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SCREENING OUT OF WHEAT VARIETIES AGAINST ARSENIC CONTAMINATED SOIL AND IRRIGATION WATER

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Abstract

Field trials on wheat were conducted at severely arsenic contaminated areas of Jessore (Chowgacha and Sharsha), Faridpur (Poranpur) and also at low contaminated Shatkhira (Benerpota) during 2010-2011 and 2011-12. The major objective of the study was to screening out of arsenic tolerant wheat varieties. Five varieties of wheat viz. Shatabdi, Bijoy, Prodip, BARI Gom-25 and BARI Gom-26 were tested. Total arsenic contents in the soils were 36.4, 32.8, 28.5 and 6.8 mg kg^{-1} for Sharsha, Chowgacha, Poranpur and Benerpota, respectively. Irrigation waters contained 0.346, 0.272, 0.238 and 0.140 mg L^{-1} arsenic for Sharsha, Chowgacha, Poranpur and Benerpota, respectively. No significant variations in yield and yield components among the tested wheat varieties was observed despite of arsenic contaminations in the irrigation water and soil. The variety, Prodip contains 0.043 and 0.028 mg kg^{-1} arsenic in straw and grain, respectively, which was lower than the other tested varieties. But arsenic contents in all of the tested wheat varieties were found much lower than that of the permissible limit (1 mg kg^{-1}). The transfer coefficient (TC) of arsenic from soil to above ground parts (straw + grain) of wheat varied slightly among the tested varieties where Prodip showed the lowest TC (0.0015-0.0018). However, BARI Gom-24 (Prodip) performed better in terms of arsenic content, uptake, biomass, yield and transfer coefficient and thus can be regarded as arsenic tolerant to a considerable extent.

Key words: Arsenic contamination, Wheat, Tolerant variety, Yield, Permissible limit

Introduction

Bangladesh agricultural sector is facing a big challenge to cope with the potential impact of arsenic (As) contamination in soil and water and its probable entry into the food chain. The average background concentration of arsenic in soils of Bangladesh is < 10 mg kg^{-1} but in some areas where soils receive As contaminated ground water irrigation, the As concentration recorded to be as high as 80 mg kg^{-1}. Sandy sediments contained 3-7 mg kg^{-1} (median: 5 mg kg^{-1}), clayey sediments contained 4-18 mg kg^{-1} (median: 9 mg kg^{-1}), whereas peaty and peaty clay sediments contained 20-111 mg kg^{-1} As (Yamazaki *et al.* 2003). Arsenic concentrations in irrigation water samples were many folds higher than

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FAO permissible limit for irrigation water (0.10 mg L^{-1}). But 24% of the total irrigated boro rice in Bangladesh is grown in areas where ground water As is > 0.05 mg L^{-1}(Karim 2001). High ground water As (0.10 -0.20 mg L^{-1}; > 0.20 mg L^{-1}) was found in the central part of the country near the Padma and Meghna rivers. Use of arsenic contaminated irrigation water leads to soil contamination with high levels of arsenic. Crops receiving arsenic-contaminated irrigation-water take up this toxic element and accumulate it in different degrees depending on the species and variety. Soil As build up during boro season over the years may reduce the yield and increase the As uptake by grain and straw of rice (Van Green *et al*. 2006). Previous studies demonstrated a significant amount of arsenic uptake by rice (Duxbury *et al*. 2003 and Wang *et al.* 2006) and edible parts of vegetable crops (Alam *et al*. 2003). Williams *et al.* (2006) conducted extensive sampling of rice throughout Bangladesh collecting 330 samples of Aman rice and Boro rice and observed a positive correlation between As in the groundwater and As in the rice. This correlation was stronger for Boro rice than that of Aman rice. Arsenic concentrations in agricultural plants varied from 0.007 to about 7.50 mg kg^{-1} (Liao *et al.*, 2005 and Dahal *et al*. 2008). Das *et al.* (2004) reported As contamination in vegetables collected from contaminated areas of Bangladesh. Farid *et al*. (2003) found higher amount of As (0.57 mg kg^{-1}) in amranth. Presence of arsenic in plants and plant products usually does not exceed 1 mg As kg^{-1} (Kiss *et al.* 1992). Wheat the second most cereal crop in Bangladesh is also cultivated in badly arsenic contaminated regions like Jessore and Faridpur. There is a general perception that upland crop like wheat may contain low amount of arsenic than that of rice. Physiological activities of wheat seedlings changed under As stress (Li *et al*. 2007). Seed germination, biomass, root length and shoot height decreased, and As accumulation increased on early seedlings of six wheat varieties as concentration increased (Liu and Zhang 2007). Arsenic concentration in wheat grain varied from (0.013 -0.086 mg kg-1) when soil contained 11-29 mg kg^{-1} As in Europe (Zhao *et al.* 2010). The content and uptake of arsenic in wheat thus need to be thoroughly investigated. Again screening out of tolerant wheat varieties needs to be done for better adaptation in the affected areas. But such studies on wheat are very scanty. It is therefore felt necessary to know the arsenic concentration in and uptake by wheat and to screening out of arsenic tolerant varieties.

