: *Heliconoides*

Type species: *Heliconoidesinflatus*

Plate 1, Figs 6, 7 (Uttar para 5, Lat. 20° 34' 49"; Lon. 92° 20' 11").

Remarks: The size of the species ranges from 0.5 to 3.0 mm. Sinistrally coiled, involute pigmented with two or three whorls. It has large paired fins. Right tentacle is much larger than the left tentacle. Typically ranges from south of Point Conception to as far south as Vizcaino Bay, Mexico.

Genus: *Limacina*

Type species: *Limacina* sp.

Plate 1, Fig. 8 (Uttar para 5, Lat. 20° 34' 49"; Lon. 92° 20' 11").

Remarks: Shell small in genus *Limacina* (average height 0.7 mm, width 0.9 mm), sinistral coiled, with about 3 whorls. Shell height 0.8 maximum width. Spire relatively low, apical angle 145 to 150°. Suture impressed. Apex small, moderately inflated. Umbilicus width 5 to 10% maximum width. Aperture narrow-oval, higher than width (Yusuke 2011). The morphology is of *Limacina* sp. is very similar to species belonging to the genus *Heliconoides,* in particular *H. mermuysi*as. It is found in Caribbean Sea and in the Indian Ocean.

Super family: Cymbulioidea

Family: Cymbulioiidae

Genus: *Gleba*

Type species: *Glebacordata* (msForskal) (Niebuhr 1776)

Plate 1, Figs 9, 10 (Uttar para 2’, Lat. 20° 34' 33.0"; Lon. 92° 20' 13.4").

Remarks: This is a shell-less pteropods with a large gelatinous slipper like pseudo conch.The pseudo conch is rounded. Diameter of the swimming plate up to 60 mm, length of the pseudo conch up to 45 mm. It is found in warm waters of Atlantic Ocean and Indian Ocean.

Family: Peraclidae

Genus: *Peraclis*

Type species: *Peraclisreticulata* (d'Orbigny 1836)

Plate 1, Figs 11, 12 (Cheradip 7, Lat. 20° 37' 1.7"; Lon. 92° 19' 22.2").

Remarks: Shell is yellowish, relatively high, and horny with three to four whorls and deep suture without radial crest. Spire is not depressed. Keel present, no aperture tooth, aperture wide and oval. Base of the aperture is pointed towards keeled rostrum. Umbilicus is very narrow or absent. Shell height is about 6 mm and diameter is 3 mm. It is typically found in South Atlantic Ocean.

Genus: *Peracle*

Type species: *Peraclediversa* (Monterosato 1875)

Synonym: *Peracle bispinosa* (Pelseneer 1965)

Plate 1, Fig. 13 (Uttar para 3, Lat. 20° 34' 36.7"; Lon. 92° 20' 9.5").

Remarks: The elongate shell has four to five whorls and a deep suture. The spire is relatively high due to the rapid increase in size of the whorls. On the last half of the body whorl a strong keel ends in a distinct aperture tooth. The aperture is wide. The height of the shell is up to 7.5 mm and maximum diameter is 6 mm. Type locality of this species is Atlantic Ocean and Mediterranean Sea.

Super family: Cavolinioidea

Family: Cavoliniidae

Genus: *Cavolinia*

Type species: *Cavolinia uncinata* (d'Orbigny 1836)

Plate 1, Figs 14, 15 (Uttar para 2, Lat.20° 34' 33"; Lon. 92° 20' 13.4").

Remarks: This species large and uncoiled cosomatous pteropod. Though the specimen is small in size, the most typical characters are the long caudal spine which is curved dorsally. The lateral spines are towards the caudal portion and the line between the tips of caudal and lateral spines is not regularly curved. Faint growth lines and transverse striation near the aperture is present on the shell. This species is found in Cape Verde, Aruba, Caribbean Sea, Indo-Pacific, New Zealand Exclusive Economic Zone. In Indian sub-continent it is available in Eastern Bay of Bengal (Nair *et al.* 1991).

Genus: *Diacria*

Type species: *Diacriatrispinosa* (Blainville1821)

Plate 1, Fig. 16 (Chera Dwip 2, Lat. 20° 34' 54.3"; Lon. 92° 20' 13.2").

Remarks: The slender shell is uncoiled but bilateral symmetrical with a long caudal spine. Relatively large shell, the lateral spines are straight, the caudal spine is proportionally short. The shell aperture is wide, length of the shell is up to 9 mm and width up to 10.5 mm.This species is exclusively marine, phytophagous and epipelagic in cold water.This forma is mainly found in the North Atlantic Ocean between 40 and 70° N (Van der Spoel and Dadon1997).

Family: *Creseidae*

Genus: *Creseis*

Type species: *Creseisclava* (Rang 1828)

Plate 1, Figs 17, 18 (Uttar para 5, Lat. 20° 34' 49"; Lon. 92° 20' 11").

Remarks: The shell is straight up to 6 mm long with a diameter of about 1 mm. The embryonic shell is rounded at its end. The caudal part in profile has two or more swelling caused by transverse rings below a concave portion ending in the perfectly round embryonic end. This species is known from the Late Quaternary of the Red Sea (Pleistocene-Holocene). This forma is mainly found in warm waters of the Atlantic, Indian and Pacific oceans.

Super family: Actionoidea

Family: Apulstridae

Genus: *Hydatina*

Type species: *Hydatinaalbocincta* (van der Hoeven 1839)

Plate 1, Figs 19, 20 (Chera Dwip 1, Lat. 20° 34' 47.8"; Lon. 92° 20' 19.2").

Remarks: Shell is medium sized, thin and globose. Body whorl is large with many microscopic colored growth striae. Radial coloration consists of lines or broad bands. Spire consists of two or three exposed whorls. Aperture is large with more or less ear shaped. The outer lip is thin and slightly sinuous. All the species of *Hydatina* are found in tropical Indo-Pacific region and in tropical Atlantic Ocean.

Order: Stylommatophora

Family: Ariophantidae

Genus: *Macrochlamys*

Type species: *Macrochlamysopipara* (Godwin 1956)

Plate 2, Figs 1, 2 (Uttar para 1, Lat.20° 34' 47.8"; Lon. 92° 20' 19.2").

Plate 2. Selected pteropods recovered from Saint Martin's Island.

Remarks: Shell medium, perforate, sub globosely depressed, surface smooth, polished and translucent. Five body whorls, slightly convex above, last whorl is rounded. Aperture is oblique, broadly lunate. Average shell length is 9 mm, width is 14 mm and aperture length is 8 mm. It is mainly found in the moist parts of the world such as India, Myanmar, Sri Lanka, Bangladesh and some other Asian countries.

Genus: *Macrochlamys*

Type species: *Macrochlamyssequax* (Benson 1836)

Plate 2, Figs 3, 4 (Uttar para 1, Lat.20° 34' 47.8"; Lon. 92° 20' 19.2").

Remarks: Shell medium, thin, perforate, depressed, polished, spire low, sides slightly concave, closely oblique strie and spiral lines are finely decussate. Aperture is slightly oblique, broadly lunate. Average shell length, width, aperture length and width is 9, 16, 9 and 6 mm, respectively (Thakur*et al*. 2012).

Subclass: Caenogastropoda

Order: Littorinimorpha

Super family: Pterotracheoidea

Family: Atlantidae

Genus: *Atlanta*

Type species: *Atlanta* sp.

Plate 2, Figs 5, 6 (Chera Dwip 4, Lat. 20° 38' 9.6"; Lon. 92° 19' 22.2").

Remarks: A relatively large, highly spired, conical shell with up to four whorls. The whorls are flat-topped at the sutures, giving step shape in side on profile. The umbilicus is large and open. The species are cosmopolitan and mainly found in Indo-Pacific, Pacific Ocean, Indo-Atlantic and the Atlantic Ocean.

Genus *Atlanta*

Type species: *Atlanta heliconoides* (Souleyet 1852 in Newman 1990)

Plate 2, Fig. 7 (Chera Dwip 5, Lat. 20° 34' 18.7"; Lon. 92° 19' 36.6").

Remarks: This is a small species (maximal shell diameter of 2 mm). The last whorl in adult shells is broadly oval to round. The keel is moderately tall and rounded in undamaged specimens, with a posteriorly-slanted corrugated texture. The spire is low conical, consisting of four to five whorls. The species shares many similarities with *A. inflata*, but is immediately distinguishable by its eye morphology. The species is cosmopolitan in tropical to subtropical waters, and is limited to the upper 100 m of the water column in Hawaiian waters.

Family: Carinariidae

Genus: *Carinaria*

Type species: *Carinarialamarcki* (Blainville 1821)

Plate 2, Fig. 8 (Uttar para 1, Lat. 20° 37' 30.9"; Lon. 92° 19' 35.7").

Remarks: The shell is broad pyramidal shaped (maximum body length is 220 mm) with the protoconch, the only part with whorls on top. The body whorl is large with coarse transverse striation. The body is almost completely transparent and can never withdraw into the shell. The shell is low conical with a high keel. It is a cosmopolitan species with a wide north-south range between 60°N and 45°S. In the Mediterranean it is common everywhere and penetrates deep into the Caribbean.

Genus: *Carinaria*

Type species: *Carinariagalea* (Benson 1836)

Plate 2, Figs 9, 10 (Uttar para 1, Lat. 20° 37' 30.9"; Lon. 92° 19' 35.7").

Remarks: This is a very large shelled pelagic snail, can be up to 5 cm long with an almost completely transparent body. The shell is high conical with a high keel. Only the broad triangular visceral nucleus is darkly pigmented. The shell is less strongly curved backwards than in *Carinarialamarcki.* Embryonic shell, with three to five whorls. Body length is up to 50 mm.This species is endemic to the Indo-Pacific Ocean and it shares its distribution pattern with *Carinaria cristata.* A much greater population is found only in the Tasman Sea.

Superfamily: Naticoidea

Family: Naticidae

Genus: *Natica*

Type species: *Naticagualteriana* (Recluz 1844)

Plate 2, Figs 11, 12 (Uttar para 5, Lat. 20° 34' 49"; Lon. 92° 20' 11").

Remarks: Small shell (maximum shell length 32 mm), solid globose with inflated body whorl and elevated spire, pointed apex surface smooth and glossy. Aperture large and semicircular. Surface ash white, ornamented with wavy vertical lines, apex partially tinged with pale bluish grey, umbilical space white and body whorl with a white band. Indo-West Pacific from southern India, Sri Lanka, the Philippines and Taiwan to Melanesia and Indonesia.

Super family: Pterotracheoidea

Family: Pterotracheidae

Genus: *Firoloida*

Type species: *Firoloidadesmarestia* (Lesueur 1817).

Plate 2, Figs 13, 14 (Chera Dwip 3, Lat. 20° 37' 30.9"; Lon. 92° 19' 35.7").

Remarks: This is a medium sized naked pelagic snail with an almost completely transparent body. The intestine is frequently full and visible. It has a small dextrally coiled shell with about 3 whorls, regularly increasing in width. The suture is clear but not very deep. The aperture is oval to round. The shell is yellow-whitish and the surface is smooth. Body length of the species is up to 40 mm. This species is found between 40°N and 40°S which is slightly further southwards than most Heteropoda.

Superfamily: Calyptraeoidea

Family: Calyptraeidae

Genus: *Crepidula*

Type species: *Crepidulawalshi* (Reeve 1859).

Plate 2, Figs 15, 16 (Chera Dwip 5, Lat. 20° 38' 9.6"; Lon. 92° 19' 36.6").

Remarks: Shell small (maximum shell length 9 mm and 23 mm in diameter), elongate-ovate, flattened, spire obsolete towards the posterior edge, margins irregular, internal shelf flattened and partly covering the aperture, arises from below the apex. Surface with fine concentric striae and coarse growth lines.

Order: Architaenioglossa

Super family: Cyclophoroidea

Family: Viviparidae

Genus: *Bellamya*

Type species: *Bellamyacrassa* (Benson 1836)

Plate 2, Figs 17, 18 (Uttar para 1, Lat. 20° 37' 30.9"; Lon. 92° 19' 35.7").

Remarks: Shell small, thicker, globose with fine transverse striations. Umbilicus perforate, spire short and blunt. Umbilical opening is prominent, generally impressed, suture often canaliculated. Aperture sub oval, columella arched.

Family: Cyclophoridae

Genus: *Pterocyclos*

Type species: *Pterocyclosrupestris* (Benson 1832)

Plate 2, Fig. 19 (Chera Dwip 3, Lat. 20° 34' 54.9"; Long. 92° 20' 14.3").

Remarks: Average shell length, width, aperture length, width are about 5, 11, 6, 4 mm, respectively (Thakur *et al*. 2012, Mitra 2014).Shell small, nearly transparent, depressed with a scarcely raised spire, finely striate. Last whorl descending moderately, aperture circular. Shell is whitish marked with zigzag chocolate lines, both above and below. Freshwater pteropod. Plays an important role in the terrestrial ecosystem as a scavenger.

Subclass: Vetigastropoda

Super family: Trochoidea

Family: Turbinidae

Genus: *Astralium*

Type species: *Astraliumsemicostata* (Kiener 1850).

Plate 2, Fig. 20 (Chera Dwip 6, Lat. 20° 34' 47.3"; Long. 92° 20' 14").

Remarks: Average shell length, width, aperture length and width are about 19, 20, 13 and 9 mm respectively (Ahmed 1995, Rao 1968). Shell small, cone shaped, longitudinal folds across the surface of the whorls. Shell sculptured with oblique axial nodules, distinct just above the suture and body shoulder. Apex not so sharp, aperture oblique ovate, covered by a flat base. Creamy white body surface with creamy spots. Wide spread in the Indian Ocean, Myanmar, Sri Lanka, the Philippines and Australia.

Result and Discussion

Species of Uttar para part: The investigation of pteropods in the Saint Martin's Island concluded to final analysis of total 41 species. Among the total species, 39% of the samples were from Thecosomata order of Heterobranchia subclass under the class of Gastropoda. The Thecosomes included 6 families, 9 genus and 16 species. The distribution of pteropods is mainly influenced by the depth of the ocean (van Straten 1972). The abundance of pteropods within different water masses depends upon certain physical and chemical properties and also by the adaptive capacities of different species. In case of Thecosome pteropods, the abundance depends on the process of calcification to grow their shells which consist of aragonite and calcium carbonate. Therefore the saturation of carbonate ions in the water is very important to their survival. Their body is made up of an aragonite and calcium carbonate shell and so they are very sensitive to ocean acidification caused by the anthropogenic CO_2 and other oceanic processes (Comeau *et al.* 2009) and also play a vital role in the cycling of carbon and carbonate.

During the field investigation, most of the pteropod species of Thecosomata were found in the Saint Martin’s part of the field area which is situated in the northern part known as

Uttar para. Within this part Thecosomes were abundant in 'Uttar para 1' station as 6 species were found there. Five species were found each in 'Uttar para 2'and 'Uttar para 5' stations, 2 species each were found at 'Uttar para 3' station and 1 species was found at 'Uttar para 4' station, 'Chera Dwip 1' station and 'Chera Dwip 7' station. Abundance of Thecosomata in Uttar para part are very young, most of them are from Holocene. All of them are predominantly shallow water species. *Gleba cordata* from 'Uttar para 2' and *Peracle bispinosa* from 'Uttar para 3' stations are exclusively warm water species. Hence their presence indicates shallower water. On the other hand 3 freshwater species of Stylommatophora order, namely *Macrochlamys opipara* and *Bellamya crassa* were found near the ferry ghat at 'Saint Martin 1' station which indicates availability of fresh water or very low percentage of salinity of the ocean water. As the Thecosomes are being survived in this region, it indicates the threat of acidification is lesser in this area. But further detailed studies on the shell morphology and their rate of decay can specify the condition of acidification. Overall it can indicate the threat of acidification is not concerning in this region though it can be concerning in near future.

The species of Chhera Dwip part mostly comprises of different orders and, families and genus than the species of Uttar para part. It is known that the abundance of a certain species depends on the depth of the ocean water. Chheradip is further ahead of the Uttar para towards the Bay of Bengal and contains deeper water than the previous area. So we can notice the changing in the abundance of different pteropod species with the increasing depth towards Chera Dwip.

The samples in this region includes one order, one family and one genus of Heterobranchia subclass, 3 orders, 8 family and 8 genus of Caenogastropoda subclass and one family and genus of Vetigastropoda subclass. Marine Caenogastropods including Littorinimorpha, Neogastropoda and Architaenioglossa orders of pteropods are abundant here. Among them, Littorinimorpha has 8 species, Architaenioglossa has 4 species and Neogastropoda has only 1 species. Thecosomes were abundant in Saint Martin part but in this region Thecosomes are infrequent. Among the total number of Thecosomes, only 19% are found here and remaining 81% are found in Uttar para part. In Chera Dwip part they were found only in 'Chera Dwip and 'Chera Dwip station. It suggests that the oceanic condition is more suitable in Uttar para area or shallower water than in Chera Dwip part which is comparatively deeper area. The reason behind it could be the threat of acidification, variation in salinity etc. Further studies in this region could be helpful to understand clearly about the decrease of the Thecosomes and in this way it is possible to construct the palaeoclimatic conditions, salinity, acidification, sea level up down etc. A thorough study over a year on pteropods in this region would be very helpful to analyze the seasonal variation of sea level rise and corresponding climatic threat in this region.

Conclusion

The Saint Martin's Island is a great resource of our country. In recent years global climate change poses a high risk to the biodiversity of coral reefs of St. Martin's. The major threats to the coral reefs are high levels of sedimentation, cyclones, storm surges and beach erosion. Global warming is a matter of major concern for coral reefs of this island as elsewhere. The purpose of the study was to identify the species of pteropods in this region and know about their characteristics. The study reveals a high abundance of The cosomes in this region. At present, The cosomes are being used as the indicator of ocean acidification in many areas of the world. So, further detailed study on this can reveal significant indication about the potential disaster in this region.

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IN VITRO SCREENING OF FUNGICIDES AND PLANT EXTRACTS AGAINST *COLLETOTRICHUM GLOEOSPORIOIDES* (PENZ.) SACC. THE CAUSAL AGENT OF ANTHRACNOSE DISEASE OF *RAUWOLFIA SERPENTINA* (L.) BENTH EX KURZ

ZUHRA YASMIN[1] AND SHAMIM SHAMSI[*]
Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

Ten fungicides *viz*., Amcogin 50 WP, Autostin 50 WDG, Capvit 77 WP, Dithane M 45, Greengel 72 WP, Haybit 80 WG, Oxivit 40 SC, Ridomil Gold MZ, Sulcox 50 WP and Tilt 250 EC at 100, 200, 300, 400 and 500 ppm concentrations were tested against, C*olletotrichum gloeosporioides* (Penz.) Sacc., the causal agent of anthracnose disease of *Rauwolfia serpentina* (L.) Benth ex Kurz following poisoned food technique. Amcogin, Autostin and Tilt showed complete growth inhibition of *C. gloeosporioides* at 100 ppm concentration. Ethanol extracts of ten plants *viz., Adhatoda vesica, Azadirachta indica, Citrus limon, Curcuma longa, Lantana camara, Moringa oleifera, Ocimum sanctum, Psidium guajava, Thuja orientalis* and *Vitex negundo* were selected to evaluate their efficacy at 5, 10, 15 and 20% concentrations against the same pathogenic fungus. Out of the ten plant extracts, *Azadirachta indica, Citrus limon, Moringa oleifera* and *Psidium guajava* showed complete radial growth inhibition of *C. gloeosporioides* at 20% concentration. Amcogin, Autostin, and Tilt are suggested as best inhibiting chemical fungicides for *C. gloeosporioides*. Extracts of *A. indica, C. limon, M. oleifera* and *Psidium guajava* were also found to be superior to other plant extracts tested in controlling the test pathogen.

Key words: In vitro screening, Fungicides, Plant extracts, C*olletotrichum gloeosporioides*, Anthracnose, *Rauwolfia serpentina*

Introduction

Rauwolfia serpentina (L.) Benth ex Kurz is a medicinal shrub belonging to Apocynaceae. The shrub is locally known as 'Sarpagandha' also known as Indian snakeroot. It grows in India, Thailand, South America and Africa. It is widely distributed in the sub-Himalayan tract from Punjab to Nepal, Sikkim and Bhutan (Ahmed *et al*. 2008). In Bangladesh it grows in Chittagong, Sylhet and Mymensingh (Chowdhury 1995). Khan *et al.* (2001) reported *R. serpentina* in red data book as endangered plant. International Union For conservation of nature (IUCN) has placed this plant under endangered status (Mabberley 2008). Root of this shrub is mostly used for insomnia

*Author for correspondence: <prof.shamsi@gmail.com>. [1]A part of Ph.D. thesis of first author.

(sleeplessness), mental disorders characterized by symptoms like convulsions, excessive talking, maniacal behavior, aggressive behavior etc.. Seventeen different alkaloids have been extracted from the bark of the root of this shrub. Serpentine is one of those alkaloids (Ghani 2003). Anthracnose is one of the destructive diseases of *R. serpentina.* C*olletotrichum gloeosporioides* (Penz.) Sacc. is the causal agents of this disease. The other diseases include Target leaf blotch, Cercospora leaf spot, Die-back, Powdery mildew and Fusarium wilt, Root-knot disease, etc. Mukerji and Bhasin (1986) and Yasmin and Shamsi (2015) reported diseases of *R. serpentina* from India and Bangladesh, respectively. Most of the research work carried out on *R. serpentina* falls under Phytochemical, Pharmacological, Biochemical and Antimicrobial disciplines, but research about its fungal diseases and control is inadequate (Yusuf *et al.* 2009 and Azmi and Qureshi 2012).

Fungicides are chemical compounds used to kill parasitic fungi or their spores. Fungi can cause serious damage in agriculture, resulting in critical losses of yield, quality and profit. Some fungicides are dangerous to human health. Plants and other organisms have chemical defenses that give them an advantage against microorganisms such as fungi. Some of these compounds can be used as fungicides. Due to environmental concerns of controlling fungal disease by toxic chemicals, researchers have focused their efforts on developing alternative methods of controlling fungal diseases. Plant extracts can be successfully exploited in modern agriculture which has recently attracted the attention of several workers. Plant constituents have been reported to be successful fungitoxicants because of low phytotoxicity, easy biodegradability and favorable effects for the growth of the host (Fawcett and Spencer 1970, Panday *et al.* 1983 and Nene and Thapliyal 1993). Extracts obtained from many plants have recently studied for their antifungal activities (Monoharachary and Reddy 1978, Miah *et al*. 1990, Hosen *et al*. 2016).

The present investigation has been undertaken to evaluate the fungi toxicity of some fungicides and plant leaves extracts *in vitro* against test pathogen *C. gloeosporioides* isolated from *R. serpentina.*

Materials and Methods

Infected leaves of *R. serpentina* were collected from field of Botanical garden, Curzon Hall Campus, Dhaka University, during the period of April, 2007 to August, 2012. In the year 2013 in addition to Botanical garden, Curzon Hall campus Dhaka University, infected leaves of *R. serpentina* were collected from Gazipur, Dhaka, Lawachara, Sylhet, Botanic garden, Chittagong University campus and Bangladesh Agricultural University campus Mymensingh. Collected samples were examined and associated fungi were isolated.

Isolation of fungi: The associated fungi were isolated following 'Tissue planting' method on PDA medium. Identification of the fungi were done following standard methods. All the isolated fungi were tested for their pathogenic potentiality.

Sub-culturing of test pathogen: Pure culture of *C. gloeosporioides* from culture slant was inoculated on PDA plates and incubated for seven days in an incubator at 25^{o} C. Five mm mycelial block from Petri plates was used for *in vitro* control of test pathogen.

The experiment was conducted in the Laboratory of Mycology and Plant Pathology, Department of Botany, University of Dhaka, Bangladesh.

Preparation of fungicides at different concentrations: Ten fungicides with different active ingredients, *viz.*, Amcogin 50 WP (50% Carbendazim, MCO Pesticide Ltd. India ACI Formulations), Autostin 50 WDG (50% Carbendazim, ISACAM Co., Hong Kong), Capvit 77 WP (Copper oxychloride, Asia Trade International), Dithane M 45 (80% Mancozeb, Bayer Crop Science Ltd.), Greengel 72 WP (64% Mancozeb, 8% Metalaxil, Green Care Bangladesh), Haybit 80 WG (Abamactin, Syngenta (BD) Ltd), Oxivit 40 SC (Copper Oxichloride, Chemet Wets & Flows Pvt. Ltd**.**), Ridomil Gold MZ (Metalaxil-Mancozeb, Syngenta (BD) Ltd.), Sulcox 50 WP (Copper Oxichloride, Haychem, Bangladesh) and Tilt 250 EC (Propiconazole, Syngenta (BD) Ltd.) were collected from the Krishi Upokoron Biponi Kendro, Khamarbari, Farmgate, Dhaka. The selected fungicides were evaluated at 100, 200, 300, 400 and 500 ppm concentrations for their *in vitro* efficacy against *C. gloeosporioides* the causal agent of anthracnose of *R. serpentina*. Concentration of fungicides was prepared following Chowdhury *et al.* (2015).

Preparation of plant extracts at different concentrations: Ethanol extracts of leaves of ten plants *viz.*, *Adhatoda vesica* Nees, *Azadirachta indica* A. Juss, *Citrus limon* (L.) Burm.f., *Curcuma longa* L., *Lantana camera* L., *Moringa oleifera* Lam., *Ocimum sanctum* L., *Psidium guajava* L., *Thuja orientalis* L. and *Vitex negundo* L. were selected to evaluate their efficacy at 5, 10, 15 and 20% concentrations against the same pathogenic fungus. The leaves were thoroughly washed in tap water, air dried and were prepared by crushing the known weight of fresh materials with ethanol in ratio of (1 : 1, w/v). The mass of a plant part was squeezed through fine cloth and the supernatants were filtered through Whatman filter paper No. 1 and the filtrate was collected in 250 ml Erlenmeyer conical flasks. The requisite amount of the filtrate of each plant extract was mixed with PDA medium in which plant extracts were in 5, 10, 15 and 20% concentrations (Khatun and Shamsi 2016). Three replications were maintained for both the experiments and control sets. The inoculated Petri plates were incubated at 25 ± 2˚C. The radial growth of the colonies of the test pathogens was measured after 5 days of incubation.

The fungitoxicity of the fungicides and plant parts extracts in terms of percentage inhibition of mycelial growth was calculated by using the following formula followed by Bashar and Rai (1991):

$$I = \frac{C - T}{C} \times 100\%$$

where, I = Per cent growth inhibition, C = Growth in control, T = Growth in treatment.

The results were statistically analyzed following computer package MSSTAT-C and means were compared using DMRT.

Results and Discussion

A total of 12 fungal species, namely *Alternaria alternata* (Fr.) Keissler, *Aspergillus niger* van Tieghme, *Colletotrichum gloeosporioides* (Penz.) Sacc., *Fusarium* spp., *Macrophoma* sp., *Nigrospora* sp., *Penicillium* spp., *Pestalotiopsis guepinii*, *Rhizopus stolonifer* (Ehrenb. ex. Fr.) Lind, and *Trichoderma viride* were isolated from anthracnose symptom of *R. serpentina.* Among the isolated fungi *C. gloeosporioides* were found to be pathogenic to *R. serpentina* (Yasmin and Shamsi 2015).

In the present investigation, among 10 fungicides tested complete inhibition of the radial growth of *C. gloeosporioides* was observed with Amcogin 50 WP, Autostin 50 WDG and Tilt 250 EC at all the concentrations used (Table1 and Plate 1. A-C.).

Capvit showed complete inhibition of the test fungus at 300, 400 and 500 ppm concentrations. Maximum 30.92% inhibition of the test fungus was recorded by Dithane M-45 at 500 ppm concentration. Diathane M-45 was not so good fungicide against the test fungus. Greengel showed maximum 48.70% radial growth of test fungus at 500 ppm concentrations. Haybit and Sulcox showed complete inhibition of the test fungus at 400 and 500 ppm concentrations. Oxivit showed 46.63 and 60.67% growth inhibition against the test fungi at 400 and 500 ppm concentration, respectively.

Performance of Ridomil MZ Gold is better than Diathane, Greengel and Oxivit. This fungicides completely inhibited the radial growth of the test fungus at 300, 400 and 500 ppm concentrations.

Table 1. Fungi toxicity of fungicides against *Colletotrichum gloeosporioides* at different concentrations.

Name of fungicides	% inhibition of radial growth of test fungus at different concentrations (ppm)				
	100	200	300	400	500
Amcogin	100 ^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Autostin	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Capvit	46.41^{b}	62.09^{b}	100^{a}	100^{a}	100^{a}
Diathane	6.04^{d}	11.35^{e}	15.46^{f}	21.98^{c}	30.92^{d}
Greengel	24.64^{c}	32.46^{c}	39.71^{d}	45.80^{b}	48.70^{c}
Haybit	24.84^{c}	35.29^{c}	46.41^{c}	100^{a}	100^{a}
Oxivit	3.93^{f}	20.79^{d}	28.09^{e}	46.63^{b}	60.67^{b}
Ridomil	3.08^{f}	6.67^{f}	100^{a}	100^{a}	100^{a}
Sulcox	42.94bc	66.10b	73.45^{b}	100^{a}	100^{a}
Tilt	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
CV%	12.48	4.44	2.32	2.65	1.91

Means followed by the same letter within a column did not differ significantly at 5% level by DMRT. Efficiency gradient of fungicides against *Colletotrichum gloeosporioides* at 100 ppm concentration: Amcogin >Autostin 50 WDG/ / Tilt 250 EC > Capvit > Ridomil Gold MZ 68 WG > Sulcox > Hayvit > Oxivit > Greengel > Diathane M 45.

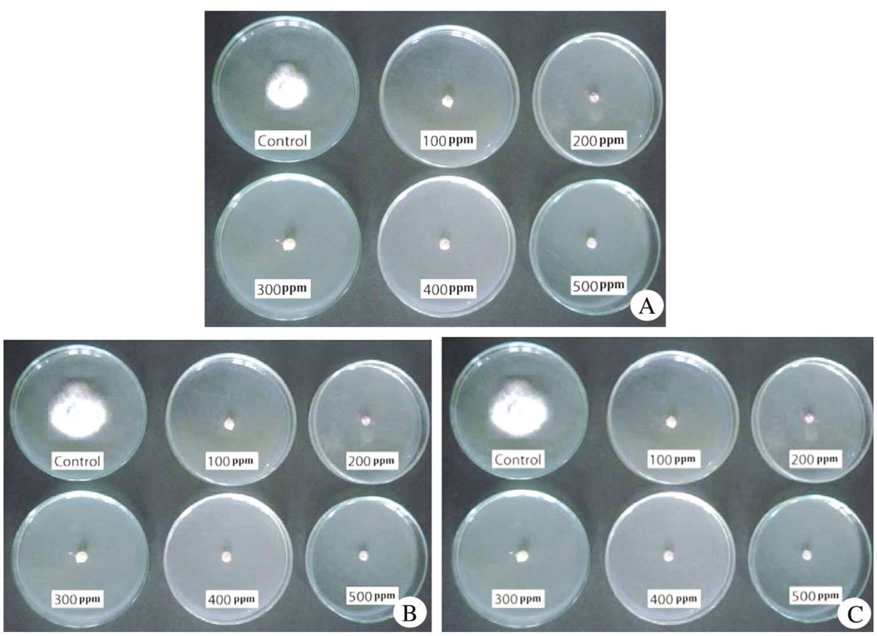

Plate 1. Fungi toxicity of fungicides against *Colletotrichum gloeosporioides* at different concentrations: A. Amcogin, B. Autostin and C. Tilt.

Laboratory evaluation of fungicides revealed that all the fungicides causes partial or complete inhibition of *C. gloeosporioides*, at all the concentration tested. Imtiaj *et al.* (2005) reported that Diathane M-45 and Ridomil MZ Gold were effective in controlling conidial germination of *C. gloeosporioides*, the causal agents of mango at 500~1000 ppm concentrations.

Table 1 presented that amongst the ten fungicides, Amcogin 50 WP, Autostin 50 WDG and Tilt 250 EC showed best result in controlling the test pathogen *in vitro*. Shamsi *et al.* (2014) reported that radial growth of *C. gloeosporioides* isolated from *Senna alata* completely inhibited by Tilt 25 EC at all the concentrations used. Sharma and Verma (2007) reported that Bavistin check the growth of *C. gloeosporioides* causal agent of anthracnose of mango (*Mangifera indica* L.), completely at 100 ppm. Hosen *et al.* (2016) observed complete inhibition of the growth of the jute pathogen *C. gloeosporioides* with Bavistin DF, Greengel 72 WP and Tilt 250 EC at 100, 200 and 400 ppm, respectively.

Results of plant extracts on the radial growth of *C. gloeosporioides* are presented in Table 2. All the plant extracts showed varied degree of growth inhibition of the pathogen at different concentrations. Out of the ten plant extracts, *A. indica, C. limon, M. oleifera* and *P. guajava* completely inhibited radial growth of test pathogen *C. gloeosporioides* at 5, 10, 15 and 20% concentrations. Leave extracts of *A. vasica, C. longa, L. camara, O. sanctum, T. orientalis* and *V. nigundo* showed 80.66, 84, 67.94, 88.60, 71 and 42.92% radial growth of test fungus at 20% concentration. The per cent inhibition of the pathogens increases with the increase of the concentration of the plant extracts in culture medium.

Prasad and Anamika (2015) reported that the extracts of *L. camara* were found to be most effective for the control of the *C. gloeosporioides*. Imtiaj *et al.* (2005) found that plant extracts such as *C. longa* was also most effective against *C. gloeosporioides* the causal agents of anthracnose of mango. Hosen *et al.* (2016) also observed inhibition of the growth of the jute pathogen *C. gloeosporioides* with *C. limon, D. metel* and *A. indica* at 20% concentration. Plant parts and their constituents of some higher plants have already been reported to be of successful nature of fungitoxicants, lesser phytotoxicity, systemicity, easily biodegradability and favourable effects of the growth of the host (Fawcett and Spencer 1970, Pandey *et al.*1983). Chakraborty *et al.* (2009) reported the efficacy of various cell free extracts of the plants against the growth inhibition of the pathogen. The effectiveness of extracts varied significantly with dosage, where 100% inhibition of the pathogen was achieved both with neem and garlic extracts.

Table 2. Fungi toxicity of plant extracta against *Colletotrichum gloeosporioides* at different concentrations.

Name of plants	% inhibition of radial growth of the pathogen at different concentrations (%)			
	5	10	15	20
Adhatoda vasica	52.11[b]	63.33[b]	78.31[a]	80.66[a]
Azadirachta indica	100 [a]	100 [a]	100 [a]	100 [a]
Citrus limon	100[a]	100[a]	100[a]	100[a]
Curcuma longa	50.00[b]	53.0[b]	67.50[a]	84.00[a]
Lantana camara	40.67[c]	49.44[b]	56.87[b]	67.94[b]
Moringa oleifera	100[a]	100 [a]	100 [a]	100 [a]
Ocimum sanctum	62.77[b]	50.71[b]	71.21a	88.60[a]
Psidium guajava	100[a]	100[a]	100[a]	100[a]
Thuja orientalis	27.67[c]	32.22[b]	64.89[a]	71.00[a]
Vitex negundo	18.85 [NS]	37.37 [c]	39.92 [b]	42.92 [b]
CV%	1.63	1.26	1.37	1.51

Means followed by the same letter within a column did not differ significantly at 5% level by DMRT. NS = Not significant. Efficiency gradient of plant extracts against *Colletotrichum gloeosporioides* at 20% concentration: *Azadirachta indica* > *Citrus limon* > *Moringa oleifera* > *Psidium guajava* > *Ocimum sanctum* > *Curcuma longa* > *Adhatoda vasica* > *Thuja orientalis* > *Lantana camara* > *Vitex negundo.*

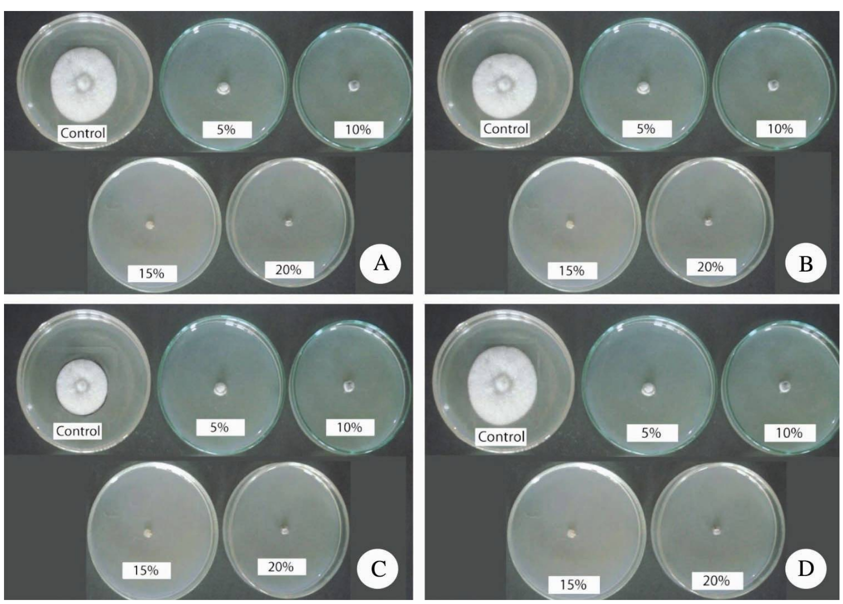

Plate 2. Fungi toxicity of plant extracts against *Colletotrichum gloeosporioides* at different concentrations: A. *Azadiracta indica* B. *Citrus lemon*, C. *Moringa oleifera* and D. *Psidium guajava.*

Ethanol extract of *Azadirachta indica* showed complete inhibition of radial growth of *C. gloeospoiroides* the causal agents of anthracnose of *Senna alata* at all concentratios used. *Citrus medica, Datura metel*, *Mangifera indica, Senna alata* and *Tagetes erecta* at 10 and 20% concentrations, were also capable of complete inhibition of radial growth of the fungus *C. gloeosporoides* isolated from *S. alata* (Shamsi *et al*. 2014). Rahul and Anamika (2015) reported that ethanol leaf extract of *Lantana camara* has the potential antifungal compound to control *C. gloeosporioides* the casual organism of papaya anthracnose. They also found the significant inhibitory effect of lemon leaf in controlling the redial growth of *C. gloeosporioides.*

Conclusion

Fungicide Amcogin 50 WP, Autostin 50 WDG and Tilt 250 EC were found to be significantly effective against *C. gloeosporioides* anthracnose of *R. serpentine*. These fungicides may be used in field trial to confirm their efficacy in controlling anthracnose of *R. serpentina*. Effect of ethanol plant extract of *Azadirachta indica, Citrus limon, Moringa oleifera* and *Psidium guajava* showed promising prospect in controlling radial growth of *C. gloeosporioides* the causal agents of anthracnose of *R. serpentina.* These ecofriendly plant extract should be studied in field experiment to evaluate their efficacy in controlling anthracnose of *R. serpentina* in field condition.

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EFFECTS OF SODIUM CHLORIDE SALINITY ON WATER RELATIONS AND ION ACCUMULATION IN TWO MUNGBEAN VARIETIES DIFFERING IN SALINITY TOLERANCE

MST. SHAHNAZ SULTANA[1], M.A. HALIM[1], FEROZA HOSSAIN[1], M. ABDUL KARIM[2] AND MOHAMMAD TALIM HOSSAIN*[1]

[1]*Department of Botany, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh*

[2]*Department of Soil Science, Faculty of Agriculture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh*

Abstract

Salt tolerance in relation to water status and plant nutrients of two mungbean varieties, BARImung 2 (salinity sensitive) and BUmung 2 (salinity tolerant) was evaluated. The seeds were grown in pots and treated with NaCl levels of 0 (control), 100 and 200 mM. Different parameters related to water relations as well as mineral nutritients were measured. The exudation rate and relative water content were decreased but water saturation deficit was increased by salinity in both the varieties. In BARImung 2 plants, the exudation rate and relative water content were lower but water saturation deficit was higher than those in BUmung 2 at both 100 and 200 mM NaCl levels. Salinity also influenced the accumulation of Na, K, Ca and Mg in leaves, stems and roots of the two said mungbean varieties. Sodium accumulation was inceseased in all the plant-parts of both the varieties in the order of stem > root > leaf but in BUmung 2 the accumulation was lower than that of BARImung 2 except in root. Potassium accumulation deceresed in all parts of both the mungbean varieties but that was lower in BUmung 2 than that of BARImung 2. The contents of Ca and Mg in all the plant-parts increased more in BUmung 2 than those of BARImung 2 with the increase of salinity levels. All these results indicated that high salt tolerance in BUmung 2 was associated with its better water status, more or less uniform mineral nutrient (Ca and Mg) distribution in different plant-parts than that in BARImung 2.

Key words: NaCl salinity, Water relation, Ion accumulation, Mungbean varieties, Salinity tolerance

Introduction

Salinity is one of the major environmental stresses, which affects plant growth and development by disturbing water relations, creating imbalance in plant nutrition and affecting plant physiological and biochemical processes (Karim *et al.* 1993, Munns 2005). Under saline conditions plant suffers from osmotic shock due to lower osmotic potential in the soil solution (Orcutt and Nilsen 2000, Rahnama *et al.* 2010). Islam (2001) pointed out that relative water content (RWC), water saturation deficit (WSD), water retention capacity (WRC) and water uptake capacity (WUC) were affected by salinity in blackgram and mungbean.

*Author for correspondence: <talim_ju@yahoo.com>.

At the whole plant level, salinity stress frequently induces an increase in Na and Cl contents as well as a decrease in K, Ca, N and Pi concentrations (Martinez and Lauchli 1994, Ahmad and Prasad 2012). Generally, Ca and K ions are decreased in plants under saline conditions (Al-Harbi 1995, James *et al.* 2011). In contrast, Ashraf and Rauf (2001) reported that under saline conditions concentrations of Na, K and Ca increased significantly in all parts of the maize seedlings. Usually salinity tolerant variety of a crop shows better water relations, low accumulation of Na, imbalance in the accumulation of nutrient elements, higher photosynthesis and finally better growth than those in salt sensitive ones. In glycophytes, salinity resistance is associated with a restriction of toxic ion absorption at the root level (Schachtman and Munns 1992) vis a vis minimum accumulation of Na and Cl in the shoot of the plant (Akita and Cabsulay 1990).

Leguminous crops are generally sensitive to salinity though there is considerable difference in salt tolerance between legume species (Maas and Hoffman 1977). Mungbean is an important glycophyte legume crop in Bangladesh. Despite the availability of a substantial number of reports on the effect of salinity on mungbean (Raptan *et al.* 2001, Kabir *et al.* 2005), the salt tolerance behavior and growth mechanisms of this crop remain unclear. To clarify salinity tolerance behavior in the present study a sensitive and a tolerant variety of mungbean were treated with NaCl salinity. The objectives of this study were to analyze the influence of salinity on water relations and mineral ion accumulation in different plant parts of two mungbean varieties differing in their salinity tolerance.

Materials and Methods

Two mungbean varieties, BARImung 2 (salinity sensitive) and BUmung 2 (salinity tolerant) were used for this experiment (Sultana *et al*. 2007). The plants were grown in pots in the research field of Botanical Garden of Jahangirnagar University. The physiological and biochemical analyses were carried out at the Plant Physiology and Plant Biochemistry laboratory of Botany Department, Jahangirnagar University and the Chemistry and Soil Science laboratory of Bangabandhu Sheikh Mujibur Rahman Agicultural University, Gazipur, Bangladesh. Each pot was filled with 12 kg of soil along with compost (made of grass, leaves and cowdung), one fourth of the soil by volume. Basal dose of fertilizers, 40 kg N, 60 kg P and 40 kg K per hectare in the form of urea, triple super phosphate and muriate of potash, respectively were thoroughly mixed with the soil. The total amount of urea was applied in two splits. The soil samples were air dried, crushed and passed through a 3 mm-pore-diameter sieve. The pots were kept under natural sunshine till harvesting (up to pre-flowering stage). There were six treatment combinations, which were comprised of two mungbean varieties and three levels of salinity. The three salinity levels were non-saline, control and 0 mM, and two salinity treatments, 100 and 200 mM NaCl. The experiment was laid out in a completely randomized design (CRD) with three replications.

Four seeds of uniform size were directly sown in the pot and then the pots were watered for easy germination. After seedling establishment, only two better seedlings were allowed to grow in each pot. Then intercultural operation, weeding and pest control measures were taken as and when necessary. The germinated seedlings were watered up to 28th day of seedling emergence. Then watering was stopped. From the 32- to 42nd days after emergence (DAE), which was before flowering stage, the mungbean plants in each treated pot were irrigated with 100 ml of NaCl solutions every day. Salt solutions were prepared artificially by dissolving 5.85 and 11.7 g/l of commercially available NaCl with distilled water to make 100 and 200 mM NaCl solutions, respectively. Tap water was served as non-saline control. To study the physiological parameters, three plants of each treatment of each variety were taken for collecting data at pre-flowering stage.

Measurement of exudation rate: Exudation rate was measured at 5 cm above from the stem base of mungbean plant. At first dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1 hr at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was measured by deducting cotton weight from the sap containing cotton weight and expressed in per hour basis.

Measurement of plant water status: The fresh leaves of same sized and same aged of five plants from each treatment were carefully separated. Fresh weights of leaf segments were taken. The collected leaf segments were kept immersed in distilled water for 24 hrs at room temperature in the dark. The turgid weights of those parts were then measured. Afterwards all the leaf materials were oven-dried at 80°C for 72 hrs in order to take dry weight. The fresh, turgid and dry weights of the leaf segments were used to determine the relative water content (RWC) and water saturation deficit (WSD) following Sangakkara *et al.* (1996).

Analyses of mineral ions concentration in different plant-parts: For analysis of Na, K, Ca and Mg, oven dried plant materials (leaves, stems and roots) at harvest were ground with a mortar and pestle. 500 mg ground samples for each ion were taken in a conical flask with 5 ml nitric-per chloric acid (nitric acid + perchloric acid, 5 : 1) dry-ashed at 200 - 220°C for 2 hrs at sand bath for digestion. After digestion distilled water was added, dissolved and made the digest up to 100 ml. Then 10 ml solution and 2 ml lanthanum chloride ($LaCl_3.7H_20$) were taken in a 100 ml conical flask and by adding distilled water the solution was made up to 100 ml. Then liquid sample was taken in a vial test tube and absorbance of respective ions was measured with Atomic Absorption Spectrophotometer (Model 170-80, Hitachi) following the methods of Yamakawa (1992).

Data were analyzed statistically following randomized complete block design using ANOVA procedure in SAS statistical software.

Results and Discussion

The data on the effect of salinity on water status, exudation rate and water saturation deficit in mungbean varieties are presented in Table 1. Exudation rate in salt treated BARImung 2 plants was much lower than that of BUmung 2 at both 100 and 200 mM NaCl levels. Compared to control plants, exudation rates of BUmung 2 decreased by 39.13 and 86.96%, while those in BARImung 2 were decreased by 74.02 and 96.06% at 100 and 200 mM NaCl, respectively (Table 1). Decreased exudation rate means lower water uptake by plants. Reduction in water uptake by plants due to salt stress has been reported by Islam (2001). Higher exudation rates in BUmung 2 disclosed that BUmung 2 plants could absorb more water than BARImung 2 under saline condition. Similar results were reported by Sangakkara *et al.* (1996) and Faruquei (2002).

Relative water content (RWC) was greater in plants grown at control than the plants grown under salinity stress (Table 1). The leaf of BUmung 2 and BARImung 2 showed identical RWC at control treatment. However, at the high salt concentration the leaf of BARImung 2 showed higher reduction (45.25%) in RWC than that of BUmung 2 (32.63%). Decreased in RWC due to salinity was reported by Kabir *et al.* (2005) in mungbean and Islam (2001) in mungbean and blackgram. It is well known that salinity decreases water potential of soil solution and plant cannot uptake water freely, and consequently RWC decreased (Orcutt and Nilsen 2000). In the present study, results indicated that BARImung 2 was found to suffer more from water stress than BUmung 2. The better water retention in BUmung 2 under saline condition obviously contributed for maintenance of higher plant growth than in BARImung 2. This result is in agreement with the report of White and Izquierdo (1991).

Water saturation deficit (WSD) showed an inverse trend of RWC (Table 1). WSD indicates the degree of water deficit in plants. Salinity increased the WSD in both the varieties compared to that of control treatment. However, the higher salt (200 mM) treated plants of BARImung 2 showed relatively higher WSD (283.25%) than that of BUmung 2 (258.04%) over control. This finding reveals that BARImung 2 suffered more from water deficit especially at high salt concentration than BUmung 2. Similar results were reported by Islam (2001) and Kabir *et al.* (2005).

Table 1. Effect of NaCl salinity on exudation rate, relative water content (RWC) and water saturation deficit (WSD) of two mungbean varieties at pre-flowering stage.

Variety	Salinity level (mM)	Exudation rate (mg/min)	Changes over control (%)	Relative water content (RWC)	Changes over control (%)	Water saturation deficit (WSD)	Changes over control (%)
BARImung 2	0	2.54 a		85.08 a		10.33 d	
	100	0.66 d	–74.02	60.13 c	–29.33	34.46 c	233.59
	200	0.10 e	–96.06	46.58 d	–45.25	39.59 b	283.25
BUmung 2	0	2.07 b		89.67 a		14.92 d	
	100	1.26 c	–39.13	65.54 b	–26.91	39.87 b	167.23
	200	0.27 e	–86.96	60.41 c	–32.63	53.42 a	258.04

In a column followed by common small letters do not differ significantly at 5% level of significance.

Accumulation of mineral ions in different plant-parts: Results of Na accumulation of two mungbean varieties are presented in Table 2. Compared to control, Na accumulation was increased with increasing salinity levels for both the varieties. At high salt concentration however Na accumulation was higher (50 and 455.56%) in leaf and stem parts of BARImung 2 than that in BUmung 2 (31.11 and 316.67%). The tolerant variety, BUmung 2 accumulated less amount of Na in most of the plant parts except root compared to BARImung 2 (Table 2). Blum (1988) also reported that tolerant crop accumulated less amount of Na than susceptible one. The findings of Karim *et al.* (1992) in triticale and Raptan *et al.* (2001) in blackgram and mungbean indicated that tolerant cultivar maintained relatively larger Na in the root and a smaller amount in the shoot compared to the salt-susceptible cultivar. In contrast to shoot, Na concentration was greatly reduced in leaf. The reduction was higher in BARImung 2 compared to that of BUmung 2 (Table 2). This observation indicated that the translocation of Na from shoot to the leaf was regulated efficiently in BUmung 2 compared to BARImung 2. Probably this might be the reason for higher tolerance of BUmung 2 to salinity stress.

Table 2. Effect of NaCl salinity on Na accumulation in two mungbean varieties at pre-flowering stage.

Variety	Salinity level (mM)	Na in leaf (mg/g)	Changes over control (%)	Na in stem (mg/g)	Changes over control (%)	Na in root (mg/g)	Changes over control (%)
BARImung 2	0	0.050 a		0.063 d		0.605 c	
	100	0.068 b	36.00	0.233 b	269.84	0.783 b	29.42
	200	0.075 c	50.00	0.350 a	455.56	0.947 a	56.53
BUmung 2	0	0.045 a		0.060 d		0.220 d	
	100	0.054 a	20.00	0.168 c	180.00	0.663 c	201.36
	200	0.059 b	31.11	0.250 b	316.67	0.795 b	261.36

In a column followed by common small letters do not differ significantly at 5% level of significance.

Results of K accumulation in two mungbean varieties are presented in Table 3. The table shows that K accumulation was decreased by salinity in all parts of both the varieties of mungbean. With the increase in salinity from 0 to 200 mM, the reduction of K in all parts of BARImung 2 was higher compared to those of BUmung 2 (Table 3). At high salt concentration the reduction percencentage of K in leaf, stem and root of BARImung 2 were 28.50, 44.41 and 49.19 whereas those were 24.37, 37.90 and 36.78 in BUmung 2, respectively (Table 3). These results indicated that BUmung 2 acumulated higher K ion than that of BARImung 2.

Salinity induced reduction in K accumulation was reported in forage crops (Datta *et al.* 1996), and blackgram and mungbean (Raptan *et al*. 2001). Under saline conditions plant cells utilize K as a metabolite to maintain turgor to escape from osmotic shock (Blum 1988). In fact, the ability to maintain metabolically significant concentration of K may be essential for salt tolerance in glycophytes (Zhang and Blumward 2001, Daşgan *et al.* 2002).

Results of Mg accumulation of two mungbean varieties are presented in Table 4. Mg accumulation was increased almost in all parts except root with the increasing salinity levels for both the varieties. However, Mg accumulation was lower in BARImung 2 than that of BUmung 2. In leaves and stems BUmung 2 accumulated higher (27.37 and 21.39%) Mg contents than those of BARImung 2 (15.32 and 14.51%, respectively) at 200 mM NaCl. The decrease in Mg content in roots of BARImung 2 was higher (46.43%) than that of BUmung 2 (22.63%) over control (Table 4). These results indicated that BUmung 2 accumulated higher Mg than that of BARImung 2. Raptan *et al.* (2001)

reported an increasing pattern of Mg accumulation in blackgram and mungbean under saline conditions, though Patil *et al.* (1995) did not find any influence of salinity on Mg accumulation in greengram. Mg accumulation in plant organs is probably helpful to maintain the osmoregulation to protect the plant cells from the osmotic shock caused by salinity (Greenway and Munns 1980).

Table 3. Effect of NaCl salinity on K accumulation in two mungbean varieties at pre-flowering stage.

Variety	Salinity level (mM)	K in leaf (mg/g)	Changes over control (%)	K in stem (mg/g)	Changes over control (%)	K in root (mg/g)	Changes over control (%)
BARImung 2	0	1.428 c		1.448 c		2.893 b	
	100	1.207 c	–15.48	1.243 c	–14.23	2.122 c	–26.65
	200	1.021 d	–28.50	0.805 d	–44.41	2.033 c	–49.19
BUmung 2	0	2.692 a		3.166 a		3.622 a	
	100	2.442 b	–9.29	2.866 b	–9.48	2.948 b	–18.61
	200	2.036 b	–24.37	1.966 c	–37.90	2.290 c	–36.78

In a column followed by common small letters do not differ significantly at 5% level of significance.

Table 4. Effect of NaCl salinity on Mg accumulation in two mungbean varieties at pre-flowering stage.

Variety	Conc. of NaCl (mM)	Mg in leaf (mg/g)	Changes over control (%)	Mg in stem (mg/g)	Changes over control (%)	Mg in root (mg/g)	Changes over control (%)
BARImung 2	0	0.359 c		0.317 c		0.659 a	
	100	0.398 bc	10.86	0.343 c	8.20	0.577 b	–12.44
	200	0.414 b	15.32	0.363 bc	14.51	0.353 d	–46.43
BUmung 2	0	0.380 bc		0.402 b		0.486 c	
	100	0.468 a	23.16	0.458 a	13.93	0.437 b	–10.08
	200	0.484 a	27.37	0.488 a	21.39	0.376 d	–22.63

In a column followed by common small letters do not differ significantly at 5% level of significance.

Table 5. Effect of NaCl salinity on Ca accumulation in two mungbean varieties at pre-flowering stage.

Variety	Conc. of NaCl (mM)	Ca in leaf (mg/g)	Changes over control (%)	Ca in stem (mg/g)	Changes over control (%)	Ca in root (mg/g)	Changes over control (%)
BARImung 2	0	3.680 c		2.160 c		3.270 a	
	100	4.640 b	26.09	2.620 b	21.30	1.860 b	–43.12
	200	5.240 ab	42.39	3.000 a	38.89	1.466 c	–55.17
BUmung 2	0	3.223 c		0.979 d		1.375 cd	
	100	4.349 b	34.94	1.738 c	77.53	1.225 d	–10.91
	200	5.540 a	71.89	2.560 b	161.49	1.171 d	–14.84

In a column followed by common small letters do not differ significantly at 5% level of significance.

Results of Ca accumulation of two mungbean varieties are presented in Table 5. The table shows that Ca accumulation was increased in leaves and stems with the increasing salinity levels for both the varieties, except roots. At high concentration of NaCl (200 mM), the percentages of Ca ion in leaf and stem of BUmung 2 were 71.89 and 161.49 whereas those in BARImung 2 were 42.39 and 38.89, respectively (Table 5). Similar results were reported by Raptan *et al*. (2001) in blackgram and mungbean. Salinity induced reduction of calcium uptake was reported by Patil *et al.* (1995) in greengram. Blum (1988) found that like some other elements Ca also acts as metabolite to protect plant cells from the osmotic shock in different crops under saline stress. The increase in Ca contents in leaves and stems was higher in BUmung 2 than those of BARImung 2 and the decrease of Ca content in roots was higher in BARImung 2 than that of BUmung 2 over control (Table 5). These results revealed that BUmung 2 accumulated higher Ca than that of BARImung 2 which indicates the high tolerance of BUmung 2 to salinity stress. Lutts *et al.* (1996) reported that Ca content was decreased with salinity in salt-sensitive genotypes while they remained at constant levels in salt-resistant ones.

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IMPACTS AND CHALLENGES ASSOCIATED WITH SHRIMP CULTIVATION IN PARULIA UNION, SATKHIRA, BANGLADESH: AN EMPIRICAL STUDY

SHAMIMA PRODHAN*, BIVUTI BHUSHAN SIKDER AND MAHBUBA NASREEN
Institute of Disaster Management and Vulnerability Studies,
University of Dhaka, Dhaka-1000, Bangladesh

Abstract

This paper offers an overview of an empirical study conducted at Parulia union in Satkhira district, Bangladesh on unplanned shrimp culture, practiced by masses that ultimately led to serious environmental degradation and socioeconomic consequences such as salinity intrusion, decline in water and soil qualities, reduction in agricultural productions, decrease in cattle production, migration, and human health hazards. The real scenarios give evidences of the impacts of imposed shrimp cultivation and the associated challenges faced by the communities including reduction in cultivable land area (59.8%), increase of *Gher* area (48.0%), increase of soil salinity (74.5%), reduction in vegetable production (67.6%), reduction in agriculture farming (67.6%), reduction in freshwater fish culture (63.7%), impacts on livelihood patterns and reduction in local varieties of crops, fruit trees, and plants. Major challenges identified by the respondents are: reduction in soil quality (41.2%), reduction in water quality (38.2%), social problems (20.6%), problems in getting safe drinking water (19.6%), landlessness (35.3%), migration (34.4%), outbreak of common diseases (19.6%) etc. Urgency of a national policy framework addressing the issue holistically is of grave importance to solve the problem.

Key words: Impact, Shrimp cultivation, Salinity intrusion, Environmental degradation

Introduction

Shrimp (*Penaeus monodon*) culture was mainstreamed in Bangladesh since 1970s (Rahman and Hossain 2013). The “*Gher*” farming system has been well suited to shrimp (Paul and Vogl 2011, Rahman *et al.* 2011) and salinity found to be linked with shrimp and considered to be a major challenge in coastal areas of Bangladesh (Hossain *et al.* 2012, Uddin and Haque 2010). Nearly 27% of arable land in the southwestern coast is affected by salinity. In recent decades, the development of commercialized shrimp farming has fueled substantial national and international debate concerning its overall unpropitious ecological and socioeconomic consequences (Islam 2008, Kabir *et al.* 2016, Saha 2017). With the change of time, shrimp farming has grown as one of the major industries in Bangladesh contributing to the national economy (Deb 1998) as cultured

*Author for correspondence: <shamimaprodhan07@gmail.com>

shrimp is considered one of the most demandable seafood products worldwide (Alam *et al.* 2005). The spectacular rise of the demand of brackish water shrimp in international market has stimulated the interests of its mass production in Bangladesh. At present, the industry has experienced a good deal of horizontal expansion and spread across the entire coastal belt (Azad *et al.* 2009, Swapan and Gavin 2011). An SRDI (2010) study underscores that salinity affected area has increased from 0.833 million hectares in 1973 to 1.056 million hectares in 2009. Recent salinity level in Satkhira district stipulates that 43% of the total salinity affected area has been incapacitated for agricultural production (Rabbani *et al.* 2013). Scientific studies over decades suggest that shrimp culture has, however, significant impacts on soil, environment, physiography, agriculture, ecosystems, economy, demography, public health, and other important socioeconomic factors (Bailey 1988, Hopkins *et al.* 1995, Páez-Osuna 2001, Primavera 2006, Ali 2006, Kabir and Eva 2014, Akber *et al.* 2017). There are also claims that it has led to disintegration of economic and social conditions of coastal rural communities (Ali 2004). Paul and Røskaft (2013) reported environmental degradation and loss of traditional agriculture due to shrimp culture. Arrangements for shrimp cultivation have reduced the availability of grazing land too and troubled local livestock. Increasing soil salinity and corresponding disruptions have emerged as one of the biggest threats to agricultural productivities (Payo *et al.* 2017, Clarke *et al.* 2015, Dasgupta *et al.* 2015). In the studied area, production of staple fruit trees such as jackfruit, date, mango, plums have also been reduced gradually. Water salinity exceeds the expected level that is required for fish production, and thereby threatens freshwater fisheries. It has also been reported that logging of saline water into fresh land degrades soil quality and adversely affects local vegetation, plants and trees, crops, fishes, livestock, environment, and public health (Khan *et al.* 2011). A feasible legal framework sustained by actionable policies could be of practical help for sustainability (Afroz and Alam 2013). The present study is an attempt to reflect on how unplanned development of shrimp aquaculture in the coastal areas of Bangladesh entailed significant impacts and drawbacks. The specific objectives of the study are as follows:

(i) To identify the impacts of water and soil salinity on agriculture farming and local varieties of crops, vegetables, fruit trees, and plants;

(ii) To understand the impacts of water salinity on freshwater fisheries, aquatic resources, and the impacts of soil salinity on livestock and poultry;

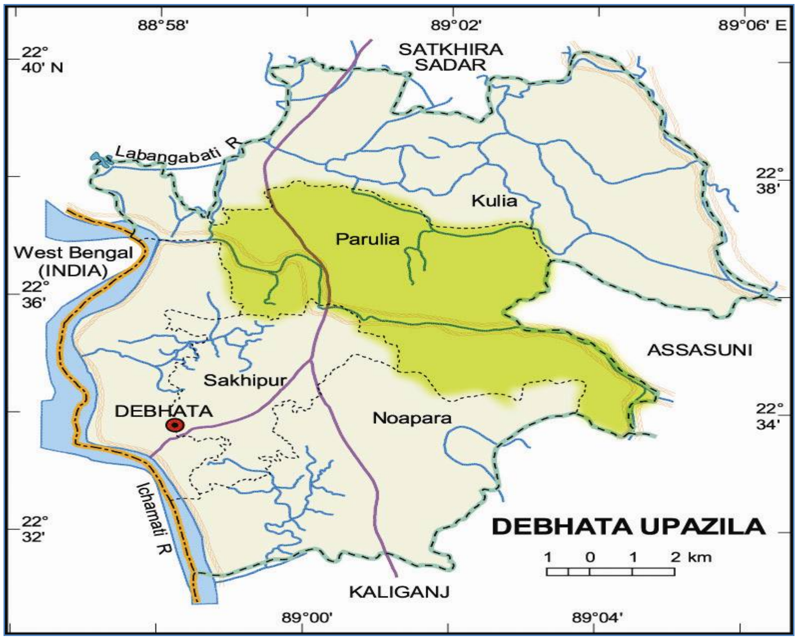
(iii) To assess how livelihood patterns of the local community have been changed due to salinity issues and

(iv) To perceive various other challenges faced by the local community of Parulia union.

Materials and Methods

A variable-based procedure was adopted in order to assess the impacts and challenges invited by commercialized shrimp cultivation practices at Parulia union, Debhata Upazila of Satkhira district (Map 1). A mixed method comprising both quantitative and qualitative approaches was employed and this empirical process required a span of at least three months. Quantitative approach includes a field survey with a structured questionnaire which was carried out in 2014 in 12 villages of Parulia union (Map 1), namely Chaltetola, Kholisakhali, Rangashishe, Koikhali, Polgadarchawk, Norarchawk, Chauddogram, Chhotosanta, Gucchogram, Patakhali, Uttar Parulia, and Dakshin Parulia. Several important criteria were considered during the selection of the fields of study which involved: (a) Areas that had been heavily exploited for commercialized shrimp cultivation, (b) areas still dependent on traditional agriculture, (c) places that encountered significant environmental degradation based on prior scientific literatures and local people's experiences and (d) locals that faced socioeconomic changes due to shrimp culture. From 12 villages, indicative of shrimp culture concentration, 102 households (HH) were selected randomly to be able to reflect the overall scenarios. While selecting the households, senior members of the family (living in those areas for more than 20 years), who were associated with shrimp farming, traditional agriculture, wage earning, day labor, and/or other low-income occupations and had experiences of the problems were considered. Socioeconomic and demographic characteristics of the respondents were also considered. A good number of women were also selected to address gender issues.

The qualitative data were collected through different tools and techniques. Four FGDs were done with farmers and community people following snowball sampling. The selection procedures for FGDs depended on people who somehow experienced the impacts of shrimp culture; also, the people who were associated with other agricultural patterns for a comparison. The locations were besides shrimp farms, open land near households to suit convenience for the participants. Ten KIIs were conducted at different locations with experts following purposive sampling techniques which include key government policymakers, district agriculture extension officers who execute various projects, and NGO executives. Two case studies were conducted too. Keen observation of the researchers also played a role. Apart, authoritative and widely cited peer-reviewed scholarly journal articles from recent scientific studies, books, documents, proceedings of conferences, and presented papers have also been reviewed as a source of secondary data. Table 1 shows some of the sociodemographic characteristics of Parulia union.



Map 1. Map showing study area (Parulia union); Source: Banglapedia, 2013.

Table 1. Sociodemographic information of Parulia union.

Parulia union	
Union: Parulia	Children under age of five: 484
Upazila: Debhata	Literacy rate: 55.66%
District: Satkhira	Principle crop: Paddy and shrimp and fish
Area: 44 km^2	River: 1 (Ichamoti)
Village: 27	Khal: 2
Households: 5752	Beel: 10
Population: 34867	Water salinity (normal): 0 - 22 ppt
Male: 17785	Water salinity (in winter): 2 - 4 ppt
Female: 17082	Soil salinity (maximize in summer): 4 - 12 ppt

Source: Development planning 2013-14, Parulia union Parishad, Debhata, Satkhira

Results and Discussion

Paul and Røskaft (2013) reported environmental degradation and loss of traditional agriculture due to shrimp culture. As shrimp farming has been expanding significantly, respondents in the study area have identified sorts of variations in their locality over more than last 40 years. Majority of the respondents has mentioned that they have observed substantial reduction of crop yields (90.3%) and freshwater fisheries (80.6%). In addition, they have noted some remarkable changes in vegetable production (61.1%), livestock ranching (51.4%), and homestead gardening (23.6%) in their locality (Fig. 1).

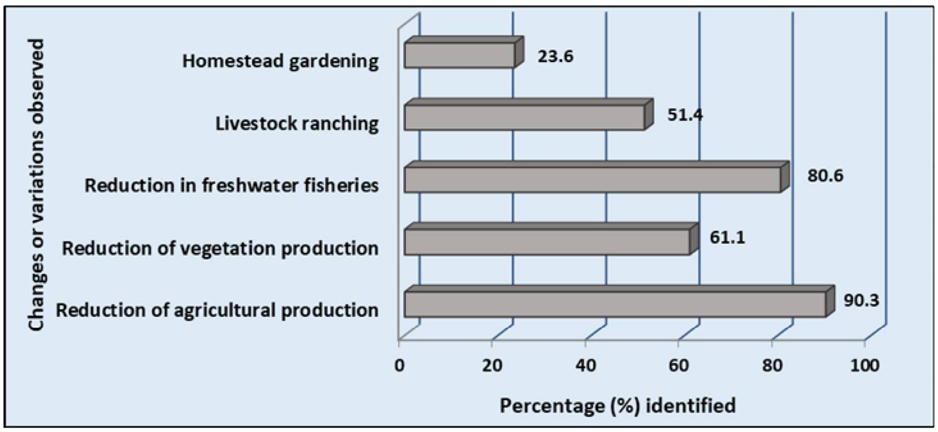


Fig. 1. Variations or changes identified by the respondents in the study area.

The socioeconomic vulnerabilities of the study area have been exacerbated by unplanned shrimp cultivation (Islam *et al.* 2012, Rahman *et al.* 2013). The percentage of cultivable land has decreased significantly and average number of lands occupied by shrimp farm has increased steadily since the introduction of shrimp cultivation. Since its introduction, shrimp farming has been expanding significantly and respondents in the study area have identified various impacts and challenges as charted in Table 2. Farmers have emphatically noted that due to the availability of saline water, they become more interested in shrimp cultivation in a *Gher* as it is instantly financially gratifying and that has given rise to the number of *Ghers* dramatically, eventually reducing traditional agricultural land. Moreover, due to the intrusion of saline water into *Ghers*, level of soil salinity is also increasing (74.5%) day by day and reducing crop yields. Besides, reduction in vegetable production (67.6%), traditional agriculture farming (67.6%), and reduction in freshwater aquaculture (63.7%) have also been identified as major impacts in this area (Table 2). Similarly, reduction of soil and water quality (41.2 and 38.2%), landlessness (35.3%), and migration (34.4%) are some of the major challenges identified (Table 2). Some (20.6%) of the respondents especially the landless and marginalized groups have stipulated that they have suffered various environmental, economic, socio-demographic, and other problems which are undesirable. Shrimp cultivation in the locality has worsened the states of livelihood and deepens the problems whereas the qualities of life are impacted gradually. Some (19.6%) of the respondents from marginalized group specifically the people from Norarchawk, Chaltetola and Rangashishe villages expressed that due to inroads of saline water, they have been suffering from various gastrointestinal diseases such as diarrhea, dysentery, stomach ache, digestive disorders etc. People of these villages are to travel miles to fetch pure fresh drinking water and sometimes suffer from dehydration.

Table 2. Impacts and challenges associated with shrimp cultivation in the study area identified by the respondents.

Impacts	Response	
	Frequency (N)	Percentage (%)
Reduction of land area	61	59.8
Increase of *gher* area	49	48.0
Increase in soil salinity	76	74.5
Vegetable production	69	67.6
Agriculture farming	69	67.6
Fresh water fish culture	65	63.7
Challenges		
Soil quality	42	41.2
Water quality	39	38.2
Social problem	21	20.6
Problems in safe drinking water	20	19.6
Landlessness	36	35.3
Migration	35	34.4
Outbreak of public disease	20	19.6

Adapted from: Field study, 2014; N = 102 (multiple frequency).

Disappearance of many local fruit trees and plant varieties have also been observed in this locality. According to respondents, yields from sweet fruit varieties such as mango, papaya, and jackfruits are on the decrease. Similarly, salinity tolerant plants such as Koroi, Gewa, Golpata etc. which are more common in the Sundarbans, gradually replacing the local plant varieties. Some of the commonly found plant and fish varieties which have replaced local varieties in the study area are listed below:

Common plant varieties in the study area: Koroi (*Albizia* sp.), Gewa (*Excoecaria agallocha*), Golpata (*Nypa fruticans*), Babla (*Acacia nilotica*), Date palm (*Phoenix sylvestris*), Sopheda (*Achras sapota*), Taal (*Borassus flabellifer*), Coconut (*Cocos nucifera*), Shimul (*Bombax ceiba*), and different types of cactus.

Common fish varieties in the study area: Tilapia (*Oreochromis mossambicus*), Pangas (*Pangasius pangasius*), Nunatengra (*Mystus gulio*), *Kurkhullo/*Mudskipper (*Apocryptes bato*), Rohu (*Labeo rohita*), Mrigel (*Cirrhinus cirrhosus*), Silver carp (*Hypophthalmichthys molitrix*), Japanese punti (*Puntius sp*), Phasa/Phaissa/Gangetic hairfin anchovy (*Setipinna phasa*) etc.

Major impacts of shrimp cultivation in Parulia union and their implications

Some of the major impacts identified in the studied area due to expansion of shrimp farming are discussed below:

Impacts on agricultural farming: It has been found that two seasons are most feasible for the farmers to cultivate paddy in a year *viz.* from (a) February - May and (b) June - November. The percentage of Boro production was found to be highest at 46.1 before and at present it is 45 (Table 3). Though farmers used to cultivate local (indigenous) Boro varieties previously, but presently they have started cultivating hybrid and high yielding paddy varieties (HYV) such as Jamaibabu 10, BIRI 28, Chini Kanai, Akhter 6, Tejdhan, Hira etc., as local varieties are not able to withstand excessive soil salinity in this area. In the period June - November, farmers also cultivate Aman together with jute. As hybrid varieties for Aman are not so available, farmers, therefore depend on salinity tolerant and high yielding Boro varieties. Also, as Boro takes less time for yields (120 - 125 days), farmers in this area are more interested in cultivating these varieties in comparison to Aman where it takes longer (140-145 days). From FGDs, it has been found that Aman is mainly cultivated in high plains such as in Uttar (North) and Dakshin (South) Parulia where soil salinity is much lower, crop production in these two villages are also higher than other villages of the study area. In addition, all the paddy varieties such as Aus, Aman, and Boro are cultivated in Dakshin Parulia. But in Uttar Parulia, Boro and mustard production remains at its highest. Paddy is not cultivated in eastern part of Parulia, but in smaller scale, it is still being cultivated with shallow and deep tube well water in the western part of the study area.

Impacts on agricultural crops, vegetables, fruit trees, and plants: From the survey and observation, it has been found that some local crop varieties are not cultivated nowadays in the study area as their production has been significantly reduced due to high level of soil salinity. Crops such as paddy, mustard, sesame, Kheshari were once very common and their production was also very high in Parulia union. Most of the crop varieties are now somewhat threatened as their production has reduced gradually. Table 4 shows some threatened crop varieties *viz.*, vegetables (74.5%), paddy (59.8%), and fruits (43.1%). However, potato (28.4%), sesame (24.5%), mustard (15.7%), jute (15.7%), various varieties of pulses such as Arahar (7.8%), Khesari (27.5%) are also identified as "kind of threatened".

Table 3. Crop cultivation periods and types of identified by the respondents in the study area.

Periods and types of crop cultivation by the respondent farmers				
	Period	Response		Crops
		Frequency (N)	Percentage (%)	
Before	November-March	13	12.7	*Robi* crop (mustard, potato, onion, vegetables)
	February-May	47	46.1	Paddy (*Boro*)
	June-November	39	38.2	Paddy, Jute (*Aman*)
	April-September	3	2.9	Paddy (*Aus*)
	Total	**102**	**100**	-----
Present	November-March	11	13.8	*Robi* crop (mustard, potato, onion, vegetables)
	February-May	36	45	Paddy (*Boro*/Hybrid)
	June-November	29	36.3	Paddy (*Aman*), Jute
	April-September	4	5	Paddy (*Aus*/Hybrid)
	Total	**80**	**100**	-----

Adapted from: Field study, 2014; N = 102 (multiple frequency).

Table 4. Threatened local crop varieties identified by the respondents.

Threatened crops identified by the respondents	Response	
	Frequency (N)	Percentage (%)
Paddy	61	59.8
Wheat	7	6.9
Mustard	16	15.7
Maize	4	3.9
Tobacco	4	3.9
Arahar	8	7.8
Sesame	25	24.5
Khesari	28	27.5
Jute	16	15.7
Fruits (mango, litchi, coconut etc.)	44	43.1
Potato	29	28.4
Onion	5	4.9
Vegetables	76	74.5

Adapted from: Field study, 2014; N = 102 (multiple frequency).

Figs 2 and 3, respectively present lists of vegetables and fruit trees in the study area of which some are critically threatened, some nearing disappearance, and some are at a level of near-extinction. Whereas others are in the stage of near extinction. Fig. 2 shows that vegetable spinach (6.5%), celery (5.6%), basil (2.8%), and arum (2.8%) ranked high in terms of extinction whereas fruits like mango (12%) ranked high in terms of extinction followed by blackberry (7.4%), jujube (4.6%), guava (3.7%), banana (3.7%) etc. (Fig. 3).

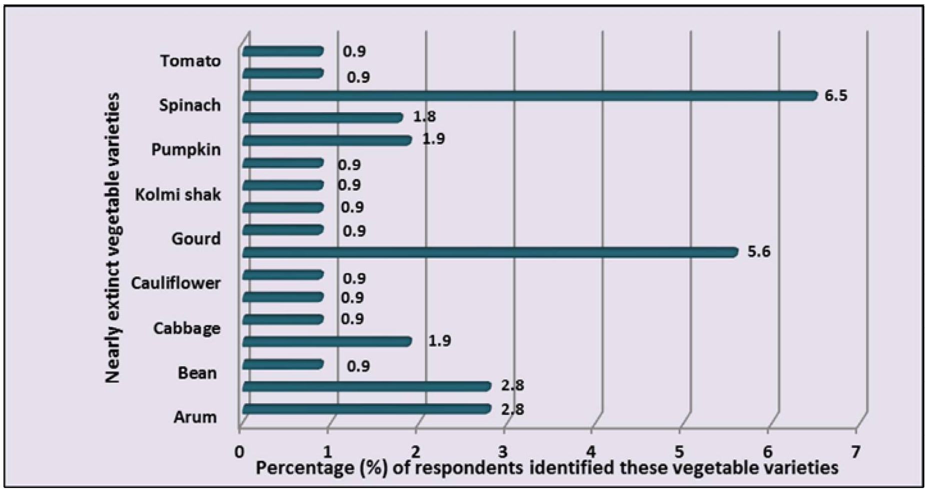


Fig. 2. Nearly extinct vegetable varieties identified by the respondents.

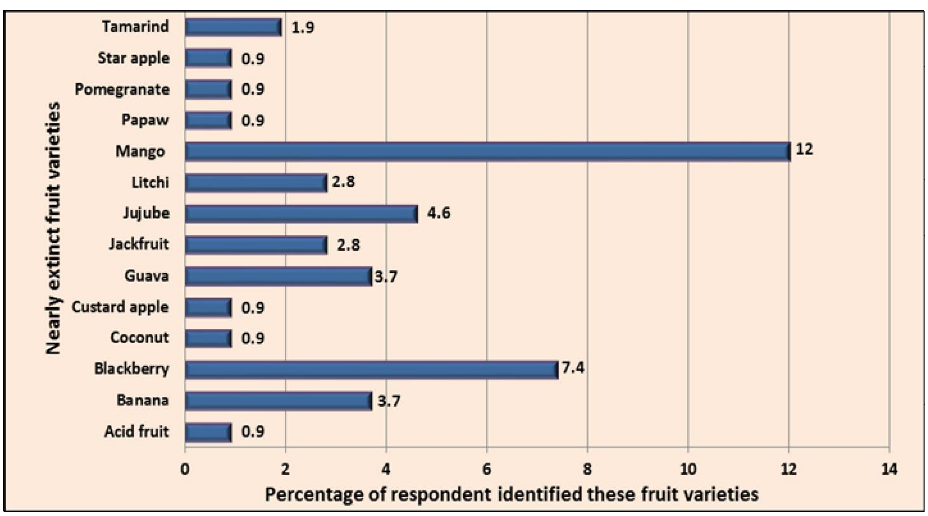


Fig. 3. Nearly extinct fruit varieties identified by the respondents.

Impacts of water salinity on freshwater fisheries: Hundreds of the ponds once used for freshwater fish cultivation are now converted to *gher* in the study area, resulting in increased water salinity which is not favorable for many of the traditional/local fish varieties such as Koi (*Anabas testudineus*), Bele (*Periophthalmodon schlosseri*), Catla (*Catla catla*) etc. are likely to decrease day by day. To meet the demands of local animal protein, farmers in this locality are now cultivating salinity tolerant mono-sex Tilapia, Vetki (Coral), Phaisa, Kurkhullo etc. fishes together with shrimp. From the findings of present study, it is assumed that freshwater fishery is going through a very critical stage. Fishes like Koi, catfish, wallago, snake-headed Murrel, and Bele (Gobi) are affected most by water salinity with percentages of 15.7, 12.7, 7.84, 6.86, 6.86, respectively (Fig. 4).

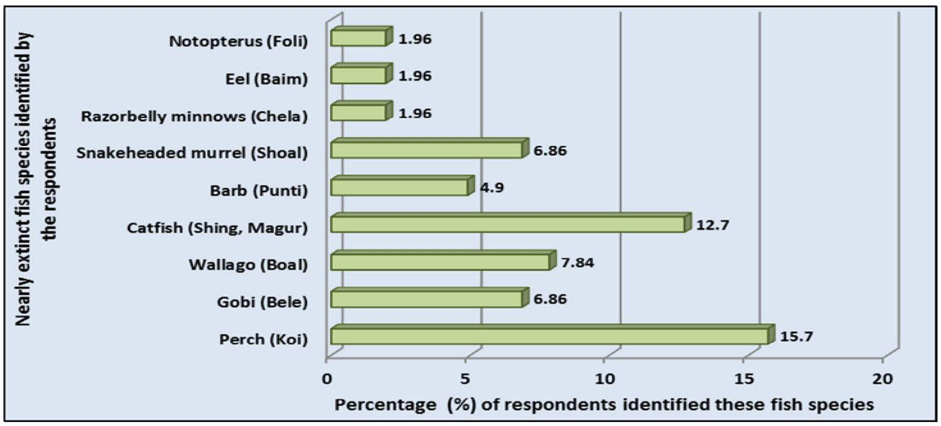


Fig. 4. Nearly extinct fish varieties identified by the respondents.

Impacts of soil salinity on livestock and poultry: It has been found that livestock ranching is experiencing diminution in Parulia union. Population of domestic animals such as cows, buffaloes, goats, and poultry are decreasing with the increase of shrimp cultivation. Reasons for the reduction of domestic animals are most likely to be attributed to scarcity of grass, straw, grazing lands, non-availability of pure drinking water, and poor living conditions. Respondents have mentioned that one bundle of "Khar" or “hay” costs BDT 80 which is beyond their affordability. The unavailability of shapla grass which was once very common in their locality and considered as staples for cows, buffaloes, and goats is now almost disappeared due to increase of soil salinity. Decrease of grazing lands as a result of shrimp culture expansion is another important reason of livestock disappearance in the study area. Therefore, it has been suggested that the unplanned expansion of shrimp *ghers* paved ways for reducing grazing land for cattle and subsequently reduced the number of livestock.

Impacts on livelihood patterns: Impacts of salinity on crop production have already been discussed. Most of the respondents have already experienced drastic yield reductions that forced farmers to change their occupation. Maximum people of the study area were engaged in agriculture (98%) and livestock ranching (72.5%) whereas presently most of them consider shrimp farming as their main livelihood activities (95.1%) (Table 5). Some (32.4%) are also found to be engaged in shrimp farm as day labor, a shifting livelihood option from agriculture day labor. Freshwater fish cultivation in this area is also reduced from 8.82 to 1.0% as a result of increased water salinity. Table 5 compares occupational changes among respondents and changing patterns of livelihoods in the study area.

Table 5. Different traditional and new occupations identified by the respondents in the study area.

Occupation	Traditional occupation		New occupation	
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage
Agriculture	100	98	2	1.96
Shrimp farming	4	3.9	97	95.1
Livestock ranching	74	72.5	3	2.9
Small business	20	19.6	4	3.9
Agricultural day labour	28	27.5	4	3.9
Shrimp farming day labour	1	1.0	33	32.4
Homestead gardening	8	7.8	2	1.96
Fresh water fisheries	9	8.82	1	1.0
Others (Govt. service, madrasa teacher etc.)	0	0	2	1.96

Adapted from: Field study, 2014; N = 102 (multiple frequency).

Challenges associated with shrimp cultivation in Parulia union

Lack of fresh drinking water and public health: Study findings indicate that salinization of domestic and agricultural water supplies are main problems in Parulia union. In a Focus Group Discussion (FGD) of Norarchawk village, participants have mentioned, due to introduction of shrimp cultivation people have severely been troubled with the dearth of safe drinking water. They have also suffered from various gastrointestinal problems such as diarrhea, dysentery, and irritable bowel syndrome (IBS) after using perilous water from nearby ponds and canals which are highly contaminated by salinity. People of this village need to walk considerable distances to fetch pure drinking water as they do not afford deep tube well. Respondents also confirmed that sometimes they even do not have enough safe water for taking a bath as most of the water bodies have been converted to *ghers*. By bathing in local waters, they are attracting various skin diseases.

Landlessness and migration: The village Norarchawk is resided by a good number of marginalized people where most of them are landless. Landless people are gradually shifting to different cities during the months of January to April when there are apparently no income opportunities in their own localities. Not only the landless but the *gher* owners also move to other cities for additional income. From the Focus Group Discussion (FGD), it has been revealed that after releasing shrimp fry into the *gher,* it takes three months to harvest; during this period, the farmers move out to other cities or in the neighboring country for additional income. Reportedly, they move to Dhaka, Chittagong, Bandarban, Khagrachhari, Tamil Nadu (India), Bihar (India), and Mumbai (India). In the migrating cities, they work in construction sites, brick kilns, and factories as they lack other skills or any alternative income generating source such as small business, grocery shops etc. Therefore, they left their localities for extra income and to ensure food security.

Socioeconomic problems: Respondents (20.6%) have identified specific social problems such as further marginalization of farmers, violations of human rights, internal chaos, and gender inequality are found to have been triggered. Though farmers work hard but they do not enjoy the benefits much gained by shrimp farming; as a result, the poor become even poorer and that led them to migrate in other cities. This has continuously fueled other socioeconomic challenges like land ownership, food insecurity, income inequality, and landlessness. Children turnout at primary education centers has also lowered.

Recommendations and Conclusion

Therefore, considering the urgency of the above-portrayed scenarios, to guarantee sustainable agriculture with economic progress of the stakeholders, our recommendations would, however, be: (i) to revise the agriculture patterns holistically, (ii) to re-strategize shrimp farming processes, and (iii) to facilitate the farmers with any technological, technical, and monetary support necessary. Getting the farmers back to traditional agricultural patterns could be an option. Local agricultural department funded by the government should subsidize the transitional farming tenures and provide technical supports to the affected farmers to bounce back. Strengthening local community by ensuring food security can help us achieve the UN SDGs.

Finally, Parulia holds the highest shrimp production niche presently in Debhata Upazila (sub-district) in Satkhira. Exploring the impacts of shrimp cultivation on agriculture and environment, socioeconomic dispositions, reduction in fruits and vegetable production, and livestock ranching, it can be stated that shrimp farming needs to be refurbished. This study unveils various implications and challenges that might have a far-reaching socioeconomic consequence. Most significant and persistent challenges faced by the community are mainly economic, environmental, social, demographic, health, and of soil and landlessness. The possibilities of wheat, mustard, and vegetables have also declined gradually and ultimately downgrading the socioeconomic basis of the community. However, some of the respondents have conceded that they do not want to be involved in shrimp farming anymore, for it does not bring any visible long-term benefits to them. Farmers in the study area expect that government would take necessary steps by facilitating proper drainage system and other relevant techniques so that they can start their traditional agriculture culture again.

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FLORISTIC STUDY IN LALPUR UPAZILA OF NATORE DISTRICT, BANGLADESH: IDENTIFICATION, DISTRIBUTION AND ECONOMIC POTENTIAL

M. OLIUR RAHMAN*, SHARIKA HASSAN AND MOMTAZ BEGUM
Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

Floristic study in Lalpur Upazila of Natore district has identified 216 species distributed in 173 genera and 72 families, of which Magnoliopsida (Dicotyledons) is represented by 188 species under 147 genera and 60 families, while Liliopsida (Monocotyledons) is constituted by 28 species under 26 genera and 12 families. In Magnoliopsida, Asteraceae is the largest family represented by 16 species, whereas in Liliopsida, Poaceae is the largest family consisting of 8 species. The genus *Solanum* is the largest in Magnoliopsida, whereas *Cyperus* is the largest genus in Liliopsida. Habit analysis reveals that herbs are represented by 118 species (55%), shrubs by 32 species (15%), trees by 50 species (23%) and climbers by 16 species (7%). Potential of the angiospermic flora has been recognized by the occurrence of 57 medicinal plant species which are used over 30 diseases for the primary health care of the local people of Lalpur Upazila. Though the study area is floristically rich, some plant species are under threats. The rare and medicinally as well as economically important species to this area need to be conserved through both *in-situ* and *ex-situ* approaches for sustainable development.

Key words: Angiosperms, Floristics, Medicinal plants, Conservation, Natore

Introduction

The importance of floristic studies has been recognized by the Conference of Parties, i.e. the signatory countries of the Convention of Biological Diversity (CBD). As a consequence of the process of implementing the Convention on Biological Diversity, the need for taxonomic knowledge as a means of underpinning biodiversity conservation is now widely accepted by governments (Heywood 2004).

The development and sustainable use of the plant resources of a country is dependent on a thorough knowledge of the flora. Sustainable use of botanical resources can play an important role in the economy of the country. The account of the flora of Bangladesh so far done is inadequate compared to the estimated huge floral diversity of the country. Considering the present pace of destruction of the forests, wetlands and the general habitats, there is an imminent danger of loosing a number of plant species even before

*Author for correspondence: <oliur.bot@du.ac.bd>.

they are identified and studied. To save the species from further annihilation, urgent exploration is necessary, firstly to record what all genetic resources we have, to explore their potential and to identify those that are threatened so that proper measures may be undertaken to conserve them.

Lalpur Upazila of Natore district lies between 24.07' and 24.18' N and between 88.52' and 89.08' E, with an area of 327.92 sq. km. The Upazila is bounded on the north by Bagatipara and Baraigram Upazilas and Ishwardi, Bheramara and Daulatpur (Kushtia) Upazilas on the south and Daulatpur, Bheramara Upazilas on the east and Bagha Upazila on the west. Lalpur Upazila consists of 10 unions, namely Lalpur, Arbab, Kadamchilan, Gopalpur, Duaria, Durduaria, Walia, Bilmaria, Salampur, Chandhupail (Fig. 1).

Fig. 1. Map of Lalpur Upazila showing the sampling sites of different unions (Source: https://photos.wikimapia.org/p/00/02/59/14/29_full.gif).

The significance of studying floristic diversity has been acknowledged and carried out in Bangladesh since last few decades (Khan 1972-1987, Khan and Banu 1972, Khan and Hassan 1984, Khan and Rahman 1989-2002). Recently, several floristic and biodiversity studies in different areas and Upazilas of Bangladesh have been done (Khan *et al*. 1994, Rahman and Hassan 1995, Khan and Huq 2001, Tutul *et al*. 2010, Rahman and Alam 2013, Rahman *et al*. 2012, 2013). However, no attention has been paid on the flora of Lalpur Upazila and its potential has never been assessed. Therefore, there is dire need to explore, identify, document and conserve the plant wealth of the area for betterment of mankind especially those plant resources which are used for primary healthcare. The objectives of the present study are three-folds, *viz.,* (i) to explore and identify the angiosperms of Lalpur Upazila of Natore district with their distributional abundance, (ii) to determine the potential of the plant species, particularly the medicinal plants, and (iii) to investigate the threatened species and suggest their conservation measures.

Materials and Methods

Five botanical expeditions from March, 2017 to April, 2018 were made to collect plant specimens from Lalpur Upazila covering all seasons. Collected specimens were processed using standard herbarium techniques (Hyland 1972), and identified by experts, consultation of standard literature, and matching with herbarium specimens deposited at both Dhaka University Salar Khan Herbarium and Bangladesh National Herbarium. The descriptions were compared with Hooker (1872-1897), Khan (1972-1987), Dassanayake and Fosberg (1980-1991) and Khan and Rahman (1989-2002). The updated nomenclature of the species has been cited following Ahmed *et al.* (2008-2009), Siddique *et al*. (2007), Rashid and Rahman (2011, 2012), The Plant List (2013), Rahman and Hassan (2017) and TROPICOS (2017). Status of occurrence of the species has been determined on the basis of field observation. Common names of the species are based on Huq (1986), and interview with the local people. The potential uses of the species including the medicinal plants have been recorded through interviews with the local people of the area, and from the relevant literature (van Valkenburg and Bunyapraphatsara 2002, Yusuf *et al*. 2009). Each species is supplemented by its local name, family name, habit, habitat, flowering and fruiting period, distribution, and potential uses.

Results and Discussion

The present study has identified 216 angiosperm taxa from Lalpur Upazila of Natore district, which belong to 173 genera and 72 families. The identified taxa along with their local name, family name, habit, habitat, flowering and fruiting time, distributional abundance, and potential use are presented in Table 3. Magnoliopsida (Dicots) is represented by 188 taxa under 137 genera and 60 families, while Liliopsida (Monocots) is constituted by 28 taxa under 26 genera and 12 families. Magnoliopsida constitute 85% while Liliopsida covers 15% of the total identified taxa.

The numbers of angiosperm taxa recognized under 72 families show variation. The family Asteraceae is the largest family in Magnoliopsida represented by 16 species, followed by Euphorbiaceae with 10 taxa. Some other large families include Solanaceae (9 taxa), Cucurbitaceae and Fabaceae (8 taxa each), Caesalpiniaceae (7 taxa), and Acanthaceae and Malvaceae (6 taxa each). In Liliopsida, Poaceae appears as the largest family bearing 8 taxa, followed by Cyperaceae with 5 taxa. Ten dominant families of the study area are shown in Fig. 2 along with their number of genera and species.

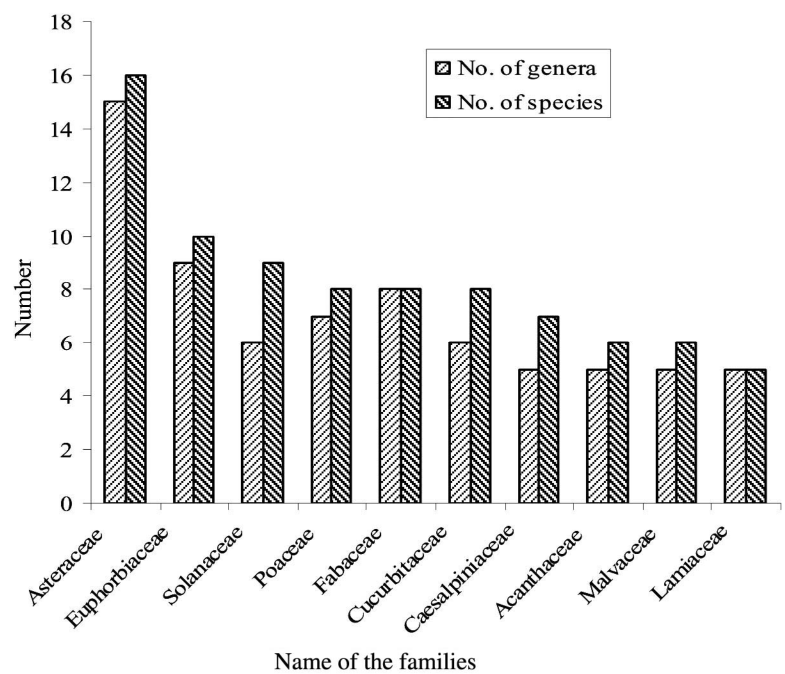

Fig. 2. Ten largest angiosperm families of Lalpur Upazila showing number of genera and species.

Ten dominant families found in Lalpur Upazila comprise 83 species that represent about 38% of the total species identified, while the remaining 62 families with a total 133 species represent 62% of the total. Twenty-three families in Magnoliopsida are represented by a single species in the present investigation.

Table 1. List of angiosperm species in Lalpur Upazila with potential uses and voucher specimen.

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Abroma augusta (L.) L. f.	Ulotkombol	Sterculiaceae	Shrub	Rs	6-12	Common	Medicinal	Sharika 73 (DUSH)
Abutilon indicum (L.) Sweet	Potari	Malvaceae	Herb	Rs	7-4	Common	Medicinal	Sharika 150 (DUSH)
Acacia auriculiformis Benth.	Akashmoni	Mimosaceae	Tree	Rs	6-2	Very common	Timber, ornamental	Sharika 166 (DUSH)
A. mangium Willd.	Mangium	Mimosaceae	Tree	Pl	5-12	Common	Timber	Sharika 223 (DUSH)
A. nilotica (L.) Del.	Babla	Mimosaceae	Tree	Rs	5-4	Common	Tannin, medicinal	Sharika 93 (DUSH)
Acalypha indica L.	Mukta-jhuri	Euphorbiaceae	Herb	Rb	12-4	Very common	Medicinal	Sharika 78 (DUSH)
Acanthus ilicifolius L.*	Hargoza	Acanthaceae	Shrub	Rb	3-7	Rare	Medicinal	Sharika 89 (DUSH)
Achyranthes aspera L.	Apang	Amaranthaceae	Herb	Wl	1-12	Very common	Medicinal	Sharika 79 (DUSH)
Aegle marmelos (L.) Correa	Bel	Rutaceae	Tree	Pl	4-12	Common	Fruits edible, medicinal	Sharika 64 (DUSH)
Agave cantula Roxb.	Cantula	Agavaceae	Herb	Pl	7-10	Common	Ornamental, fibre	Sharika 212 (DUSH)
Ageratum conyzoides L.	Ochunti	Asteraceae	Herb	Rs	11-6	Common	Medicinal	Sharika 36 (DUSH)
Albizia lebbeck (L.) Benth. & Hook.	Shirish	Mimosaceae	Tree	Rs	4-10	Common	Timber	Sharika 148 (DUSH)
A. procera (Roxb.) Benth.	Shil-Koroi	Mimosaceae	Tree	Rs	6-11	Common	Timber	Sharika 171 (DUSH)
Alocasia macrorrhizos (L.) G. Don in Sweet	Man Kochu	Araceae	Herb	Rb	6-11	Very common	Tuber edible, medicinal	Sharika 229 (DUSH)
Alstonia macrophylla Wall. *ex* G. Don	Chaatim	Apocynaceae	Tree	Pl	6-1	Common	Medicinal, oil	Sharika 169 (DUSH)
Alternanthera philoxeroides (St.) Griseb.	Helencha	Amaranthaceae	Herb	Wp	3-6	Common	Vegetable, medicinal	Sharika 47 (DUSH)
A. sessilis R. Br.	Chanchishak	Amaranthaceae	Herb	Fl	1-12	Common	Medicinal, vegetable	Sharika 16 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Amaranthus spinosus L.	Katanotey	Amaranthaceae	Herb	Rs	1-12	Common	Leafy vegetable, medicinal	Sharika 7 (DUSH)
A. tricolor L.	Lal shak	Amaranthaceae	Herb	Pl	1-12	Common	Vegetable	Sharika 172 (DUSH)
A. viridis L.	Notey shak	Amaranthaceae	Herb	Rs	1-12	Common	Leafy vegetable	Sharika 76 (DUSH)
Ammannia multiflora Roxb.	Jonglimendi	Lythraceae	Herb	Fl	7-9	Common	-	Sharika 204 (DUSH)
Andrographis paniculata (Burm. f.) Wall. *ex* Nees*	Kalomegh	Acanthaceae	Herb	Vt	11-5	Rare	Medicinal	Sharika 117 (DUSH)
Anisomeles indica (L.) Kuntze	Gobura	Lamiaceae	Herb	Fl	10-6	Common	Essential oil, medicinal	Sharika 69 (DUSH)
Annona reticulata L.	Nona	Annonaceae	Tree	Cu	10-1	Common	Fruits edible	Sharika 214 (DUSH)
A. squamosa L.	Aata phol	Annonaceae	Tree	Cu	3-12	Common	Fruits edible	Sharika 136 (DUSH)
Arachis hypogaea L.	China badam	Fabaceae	Herb	Ch	3-12	Common	Fruits edible	Sharika 43 (DUSH)
Argemone maxicana L.	Shialkanta	Papaveraceae	Herb	Fl	2-6	Common	Medicinal	Sharika 14 (DUSH)
Artocarpus lacucha Buch-Ham.	Deua	Moraceae	Tree	Cu	2-9	Common	Fruits edible	Sharika 61 (DUSH)
Arundo donax L.	Nalkhagra	Poaceae	Herb	Rs	6-12	Very common	-	Sharika 47 (DUSH)
Averrhoa carambola L.*	Kamranga	Oxalidaceae	Tree	Pl	9-3	Rare	Fruits edible	Sharika 152 (DUSH)
A. bilimbi L.*	Bilombi	Oxalidaceae	Tree	Cu	10-2	Rare	Fruits edible	Sharika 206 (DUSH)
Azadirachta indica A. Juss.	Neem	Meliaceae	Tree	Pl	3-7	Very common	Medicinal	Sharika 94 (DUSH)
Baccaurea ramiflora Lour.	Latkan	Euphorbiaceae	Tree	Cu	6-9	Common	Fruits edible	Sharika 92 (DUSH)
Bacopa monnieri (L.) Pennell*	Brammi	Scrophulariaceae	Herb	Fl	5-12	Rare	Medicinal	Sharika 119 (DUSH)
Barringtonia acutangula (L.) Gaertn.*	Hijol	Lecythidaceae	Tree	Fl	5-9	Rare	Medicinal	Sharika 191 (DUSH)
Benincasa hispida (Thunb.) Cogn.	Chal kumra	Cucurbitaceae	Herb	Cu	5-11	Common	Vegetable, medicinal	Sharika 167 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Beta vulgaris L.*	Beet palong	Chenopodiaceae	Herb	Cu	3-4	Rare	Leafy vegetable, medicinal	Sharika 127 (DUSH)
Blumea lacera (Burm.f.) DC.	Kukurshunga	Asteraceae	Herb	Fl	9-2	Common	Medicinal	Sharika 27 (DUSH)
B. membranacea Wall. *ex* DC.	Kuksung	Asteraceae	Herb	Rs	1-3	Common	Medicinal	Sharika 180 (DUSH)
Boerhavia diffusa L.	Punarnava	Nyctaginaceae	Herb	Rs	4-8	Common	Medicinal	Sharika 55 (DUSH)
Bombax ceiba L.	Shimul tula	Bombacaceae	Tree	Pl	2-5	Common	Fibre	Sharika 189 (DUSH)
B. insigne Wall.*	Bharoti shimul	Bombacaceae	Tree	Rs	12-4	Rare	Fibre, Timber	Sharika 156 (DUSH)
Bougainvillea spectabilis Willd.	Baganbilash	Nyctaginaceae	Shrub	Pl	1-12	Common	Ornamental	Sharika 107 (DUSH)
Caesalpinia bonduc (L.) Roxb.	Nata	Caesalpiniaceae	Climber	Rs	7-3	Common	Medicinal	Sharika 209 (DUSH)
Calotropis gigantea Br.	Akanda	Asclepiadaceae	Shrub	Rs	1-12	Very common	Medicinal	Sharika 01 (DUSH)
Canna indica L.	Kolaboti	Cannaceae	Herb	Pl	4-11	Common	Ornamental, medicinal	Sharika 227 (DUSH)
Capsicum frutescens L.	Morich	Solanaceae	Shrub	Pl	1-12	Common	Spice	Sharika 104 (DUSH)
Careya arborea Roxb.*	Biri-pata	Lecythidaceae	Tree	Vt	5-7	Rare	Fruits edible, medicinal, timber	Sharika 163 (DUSH)
Cassia fistula L.	Shonalu	Caesalpiniaceae	Tree	Rs	3-6	Very common	Ornamental	Sharika 178 (DUSH)
Casuarina equisetifolia L.	Jhau	Casuarinaceae	Tree	Rs	2-11	Common	Ornamental	Sharika 179 (DUSH)
Cajanus cajan (L.) Millsp.	Orohor	Fabaceae	Shrub	Cu	1-12	Common	Pulse	Sharika 199 (DUSH)
Cayratia trifolia (L.) Domin	Anol-lota	Vitaceae	Climber	Vt	1-12	Common	Medicinal	Sharika 233 (DUSH)
Celosia cristata L.	Morog phul	Amaranthaceae	Herb	Pl	1-12	Common	Ornamental	Sharika 67 (DUSH)
Centella asiatica (L.) Urban.	Thankuni	Apiaceae	Herb	Fl	3-12	Common	Medicinal	Sharika 154 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Chenopodium album L.	Bothua Shak	Chenopodiaceae	Herb	Ch	12-3	Common	Leafy vegetable, medicinal	Sharika 41 (DUSH)
C. ambrosioides L.	Bon botua	Chenopodiaceae	Herb	Ch	11-2	Common	Medicinal	Sharika 98 (DUSH)
Chrozophora rottleri (Geiseler) A. Juss. *ex* Spreng.	Khudi-okra	Euphorbiaceae	Herb	Wl	3-10	Common	Medicinal	Sharika 44 (DUSH)
Cinnamomum tamala Nees.	Tejpata	Lauraceae	Tree	Pl	2-11	Common	Spice, medicinal	Sharika 128 (DUSH)
Cirsium arvense (L.) Scop.	Shial-kata	Asteraceae	Herb	Fl	2-6	Common	Medicinal, oil, alkaloid	Sharika 09 (DUSH)
Cissus assamica (Lawson) Craib	Amasha-lota	Vitaceae	Climber	Fl	4-10	Common	-	Sharika 238 (DUSH)
Citrus aurantifolia (Christm. & Panzer) Swingle	Lebu	Rutaceae	Tree	Pl	3-9	Common	Fruits edible	Sharika 77 (DUSH)
C. limon (L.) Burm. f.	Gura-lebu	Rutaceae	Tree	Pl	3-11	Common	Fruits edible	Sharika 158 (DUSH)
Cleome gynandra L.	Shada hurhuria	Capparaceae	Herb	Rs	1-12	Common	Fruits edible, Medicinal	Sharika 17 (DUSH)
C. viscosa L.	Hurhuria	Capparaceae	Herb	Rs	1-12	Common	Medicinal	Sharika 161 (DUSH)
Clerodendrum viscosum Vent	Bhaat	Verbenaceae	Shrub	Rs	1-12	Very common	Medicinal	Sharika 22 (DUSH)
Clitoria ternatea L.	Aparajita	Fabaceae	Herb	Vt	6- 3	Common	Medicinal, dye, tannin	Sharika 164 (DUSH)
Coccinia grandis (L.) Voigt	Telakucha	Cucurbitaceae	Herb	Vt	3-12	Very common	Medicinal	Sharika 10 (DUSH)
Colocasia esculenta (L.) Schott	Kochu	Araceae	Herb	Wl	5- 9	Very common	Vegetable, medicinal	Sharika 130 (DUSH)
Commelina benghalensis L.	Kanchira	Commelinaceae	Herb	Wt	2-12	Common	Green vegetable	Sharika 34 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Crotalaria juncea L.	Shon	Fabaceae	Herb	Fl	2-5	Common	Fibre, medicinal	Sharika 143 (DUSH)
Croton bonplandianum Bail.	Bon-dhoney	Euphorbiaceae	Herb	Fl	4-8	Common	Medicinal	Sharika 12 (DUSH)
Chrysopogon aciculatus (Retz.) Trin.	Premkata	Poaceae	Herb	Fl	1-12	Very common	Rough lawn	Sharika 215 (DUSH)
Curcuma longa L.	Holud	Zingiberaceae	Herb	Cu	7- 9	Common	Rhizome edible, medicinal	Sharika 155 (DUSH)
Cuscuta reflexa Roxb.	Shorno-lota	Cuscutaceae	Herb	Rs	7- 3	Common	Medicinal	Sharika 124 (DUSH)
Cynodon dactylon Pers.	Durbaghash	Poaceae	Herb	Fl	1-12	Very common	Medicinal	Sharika 85 (DUSH)
Cyperus difformis L.	Behua	Cyperaceae	Herb	Rf	7-12	Very common	Cattle food	Sharika 25 (DUSH)
C. rotundus L.	Mutha ghash	Cyperaceae	Herb	Rf	1-12	Very common	Medicinal	Sharika 40 (DUSH)
Datura metel L.	Dhutra	Solanaceae	Herb	Rs	1-12	Common	Medicinal	Sharika 105 (DUSH)
Delonix regia (Boj.) Raf.	Krishnochura	Caesalpiniaceae	Tree	Rs	4-8	Common	Ornamental, Timber	Sharika 195 (DUSH)
Desmodium triflorum (L.) DC.	Kodaliya	Fabaceae	Herb	Fl	1-12	Common	Medicinal	Sharika 118 (DUSH)
Dillenia indica L.	Chalta	Dilleniaceae	Tree	Pl	5-2	Common	Timber, fruits edible	Sharika 157 (DUSH)
Dioscorea alata L.*	Chupri-alu	Dioscoreaceae	Climber	Cu	10-12	Rare	Tuber edible	Sharika 194 (DUSH)
Diospyros blancoi A. DC.	Bilati-gab	Ebanaceae	Tree	Pl	3-8	Common	Medicinal	Sharika 165 (DUSH)
D. malabarica (Desr.) Kost.	Deshi-gab	Ebanaceae	Tree	Pl	5-8	Common	Medicinal	Sharika 176 (DUSH)
Duranta repens L.	Kantamehedi	Verbenaceae	Shrub	Rs	1-12	Common	Hedge plant, medicinal	Sharika 109 (DUSH)
Eclipta alba (L.) Hassk.	Keshoraj	Asteraceae	Herb	Fl	1-12	Common	Medicinal	Sharika 50 (DUSH)
Eichhornia crassipes (St.) Sol.-Lau.	Kochuripana	Pontederiaceae	Herb	A	1-12	Common	Manure, fodder	Sharika 81 (DUSH)
Elaeocarpus varunua Buch..-Ham *ex* Masters	Jalpai	Elaeocarpaceae	Tree	Rs	2- 9	Common	Fruits edible	Sharika 184 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Eucalyptus citriodora Hook.	Eucalyptus	Myrtaceae	Tree	Rs	1-12	Common	Timber	Sharika 234 (DUSH)
Eupatorium ayapana Vent.	Ayapan	Asteraceae	Shrub	Pl	2-3	Common	Medicinal	Sharika 63 (DUSH)
Euphorbia hirta L.	Dudhia	Euphprbiaceae	Herb	Fl	1-12	Very common	Medicinal	Sharika 121 (DUSH)
Ficus benghalensis L.	Bot	Moraceae	Tree	Rs	5-7	Common	Medicinal	Sharika 129 (DUSH)
F. hispida L.f.	Dumur	Moraceae	Shrub	Rs	4-8	Common	Medicinal	Sharika 186 (DUSH)
F. religiosa L.	Ashwathwa	Moraceae	Tree	Rs	3-9	Common	Medicinal	Sharika 219 (DUSH)
Fimbristylis miliacea (L.) Vahl	Bara-javani	Cyperaceae	Herb	Rf	5-11	Common	-	Sharika 52 (DUSH)
Flacourtia indica (Burm. f.) Merr.	Boichi	Flacourtiaceae	Shrub	Fl	1-6	Common	Medicinal	Sharika 159 (DUSH)
Foeniculum vulgare Mill.	Pan mohuri	Apiaceae	Herb	Cu	11-2	Common	Flavouring food	Sharika 49 (DUSH)
Glinus oppositifolius (L.) A. DC.	Gima shak	Molluginaceae	Herb	Fl	1-12	Common	Leafy vegetable	Sharika 182 (DUSH)
Glycosmis pentaphylla (Retz.) A. DC.	Datmajon	Rutaceae	Shrub	Rs	1-12	Common	Fruits edible, medicinal	Sharika 126 (DUSH)
Gnaphalium luteo-album L.	Kamra	Asteraceae	Herb	Rs	3-7	Very common	Medicinal	Sharika 37 (DUSH)
Grangea maderaspatana (L.) Poir.	Nemuti	Asteraceae	Herb	Fl	12-5	Common	Medicinal	Sharika 51 (DUSH)
Hemidesmus indicus Br.	Anantamul	Asclepiadaceae	Climber	Rb	7-12	Common	Medicinal	Sharika 19 (DUSH)
Heliotropium indicum L.	Hatishur	Boraginaceae	Herb	Fl	1-12	Very common	Medicinal	Sharika 38 (DUSH)
Hibiscus rosa-sinensis L.	Joba	Malvaceae	Shrub	Pl	1-12	Very common	Ornamental, medicinal	Sharika 114 (DUSH)
H. tiliaceus L.	Bolla	Malvaceae	Tree	Pl	1-12	Common	Fibre	Sharika 185 (DUSH)
Hydrilla verticillata (L. f.) Rl.	Jhangi	Hydrocharitaceae	Herb	A	1-12	Common	Medicinal	Sharika 154 (DUSH)
Hyptis suaveolens (L.) Poit.	Tokma	Lamiaceae	Herb	Fl	1-12	Common	Medicinal	Sharika 68 (DUSH)
Ichnocarpus frutescens (L.) R. Br.	Loi lata	Apocynaceae	Twining shrub	Fl	7-2	Common	Medicinal	Sharika 160 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Ipomoea aquatica Forsk.	Kalmishak	Convolvulaceae	Herb	A	1-12	Common	Leafy vegetable	Sharika 06 (DUSH)
I. batatas L.	Misti alu	Convolvulaceae	Climber	Pl	12-5	Common	Tubers edible	Sharika 211 (DUSH)
I. fistulosa St. *ex* Choisy	Dhol kalmi	Convolvulaceae	Herb	Fl	1-12	Common	Hedge plant	Sharika 02 (DUSH)
Ixora coccinea L.	Rongon	Rubiaceae	Shrub	Pl	1-12	Common	Ornamental	Sharika 230 (DUSH)
Jatropa gossypifolia L.	Lal bherenda	Euphorbiaceae	Shrub	Rs	4-7	Common	Medicinal	Sharika 133 (DUSH)
Justicia adhatoda L.	Bashok	Acanthaceae	Shrub	Pl	1-4	Very common	Medicinal	Sharika 192 (DUSH)
J. gendarussa L.	Jagatmardan	Acanthaceae	Shrub	Rs	12-5	Very common	Medicinal	Sharika 11 (DUSH)
Kyllinga brevifolia Rottb.	Greenkylinga	Cyperaceae	Herb	Rf	3-12	Very common	-	Sharika 224 (DUSH)
Lablab purpureus (L.) Sweet.	Sheem	Fabaceae	Climber	Cu	11-3	Common	Vegetable, medicine	Sharika 137 (DUSH)
Lagenaria siceraria (Mol.) Stan.	Lau	Cucurbitaceae	Climber	Cu	2-5	Very common	Vegetable	Sharika 213 (DUSH)
Lannea coromandelica (Houtt.) Merr.*	Jiga	Anacardaceae	Tree	Fl	2-6	Rare	Medicinal	Sharika 149 (DUSH)
Lasia spinosa (L.) Thw.	Kanta kochu	Araceae	Herb	Wp	1-11	Very common	Vegetable, medicinal	Sharika 111 (DUSH)
Launaea asplenifolia Hk. f.	Tikdana	Asteraceae	Herb	Rs	1-7	Common	Medicinal	Sharika 21 (DUSH)
Lemna perpusilla Torr.	Khudipana	Lemnaceae	Herb	A	8-12	Common	Water purifier	Sharika 228 (DUSH)
Leonurus sibiricus L.	Rokto dron	Lamiaceae	Herb	Fl	1-12	Common	Medicinal	Sharika 54 (DUSH)
Leucaena leucocephala (Lamk.) de Wit.	Ipil-ipil	Mimosaceae	Tree	Pl	3-11	Common	Timber, dye, forage	Sharika 203 (DUSH)
Leucas aspera L.	Shet dron	Lamiaceae	Herb	Fl	6-11	Common	Medicinal, leafy vegetable	Sharika 24 (DUSH)
Lippia alba L.	Bhutraj	Verbenaceae	Shrub	Rs	1-12	Common	Medicinal	Sharika 86 (DUSH)
Litsea glutinosa (Lour.) Rob.	Menda	Lauraceae	Tree	Fl	4-1	Common	Medicinal	Sharika 72 (DUSH)
L. monopetala (Roxb.) Pers.	Kat-menda	Lauraceae	Tree	Fl	3-11	Common	-	Sharika 99 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Ludwigia adscendens (L.) Hara	Keshordam	Onagraceae	Herb	A	3-12	Common	Medicinal	Sharika 174 (DUSH)
Luffa acutangula Roxb.	Jhinga	Cucurbitaceae	Climber	Cu	6-9	Common	Vegetable	Sharika 188 (DUSH)
L. cylindrica (L.) Roem.	Dhundul	Cucurbitaceae	Climber	Cu	6-12	Common	Vegetable	Sharika 153 (DUSH)
Lycopersicon esculentum Mill.	Tomato	Solanaceae	Herb	Cu	11-1	Very common	Vegetable, medicinal	Sharika 142 (DUSH)
Melia azedarach L.	Gora-neem	Meliaceae	Tree	Pl	3-7	Common	Medicinal	Sharika 32 (DUSH)
Melochia corchorifolia L.	Tiki-okra	Apiaceae	Herb	Rs	3-6	Common	Medicinal	Sharika 103 (DUSH)
Mikania cordata (Burm. f.) Kost.	Asham-lata	Asteraceae	Climber	Rs	8-2	Common	Medicinal	Sharika 218 (DUSH)
Mirabilis jalapa L.	Shondamaloti	Nyctaginaceae	Herb	Pl	3-5	Common	Ornamental	Sharika 177 (DUSH)
Momordica charantea L.	Korolla	Cucurbitaceae	Herb	Cu	5-9	Very common	Vegetable, medicinal	Sharika 100 (DUSH)
Monochoria hastata (L.) Solms.	Baranukha	Pontederiaceae	Herb	A	1-12	Common	Medicinal	Sharika 197 (DUSH)
M. vaginalis (Burm. f.) Presl.	Mukha kochu	Pontederiaceae	Herb	A	5-1	Common	Vegetable, Medicinal	Sharika 65 (DUSH)
Moringa oleifera Lamk.	Shojina	Moringanaceae	Tree	Cu	9-3	Very common	Vegetable, medicinal	Sharika 74 (DUSH)
Nelsonia canescens (Lamk.) Spreng.	Paramul	Acanthaceae	Herb	Rs	9-2	Common	Medicinal	Sharika 70 (DUSH)
Neolamarckia cadamba (Roxb.) Merr.	Kodom	Rubiaceae	Tree	Pl	7-12	Common	Timber, ornamental	Sharika 239 (DUSH)
Nicotiana plumbaginifolia Viv.	Bon-tamak	Solanaceae	Herb	Fl	3-12	Common	Medicinal	Sharika 45 (DUSH)
Nymphaea nouchali Burm. f.	Nil-shapla	Nymphaeaceae	Herb	A	1-12	Very common	Vegetable	Sharika 131 (DUSH)
N. pubescens Willd.	Shada shapla	Nymphaeaceae	Herb	A	1-12	Very common	Vegetable, medicinal	Sharika 210 (DUSH)
N. rubra Roxb. *ex* Andr.	Lal shapla	Nymphaeaceae	Herb	A	7-1	Very common	Vegetable	Sharika 151 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Nymphoides indicum (L.) Kuntz.	Chand-mala	Menyanthaceae	Herb	A	9-2	Common	Medicinal	Sharika 196 (DUSH)
Ocimum tenuiflorum L.	Tulsi	Lamiaceae	Herb	Pl	1-12	Common	Medicinal	Sharika 57 (DUSH)
Oryza sativa L.	Dhaan	Poaceae	Herb	Cu	8-6	Very common	Seed edible	Sharika 140 (DUSH)
Panicum repens L.	Dhani ghash	Poaceae	Herb	Fl	1-12	Common	-	Sharika 226 (DUSH)
Passiflora foetida L.*	Jhumka-lata	Passifloraceae	Herb	Fl	5-12	Rare	Ornamental	Sharika 198 (DUSH)
Paederia cruddasiana Prain*	Gondho bhaduli	Rubiaceae	Climber	Fl	6-1	Rare	Medicinal	Sharika 46 (DUSH)
Peperomia pellucida Kunth.	Luchipata	Piperaceae	Herb	Pl	7-8	Common	Medicinal	Sharika 110 (DUSH)
Persicaria glabra (Willd.) Gomez de la Maza	Lal-kukri	Polygonaceae	Herb	Fl	6-2	Common	Medicinal	Sharika 193 (DUSH)
P. hydropiper (L.) Spach	Pakurmul	Polygonaceae	Herb	Fl	7-4	Common	Medicinal	Sharika 13 (DUSH)
P. orientalis (L.) Spach	Bon-panimorich	Polygonaceae	Herb	Wp	3-7	Common	Antibacterial	Sharika 181 (DUSH)
Phaseolus vulgaris L.	Farash bean	Fabaceae	Climber	Cu	11-3	Common	Fruits edible, medicinal, dye	Sharika 170 (DUSH)
Phyllanthus niruri L.	Bhui amla	Euphorbiaceae	Herb	Rs	7-9	Common	Medicinal	Sharika 67 (DUSH)
P. reticulatus Poir.	Chitki	Euphorbiaceae	Shrub	Rs	3-9	Common	Medicinal	Sharika 96 (DUSH)
Phragmites karka (Retz.) Trin. *ex* Steud.	Nalkhagra	Poaceae	Herb	Rb	1-12	Very common	Medicinal, fibre	Sharika 90 (DUSH)
Phyla nodiflora (L.) Greene	Bhui-okra	Verbenaceae	Herb	Cl	1-12	Common	Medicinal	Sharika 190 (DUSH)
Physalis minima L.	Potka phul	Solanaceae	Herb	Fl	1-12	Common	Medicinal	Sharika 22 (DUSH)
Piper nigrum L.*	Golmorich	Piperaceae	Climber	Rs	7-12	Rare	Edible, medicinal	Sharika 56 (DUSH)
Pistia stratiotes L.	Topapana	Araceae	Herb	A	9-3	Common	Medicinal	Sharika 59 (DUSH)
Pithecellobium dulce (Roxb.) Benth.	Jilapi phul	Mimosaceae	Shrub	Pl	1-7	Common	Hedge plant, dye	Sharika 217 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Polyalthia longifolia (Sonn.) Thw.	Debdaru	Annonaceae	Tree	Rs	3-9	Common	Timber, ornamental	Sharika 168 (DUSH)
Polygonum plebejum Br.	Panimorich	Polygonaceae	Herb	Wp	1-4	Common	Leafy vegetable, antibacterial	Sharika 35 (DUSH)
Portulaca oleracea L.	Bara-lunia	Portulacaceae	Herb	Wl	1-12	Common	Leafy vegetable, medicinal	Sharika 05 (DUSH)
Pouzolzia zeylanica (L.) Benn.	Kullaruki	Apiaceae	Herb	Rs	5-12	Common	-	Sharika 237 (DUSH)
Rauvolfia serpentia Benth. *ex* Kurz*	Shorpo-gondha	Apocynaceae	Herb	Fl	4-9	Rare	Medicinal	Sharika 220 (DUSH)
Ricinus communis L.	Bherenda	Euphorbiaceae	Tree	Rs	1-12	Common	Medicinal, oil	Sharika 75 (DUSH)
Ruellia tuberosa L.	Chatpotey	Acanthaceae	Herb	Rs	1-12	Common	Ornamental	Sharika 08 (DUSH)
Rumex maritimus L.	Bon-palong	Polygonaceae	Herb	Fl	1-5	Very common	Vegetable, Medicinal	Sharika 30 (DUSH)
Saccharum officinarum L.	Akh	Poaceae	Shrub	Cu	7-9	Very common	Fruits edible, Sugar	Sharika 26 (DUSH)
S. spontaneum L.	Kash	Poaceae	Shrub	Fl	1-12	Common	Fibre	Sharika 187 (DUSH)
Salix tetrasperma Roxb.	Panijuma	Salicaceae	Tree	Rb	11-3	Common	-	Sharika 235 (DUSH)
Schoenoplectus supinus (L.) Palla	Potpote	Cyperaceae	Herb	Rb	7-2	Common	Edible	Sharika 31 (DUSH)
Scoparia dulcis L.	Bondhoney	Scrophulariaceae	Herb	Rs	1-12	Common	Medicinal	Sharika 18 (DUSH)
Senna alata (L.) Roxb.	Dadmardan	Caesalpiniaceae	Tree	Rs	8-1	Common	Medicinal	Sharika 60 (DUSH)
S. sophera (L.) Roxb.	Kashundi	Caesalpiniaceae	Shrub	Rs	8-7	Common	Medicinal	Sharika 125 (DUSH)
S. tora (L.) Roxb.	Kalkasham	Caesalpiniaceae	Herb	Rs	7-12	Common	Medicinal	Sharika 141 (DUSH)
Sesamum indicum L.	Til	Pedaliaceae	Herb	Fl	2-9	Common	Oil	Sharika 231 (DUSH)
Setaria glauca (L.) P. Beauv.	Kauni	Poaceae	Herb	Rs	7-7	Common	Medicinal	Sharika 03 (DUSH)
Sida acuta Burm. f.	Berela	Malvaceae	Herb	Rs	7-4	Common	Medicinal	Sharika 66 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Solanum melongena L.	Begun	Solanaceae	Herb	Cu	9-3	Very common	Vegetable	Sharika 113 (DUSH)
S. nigrum L.	Tit-begun	Solanaceae	Herb	Cu	1-12	Very common	Vegetable	Sharika 15 (DUSH)
S. sisymbrifolium Lamk.	Kanta begun	Solanaceae	Herb	Rs	1-12	Common	Vegetable	Sharika 20 (DUSH)
S. virginianum L.	Jongla begun	Solanaceae	Herb	Rs	1-2	Common	Vegetable	Sharika 115 (DUSH)
Sonchus oleraceus L.	Titliya	Asteraceae	Herb	Wl	2-5	Common	Medicinal	Sharika 04 (DUSH)
Spilanthes calva DC.	Marhatitiga	Asteraceae	Herb	Rs	1-12	Common	Medicinal	Sharika 200 (DUSH)
Spondias pinnata (L. f.) Kurz	Deshi amra	Anacardiaceae	Tree	Pl	2-7	Common	Fruit edible	Sharika 232 (DUSH)
Stephania japonica (Thunb.) Miers.	Nimuka	Menispermaceae	Climber	Rs	3-7	Common	Medicinal	Sharika 132 (DUSH)
Synedrella nodiflora (L.) Gaentn.	Relanodi	Asteraceae	Herb	Rs	1-12	Common	Medicinal	Sharika 86 (DUSH)
Swietenia mahagoni (L.) Jacq.	Mehgoni	Meliaceae	Tree	Rs	4-11	Common	Timber	Sharika 122 (DUSH)
Tabernaemontana divericata (L.) R. Br. *ex* Roem & Schult.	Togor	Apocynaceae	Shrub	Pl	5-1	Common	Ornamental	Sharika 58 (DUSH)
Tamarindus indica L.	Tentul	Caesalpiniaceae	Tree	Pl	4-12	Common	Fruits edible, medicinal	Sharika 139 (DUSH)
Tamarix gallica L.	Bon-jhau	Tamaricaceae	Shrub	Fl	3-6	Common	-	Sharika 236 (DUSH)
Tecoma stans (L.) H.B.& K.	Shonapati	Bignoniaceae	Shrub	Rs	5-12	Common	Timber, medicinal	Sharika 221 (DUSH)
Thespesia populnea (L.) Sol. *ex* Corr.	Parash pipul	Malvaceae	Tree	Rs	7-1	Common	Edible, medicinal	Sharika 205 (DUSH)
Thevetia peruviana (Pers.) K. Schum.	Holde korobi	Apocynaceae	Shrub	Pl	1-12	Common	Fruit edible, medicinal	Sharika 134 (DUSH)
Tinospora cordifolia (Willd.) Hook. f.	Galuncha	Menispermaceae	Climber	Rs	1-7	Common	Medicinal	Sharika 162 (DUSH)

(Contd.)

Scientific name	Local name	Family name	Habit	Habitat	Fl. &Fr.	Distribution	Potential uses	Voucher specimen
Toona ciliata J. Roem.*	Toon	Meliaceae	Tree	Rs	1-6	Rare	Medicinal, essential oil	Sharika 207 (DUSH)
Trema orientalis (L.) Bl.*	Jibon	Ulmaceae	Tree	Rs	12-4	Rare	Timber	Sharika 95 (DUSH)
Trewia polycarpa Benth.	Batul	Euphorbiaceae	Tree	Rs	5-10	Common	Timber	Sharika 183 (DUSH)
Trichosanthes cucumerina L.	Bon Patal	Cucurbitaceae	Herb	Cu	6-10	Common	Medicinal	Sharika 112 (DUSH)
T. tricuspidata Lour.*	Makal	Cucurbitaceae	Herb	Fl	7-12	Rare	Medicinal	Sharika 135 (DUSH)
Tridax procumbens L.	Tridara	Asteraceae	Herb	Rs	1-12	Very common	Medicinal	Sharika 62 (DUSH)
Triumfetta rhomboidea Jacq.	Bon-okra	Tiliaceae	Herb	Fl	8-1	Common	Medicinal	Sharika 216 (DUSH)
Typha domingensis (Pars.) Poir. *ex.* Steud*	Hogla	Typhaceae	Herb	Rb	5-6	Rare	Medicinal	Sharika 225 (DUSH)
Urena lobata L.	Bon-okra	Malvaceae	Shrub	Rs	1-12	Common	Fibre	Sharika 91 (DUSH)
Vernonia cinerea (Roxb.) Less.	Choto kukshim	Asteraceae	Herb	Fl	1-12	Common	Medicinal	Sharika 116 (DUSH)
Vigna mungo (L.) Hepper	Mashkalai	Fabaceae	Herb	Cu	11-1	Common	Medicinal	Sharika 208 (DUSH)
Vitex negundo L.	Nishinda	Verbenaceae	Shrub	Fl	9-2	Common	Medicinal	Sharika 102 (DUSH)
Xanthium indicum Koenig	Ghagra	Asteraceae	Herb	Rs	1-12	Very common	Leafy vegetable, medicinal	Sharika 48 (DUSH)
Zizipus mauritiana Lamk.	Kul, Boroi	Rhamnaceae	Shrub	Pl	9-3	Very common	Fruits edible	Sharika 201 (DUSH)
Z. oenoplea (L.) Mil.	Bon-Boroi	Rhamnaceae	Shrub	Vt	7-12	Common	Medicinal	Sharika 146 (DUSH)

*Denotes rare species. Habitat: Rs = Roadside, Pl = Planted, Rb = River bank, Wl = Waste land, Wp = Wet places, A = Aquatic, Fl = Fellow land, Cu = Cultivated, Ch = Char, Vt = Village thickets, Cu = Cultivated, Rf = Rice field, Ll = Low land. The numbers 1, 2, 3, etc. denote the months.

Medicinal Plants: The present study has identified 57 medicinal plants used by the local people of Lalpur upazila for their primary healthcare which are used for treatment of over 30 ailments (Table 2).

Table 2. Medicinal plants used by local people of Lalpur Upazila for primary healthcare.

Scientific name	Family name	Local name	Part(s) used	Medicinal uses
Achyranthes aspera	Amaranthaceae	Apang	Root	Jaundice, Pain
Aegle marmelos	Rutaceae	Bel	Fruit	Dysentery, Constipation
Ageratum conyzoides	Asteraceae	Akunti	Root, stem, leaf	Wound, Sores
Albizia lebbeck	Mimosaceae	Shirish	Bark	Cancer, Bronchitis, Asthma
Alstonia macrophylla	Apocynaceae	Chaatim	Bark	Chronic diarrhoea
Alternanthera philoxeroides	Amaranthaceae	Helencha	Whole plant	Constipation, Indigestion
A. sessilis	Amaranthaceae	Chanchi Shak	Whole plant	Indigestion, Snake bite
Amaranthus spinosus	Amaranthaceae	Kantanotey	Whole plant	Chest pain
A. viridis	Amaranthaceae	Noyte shak	Whole plant	Snake-bite
Azadirachta indica	Meliaceae	Neem	Leaf	Scabies, Menstruation, Diabetes
Blumea lacera	Asteraceae	Kukurshunga	Flower, leaf	Stomach-ache, Rheumatic fever
Calotropis procera	Asclepiadaceae	Akand	Leaf, flower, twig	Hernia, Rheumatic pain
Cassia fistula	Caesalpiniaceae	Sonalu	Seed, leaf, flower	Constipation, Diabetes
Centella asiatica	Apiaceae	Thankuni	Whole plant	Dysentery, Brain tonic, Fever
Citrus limon	Rutaceae	Lebu	Fruit	Fever, Appetizer
Clerodendrum viscosum	Verbanaceae	Bhaat	Leaf, root	Scabies, Diabetes, Rheumatism
Coccinia grandis	Cucurbitaceae	Telakucha	Leaf	Diabetes
Colocasia esculenta	Araceae	Kachu	Corm, leaf	Blood purifier, Brain tonic
Commelina benghalensis	Commelinaceae	Dhol pata	Whole plant	Itching, Urinary burning
Croton bonplandianus	Euphorbiaceae	Kanchira	Leaf, seed	Eczema
Curcuma longa	Zingiberaceae	Holud	Rhizome	Blood purifier
Cuscuta reflexa	Cuscutaceae	Swarna-lata	Stem	Jaundice, Diabetes
Cynodon dactylon	Poaceae	Durba	Whole plant	Diaphoretic and antipyretic
Cyperus rotundus	Cyperaceae	Mutha ghas	Root	Dyspepsia, Urinary concretions
Dillenia indica	Dilleniceae	Chalta	Fruit	Diarrhoea, Dysentery
Eclipta alba	Asteraceae	Kashoraj	Whole plant	Fever, Leucoderma, Hair tonic
Euphorbia hirta	Euphorbiaceae	Dudhia	Whole plant	Cough, Bronchitis

(Contd.)

Scientific name	Family name	Local name	Part(s) used	Medicinal uses
Ficus benghalensis	Moraceae	Bot	Bark, leaf	Diabetes, Impotence
F. hispida	Moraceae	Dumur	Fruit	Tonic
F. religiosa	Moraceae	Aswathwa	Bark	Skin disease
Glycosmis pentaphylla	Rutaceae	Datmajon	Leaf, stem	Dysentery, Jaundice, Fever
Hyptis suaveolens	Lamiaceae	Tokma	Root, leaf	Constipation, Skin disease
Ichnocarpus frutescens	Apocynaceae	Loi lata	Root, leaf	Fever, Skin disease
Justicia adhatoda	Acanthaceae	Basak	Root	Diarrhoea
Lannea coromandelica	Anacardiaceae	Jiga	Bark, leaf	Chicken pox
Leucas aspera	Lamiaceae	Shetodrone	Whole plant	Arthritic pain
Litsea monopetala	Lauraceae	Kat menda	Bark	Pain, Silkworm
Ludwigia adscendens	Onagraceae	Mulsi shak	Whole plant	Dysentery
Mikania cordata	Asteraceae	Assam lata	Leaf	Cut injury
Momordica charantea	Cucurbitaceae	Karola	Fruit, leaf	Diabetes, Blood pressure
Neolamarckia cadamba	Rubiaceae	Kadam	Stem bark, leaf	Body pain
Ocimum tenuiflorum	Lamiaceae	Tulsi	Leaf	Cold, Cough, Bronchitis
Paederia cruddasiana	Rubiaceae	Gandabhadali	Leaf	Abdominal pain, diarrheoa
Passiflora foetida	Passifloraceae	Jhumka lata	Whole plant	Diabetes
Peperomia pellucida	Piperaceae	Pipul	Whole plant	Asthma, Arthritic pain
Persicaria hydropiper	Polygonaceae	Bishkatali	Leaf, seed, root	Allergy, Stomach pain
Phyllanthus reticulatus	Euphorbiaceae	Chitki	Root, stem. bark	Malaria
Rauvolfia serpentina	Apocynaceae	Swarpagandha	Root, bark, leaf	Hypertension, Mental disorder
Scoparia dulcis	Scrophulariaceae	Bandhone	Whole plant	Malaria, Diarrhoea
Senna alata	Caesalpiniaceae	Dadmordon	Leaf	Ringworm, Constipation
Spilanthes calva	Asteraceae	Surya kannya	Leaf, flower	Toothache
Stephania japonica	Menispermaceae	Nimuka	Root, leaf	Dysentery, Diarrhoea, Fever
Swietenia mahagoni	Meliaceae	Mehogoni	Stem bark	Diabetes
Tamarindus indica	Caesalpiniaceae	Tentul	Fruit, leaf, bark	Hypertension, Tonic, Asthma
Toona ciliata	Meliaceae	Toon	Bark, flower	Menstrual disorders
Vitex nigundo	Verbenaceae	Nishinda	Leaf, fruit	Ulcer, Rheumatism, Asthma
Ziziphus mauritiana	Rhamnaceae	Boroi	Fruit, bark, root	Scabies, Diarrhoea, Fever

The study reveals that herbs are represented by 118 species (55%), shrubs by 32 species (15%), trees by 50 species (23%) and climbers by 16 species (7%). This pattern of habit groups were the indication of the progressive succession of the vegetation. The study also shows that 113 species are perennial and 103 are annual.

In the study area, the most common homestead species are *Hibiscus rosa-sinensis, Ocimum tenuiflorum, Averrhoa carambola, Swietenia mahagoni* etc. Other commonly found species in the homestead are *Areca catechu, Achyranthes aspera, Alocasia macrorrhizos, Barringtonia acutagula, Calotropis gigantea* and *Clerodendrum viscosum.* Some climbers such as, *Cayratia trifolia, Stephania japonica* etc. grow with the support of homestead trees. *Cuscuta reflexa* observed on the homestead trees as a parasite. Commonly growing roadside plants are *Eucalyptus citriodora*, *Phyllanthus reticulatus*, *Glycosmis pentaphylla, Heliotropium indicum, Solanum nigrum, Croton bonplandianum, Leucus aspera, Cassia fistula* etc. The floating macrophytes which are common in the study area include *Pistia stratiotes, Lemna perpusilla, Eichhornia crassipes* etc. Shallow water bodies support the taxa like *Nymphaea nouchali, Ipomoea aquatica,* etc. Of the recorded species from Lalpur Upazila, 158 were commonly found throughout the study area, 39 species were very common, whereas 19 species were found rare. Some of the rare plants in Lalpur Upazila as revealed from the field investigation are *Andrographis paniculata*, *Averrhoa carambola, A. bilimbi*, *Bacopa monnieri, Barringtonia acutangula*, *Bombax insigne*, *Careya arborea*, *Dioscorea alata*, *Lannea coromandelica*, *Passiflora foetida*, *Paederia cruddasiana*, *Toona ciliata*, *Trema orientalis*, *Trichosanthes tricuspidata* and *Typha domingensis*. Among them *Andrographis paniculata* and *Bombax insigne* are listed as threatened in the Red List of vascular plants of Bangladesh (Khan *et al*. 2001).

The present study has identified some threats to the angiospermic flora of Lalpur Upazila, *viz*. habitat destruction, industrialization, urbanization and over-exploitation of medicinal plants. A number keystone species including medicinal plants might disappear in near future from the study area due of these threats. Therefore, necessary steps should be undertaken to conserve the plant species along with habitat protection. Some of the important measures to be undertaken to conserve plant diversity include: protection of habitat degradation, preparation of distribution map of the species of the studied area, building public awareness for preservation of plant diversity, conservation of medicinal, rare and threatened species, and documentation of traditional usage of the medicinal plants. In conclusion, a long-term monitoring program on the existing flora of Lalpur Upazila of Natore district along with their conservation through both *ex situ* and *in situ* approaches need to be adopted.

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GEOLOGICAL AND GEOPHYSICAL OBSERVATIONS TO DETERMINE THE GAS SEEPAGE SOURCE OF TITAS GAS FIELD REGION, BANGLADESH

SOUROV DATTA BIJOY*****, MD. YOUSUF GAZI*****, S.M. MAINUL KABIR AND BADRUL IMAM

Department of Geology, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

Titas Gas Field, the largest gas field in Bangladesh, has been encountering gas seepages in numerous points at the surface in an area of about 7 sq. km. at the southeastern part of the field since 2006. Gas has been seeping through the water wells, small and large holes in the fields including agricultural lands, in the river and through the cracks in the ground. The present research attempts to point out the source of the gas seepages based on the field studies, wireline log analyses and other available borehole data. A reconnaissance resistivity survey has been carried out around the high seepages area to detect any evidence of shallow subsurface fault. No fault was detected by resistivity survey in the shallow depth in the seepage area and thus fault as a conduit for the seepage could not be confirmed. Primarily, all wells of Titas Well Location (TWL-C) (Titas-06, 08, 09 and 10) were suspected as possible source wells as the surface distribution of seepages generally clusters around TWL-C. Titas-06 and Titas-08 were taken out of suspect list as the gas seepage distributions do not follow well path and cement bonding against reservoir sands including 'A' sand in these two wells are also good. Gas seepages follow the well trajectories of Titas-09 and 10 wells but cement bonding against 'A' gas sand in Titas-09 also discarded the well as a probable source of the gas seepage. Also, the suggestion that Titas well-03 could be a source of gas seep is also ruled out because of the fact that it is located 3 km away from the seepage area, there is no evidence of any seepage in between the well 3 and the seepage area, and the gas sands are also well protected. The above evidences turned the whole focus onto Titas-10. Gamma ray, resistivity, density, sonic and neutron log signatures recorded initially in the Titas-10 well strongly indicated a major gas sand and has been designated 'A_1' gas sand. On the basis of various logs including CBL/VDL log it is evident that about 23 meters (3157-3180-meter MD) gas sand at the top which is not protected by cement. It is most likely source of gas seeps in Titas gas field is the gap in the cement protection at the top of A sand in Titas-10 well.

Key words: Titas gas field, Gas seepage, Resistivity survey, Wireline log, Cement bond

Introduction

Natural hydrocarbon seepages are a well-known occurrence throughout the world and historical references to seepage date back to earliest recorded history (Hunt 1979, Link 1952, Tinkle *et al.* 1973, Kolpack 1977, Fischer and Stevenson 1973, Estes *et al.* 1985).

*Author for correspondence: <geodatta@gmail.com>, <yousuf.geo@du.ac.bd>.

Natural gas seepages often appear in tectonically unstable areas like continental boundaries where gas come out of the ground due to temperature, pressure or concentration gradient through fault-like features (Sibson 1996).

Natural gas seepages had been observed all over the world (Etiope *et al.* 2009). In Bangladesh, natural gas seepages are observed in many places in the folded belt i.e Sitakund structure, Dakhin Nila structure while oil seepages are observed in Olatong structure, St. Martin's Island etc. In Bangladesh, human-induced natural gas seepages are caused by events like the blowout of drilling exploratory wells, error in drilling and completion of appraisal or production well and so on. Gas seepages due to the blowout of wells are found in Haripur (Sylhet); Magurchara, (Moulvibazar); Chattak, (Sunamganj). Sylhet-1 in 1955 and Sylhet-4 in 1962 have encountered gas at shallow depth while drilled and resulted in a blowout of drilling equipment and since then, gas leaks from fissures in the well site and catch fire on ignition. A similar blowout incident took place in Moulvibazar-1 in 1997 because of inappropriate casing setting against loose Tipam sand and eventually caused gas to spread through the loose sand layer which escaped to the surface at several points. Error in proper casing against loose Tipam sand led to blowing out of Chattak-2 (Tengratila) well in an identical fashion while gas escaped in loose sand and rushed up to the surface at several points (Imam 2013). These seepages are generally short lived although there are cases where seepages continue to show live gas escaping through the surface for a considerable time span. Gas seepages in Titas gas field are the consequence of human-induced error in the well drilling and completion procedures. There has not been any blowout in Titas field wells, but in certain areas, the poor cementation against one of the major reservoir sands has been suggested to be the cause of gas escape and eventual seepages to the surface. As a consequence, gas seepage continues in the area till date.

Titas gas field started to encounter seepage of very significant amount of gas through hundreds of points including fissures and cracks on the ground and river there, scattering over agricultural fields, water bodies and the Titas river. Also, seepages occur with the tube well which suffered continuous and uncontrolled flow of water with gas. The seeping water was hot and tainted with petroleum. Gas also seeps through ground cracks which remain undetected until it comes in contact with fire. Gas is leaking in form of huge bubbles through the riverbed of Titas river at different spots. Gas seepage problems were first identified in November, 2006. Petrobangla made some initial investigations in which it was suggested that the seeping gas is thermogenic and not biogenic shallow gas. The recommendation was made to work over some of the wells especially 8, 9 and 10. It was decided to do workover job in Titas-3, while for some unknown reasons the well was killed and abandoned permanently. However, this has apparently failed to stop the seepage and the gas seepage continues to present days even after more than nine years of killing Titas-3.

The objective of this study is to evaluate the surface distribution of the gas seepage of Titas gas field and to find the causes and source of the seepage. The study also correlates the present-day surface trend of gas seepages with subsurface well trajectories of several deviated Titas wells. There have been a few investigations both in national and international standard after the seepages were noticed first. But there is no research work available in the academic sphere on the gas seepage source investigation of Titas gas field. Overall, there is a good database in terms of availability of some wireline logs which include gamma ray log, resistivity log, sonic log, neutron log, density log, cement bonding log (CBL/VDL log) etc. Among them, CBL/VDL log is very much important as this log was used to identify the poor cement bonding in several Titas wells and examine whether these poor bonding intervals coincide with gas seeping depth in the well. Titas daily production data of well 1-16 from all ‘A’, ‘B’ and ‘C’ gas sands along with wellhead pressure data was also collected which also helped to track noticeable changes in production from targeted wells as well as to monitor if there was distinguishable drop in wellhead pressure which might be evident to argue a well as a defective well. Resistivity data obtained in the seepage affected area was of shallow depth which extended to only 120-meter depth where no trace of shallow fault was found, if data up to 300-meter depth could be imaged by the resistivity survey, there might be a possibility to find out some shallow fault which could be explained as conduit for seeping gas from major reservoir.

Regional geologic settings of the study area: Bangladesh occupies a large part of the Bengal basin which is bounded by the peninsular shield area of Rajmahal hills in the west, the Arakan-Yoma anticlinorium and the Naga-Lushai orogenic belts in the east, the Shillong plateau and the Himalayan foredeep in the north and the Bay of Bengal in the south (Coleman 1969, Evans 1964). The Sylhet trough lies in the north-eastern part of Bangladesh which is the site of seven gas producing and an oil field (Fig. 1) (Banu and Hossain 2000).

The eastern part of the Sylhet trough lies in the frontal deformation zone of the Indo-Burman ranges (Alam *et al*. 2003, Johnson and Alam 1991). North-south trending folds that are uplifted in the Chittagong-Tripura fold belt plunge northward into the Sylhet trough subsurface (Khan *et al.* 2006). The anticlines are commonly faulted, and many produce gas (Hiller and Elahi 1984, Lietz and Kabir 1982). The Sylhet trough is bounded to the north by the Shillong plateau, which is underlain by a basement complex of Archean gneiss and minor greenstone and upper Proterozoic granite (Acharyya *et al.* 1986). The Surma series of Miocene consisting of Bhuban and Bokabil formations has excellent development in Surma Trough (Johnson and Alam 1991). Structurally, Sylhet trough has formed due to simultaneous interaction of two major tectonic elements, the rising Shillong massif in the north and westward moving Indo-Burman mobile fold belt on Burmese plate (Johnson and Alam 1991).

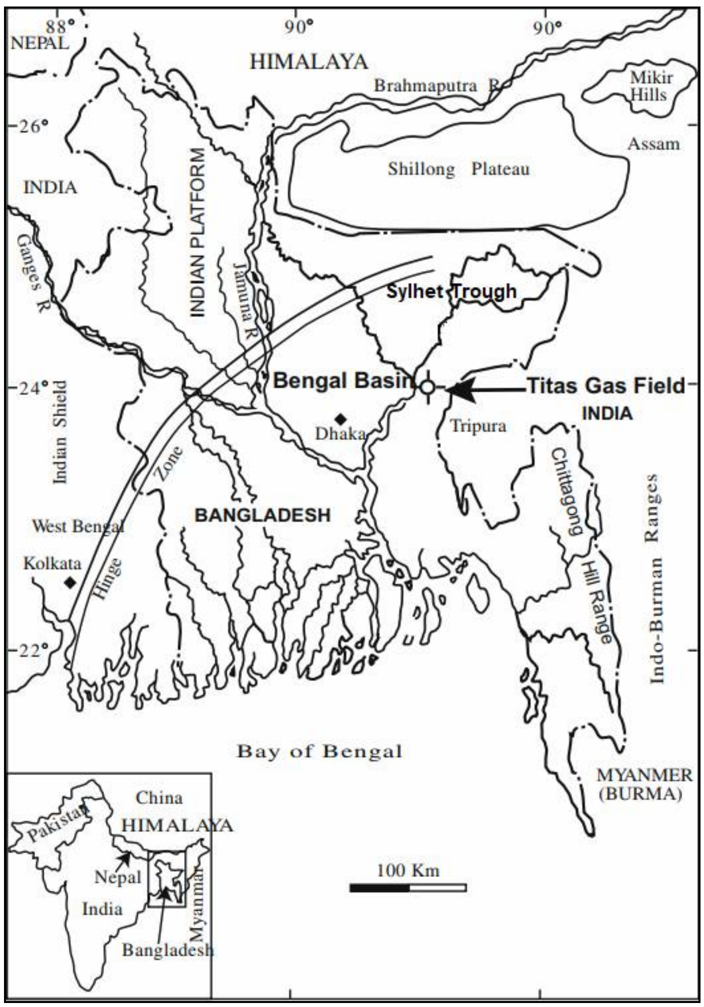

Fig 1. Regional geologic settings and location of Titas gas field (modified after Alam *et al.* 2003).

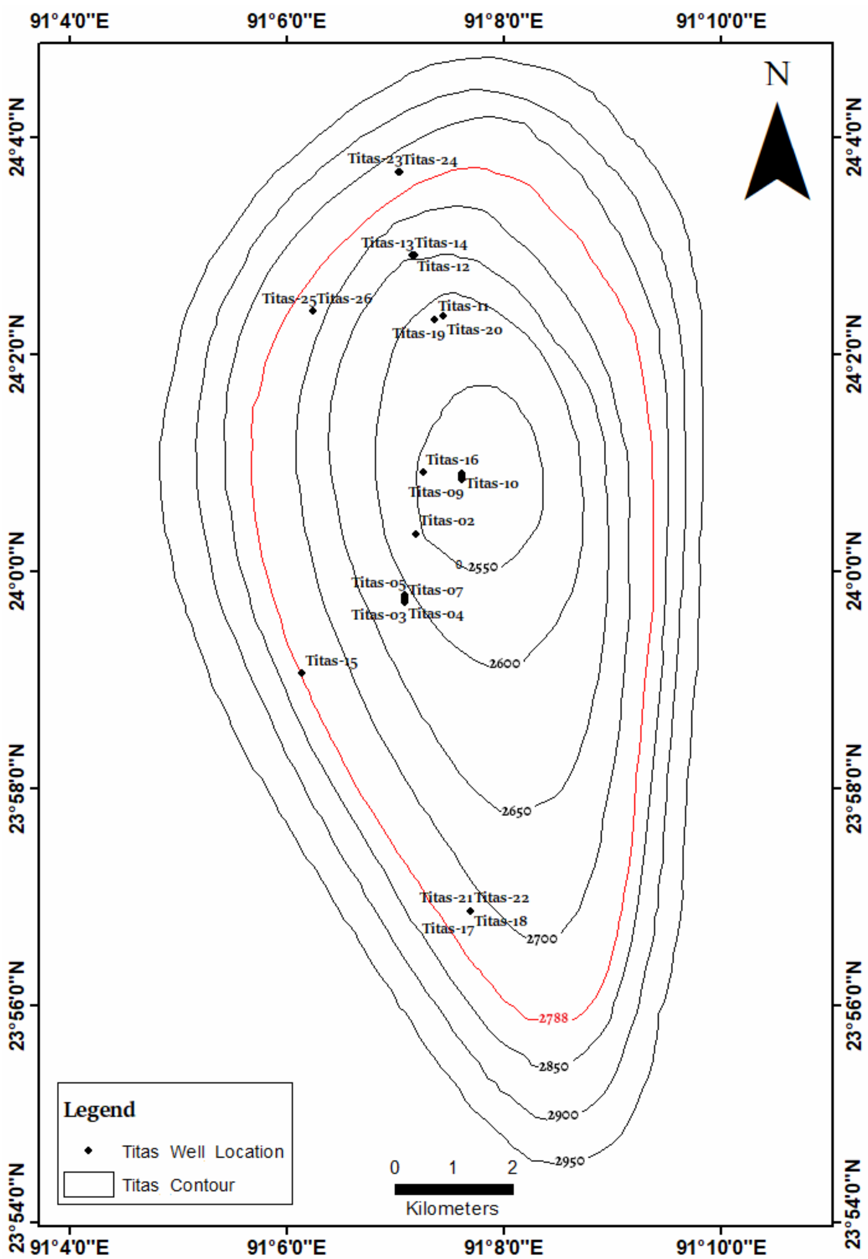

Fig. 2. Titas depth contour map showing N-S trending elongated anticlinal structure.

Western zone of Sylhet trough consists of relatively simpler geological structures (Fig. 2). The eastern zone is the most prospective gas and oil province of Bangladesh (Biswas 2005).

Titas structure: Titas structure lies on the southern fringe of Sylhet trough and on the western margin of the Chittagong Tripura frontal fold belt (Matin *et al.* 1984). The structural trend main axis lies along N-S direction, with a broader northern nose and steeper eastern flank (Fig. 3). The eastern flank is steeper than the western flank with the former dipping up to 15° and the latter dipping not more than 7°. The dip is much gentler in the north-south direction at 3° and indicates stronger compression and uplift (Imam 2013). This structure has one of the largest closures among the gas fields in this basin, measuring in excess of 16 kilometer by 8 kilometers at the topmost pay sand level. There is no surface expression of this structure as it is covered by the Titas-Meghna flood plain (Imam 2013). The reservoir sands in the area are composed of stacked sands which are divided into three groups 'A', 'B' and 'C' sands. Group 'A' sands are the most prolific in terms of petroleum generation which are the dominant constituent of the reservoirs in the Titas field. This sand zone consists of sandstone which is light grey to white with a salt and pepper texture, very fine to fine grain and subangular to sub-rounded. The siltstone and shales are found to be interbedded with the sandstone. The sandstones are separated by shales and also have shale bedding within them. These sands constitute the gas reservoir within the area (Farhaduzzaman *et al.* 2015).

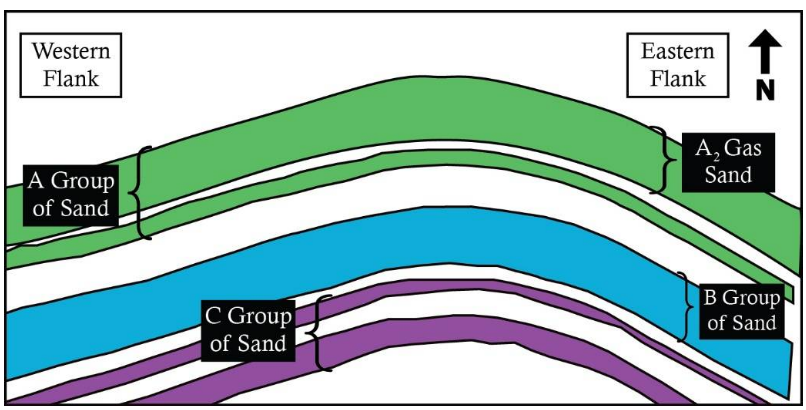

Fig. 3. Schematic diagram of Titas anticlinal structure with steeper eastern flank and gentler western flank. (modified after Miah and Howladar 2014).

Overview of petroleum geology: Gas samples from the seepages collected by BAPEX and BGFCL were analyzed in both BAPEX and BUET laboratory. All the analyses indicated that the gas is thermogenic and only source of this type of gas in this area are the gas reservoirs of the gas field, more precisely the ‘A’ group of sands (Huq 2009).The gas sands of Titas gas field represent a geological set. Five major gas sands occur in the Titas gas fields which are denoted as A_2, A_3, A_4, B_3 and C_3 from top to bottom.

The minor gas sands of Titas gas field, i.e. B_1, B_2, C_1, C_2 and C_4 in the western flank and B_0-E, B_1-E, B_2-E, C_0-E, C_1-E, C_2-E, C_4-E are of limited spatial extent. As far as the major gas sands of Titas gas fields are the main concern, the most significant gas sands are A_2, A_3, A_4, B_3 and C_3. ‘A_2’ sand is the thickest among all gas sands hence the most productive sands also. The C_3 sands are thinnest of the five major sands. The sands show a more or less uniform thickness of 50 ft ± throughout the field, indicating a homogeneous energy condition when they were deposited. The gas reserve of Titas gas field was calculated in 2010 by RPS energy consultants to be 6.36 Tcf, with some more development work done. Cumulative production of the field till July 31, 2017 is 4383.102 billion cubic feet (bcf) gas which is 57.81% of the total recoverable reserve. Out of 27 wells, 24 wells are producing gas every day.

Materials and Methods

The investigation has been done to find out the reasons behind the gas seepage problem, the credible sources of seepage in Titas gas field. Various types of data were a prerequisite for this job and were collected from different sources. Titas well location was gathered from BAPEX and plotted on a map. Gamma ray log, resistivity log, sonic log, density log, neutron log and CBL/VDL log of Titas-10 well were assembled from BAPEX and evaluated for major gas sand reservoirs identification and for the assessment of cement bonding condition against all major gas sands in the well. Scrutinizing this cement bond log was very helpful in recognizing the potential sources of gas seepages. A reconnaissance was conducted in the seepage affected area in Brahmanbaria sadar Upzilla. A resistivity survey was directed in order to identify shallow subsurface fault which might be a potential conduit for surface seeping gas. Data were acquired from the survey using superstring R8 and analyzed for fault identification using AGI EarthImager 2D software. Seepage points in the locality from both ground and water body were inspected, photographed and the coordinates of these seepages were collected. These seepage points were plotted on a map to overview the surface distribution and analyzed to identify any kind of connection with Titas wells trajectories. Overall, almost all of data which could be beneficial to the research work were collected and analyzed during the period.

Results and Discussion

Resistivity survey: The electrical resistivity surveys have been conducted using dipole-dipole electrode configuration to investigate underground lithology, structure, layers, discontinuities and the main focus was on identifying traces of subsurface fault. The electrode spacing for each line is 8 meter and no roll-along surveys have been recorded, so the total distance coverage for the lines was (83 × 8) = 664 meter. Overall, three resistivity lines have been recorded in Titas-Meghna floodplain near Titas-06, 08, 09 and 10, where surface gas seepage is very prominent (Fig. 4). The resistivity lines are denoted by Line A, Line B, Line C, respectively. Lines A and C have been recorded along the major N-S trending anticlinal axis of Titas gas field while Line B has been taken across the axis where gas seepages are more prominent.

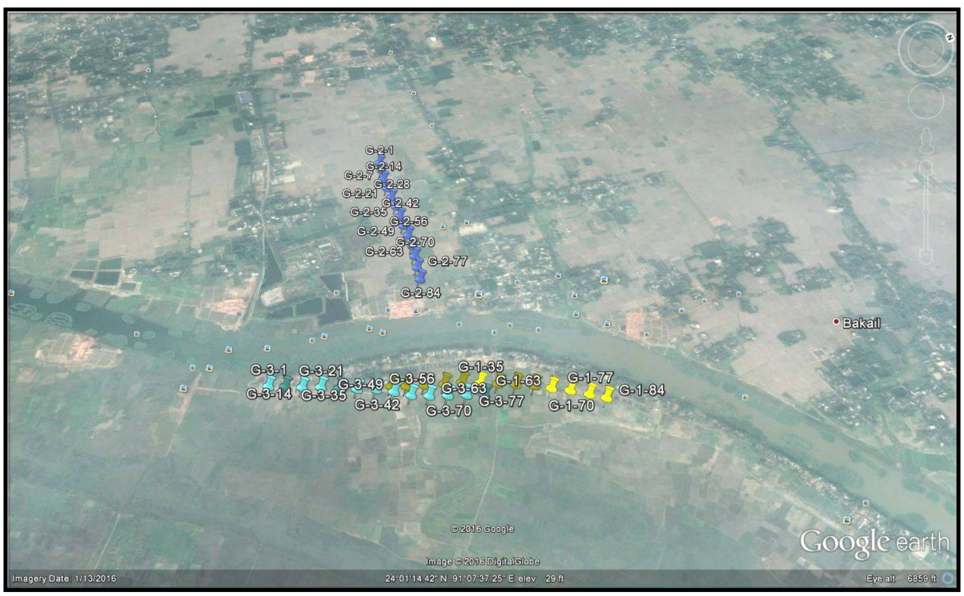

Fig. 4. Google image showing resistivity survey locations: Titas Line A (yellow color), Titas Line B (blue color) and Titas Line C (green color).

Line A is showing lower resistivity throughout the section though it is showing higher value in low electrode end than in high electrode end. The line is also showing high resistivity within 20 meters below the surface which is confined from the center point of the line to high electrode end (Fig. 5). This high resistivity layer indicates the lithology to be fine grained sand body while the surroundings are composed of thick shale layer.

Line B is showing high resistivity layer continuous throughout the area within 50 meters below the surface. The resistivity value is even higher in high electrode end than in low electrode end. The high resistivity layer is indicated as fine-grained sand body of Titas floodplain. Below this, there is a low resistivity layer which continuous throughout the line (Fig. 6). This thin low resistivity layer has been detected as shale. There is another high-resistivity layer at the bottom of the section which is also continuous throughout the line which could be an indicator of shallow gas pocket.

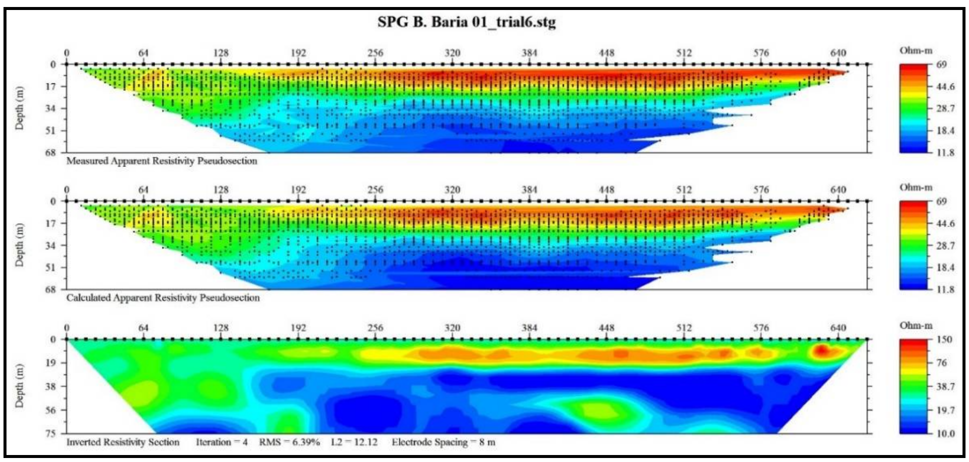

Fig. 5. Titas Line A resistivity section.

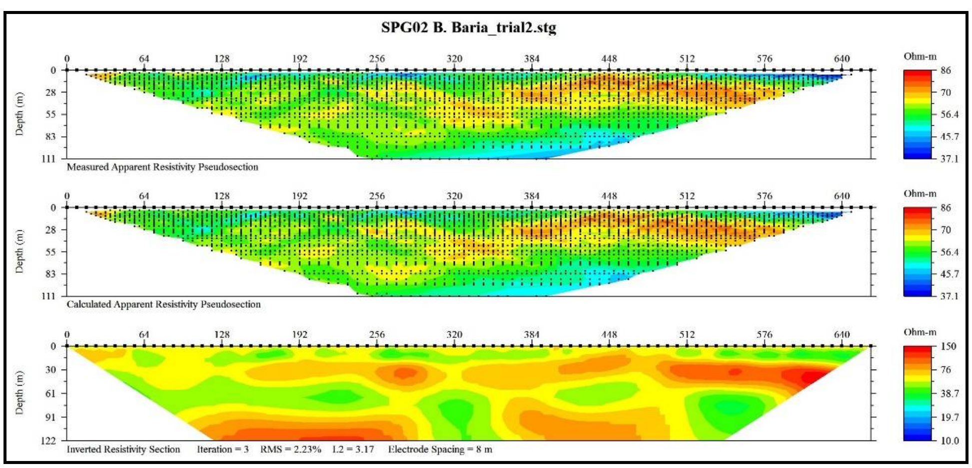

Fig. 6. Titas Line B resistivity section.

Line C is showing very low resistivity at the bottom of the section which indicates a thick shale layer of floodplain deposit which is around 60 meters below the surface. The upper part is showing low to moderate resistivity continuously from low electrode end to high electrode end indicative of floodplain deposit. There is a small resistivity change from the surrounding low resistivity layers (Fig. 7). The high resistivity portion of the section could be just a sand body or it could be shallow gas pocket surrounded by shaly floodplain deposits. The data recorded are more or less continuous in the resistivity line and no abrupt change was observed. Therefore, the resistivity lines do not show any indication of faults.

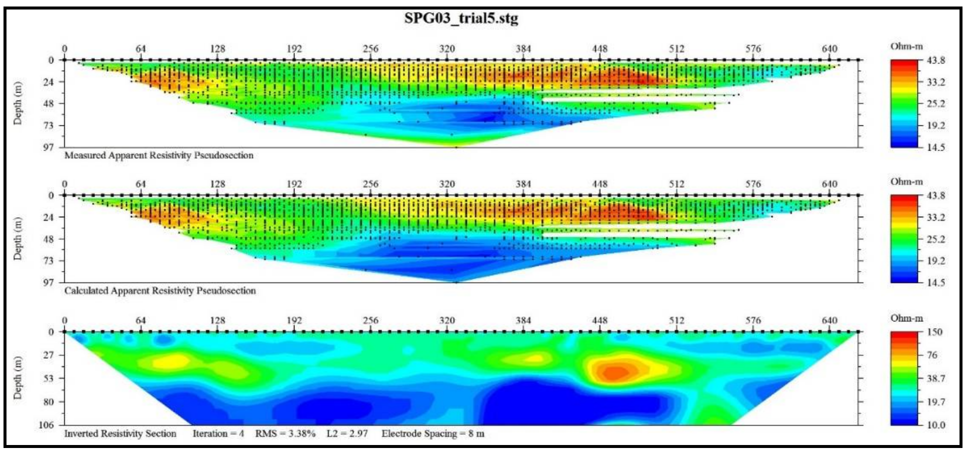

Fig. 7. Titas Line C resistivity section.

Wireline log analysis: Major reservoir sands 'A_1', 'A_2', 'A_3', 'A_4', 'B_3' and 'C_3' in Titas-10 well has been identified using various wireline log i.e. gamma ray log, resistivity log, sonic log, neutron porosity log and density log. All gas sands were marked in terms of their depths and their thickness has been noted. Lithologies have been identified in terms of gamma ray log in Titas-10 well while shale layers give higher values of average 129 API units and gas bearing sands show lower gamma ray values ranging on an average from 94-111 API units for each gas sands.

Gas sands have been determined by comparing resistivity values where water-bearing sand has the lowest value (av. 5.42 Ω-m) followed by shale (av. 9.63 Ω-m). Sands containing gas showed the highest values in different intervals ranging from 20 to 34 Ω-m on an average for every gas sand. Lithologies have also been established by studying sonic log while shale shows highest interval transit time of av. 87 μs/ft. and gas sands display slightly higher interval transit time (ranging from 76 to 87 µs/ft.) than water bearing sand (avg. 69.8 µs/ft.). Formations have been studied on the basis of neutron porosity log of Titas-10 well, which shows highest value in shale formation (av. 0.37) while gas bearing sand showed lower values (ranging from 0.19 to 0.24) than water bearing sand (av. 0.28). The density log values of gas bearing sands vary from 2.31 to 2.51. ‘A_1’ sand in Titas-10 well has also been identified, and top and bottom of the sand has been demarcated studying neutron and density composite log.

Table 1. Top and bottom of major gas sands in Titas-10 well demarcated from gamma ray log, resistivity log, sonic log, neutron porosity log and density log.

Gas sand	Top (m)	Bottom (m)
‘A_1’	3157	3187
‘A_2’	3199	3241
‘A_3’	3251	3287
‘A_4’	3301	3337
‘B_3’	3486	3522
‘C_3’	3591	3610

Low amplitude in CBL and strong formation signals in VDL indicates good cement bonding against the formation. High amplitude value in CBL, no formation signals in straight VDL and "V" type Chevron patterns at collar locations suggest the studied formation to be devoid of cement. Cement bond log of Titas-10 well has been studied and analyzed in order to infer the cement bond condition against targeted ‘A_1’ gas sand. It is distinctly observed that cement bond log value of ‘A_1’ gas sand of Titas-10 well ranges from 7 mV to 85 mV with an average of 44.14 mV, which indicates the cement bond condition in 3157 - 3180 m interval is very bad (Table 2). There is a 2 - 3 m interval with good to fair cement bonding (3163 - 3168 m) in the top zone of ‘A_1’ gas bearing sand, however the overall cement bond status against ‘A_1’ sand is very poor.

Surface seepage distribution and extent: The areal extent of gas seepage distribution is around 7 sq. km. Seeping of gas has been seen in numerous locations as agricultural lands, ponds, tube wells and river. Gas is leaking through these points and escaping to the surface (Fig. 8). Locals started collecting the gas to use gas for household purpose and to run small industries soon after the gas seepages noticed. Noticeable seepage points have been studied and the GPS coordinates have been collected and plotted to create seepage distribution map.

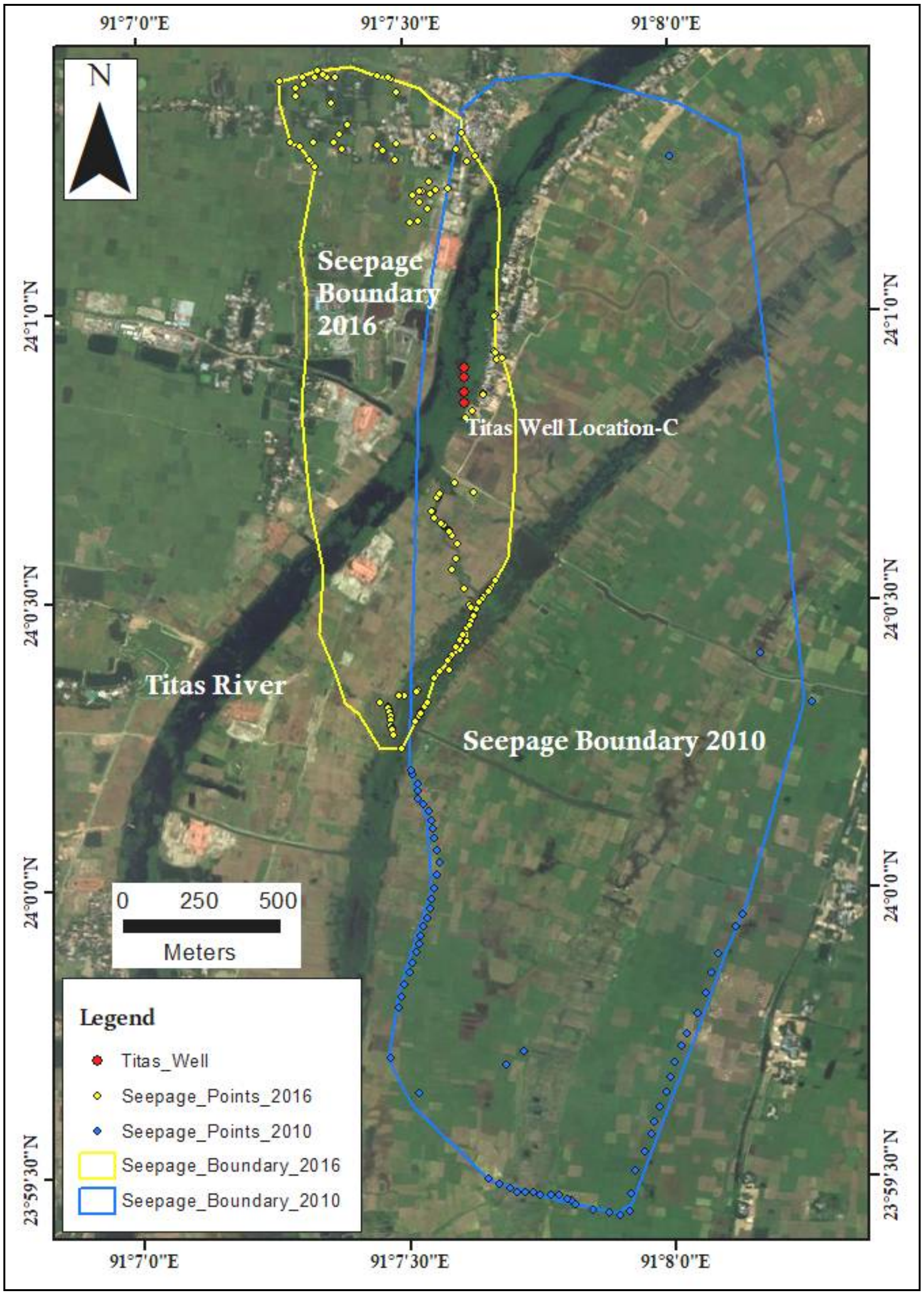

Fig. 8. Titas seepage distribution map over time.

Seepages in relation to wells: Gas seepages distribution is more or less same over time. These seepages are observed around the central area of Titas Well Location C which includes Titas Well nos. 6, 8, 9 and 10 (Fig. 9). Changes in seepage distribution over time, remained more or less close to Titas Well Location C than others.

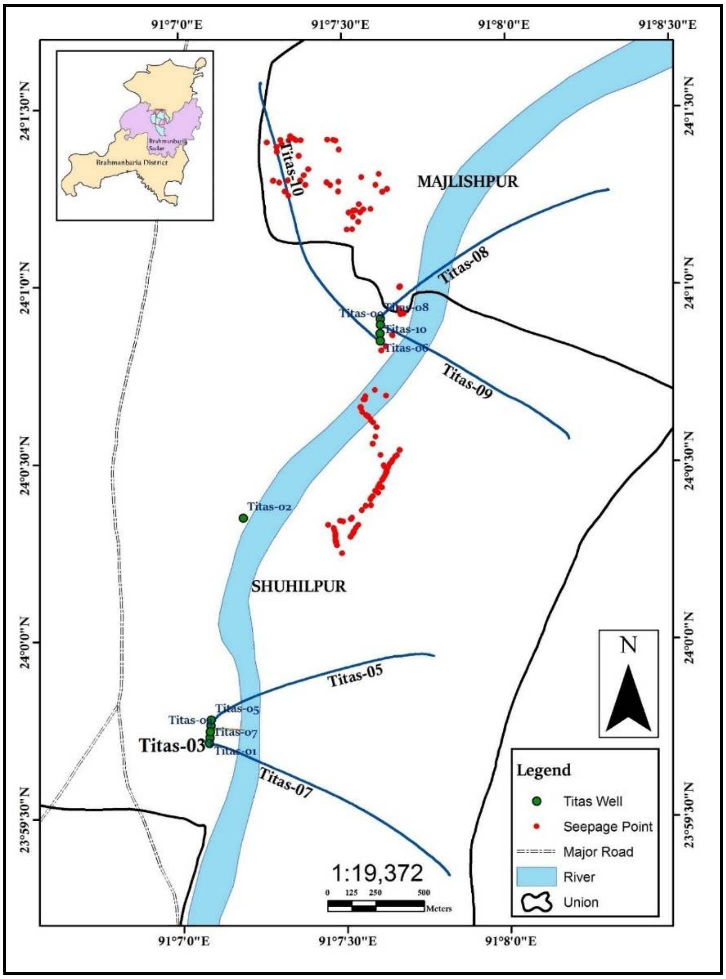

Fig. 9. Titas gas seepages in relation to wells.

Some of the Titas wells are deviated well, their subsurface locations are plotted on the map with surface seepage distribution. Subsurface location of Titas well no. 8, Titas Well no. 9 and Titas Well no. 10 overlaps with surface seepage distribution pattern, whereas the location of vertical Titas well no. 3 is almost 3 km away from the current seepage points, which has been killed with an idea of being the contributor of Titas gas seepage. This map indicates the seeping gas from the main reservoir could be migrated where fault line may work as a conduit from direct below subsurface where Titas Well nos. 8, 9 and 10 are located and Titas well no. 3 might not be the faulty well at all.

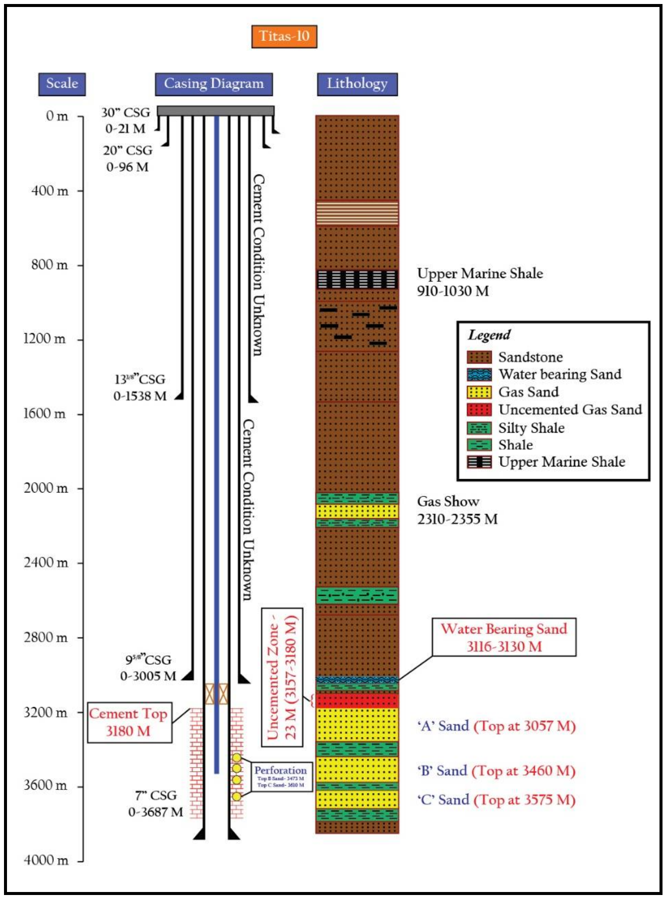

Fig. 10. Schematic diagram of Titas Well No. 10 showing casing and cementing against rock type.

Sources of gas seepage: BGFCL first noticed gas seepages in the southeastern part of Titas gas field beside Titas river in November, 2006. They have made a committee submitted a report to Petrobangla in February, 2007. The surface seepage distribution map indicated that any of the wells located at Titas Well Location C could be responsible for this unprecedented gas seepage. The expert committee closely observed and studied well history, production data, drilling data and geological data and interpreted all log data available for the above-mentioned wells located at location C. Finally, the committee theorized that the source of gas seepage could be from the well nos. 8, 9 or 10. They recommended to conduct circulating cement squeeze job and to run necessary logs specially CBL-VDL in well nos. 8, 9 and 10 by appointing expert well control specialist.

Comments on seepage source: Titas-10 well has drawn all the attractions as all newest and still existing seepages coincide along the Titas-10 well trajectory. Cement bond analysis illustrate that top of cement against major gas sands is at 3180 m MD while top of ‘A’ gas sand resides at 3157 m MD. This (3157 m MD-3180 m MD) uncemented zone is most possibly responsible behind gas seepages in Titas gas field. There is also a water bearing sand at 3116-3130 m MD. There is a possibility of cross-flow of gas and water between water bearing sand and gas sand ‘A’ which might eventually cause gas to leak to the surface. Moreover, ‘A’ sand in Titas-10 well was found dry which clearly bolster the assumption of gas leaking from this well, while log signatures in the sand directed that there was enough gas to flow into the well. Accordingly, prior to these facts it can be distinctly claimed that the top of ‘A’ gas sand (A_1) in Titas-10 well is the sole contributor of Titas gas seepages (Fig. 10).

Table 2. Detail well information including cement bond condition in Titas gas field.

Well No.	Year	Well type	Drilled depth	‘A’ sand encounter	‘B’ sand encounter
Titas-03	1969	Vertical	2839 m	2617 m	-
Titas-08	1985	Directional	3583 m MD	3038 m MD	3292 m MD
Titas-09	1987	Directional	3625 m MD	3057 m MD	3310 m MD
Titas-10	1988	Directional	3699 m MD	3157 m MD	3460 m MD

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‘C’ sand encounter	Top of cement	Cement bond condition
-	1678m	Quite good against ‘A’, ‘B’ and ‘C’ sand
3438 m MD	2800 m MD	Quite good against ‘A’, ‘B’ and ‘C’ sand
3462 m MD	3033 m MD	Good against ‘A’, ‘B’ and ‘C’ sand
3575 m MD	3180 m MD	Top of ‘A’ sand is unprotected

Conclusion

Titas gas seepages have been observed in the proximity of Titas well location C, from where Titas-6, 8, 9 and 10 have been drilled and still producing gas. Surface seepage distribution has been paralleled with well paths of nearby wells of location-C and found to be coincided with Titas-9 and 10 well paths. No traces of fault or fracture was recognized in any of the three resistivity lines acquired.The abandoned Titas-3 well has been cleared out of discussion as the well location is almost 3 km far from seepage affected area while no indication of fault in resistivity survey supported this action.

Numerous remaining seepages in the affected area suggest the decision of killing Titas-3 well was wrong. Despite of based in the seepage disturbed area, Titas-8 and 9 wells have been cleared out of suspicion as cement bonding against major reservoir sands of these two wells are good to excellent.Titas-10 well has been studied with great care as most of recent and existing seepages lie along the well trajectory of this well. Resistivity, sonic, neutron and density log signatures of Titas-10 well evidently shows that 'A_1' sand is a good gas bearing sand and gas has been producing for many years in other Titas wells from this sand. The structurally high Titas-10 well cannot just be expelled by producing in some other wells. Therefore, gas seeping from this sand must have to be the only explanation behind the dry 'A_1' sand. Log signatures show that 'A_1' and 'A_2' gas sands are separated only by a 6-meter-thick shale in Titas-10 well. It has also been inferred that the quality of this shale is not quite good. There is a slight possibility of gas migration from 'A_2' sand to 'A_1' sand by breaching this shale layer. No drill stem test has been conducted in 'A_2' sand in Titas-10 well so far, therefore, it cannot be sure whether gas is also leaking from 'A_2' sand or not. No one can say that all the gas leaking from the reservoir is seeping to the surface. A certain portion of gas might have accumulated in small localized traps. It will be extremely risky to drill wells in this field if there is the possibility of presence of shallow gas in unknown horizons. This gas might also affect the quality of the future seismic survey.

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DEVELOPMENT, HOST PREFERENCE AND LEAF CONSUMPTION OF THE LIME SWALLOW TAIL BUTTERFLY, *PAPILIO POLYTES ROMULUS* CRAMER (PAPILIONIDAE: LEPIDOPTERA) ON CITRUS

M.M.H. KHAN*, M.N. MOLLA AND M.A. RAHMAN
Department of Entomology, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

Abstract

Studies were conducted to know the developmental period and host preference of the lime swallow tail butterfly, *Papilio polytes romulus* Cramer and leaf consumption by its larvae on citrus in the laboratory. Ten Citrus host plants such as Kagoji lime-BAU-1, BAU-2, BAU-3, BAU-4, BARI kagoji, elachi lime, sweet orange, orange, jamir and Pumelo were used as study materials. Results revealed that the most preferred host of *Papilio polytes romulus* L. was Elachi followed by BAU-3 and Orange while the least preferred host was Pumelo. Eggs were pale yellow and spherical. The average length of newly hatched caterpillars, 2nd, 3rd, 4th and 5th instar larvae were 2.32 mm, 10.75 mm, 14.50 mm, 24.80 mm and 39.50 mm, respectively. The mean duration of 1st, 2nd, 3rd, 4th, 5th instar larvae and pre-pupa were 2.20, 2.15, 2.35, 2.25, 2.35 and 1.0 days, respectively. The average length of the pupal stage, adult male and female butterfly were 29.50, 24.00 and 25.75 mm, respectively. The mean longevity of female and male was 6.5 and 3.9 days. The percentage of leaf area consumed was increased with increasing the age of larvae. The highest percentage of leaf area was consumed by the 5th instar larva (100) followed by 4th instar (75) while the lowest percentage of leaf area was consumed by the 1st instar larva (15) in 72 hours after release.

Key words: Lime swallow tail butterfly, Development, Host preference, Leaf consumption, Citrus

Introduction

Citrus crop posses great adaptability to various climatic conditions and hence grown equally both in tropical and subtropical regions as well as some favourable parts of the temperate regions of the world. It stands in second position in the world and third among all subtropical fruits (Samson 1986). In Bangladesh citrus crop covers an area of about 5786 acres with an annual production of 68721 M tonnes (BBS 2016). The yield of citrus in Bangladesh is very low compared to other countries due to insect pests, diseases and planting of low yielding varieties. Citrus is attacked by a large number of insect pests which cause decline in yield (Chadha 1970). About 823 species of insects and mites attack citrus trees in the world (Ebeling 1959). Among the various insect pests that attack citrus, a few are pests of major importance, namely lemon butterflies, swallow tail

*Author for correspondence: <mohasin1965@pstu.ac.bd>.

butterfly, citrus leaf miner, citrus psylla, whiteflies, scale insects and mealybugs. *Papilio polytes romulus* Cramer, the lime swallow tail, is one of the most common and wide spread members of the family Papilionidae. It is also known as the common mormon, lime swallow tail, citrus swallow tail or chequered swallow tail and is found throughout Southern Asia. It is widely distributed from Farmosa to Arabia including Burma, Bangladesh, Ceylon, India and Pakistan (Butani 1973). It is a regular pest in nurseries, young seedlings, and on new flush of full grown up trees. Pest activity was severe during October to December (Lakshminarayanamma 2000). Most of the *Papilio* species reported till now preferably feed on various plants of Rutaceae family with special preference towards both wild and cultivated species of *Citrus*. *Papilio polytes romulus* attacks only the younger and tender leaves of the new flushes. Severe infestation results in defoliation of the tree (Bhutani and Jotwani 1975) and leads to retarded plant growth and decreases fruit yield (Pruthi 1969). For proper management of any insect pest, it is important to know the developmental strategy, morphometrics and feeding behavior of the insect. The sufficient information regarding development strategy, morphometrics and feeding behavior of the lime swallow tail butterfly is very scanty in Bangladesh.

The study includes parameters such as duration of life stages, morphometrics, host preference and leaf consumption of this insect. Therefore, the present research program was undertaken to know the developmental period and host preference of different immature stages of the lime swallow tail butterfly and leaf consumption by the larvae of this insect.

Materials and Methods

Studies were conducted in the laboratory, Department of Entomology, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali, Bangladesh during October to December, 2016. The eggs and larvae of *Papilio polytes romulus* were collected from citrus trees of the campus of PSTU on October, 2016. The collected larvae were reared on citrus leaves in the laboratory condition at 25.2 - 26.5^{0}C room temperature, 71 - 80% relative humidity, and a photoperiod of L12 : D12, until adult emergence. To observe the development of the adult butterflies for the study, different stages of the larvae available were collected from lemon plants of the university campus. They were placed singly on 10 Petri dishes (15 cm diameter) with young lemon leaves (variety BARI Kagoji lime, *Citrus aurantiifolia* Swingle). Those 10 Petri dishes were used as 10 replicates. The leaves were supplied as food for the larvae and were changed every 24 hours interval. Water soacked cotton ball was used around petiole to keep the leaves fresh. The durations and the number of moultings of each larval instar were noted. The larval instars were determined by the presence of exuviae. As they reached final instar, the larvae were placed on twigs of lemon plants. Finally, those were set in 10 glass jars (14 cm × 8 cm) to assist in pupation. The base of the twig was set in a narrow mouthed bottle filled with water to keep that fresh. Days required for the completion of the pupal stages were also recorded. When the adults emerged, the longevity of adult was recorded.

The study was carried out in a free choice test. Ten *Citrus* host plants, such as BAU-1, BAU-2, BAU-3, BAU-4, BARI Kaghzi (*Citrus aurantiifolia* Swingle var. Kaghzi lime), elachi lime (*Citrus aurantiifolia*), sweet orange or malta (*Citrus sinensis* L. var. Washington Navel), orange (*Poncirus trifolia* or *Citrus aurantium* L. var. Khatta), Jamir (*Citrus assamensis*) and Pumelo (*Citrus grandis*) were selected from the germplasm centre of PSTU for this study. Ten leaves of 10 different citrus host plants were randomly selected and collected. The collected leaves were placed in a wooden box measuring 50 cm × 40 cm × 5.5 cm with glass lid maintaining equal distances among all leaves. The larvae of lime swallow tail lime butterfly were released in a central point of box. The preference of host leaves by the larvae were observed and recorded at 24 hrs after release. The percentage of leaf area feeding was measured by eye estimation.

Different larval stages were used in this experiment. Preliminary studies were conducted to determine the area (%) of leaves consumed by each larval stage in 24, 48 and 72 hours after release (HAR). The leaves were collected from the respective plants and the end part of their petiole was wrapped with moistened cotton to prevent dehydration prior to placing them in the Petri dish. Thereafter, the larvae starved for 4 - 5 hrs were introduced to each Petri dish containing the respective combination of leaves and allowed to feed on the leaves for 24 hrs period. All larval instars were fed with leaves from elachi lime in no choice test in Petri dishes (15 cm).

Results and Discussion

A. Developmental stages of lime swallow tail butterfly egg: The eggs of the common mormon are laid singly on young stem, petiole or underside of the leaves of the host plants. The egg is pale creamy yellow with a finely roughened surface. It is nearly spherical with a diameter from 1.0 to 1.2 mm (Plate 1), but became dark as the larva developed within. The egg takes about three days to mature. Radke and Kandalkar (1988) stated that spherical and pale yellow eggs are laid singly on the upper surface of young leaves. These darken as the larva develops within, and hatch after 5 - 9 days. A single female laid 15 - 22 eggs.

Larval development: There were only five larval instars of the butterfly which totally lasted for 8.70 to 13.90 days. The average duration of first to fifth instars was 2.20, 2.15, 2.35, 2.25 and 2.35 days, respectively (Table 1).

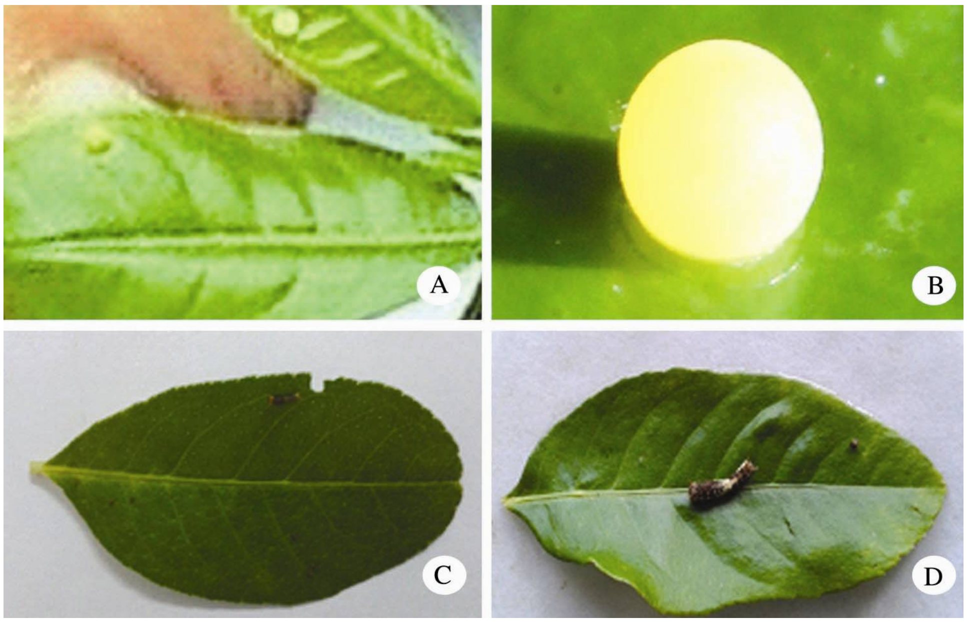


Plate 1. Egg (A - normal size; B - enlarged form), 1st (C) and 2nd (D) instar larval stages of the lime swallow tail butterfly.

Table 1. Duration of different life stages of the lime swallow tail butterfly.

Developmental stage	Duration (Days)	
	Range	Mean
1st instar larva	1.8 - 2.6	2.20
2nd "	1.6 - 2.7	2.15
3rd "	1.8 - 2.9	2.35
4th "	1.7 - 2.8	2.25
5th "	1.8 - 2.9	2.35
Prepupa	1.0 - 1.0	1.0
Pupa	13 - 14	13.5
Adult longevity male	3.6 - 4.2	3.9
Adult longevity female	6.0 - 7.0	6.50

First instar larva: Newly hatched caterpillars were less spiny, cylindrical in shape, light brown to brownish black in colour with thorax thicker than rest of the body having dirty white mark on dorsal side showing resemblance to bird’s excreta (Plate 1). The length and width of newly hatched caterpillar on an average measured 2.32 and 0.44 mm, respectively. The average length, width at middle, and posterior points of the first instar larva were 5.50, 2.00 and 1.00 mm, respectively (Table 2). The average duration of the first instar larva was 2.20 days with the range of 1.80 to 2.60 days (Table 1). The findings regarding the 1st instar larvae were in agreement with the reports of Resham *et al.* (1986) and Maheswarababu (1988).

Table 2. Morphometrics of immature stages, adult and wing expansion of the lime swallow tail butterfly.

Stages and appendage	Size (mm)		
	Length	Width	
		Middle	Posterior
1st instar larva	5.50	2.00	1.00
2nd "	10.75	2.92	1.58
3rd "	14.50	3.50	3.00
4th "	24.80	5.13	3.75
5th "	39.50	7.20	6.00
Pre-pupa	27.72	7.65	6.25
Pupa	29.50	8.00	5.63
Adult male	24.00	4.00	2.50
Adult female	25.75	5.75	3.00
Fore wing expansion	37.50	24.00	-
Hindwing expansion	28.50	23.00	-

Second instar larva: The second instar larvae were less spiny and dark brown in colour with a dirty white line present obliquely along lateral sides of the abdomen and with a break on the dorsal side. A horn-like structure was present on the dorsal side of the last body segment (Plate 1). The average size of the second instar larvae in length, width at middle and posterior points was 10.75, 2.92 and 1.58 mm, respectively (Table 2). The average second instar larval period was 2.15 days with a range from 1.60 to 2.70 days (Table 1). These results differ with the observations made by Ganguli and Ghosh (1967) recording 7.00 and 2.00 mm in length and width, respectively. This deviation might be due to differences in climatic factors and also due to seasonal variations from year to year.

Third instar larva: The third instar larvae resembled the second instar larvae except in size (Plate 2). The average length, width at middle, and posterior points of the third instar larvae were 14.50, 3.50 and 3.00 mm, respectively (Table 2). The average third instar larval period was 2.35 days with range from 1.80 to 2.90 days (Table 1). Similar observations were also reported by Maheswarababu (1988) and Asokan (1997).

Fourth instar larva: The fourth instar larvae were black in colour with a little greenish tinge and whitish bands could be seen on meso and meta thoracic segments laterally, anterior part of abdomen and on last anal segments. Two red coloured sacs or osmeteria opening in the first thoracic segment were observed dorsally at the anterior portion (Plate 2). The average size of the fourth instar was 24.80 mm in length, 5.13 mm in width at middle and 3.75 mm in width at posterior points (Table 2). The average fourth instar larval period was 2.25 days with a range from 1.70 to 2.80 days (Table 1).

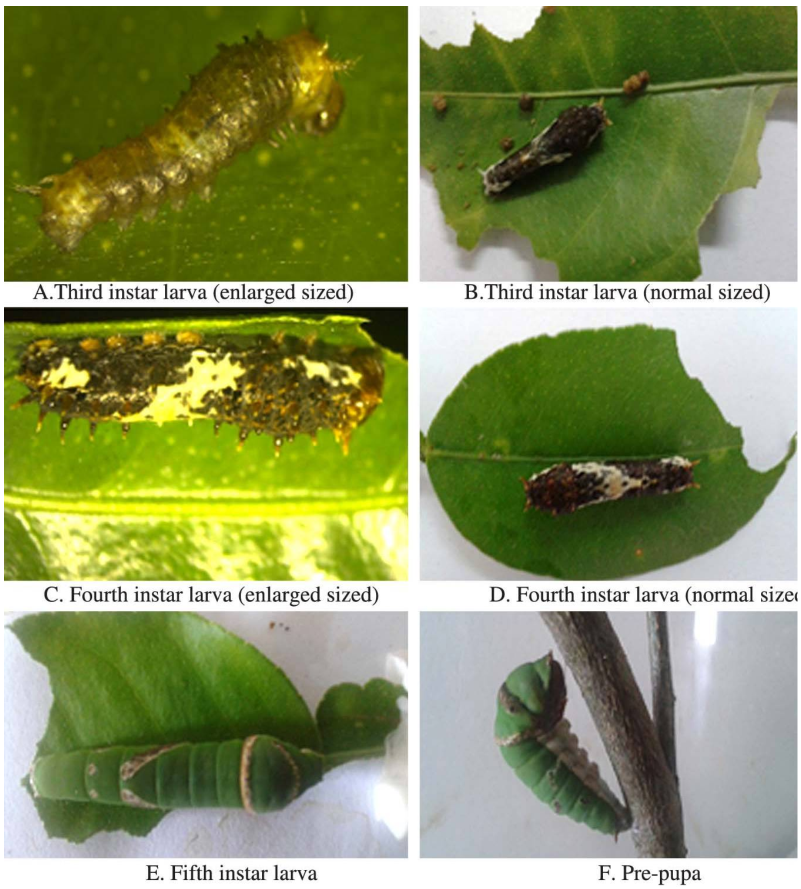


Plate 2. The 3rd (A&B), 4th (C&D), 5th (E) instar larval and pre-pupal (F) stages of the lime swallow tail butterfly.

Fifth instar larva: The fifth instar larvae were yellowish green or green in colour. Brownish stripes present on eighth and ninth sternites with two semi circular yellowish bands on elevated portion of the body. Two eye-like spots were present on second thoracic segment and a horn like structure was found on the dorsal side of the last body segment (Plate 2). The average length, width at middle and posterior points of the fifth instar larva were 39.50, 7.20 and 6.00 mm, respectively (Table 2). The average duration of the fifth instar larva was 2.35 days with a range from 1.80 to 2.90 days (Table 1). The fourth and fifth instar larvae both had an osmeterial gland in the first thoracic segment and this organ was defensive in function. These descriptions were in agreement with Leslie and Berenbaum (1990) who reported that secretions produced by osmeterium contained iso-butyric acid, 2-methyl butyric acid and small quantities of methyl and ethyl esters.

In the present study there are five larval instars, similar to that reported by Mushtaque (1964), but differing slightly from Badawi (1981) who reported 5 - 6 larval instars. In our study the duration of the larval stage (8.70 - 13.90 days) was found to be shorter than ranges reported in the literature, specifically 13 - 26 days by Mishra and Pandey (1965), 18 - 25 days by Sharifi and Zarea (1970), 11 - 31 days by Badawi (1981), 16 days (Rafi *et al.* 1989) and 11 - 30 days by Rafi *et al*. (1999b). The longer periods were reflective of cool-weather larval development. Corbet and Pendlebury (1992) stated that at this stage the mature larvae suffer heavy mortality. The larvae of this species can often be found in the company of the larvae of *Papilio polytes* and *P. memnon*, which are very similar in appearance. The larval stage generally lasts 15 - 26 days, depending on temperature. These observations regarding pre-pupa were in conformity with Maheswarababu (1988) and Asokan (1997), Resham *et al.* (1986).

Pre-pupa: Before changing to pre-pupa the caterpillar shrunk inside and it hangs from the twig with the help of a silken girdle (Plate 2). These were in agreement with Atwal (1964). The pre-pupal period was observed lasted for one day (Table 1). The average pre-pupal length, width at middle, and posterior end was 27.72, 7.65 and 6.25 mm, respectively (Table 2).

Pupa: Pupation takes place a day later. The pupa suspends itself with a silk girdle from the stem. Pupae were naked and varied in colour from green, straw to brown majority being green in colour with several black markings on the body. The pupa was initially green in colour and at the time of adult emergence it turned to light brown to brown colour. In the green form, the pupa is mainly green with a large yellowish diamond-shaped on the dorsum of the abdominal segments. In the brown form, the pupa is manly greyish to darker shades of brown. After 8 days of development, the pupa turns black as the development within the pupal case comes to an end. The next day the adult butterfly emerges from the pupal case. The wings and abdomen of the adult inside the pupal case were clearly seen at the end of the pupal stage (Plate 3). The average length, width at middle, and posterior points of the pupal stage were 9.50, 8.00 and 5.63 mm, respectively (Table 2). These were in conformity with the observations of Atwal (1964) and Resham *et al.* (1986). The duration of the pupal period was on an average of 13.50 days (Table 1). Ganguli and Ghosh (1967), Sharifi and Zarea (1970) and Radke and Kandalkar (1988) observed similar trends in the duration of pupa.

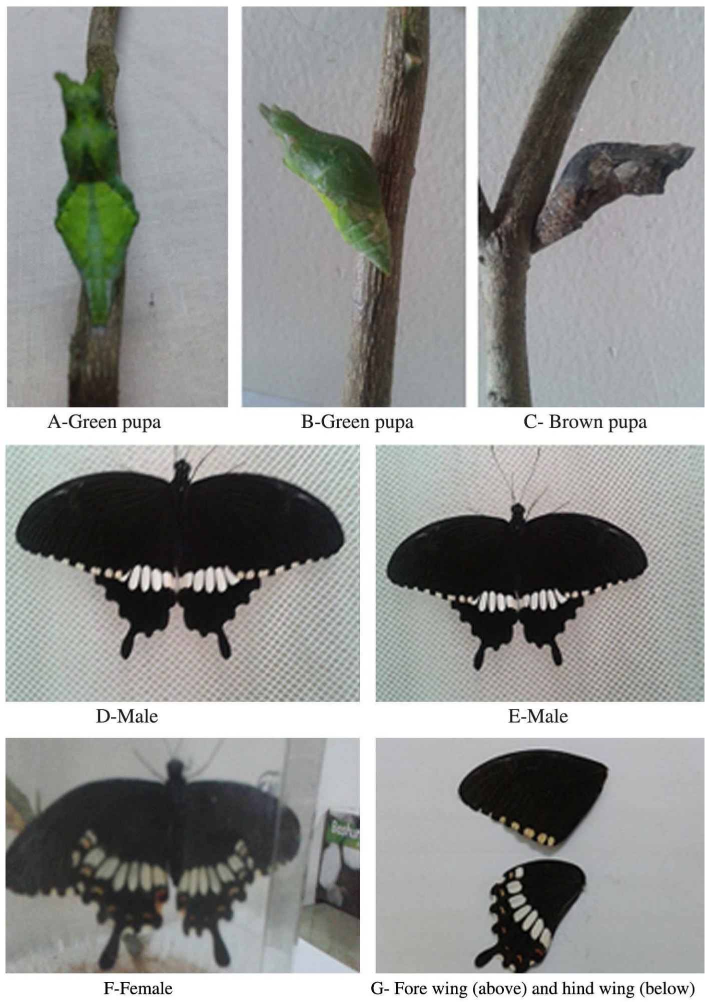


Plate 3. Pupal (A-C) and adult stages (D-F), wings (G) of the lime swallow tail butterfly, *P. polytes romulus.*

The length of the pupal stage was 13 - 14 days which is similar or dissimilar to the reports published in the literature, specifically 18 days in Rafi *et al*. (1989), 7 - 21 days in Rafi *et al*. (1999b), 11.7 days in Badawi (1981), and 9.4 - 12.2 days in Sharifi and Zarea (1970). Sharifi and Zarea (1970) reported that the pupal stage of *P. demoleus* is very sensitive to temperature undergoing diapause in winter, any rise in temperature above 25°C caused the adult emergence from the pupae. The same results were observed during the present study. Talbot (1939) reported that greenish pupal color was due to pupal development in proximity to leaves or any other green object, and brown pupal color was due to proximity to brown objects. Our observations support these findings. Tauber *et al.* (1986) reported that pupal polymorphism does not affect rate of development of the adult. The brown pupa of *P. polytes romulus* is remarkably similar to that of *Heraclides andraemon* in shape, color, and pattern (Plate 2). However, *P. demoleus* also has green with yellow and pinkish-brown color forms of the pupa (Lewis 2009), which are very different from *H. andraemon.* Pupal stage lasts approximately 12 days. Twelve or more generations are possible under local citrus-growing conditions (Segarra-Carmona *et al*. 2010).

Adult: Adult butterflies were large and beautiful with wide wing spread. Head, thorax and legs were black with creamy yellow streaks on either side, whole abdomen. The body was covered with black and yellow hairs. Fore wings were triangular in shape while hind wings were rounded. The wings were black with yellow markings. There were two rows of parallel yellow spots along outer margins of wings and a brick red oval patch on posterior angle of the hind wing. The beautiful undersides of its wings are fully displayed as it dries its wings for the first few hours after eclosion. Antennae were black and club shaped (Plate 3). These descriptions were in agreement with the findings of Resham *et al.* (1986) and Maheswarababu (1988). The average length, width at middle and posterior points of male butterfly were 24.00, 4.00 and 2.50 mm, respectively while in the female butterfly these were 25.75, 5.75 and 3.00 mm, respectively (Table 2). These were in conformity with the findings of Resham *et al.* (1986) and Maheswarababu (1988). The male to female sex-ratio was 1:2.25 on sweet orange. The length and width at middle of fore wing expansion were 37.50 and 24.00 mm, respectively while these were in hind wing expansion was 28.50 and 23.00 mm, respectively (Table 2).

Adult longevity: The female adults lived longer than the male ones. The longevity of female and male was 6.0 to 7.0 and 3.6 to 4.2 days with an average of 6.5 and 3.9 days when provided with 10% sugar solution as a food (Table 1). The variation in adult longevity was in agreement with the findings of Singh and Gangwar (1989) who reported the longevity female and male was 5.80 and 5.10 days, respectively.

B. Host preference under laboratory condition: The host preference of *Papilio polytes romulus* was documented by measuring leaf area feeding by larva in free choice test on each variety of *Citrus*. The per cent leaf area feeding by larva of lime swallow tail butterfly on different *Citrus* varieties after 24 hours of release is presented in Fig. 1 and Plate 4. The highest per cent leaf area feeding (50) was observed in BAU-3 kagoji lime which was identical to elachi lime (50) followed by orange (45), BARI kagoji lime (20), BAU-2 (20) and jamir (20) while the lowest percent leaf area feeding was in pumelo (1) followed by sweet orange (5), BAU-4 (7) and BAU-1 (10). The host preference of *Papilio polytes romulus* is as follows, in decreasing order was Elachi > BAU-3 > Orange > BARI kagoji ≥ BAU-2 ≥ Jamir > BAU-1 > BAU-4 > Sweet orange > Pumelo. In the present study, *Papilio polytes romulus* infested different citrus species and was the most prevalent and destructive pest in terms of its foliage damaging ability. *Papilio polytes romulus* is a major pest of the plant family Rutaceae (Atwal 1976) and can breed on all varieties of wild and cultivated citrus. In the present study 10 different varieties of citrus were evaluated as host plants. Singh and Gangwar (1989) reported that different citrus affect the growth rate of *P. demoleus* in India; they found that the G.I. value was highest in *Citrus reticulata*, followed by *Citrus madurensis*, and was least in *Citrus medica*. Adult longevity was highest on *Citrus reticulata*. Rafi *et al*. (1999a) reported in their field trial of 11 different Citrus species and the varieties that ovipositing wild females showed

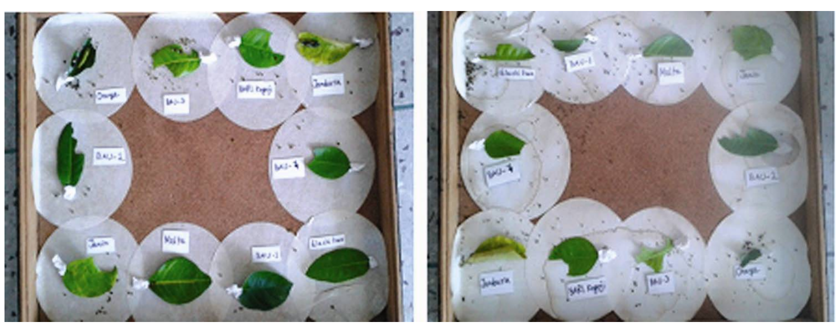


Plate 4. The leaves of different citrus varieties used as food of larvae for host preference study.

a decided preference for *Citrus aurantium* and *Citrus reticulata*. Females in this study showed similar preference for these two citrus hosts. Furthermore, in our experience, the plants with greater density of tender leaves had a higher number of eggs. Yunus and Munir (1972) showed that *P. demoleus* larvae would accept leaves of at least 19 citrus species or varieties, but demonstrated some differences in larval consumption rates, development times, and mortality between the hosts.

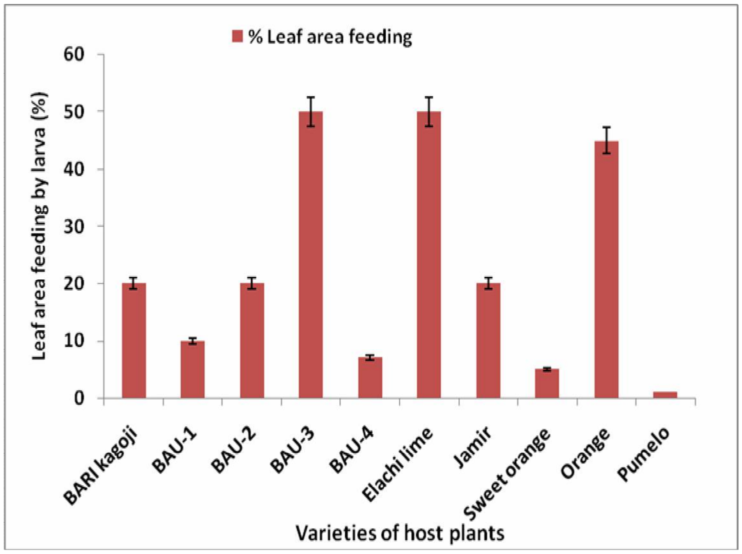


Fig 1. Host preference of lime swallow tail butterfly determined through leaf area feeding by larvae on different *Citrus* varieties in 24 hours after release in free choice test.

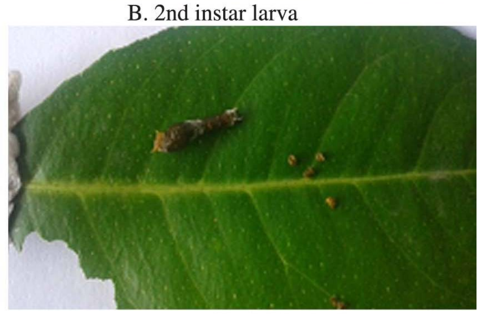
C. Leaf consumption by larvae of lime swallowtail butterfly: The percentage of leaf area consumed by different larval stages in 24, 48 and 72 hrs after release (HAR) is presented in Fig. 2 and Plate 5. The highest percentage of leaf area was consumed by the 5th instar larva in 24 (35), 48 (42) and 72 HAR (100) followed by the 4th instar (30, 35 and 75, respectively) and the 3rd instar (15, 28 and 65, respectively) for the same period. The lowest percentage of leaf area was consumed by the 1st instar larva (1, 10 and 15, respectively) followed by the 2nd instar (9, 15 and 25, respectively) in 24, 48 and 72 HAR. From this study it was evident that the percentage of leaf area consumed increased with increasing the age of larvae. This might have caused due to the requirement of different quantity of food by its different larval stages.

It is obvious from the Fig. 2 and Plate 5 that *C. aurantifolia* leaves were generally the most preferred by the fifth instar larvae. The fifth instar larva was less selective about its food than the earlier instars because at this stage the larva needed a lot of nutrients (volume) to transform into pupa. It has been reported that 80% of food consumed during the larval stage occurs in the fifth instar. Young larvae are generally more sensitive to food quality, including nitrogen and secondary metabolites; also, the older larvae are able to feed on a wider range of host plants (Waldbauer and Friedman 1991). Although the pupal stage is non-feeding, there are massive physical transformations that occur during

A.1st instar larva

B. 2nd instar larva

C. 2nd instar larva



D. 3rd instar larva

E. 3rd instar larva

F. 4th instar larva

G. 4th instar larva late stage

H. 5th instar larva

Plate 5 (A-H). Leaf consumption by different instar larvae of lime swallow tail butterfly.

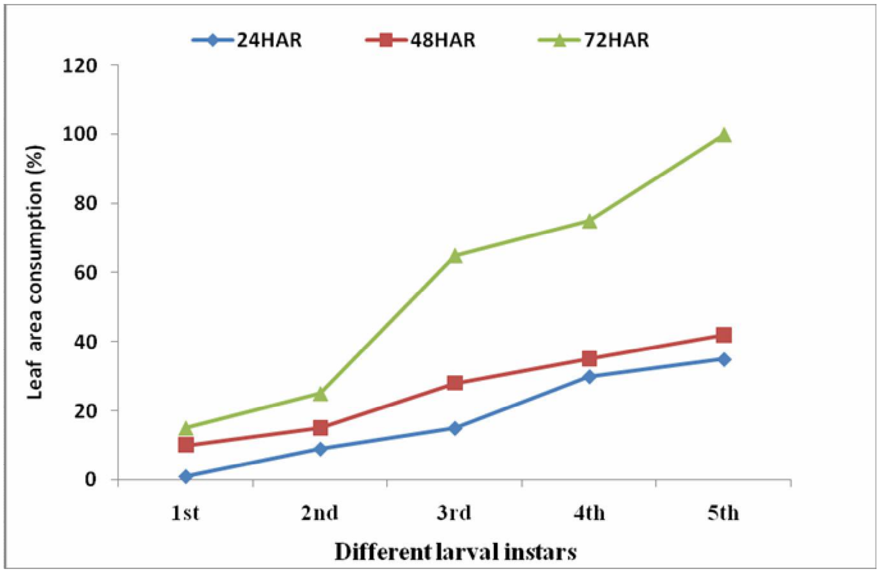


Fig. 2. The percentage of leaf area consumed by different larval instars in 24, 48 and 72 hrs after release on BAU-3 kagoji lime.

pupation. Therefore, the fifth instar larva consumes a lot of food and consequently becomes less discriminate in terms of the plants it consumed. Early instars often feed on young leaves, while later instars can also utilize mature leaves, because the young instar need to the higher nutrition for growth (Floater 1997). In addition, young larvae are more sensitive to mechanical leaf traits (e.g. toughness) owing to their smaller mouth parts and less developed musculature (Hochuli 2001). The low preference for *M. koenigii* leaves may have been due to their tougher texture compared to the leaves of *Citrus* spp. The stronger odor of the curry leaves could also be a feeding deterrent for the younger instar of *P. polytes*. The first instar always prefer young leaves which contain less of the secondary metabolites, less fiber (Cizek 2005), and toughness (Coley and Barone 1996). This is very important especially for the first instar larva because of its fragile body and poor mobility (Zalucki *et al.* 2002). There are three important factors, which determine the affinity of young larvae on suitable food choice. First is the provision of energy and the size of the larvae because the ability to cut through leaves depends on the size of head capsule, mass of chewing muscles and mandible morphology (Hochuli 2001). Second is the breakdown of ingested nutrient into fragments; toughness of food material may affect the end size of the food particles. Third is the absorption of food across the gut epithelium. The absorption efficiency of the digested nutrients is also positively correlated with the gut or body sizes. The later instars could move and feed on many parts of the plant. The fifth instar larvae for example are bigger and stronger; therefore, they feed on both young and mature leaves and on young stems. The older larvae of *Cotacola* spp. (Lepidoptera: Noctuidae) could consume all parts of host plants because they could move about easily (Gall 1990).

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ESTIMATION OF CARBON STOCK IN THE PEAT SOILS OF BANGLADESH

M. J. UDDIN* AND A.S.M. MOHIUDDIN
Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

There are a very few study on the estimation of carbon stocks in the peat soils of Bangladesh. There are three categories of peat soils in Bangladesh: Sapric peat, Hemic peat and Fibric peat. A study was conducted in these three kinds of peat soils at 100 cm depths regarding their stock. The study shows that the carbon in peat soils is about 0.12 Pg whereas it was about 0.25 Pg during 1970s. So, it was found that soil organic carbon loss is alarming and it has been reduced by half during 50 years of agricultural intensification in Bangladesh. These peat soils are losing their carbon due to the decrease of inundation level by climate change, intensive agricultural use and even fuel use for cooking purposes by the local stakeholders. So, it is very much urgent to take steps in preserving the peat soils of Bangladesh.

Key words: Estimation, Carbon stock, Peat soils

Introduction

Peatlands occupy approximately 3% of global land area, but this storage is roughly 30% of the world's soil carbon (Gorham 1991, Bridgham *et al.* 1995, Limpens *et al.* 2008). Therefore, peatlands represent an important long-term sink for atmospheric carbon dioxide (CO_2) some of which is released following drainage and land use change. The restoration of peatland ecosystem functions has been suggested as one of the most cost-effective ways of reducing greenhouse gas (GHGs) and mitigating the effects of climate change.

Tropical wetland forests containing organic soils - mangroves and freshwater peat swamps- are significant global carbon stores (Donato *et al.* 2011). Page *et al.* (2011) estimated 88.6 Pg are stored in tropical peatlands worldwide, with 68.5 PgC (77%) occurring in Southeast Asia. Similarly, Donato *et al.* (2011) estimated mangroves may contain up to 20 Pg C globally. Tropical wetland forests are susceptible to large scale C losses, due to their high C storage and rapid rates of deforestation (Langner *et al.* 2007, Miettinen and Liew 2010 a, b). Further concern is the vulnerability o f tropical wetland

*Author for correspondence: <mjuddin66@yahoo.com>.

C pools exacerbated by predicted consequences of global climate change: ENSO-related droughts and subsequent fires, altered precipitation patterns, increasing frequency and severity of tropical cyclones and sea level rise (Ellison and Stoddart 1991, Li *et al.* 2007, Field *et al.* 2009).

Land conversion on peatlands results in immediate massive C fluxes to the atmosphere due to drainage, deforestation and burning followed by longer-term oxidative losses contingent on hydrological conditions (Hooijer *et al.* 2010, Murdiyarso *et al.* 2010, Hergoualc'h and Verchot 2011). Murdiyarso *et al.* (2010) estimated that 25% of all C emissions from converting peat forest to industrial plantation (a dominant land use transition of tropical peatlands in Indonesia; Miettinen *et al.* 2012) occur from initial burning to clear land. Each year, large areas of peatlands burn throughout Indonesia with fire recurring frequently in areas where peat is drained and degraded. During the unusually severe fire season of 1997, drought conditions prompted opportunistic and uncontrolled burning which eventually affected over 2 Mha of wetland ecosystems throughout Indonesia, resulting in C losses commensurate with the 1.5 Pg C average annual flux from global land use change from 1990 - 2005 (Taconni 2003, Page *et al.* 2002, Langmann and Heil 2004).

There are a very few study on the estimation carbon stocks in the peat soils of Bangladesh. Peat soils are the major store house of organic carbon where there is a scope to use this carbon and energy in mitigating climate change. In the developed countries, peat soils are used in various ways of climate change mitigation. In Bangladesh, exploration of this resource may provide valuable information regarding its usage by estimating the storage. On the other hand, possibly due to the decrease of inundation level in Bangladesh and consequent intensive agricultural usage (Brammer 2002), the peat soils are losing its carbon contents, and thus peat land ecosystems are degrading. So, exploring the carbon storage as well as its sustainable usage is very much important in the recent days. In this connection, an attempt has been undertaken to estimate carbon stock in the peat soils of Bangladesh under present situation of climate change.

Materials and Methods

Three soil profiles were selected covering the peat land soils of Bangladesh. There are a total of 9 profiles of peat in Bangladesh (Table 1). The selection of the soil profiles were done based on the sapric peat, hemic peat and fibric peat. Soil color study in the field recognized the nature of peat (Table 2). It may be noted that out of 9 profiles, 3 cover Sapric peat or (well decomposed peat with fibre content less than 15%) profiles representing 3 soil series: Hakaluki, Satgaon and Sarail etc. Similarly; Hemic peat or (half decomposed peat with fibre content 15 - 75%) profiles cover the 3 soil series: Rajoir, Satla and Mohonganj; and the fibric peat (immature peat with fibre content greater than 75%) or profiles cover the 3 soil series: Harta, Juri and Tarala etc.

Table 1. A list peat basin soils of Bangladesh along with their areas and USDA names.

Soil series	Areas (ha)	USDA names
Hakaluki	4,953	Fluvaquantic Haplosaprists
Sarail	595	Typic Haplosaprists
Satgaon	722	Fluventic Haplosaprists
Rajoir	18,412	Typic Haplohemists
Satla	48,505	Typic Haplohemists
Mohanganj	4,930	Hydric Haplohemists
Harta	44,273	Typic Haplofibrists
Juri	2,035	Hydric Haplofibrists
Tarala	604	Hydric Haplofibrists

Source: Rahman 2005, Hussain *et al.* 2003.

Table 2. Indicators used for differentiating peat maturity in the field.

Indicators	Fibric (immature) peat	Hemic (medium maturity) peat	Sapric (mature) peat
Decomposition stage	Peat at early decomposition stage, with its original materials still recognizable.	Half-decomposed peats, with some original materials are still recognizable.	Decomposed peat in which the original materials are no longer recognizable.
Colour	Brown-light brown	Brown	Dark-brown-black
When squeezed in the palm, the amount of fiber remained	More than two-thirds of the initial amount.	One-to-two-thirds of the initial amount.	Less than one-third of the initial amount.

Soil samples from a depth of 1 m of all three profiles were collected in thick polythene bags. The soil samples were air dried under shade. The samples were then gently ground with rolling wooden rod and also with a wooden hammer and passed through 0.5 mm sieve and mixed thoroughly. The samples were then preserved in plastic bags for C analysis.

Soil organic carbon was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and Sommers (1982). Bulk density was measured by core method as described by Blake and Hartge (1986). The total soil organic carbon (TSOC) stock or storage was calculated using the equations of Batjes (1996), Chen *et al.* (2007), Zhang *et al.* (2013). It may be noted that the bulk density and SOC concentration (%) are the two prerequisites for estimating SOC stock or storage. Thus, the SOC storage was calculated using the following equations (Batjes 1996, Chen *et al.* 2007, Zhang *et al.* 2013).

Total soil organic carbon (TSOC) = $SOC_i \times B_i \times D_i$

where, SOC_i is the SOC content on the i^{th} layer (g/kg);

B_i is the bulk density of the i^{th} layer (g/cc), and D_i is the depth of the i^{th} layer (cm).

Results and Discussion

Guidelines for estimating greenhouse gas (GHG's) emissions from agriculture, forestry, and other land uses are provided by the Intergovernmental Panel on Climate Change (IPCC). The IPCC guidance includes specific details for estimating C stocks of upland forest ecosystems; however, specific provisions for tropical wetland organic soils and peatlands are seriously lacking (IPCC 2006). The close relationship between C density and bulk density allows for a reasonably accurate estimation of peat C stocks for tropical organic soils.

Eswaran *et al.* (1995) estimated soil organic carbon contents in the soil orders at global level. From the above data sets, Hussain (2002) estimated that the soils of Bangladesh have a total of 2.2 Pg of organic carbon. The Histosols in Bangladesh occupy an area of slightly more than a million ha and it contains 0.25 Pg organic C (Table 3). Possibly, this is the base line data sets of organic carbon mass in the soils of Bangladesh. There is a serious lacking of SOC stock or storage data sets in Bangladesh even for peat soils. This quantity of organic carbon present in the Histosols may be significant as C sink. But at present, these peats are used for agriculture as well as fuel where C is released to the air after the decomposition of peat. In the tropics, most Histosols are still under forest, though most of them are cleared for agriculture and other purposes.

The mean bulk density distribution in the Hakaluki and Rajoir soil (ranges from 0.62-0.63g/cc) is more or less same where as in Harta soil (0.53 g/cc), it is lower than the other two soils (Table 4). Agus *et al.* (2011) noted that the range of peat soil bulk density is generally about 0.02 - 0.30 g/cc depending on the maturity, compaction as well as the ash contents. They also reported that on average bulk density for Southeast Asia peatlands indicates a broad range and considerable variation depending on its land uses. In Bangladesh, peatlands are mostly used for Boro rice, shrimp and vegetable where there is a little scope of soil carbon sink.

Table 3. Organic carbon mass in the soils of the world and of Bangladesh.

Soil orders	Area (10^3 km^2)			Organic C (Pg)*		
	Global	Tropical	Bangladesh	Global	Tropical	Bangladesh**
Entisols	14921	3256	14.2	148	19	0.14
Inceptisols	21580	4565	97.5	352	60	1.59
Ultisols	11330	9018	0.89	105	85	0.08
Histosols	**1745**	**286**	**1.2**	**357**	**100**	**0.25**
Alfisols	18283	6411	1.2	127	30	0.03
Misc. land	7644	1358	24.0	18	2	0.05
Total	-	-	147.0	-	-	2.20

*Pg = Petagram = 1×10^{15} (Source: Eswaran *et al.* 1995); Hussain 2002**

Table 4. Bulk density distribution (g/cc) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	0.88	0.91	0.90
20 - 40	0.65	0.85	0.90
40 - 60	0.60	0.65	0.52
60 - 80	0.28	0.40	0.50
80 - 100	0.28	0.30	0.35
Mean	0.53	0.62	0.63

Soil organic carbon (SOC) distribution in the Harta soils ranges from 10.09 to 21.53 per cent from surface to 100 cm depth and the mean organic carbon is 15.03 per cent (Table 5). Soil organic carbon distribution in the Hakaluki soils ranges from 6.63 to 15.01 per cent from surface to 100 cm depths and the mean organic carbon is 11.18 per cent. Soil organic carbon distribution in the Rajoir soils ranges from 12.10 to 28.20 per cent from surface to 100 depths and the mean organic carbon is 20.66 per cent. So, the soil organic carbon distribution in the peat soils of the study site ranges from 11.18 to 20.66 per cent (Table 5).

Agus *et al.* (2011) reported that peat soils contain 18 - 58% carbon. They also reported that in Southeast Asia, soil organic carbon in peat lands varies in a broad range and considerable variation depends on their local land uses, land covers and land conditions. In Bangladesh, peatlands are mostly used for agricultural purposes where there is a considerable loss of organic carbon rather than sink. On the other hand, there is no forest cover in the peatlands of Bangladesh as such diversified use of peatland is limited.

Table 5. Soil organic carbon distribution (%) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	10.09	6.63	12.10
20 - 40	11.24	8.83	12.59
40 - 60	12.21	10.54	24.20
60 - 80	20.12	14.91	26.21
80 - 100	21.53	15.01	28.20
Mean	15.03	11.18	20.66

Soil organic carbon storage in the Harta soils varies from 11.27 to 17.76 kg/m^2 and the total storage is about14.07 kg/m^2 up to 100 cm depth of the soil (Table 6). Harta soils are mainly dominated by the rice-shrimp integrated cultivation. Soil organic carbon storage in the Hakaluki soils varies from 9.00 to 15.01 kg/m^2 and the total storage is about 12.34 kg/m^2. Hakaluki soils are used for the cultivation of Boro rice and in the dry season these are used for grazing grass land. Soil organic carbon storage in the Rajoir soils varies from 19.75 to 26.21 kg/m^2 and the total storage is about 23.11 kg/m^2. Rajoir soils are used for the cultivation Boro rice and it remains waterlogged almost for the whole year. So, it was found that soil organic carbon storage in the study sites varies from 12.34 to 23.11 kg/m^2 (Table 6). The variation in the soil organic carbon storage possibly due to the land use, inundation level and land cover variations.

Table 6. Soil organic carbon storage (kg/m^2) at different soil depths across the peat soils.

Depths (cm)	Harta	Hakaluki	Rajoir
0 - 20	17.76	12.06	21.78
20 - 40	14.62	15.01	22.66
40 - 60	14.65	13.70	25.17
60 - 80	11.27	11.92	26.21
80 - 100	12.05	9.00	19.75
Mean SOC Kg/ m^2	14.07	12.34	23.11

Soil organic carbon stock across the peat soils of Bangladesh at 100 cm depths was estimated to be about 0.12 Pg (Table 7) which is very low in relation to other tropical countries. It was reported in 1970s that C stock across the peat soils of Bangladesh was about 0.25 Pg. The increasing demand for land resources has led to a high pressure for the use of peatlands for producing agricultural commodities. Thus, the conversion and draining of peat to create favorable conditions for aerobic crops, changed the role of peat land from C sink to C loss. Long-term drainage and conversion to farmland of peatlands has repeatedly caused major subsidence and carbon loss (Hutchinson 1980). On the other hand, peat fire for fuel purpose by the local stake holders in the dry season becomes more prevalent in some areas of Bangladesh which makes CO_2 emissions. Due to the long-term inundation, peat surface subsides; it loses its functions as the C storage and hydrological condition control which stores water during the rainy season and releases it gradually during the dry season. Thus, subsidence in the dry season is associated with peat compaction, and CO_2 emissions.

Table 7. Carbon stock (Pg) across the peat soils of Bangladesh at 100 cm depths.

Soil series	Areas (ha)	SOC stock (Pg)
Hakaluki	4,953	0.0031
Sarail	595	0.0003
Satgaon	722	0.0004
Rajoir	18,412	0.1202
Satla	48,505	0.0560
Mohanganj	4,930	0.0056
Harta	44,273	0.0315
Juri	2,035	0.0014
Tarala	604	0.0004
Total	1,25,029	0.1202

There are several factors that alter the function of peat land from a sink into a CO_2 source which are most common in Bangladesh.

1. Land clearing that increases the amount of sunlight onto the peat surface so that soil temperature and the activity of decomposing microorganisms increase. Water hyacinth and rice straw increases the availability of fresh organic matter that easily decomposes into CO_2 under aerobic, and CH_4 under anaerobic conditions.

2. Drainage that decreases the peat water table on the site and surrounding areas that are under agricultural crops/covers. Drainage changes the soil conditions from anaerobic to aerobic and increases CO_2 emissions.

3. Collection of peat in the dry season for fuel increases CO_2 emissions owing to burning or oxidation of one or a combination of plant biomass, and peat layers. Fires often occur during land-use change from forest to agriculture or other land uses in the tropical countries. Fires also occur during long drought periods. Under traditional farming practices, burning are done to reduce soil acidity and improving soil fertility. But, on the other hand, this practice increases the contribution of peat to CO_2 emissions.

4. The addition of fertilizers such as nitrogen fertilizers lowers the C/N ratio of soil and encourages the decomposition of organic matter by microorganisms, followed by the release of CO_2. Nitrogen fertilizer also contributes to N_2O emission. Fertilizing with manure or the addition of ameliorants that increase the pH of peat may also accelerate peat decomposition.

These soils can be improved by allowing sediments from the adjoining tidal rivers to settle on the peat basins. This sedimentation process should be continued for several years to develop the land for agricultural purposes. Peatland is an important carbon and water storage and the loss of these functions due to drainage has become a national and global concern. However, the activity of peat fire, loss of water table depth as well as carbon emission is hot issue now-a-days under recent situation of climate change. These strongly suggest research on this aspect. Technical, incentives and regulatory measures must be enhanced to make the best benefits of the use of peatland. Furthermore, exploration of economically competitive crops under un-drained system should also be prioritized.

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MECHANISM OF THE ABSORPTION OF CO_2 IN IONIC LIQUID DIMER

KALYAN DHAR[1*]

Dept. di Chimica Materiali e Ingegneria chimica "G. Natta", Politecnico di Milano, via Mancinelli 7, 20131 Milano, Italy

Abstract

The density functional theory (DFT) calculations with the modern continuum solvation model (IEFPCM-SMD) was used to study the mechanism of CO_2 absorption at room temperature using ionic liquid such as, [EMIM][BF_4] (1-ethyl-3-methylimidazolium tetrafluoroborate) monomer and dimer ionic liquid [IL] dimer comprises two couple of anions and cations, so that more intermolecular interactions are established than in the single IL pair. In this paper, we determined the minimum energy structures and to determine the possible binding sites for CO_2 absorption in [EMIM][BF_4] monmer and dimer; by comparing the relative minimum energy of [EMIM][BF_4] in the presence and in absence of CO_2. It was found that CO_2 is stabilized by the multiple interactions with several anions. When CO_2 penetrates the IL monomer or dimer, through gas-to-liquid diffusion, the O-C-O (CO_2)-BF_4 intermolecular bond is likely to be formed immediately and bind the CO_2 molecule. This result suggests that ionic liquid dimer is suitable for the absorption of CO_2.

Key words: Density functional calculations, Absorption of CO_2, Anionic effect, [EMIM][BF_4], CO_2.

Introduction

Currently, because of environmental concerns, there is much interest in the development of technologies that may be able to efficiently remove CO_2 from exhaust gases and thus avoid its dispersion in the atmosphere. Ionic liquids (IL) are generally liquid salts with a very low melting point, often lower than room temperature. There are many properties that make IL interesting as process electrolytes. For instance they have very small vapor pressure, good solvents for many substances, not flammable or toxic, have high thermal stability. The low melting point is favored by the use of bulky, barely symmetric and (often) charge delocalized cations or polarizable and charge delocalized anions, which determine what is known as packing frustration (Dhar and Fahim 2016). Ionic liquids are strongly characterized by ionic pairs. The properties can be modified by changing cations and anions. Moreover, modulation of physico-chemical properties (e.g. hydrophobicity) can be obtained by suitable combination of anions and cations. The systems investigated

[*]Author for correspondence: <kalyankumar.dhar@polimi.it>. [1]Present address: University of Liberal Arts, Bangladesh.

described in the results and discussion sections, is the ensemble of minimum energy structures accessible to CO_2 when absorbed in the [EMIM][BF_4] ionic liquid monomer, dimer, and the analysis of the main reaction channels possible for CO_2 absorption (Dhar and Cavallotti 2014).

The density functional study (DFT) of the IL structure and the understanding of the reaction mechanism of the absorption process is one of the possible approaches that can be used to improve this technology (Dhar 2014). This approach was followed in this work. The adopted computational approach consisted of DFT simulations performed using an implicit solvation model. The two systems investigated described in the results and discussion sections, are the ensemble of minimum energy structures accessible to CO_2 when absorbed in the [EMIM][BF_4] monomer and dimer and the analysis of the main reaction channels possible for CO_2 binding site when absorbed on a RTIL both in water and in presence of a [EMIM][BF_4]. The choice of the [EMIM][BF_4] IL for the simulations was determined by the fact that CO_2 absorption is possible. Noteworthy [EMIM][BF_4] ionic liquid can be obtained at a low cost compared to other ionic liquids. The solubility and diffusibility of CO_2 in IL were investigated in this work.

Materials and Methods

To study the adsorption of CO_2 in ionic liquid, simulations were performed by studying the [EMIM][BF_4] monomer and dimer in presence and in absence of CO_2. Simulations were performed both in vacuum and in solution, which was modeled using the Polarized Continuum Model (PCM). Minimum energy structures, interaction energies, binding energies and clustering energies of complexes, reactants, products were determined using density functional calculations (DFT) (Pople *et al.* 1992). Quantum mechanical calculations were performed using the B3LYP hybrid functional (Raghavachari 2000). All simulations were performed with the Gaussian 09 quantum chemistry software suite program using the minimum energy cluster structures. Simulations were performed in water, modeling the solvent with the implicit PCM model. SMD model is based on the quantum mechanical charge density of a solute molecule interacting with a continuum description of the solvent. The model is called SMD, where the "D" stands for "density" to denote that the full solute electron density is used without defining partial atomic charges. "Continuum" denotes that the solvent is not represented explicitly but rather as a dielectric medium with surface tension at the solute-solvent boundary. The SMD model was used to calculate the cavitation and non-polar contributions to the energy. The stability of all minimum energy structures were checked through frequency calculations.

All the graphical sketches inserted in this paper were produced using the Molden 4.4 visualization program (Schaftenaar and Noordik 2000).

Results and Discussion

Absorption of CO_2 in dimer: Firstly the computed energy structures of dimers [EMIM][BF_4] IL and secondly the absorption of CO_2 in dimer [EMIM][BF_4]$_2$ have been described. By dimer, we refer to system including two ionic pairs.

Absorption of CO_2 in 2[EMIM]$^+$2[BF_4^-]$^-$dimer: An analysis of the structures of [EMIM][BF_4] IL dimer is reported and the relationship of such structures with CO_2-[EMIM][BF_4] monomer is discussed. Simulations were performed both in vacuum and using the implicit polarized solvation model. Ionic liquids structures are optimized by ab initio calculations at B3LYP/6-31+G(d,p) level. (Figs 1 to 3). The same level of theory is then used to study the absorption of CO_2. Their x, y, z coordinates are given in the supporting information. Energies not corrected for BSSE and ZPE. The SCF energies, vibrational frequency, and lastly interaction energies of the [EMIM][BF_4] and [EMIM][BF_4]-CO_2 system have been collected in Tables 1 to 3. IL dimer comprise two couples of anions and cations, so that more intermolecular interactions are established than in the single IL pair. It was observed that the formation of H bonds between oxygen and hydrogen atoms could stabilize the structure of the complex. Similarly it was also found that CO_2 is stabilized by the formation of multiple interactions with several anions. When CO_2 penetrates the IL monomer or dimer, through gas-to liquid diffusion, the O-C-O (CO_2)-BF_4 intermolecular bond will be formed immediately and bind the CO_2 molecule. The energy of interaction between two ion pairs in solution was established for the gas phase and in solution and is presented in Table 1. It can be observed the clustering energies are small, thus indicating that the mutual interaction between dimer and the interaction with water are comparable.

Table 1. Ionic liquid monomer, dimers and their corresponding clustering energies calculated at the B3LYP level in gas and liquid phase at 6-31+g(d,p) basis set.[a]

IL([EMIM]+[BF4]$^-$	Gas phase energies	Liquid phase energies
1EMIM1BF_4 (monomer)	–769.27	–769.31
2EMIM2BF_4 (dimer)	–1538.57	–1538.62
Clustering energies	–1.08 kcal/mol	0 kcal/mol

[a]Energies not corrected for BSSE and ZPE and reported in kcal/mol. Geometry and energy optimized at the same level of theory. Relative energies are reported in kcal/mol (1 Hartree/particle = 627.5 kcal/mol).

However, for the sake of simplicity, the liquid phase computed minimum energy structure of the monomer with CO_2 is introduced in order to facilitate the interpretation of the peculiarities of the dimer structure. For this purpose the structures of the ionic pair and monomer with and without CO_2 are shown in Figs 1-3. Their corresponding x, y, z coordinates are reported. It is worth to point out that the ion pair dimer is a better model to study CO_2 absorption than the single ion pair. It is also affordable in terms of computational cost. The absorption energy of CO_2 calculated using the IL monomer and pair model is reported in Table 3. It can be observed that the bonding energy of CO_2 in [EMIM][BF_4] monomer is –2.05 kcal/mol, whereas the ion pair dimers bonding energy is –2.80 kcal/mol. In Fig.1 (ion pair monomer) and Fig. 2 (the ion pair dimer) are reported. The structures monomer -CO_2 and Dimers -CO_2 (Complex 2), are reported in Figs 3-4 respectively. It can be seen that the two imidazolium rings have parallel positions in the case of the dimer CO_2-[EMIM][BF_4] system.

The common characteristic feature of this conformer is that each anion shares the H5 side of one cation and the H4 side of the other cation. The two ion pair is thus a good model to absorb CO_2 in this system. The alkyl group of the ionic liquid is sufficient to obtain larger surface area and bigger specific molar volume (V_M). Generally free volume (V_f) of a molecule has a linear correlation with V_M. The larger volume of this IL complex results higher solubility of CO_2 than smaller ones**.** This is another critical pathway to increase the solubility of CO_2 in [EMIM][BF_4] ionic liquid. Minimum energy structures of monomer ion pair and dimer ion pair are reported in Figs 1 and 2, respectively.

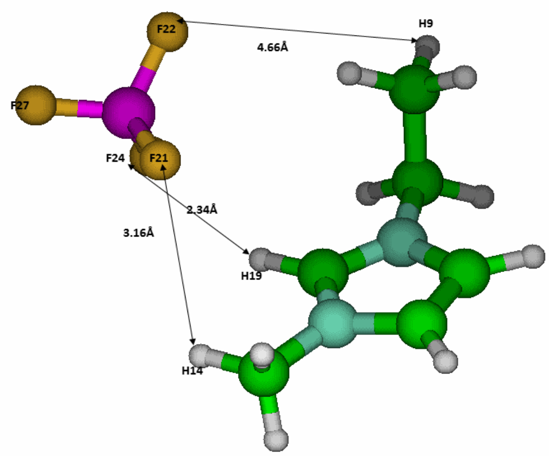

Fig. 1. Optimized ion pair monomer minimum energy structure in liquid phase.

Some key distances are reported in Fig.1. H(19)-F(24) distance is 2.34 Å. All distances. Corresponding vibrational analysis is carried out to ensure the absence of negative frequencies and verify the existence of a true minimum.

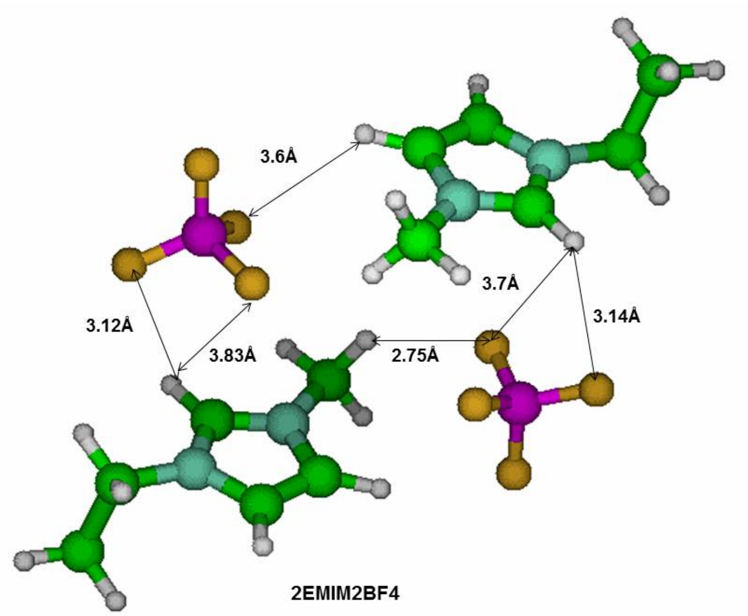

Fig. 2. Optimized ion pair dimers in liquid phase.

The structure of [EMIM][BF_4]-CO_2 dimer in liquid phase is reported in Fig. 4. Structures are stable and fully optimized. Monomer CO_2 system are less stable in comparison to the liquid phase energy than dimer by 2.05 and 2.81 kcal mol^{-1}. In the system of CO_2-monomer, the BF_4 anion is located on the methyl side and the ethyl side at the back of the imidazolium ring, respectively. However, it is interesting to mention that oxygen atom of CO_2 is almost coplanar with the imidazolium ring. C-F distances between the C atom of CO_2 and the nearest F atom. The corresponding C-H distances between the C atom of CO_2 and the nearest H is shown in Fig. 3 i.e. atom (C (25) –H (24)) distance is 4.05Å.

Complex 2 (Fig. 4) indicates the possible binding site of the CO_2 molecule. It is also reported that the EMIM ring is parallel and the anionic interaction between CO_2 molecules is always higher than the cation. Dimer-CO_2 and the optimized distances between F (14) - C (CO_2) at 3.05 Å and the F (11) - C (CO_2) at 2.95 Å are reported in the figure. Minimum energy structure is the most stable, where CO_2 is located near the methyl group in [EMIM][BF_4] IL.

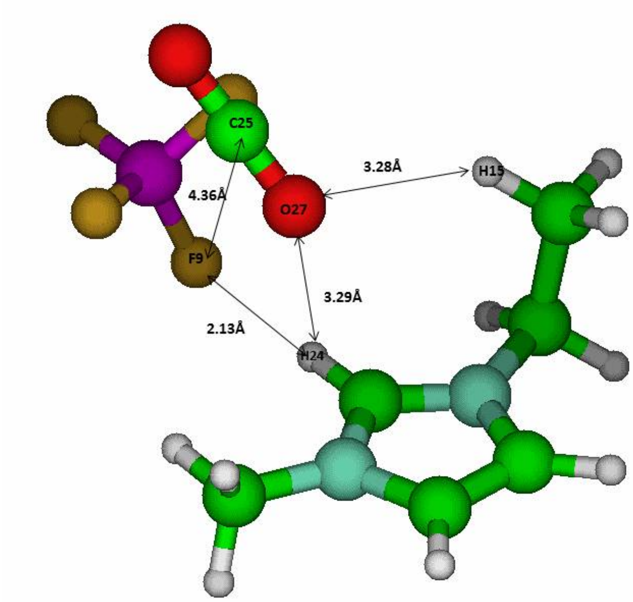

Fig. 3. Complex-1 (monomer) and the possible binding site of the CO_2 molecules. Optimized ion pair monomer with CO_2 in liquid phase.

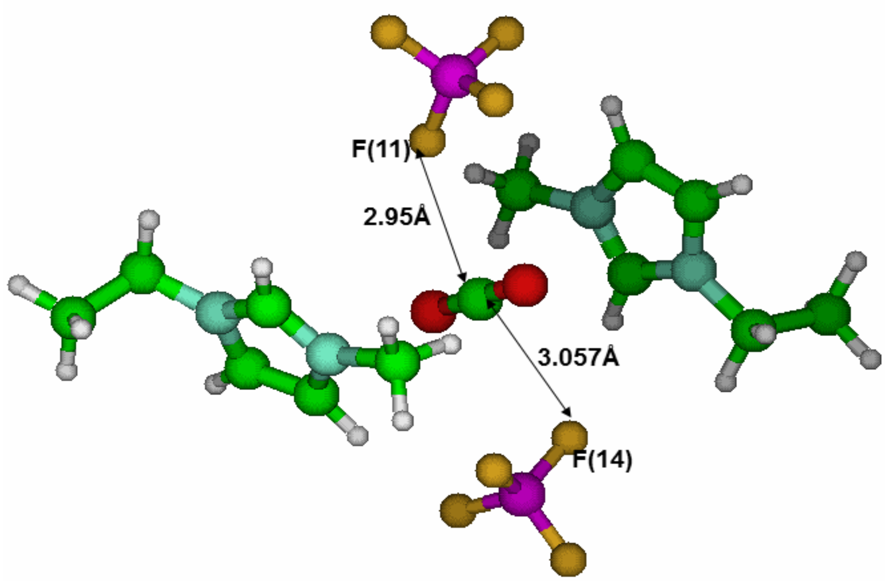

Fig. 4. Complex-2 optimized ion pair dimers with CO_2 in liquid phase.

Table 2. Optimized structures and some key distances.

CO_2 IN EMIM BF_4	C-H distance (Å)	C-F distance(Å)	O-H distance(Å)
Ion pair EMIMBF4		2.34	
Conformer1 (Monomer)	4.05	3.02	3.18
Ion pair dimer	--	2.75	--
Conformer (Dimer)	4.09	2.95	3.29

It is worth to point out that (Table 3) the binding energy in gas phase vary from –3.45 kcal/mol (monomer) to –1.81 kcal/mol (dimer). This is also a new insight for the CO_2 absorption process in [EMIM][BF_4].

Table 3. CO_2 in Ionic liquid and their corresponding interaction energies calculated at the B3LYP/6-31+G(d,P) level using the IEF-PCM model for implicit solvent simulations.

CO_2 in IL([EMIM] + $[BF4]^-$	Gas phase	Liquid phase
	Binding energies (kcal/mol)	Binding energies (kcal/mol)
Monomer	–3.45	–2.05
Dimer	–1.81	–2.80

The CO_2 absorption process is better to carry out in liquid phase with di-electric constant 12. Simulations are used to analyze the structural behavior of CO_2+ ionic liquids systems as a function of composition. The results show the different structuring of CO_2 around cation and anion, the anionic effect is explained considering the larger expansion upon CO_2 absorption for $[BF_4]^-$ containing systems.

The author performed theoretical calculation of the [EMIM][BF_4] ionic liquid structure and of the CO_2 absorption process. Minimum energy structures, interactions energy, clustering energies and binding energy of the IL were calculated. CO_2 minimum energy structure in [EMIM][BF_4] IL and [EMIM]$[BF_4]_2$ IL systems is estimated. As it can be observed that the clustering energies are small, thus indicating the mutual interaction between dimer and the interaction with water are comparable. It is found that monomer CO_2 system are less stable in comparison with the ionic liquid phase energy than dimer. Moreover the bigger volume of this IL complex dimer result higher solubility of CO_2 than smaller ones. The result shows that the structure of ionic liquid monomer and ion pair dimer are absorbing CO_2 due to structure sensitivity of anion.

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PESTICIDE RESIDUE ANALYSIS IN POND AND CANAL WATER SAMPLES FROM THE COASTAL REGION OF BANGLADESH

M.A. UDDIN*, M.H. RASHID, N.U.A. CHOWDHURY [1], M. NESHA, M.A.Z. CHOUDHURY AND M.A. RAHMAN

Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Ganakbari, Savar, G.P.O Box-3787, Dhaka-1000, Bangladesh

[1]Department of Biochemistry and Molecular Biology, Tejgaon College, Dhaka, Bangladesh

The concentrations of pesticides were determined using high performance liquid chromatography (HPLC) of 15 pond water and 10 canal water samples around the paddy or vegetable fields from Sadar Upazila, Lakshmipur (Coastal area). The analysis showed that some water samples were contaminated with organophosphorus and carbamate pesticides. The residue level of diazinon ranged from 0.315 to 0.441 μg/l whereas the carbaryl ranged from 0.136 to 0.204 μg/l. The level of carbofuran was found in the range of 0.373 to 2.208 μg/l, which were above the maximum acceptable levels of total and individual pesticide contamination.

Bangladesh is predominantly an agricultural country with an area of 1,47,570 km^2 (Hossain *et al*. 2015). Paddy production in Bangladesh has developed from a main occupational activity carried out by the farmer. One of the biggest problems confronting paddy farmers in Bangladesh is diseases and pests which ravage their crops. Paddy generally attracts a wide range of pests and diseases and requires intensive pest management (Dinham 2003). The pest control practices in paddy production in Bangladesh involve mainly the applications of highly toxic pesticides. Pesticides have contributed significantly to improve yields of crops, increasing the production of food grains. So, the use of pesticide is now an inherent part of agriculture for pest control (Bagchi *et al.* 2008). But the practice of indiscriminate use of insecticides leads to build up of pesticide residues in the product, destruction of beneficial insects, pest resurgence, pesticide exposure to farm workers that cause various types of cancer and environmental pollution (Rashid *et al.* 2015). The World Health Organization (WHO 2001) estimated that there are 3 million cases of pesticide poisoning each year and up to 2,20,000 deaths, primarily in developing countries. Hence, water should be free from pesticides, as presumably all populations worldwide are exposed to pesticides (Fardous *et al.* 2015). The aim of this study was to investigate the levels of pesticides in different pond and canal water samples in Sadar Upazila, Lakshmipur district, Bangladesh as well as to

*Author for correspondence: <aminifrb@yahoo.com>.

compare the results of this study with WHO’s guideline values. This study also suggests some recommendations to protect pesticide contamination in pond and canal water near paddy and vegetable fields.

Twenty five water samples (15 pond water and 10 canal water samples) were collected from Sadar Upazila of Lakshmipur district near the coastal area (Fig. 1). After collecting the samples, they were preserved in a deep fridge (−20ºC) for avoiding loss of the pesticide residues. Water samples (500 ml) were placed in a separating funnel. Fifty gm of NaCl was added to each funnel and shaken with 150 ml of mixed solvent (Hexane: dichloromethane = 1 : 1) for 10 minutes and allowed to settle for 15 minutes. The upper organic layer was collected and the lower aqueous layer was washed two times with 75 ml of the solvent mixture at each wash. Ten gm of anhydrous Na_2SO_4 was added to the three combined organic layers, it was allowed to settle and the decanted organic solvent was then evaporated by rotary vacuum evaporator to dryness. Finally, 1 ml acetonitrile was added prior to the volume of dried extract to inject into HPLC. The spike recoveries

Fig. 1. Map of Sadar Upazila from where samples were taken collected place.

were observed in the range of 76 - 99% for pesticides. Injections of the aliquots were done by micro syringe into HPLC. Tentative identification of the suspected pesticides was carried out in relation to the retention time (RT) of the pure analytical standards. Quantification was made with a freshly prepared standard curve of the relevant (standard) pesticide. Analysis was done by HPLC fitted with Photo Diode Array (PDA) detector.

The results indicated that contamination of water with organophosphate and carbamate pesticides have been found in both pond and canal water (Tables 1 and 2). The carbofuran contaminated pond water samples were from the mosque pond of Lakshmipur Sadar market (WSP2 : 1.792 µg/l), Monir Uddin Pathwarybari pond (WSP3: 0.905 µg/l), Miahbari pond (WSP9: 2.082 µg/l), Torabgonj Borobari pond (WSP13 : 2.208 µg/l), Torabgonj bazaar pond (WSP14 : 0.994 µg/l) and canal water samples were from WAPDA canal west point (WSC2 : 0.373 µg/l) and Rahmat Khali canal near Meghna river (WSC6 : 1.267 µg/l). Carbaryl was identified in two water samples, the highest concentration was from Torabgonj Borobari pond (WSP13: 0.204 µg/l) and the

Table 1. Amount of carbamate and organophosphorous residues in pond water samples of Sadar Upazila, Lakshmipur.

Sample No.	Carbamate pesticide residues (µg/l)		Organophosphorus pesticide residues (µg/l)	
	Carbofuran	Carbaryl	Diazinon	Malathion
WSP1	BDL	BDL	BDL	BDL
WSP2	1.792	"	"	"
WSP3	0.905	"	0.361	"
WSP4	BDL	"	BDL	"
WSP5	"	"	"	"
WSP6	"	"	"	"
WSP7	"	"	"	"
WSP8	"	"	"	"
WSP9	2.082	"	0.431	"
WSP10	2.082	"	BDL	"
WSP11	BDL	"	"	"
WSP12	"	"	"	"
WSP13	2.208	0.204	0.441	"
WSP14	0.994	BDL	BDL	"
WSP15	BDL	"	"	"

WSP = Water sample of pond, BDL = Below detection limit.

lowest concentration was from WAPDA canal near Lakshmipur bus terminal (WSC5: 0.136 µg/l). Field studies have indicated a half-life of 26 to 110 days in soil. Carbamate pesticides are degraded in water by hydrolysis, microbial decomposition, and photolysis (WHO 2003 and Thapar *et al.* 1995). Among the organophosphate pesticides, diazinon and malathion were analyzed. Malathion was not detected in any of the water samples during the present investigation. The diazinon contaminated pond water samples were Monir Uddin Pathwarybari pond (WSP3 : 0.361 µg/l), Miahbari pond (WSP9: 0.431

μg/l), Torabgonj Borobari pond (WSP13 : 0.441 μg/l) and canal water samples were WAPDA canal north point (WSC4 : 0.315 μg/l).

Table 2. Amount of carbamate and organophosphorous residues in canal water samples of Sadar Upazila, Lakshmipur.

Sample No.	Carbamate pesticide residues (μg/l)		Organophosphorus pesticide residues (μg/l)	
	Carbofuran	Carbaryl	Diazinon	Malathion
WSC1	BDL	BDL	BDL	"
WSC2	0.373	"	"	"
WSC3	BDL	"	"	"
WSC4	"	"	0.315	"
WSC5	"	0.136	BDL	"
WSC6	1.267	BDL	"	"
WSC7	BDL	"	"	"
WSC8	"	"	"	"
WSC9	"	"	"	"
WSC10	"	"	"	"

WSC = Water sample of canal, BDL = Below detection limit.

The organophosphate pesticides have limited persistence and degrade fairly rapidly in soil (Shahgholi and Ahangar 2014). The results suggested that the frequent high concentrations (over guideline values) of pesticide residues detected in some selected pond water and canal water are probably due to the extensive utilization of pesticides in nearby paddy fields. Constant drainage of paddy fields and limited knowledge of appropriate ways of administrating pesticides are the main influencing factors to transport pesticides into the pond and canal water phase. This contamination poses a threat to human health as they use it for drinking purpose.

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