Materials and Methods

A screening study was conducted to observe the performance of wheat varieties grown in arsenic contaminated soil and with contaminated irrigation water. In case of first year (2010-2011), the study was conducted in Poranpur (Faridpur) and Benerpota (Satkhira) which represented AEZ 12 and 13, respectively. The initial level of total As in soil was 28.6 mg kg^{-1} at Poranpur while 6.8 mg kg^{-1} at Benerpota. The tested varieties were Shatabdi (V_1), Bijoy (V_2), Prodip (V_3) and BARI Ghom-26 (V_4). However, incase of second year (2011-2012), the study was conducted in highly contaminated area at Chowgacha and Sharsha of Jessore under AEZ 11 and also at Poranpur of Faridpur

including one more variety (BARI Gom-25). The background level of total As in soil was 32.8, 36.4 and 28.5 mg kg^{-1} for Poranpur, Chowgacha and Sharsha, respectively (Table 1). Arsenic contents in irrigation waters were 0.272, 0.346, 0.238 and 0.140 mg L^{-1} for

Table 1. Nutrient status and arsenic (As) contents in irrigation water and soils at the experimental sites.

Item	Location				Critical level
Soil properties	Poranpur	Benerpota	Chowgacha	Sharsha	
pH	7.6	7.8	7.2	7.3	-
Organic matter (g kg^{-1})	15.4	11.1	13.2	16.0	-
Total-N (%)	0.06	0.05	0.08	0.09	0.12
Exchangeable Ca (cmol kg^{-1})	11.6	10.4	13.8	12.1	2.0
Exchangeable Mg (cmol kg^{-1})	3.8	2.7	2.9	3.3	0.8
Exchangeable K (cmol kg^{-1})	0.21	0.26	0.18	0.14	0.12
Available P (mg kg^{-1})	13.0	15.6	15.2	11.5	10
Available S (mg kg^{-1})	16.2	19.2	18.4	13.5	10
Available Zn (mg kg^{-1})	0.52	0.32	0.36	0.64	0.60
Available Fe (mg kg^{-1})	42.5	39.2	33.6	38.1	4.0
Available Mn (mg kg^{-1})	6.1	4.8	4.3	5.4	1.0
Available B (mg kg^{-1})	0.32	0.35	0.22	0.26	0.2
Total As content in soil (mg kg^{-1})	28.5	6.8	36.4	32.8	20.0
As content in irrigation water (mg L^{-1})	0.272	0.140	0.346	0.238	0.100

Poranpur, Chowgacha, Sharsha and Benerpota, respectively. The crop was fertilized with $N_{120}P_{30}K_{90}S_{15}Zn_2B_1$ kg ha^{-1} (BARC 2005). Two-third of nitrogen and all of phosphorus, potassium, sulphur, zinc and boron were applied as basal during final land preparation. The remaining one-third of nitrogen was applied at 21 days after sowing (DAS) then a light irrigation was applied. Crop was further irrigated at maximum tillering stage (50 DAS) and also at initial grain filling stage (72 DAS). The crop was harvested at its right stage of maturity. Data on yield and yield components were recorded accordingly.

Soil analysis: The collected samples were analyzed for total As content (Alam *et al*., 2001). The As content in soil and plant parts was determined after digestion with concentrated nitric acid and hydrogen peroxide mixture (2:1). An amount of 0.5 g sample was taken in digestion tube. Then 5 ml of 12 M HNO_3 was added in the tube and mixed with a watch glass or vapour recovery device and allowed to stand for over night. The sample was heated without boiling at $95^0 \pm 5^0$ C for 10-15 hour and was allowed to cool and again 5 ml of 12 M HNO_3 was added, the cover was replaced, and sample was heated at $95^0 \pm 5^0$ C for 30 minutes. This step (addition of 5ml of conc. HNO_3) was repeated until no brown fumes were given off by the sample. After completion of digestion with HNO_3, the sample was allowed to cool. Then 2 ml of water and 3 ml of 30% H_2O_2 were added, and the vessel was covered with a watch glass and returned to the heat source for warming and to start to peroxide reaction. Heating was continued until the effervescence subsides and then the vessel allowed cooling. Then 1 ml of 30% H_2O_2 was added in aliquots with warming until the effervescence was normal or until the general sample

appearance was unchanged. After cooling, the digest was removed by filtration and allowed to settle. After that, the sample was transferred in to 100 ml volumetric flask and volume was made up to the mark with distilled water. For the reduction of As^{V} to As^{III}, 1 ml mixture (5% w/v) of KI and ascorbic acid was added to 1 ml of aliquot. The hydride of arsenic (AS_3H_3) was generated using sodium borohydrate and HCl. The total arsenic content in soil and plant was determined by flow injection hydride generation atomic absorption spectroscopy (FI-HG-AAS), using a Varian Model AA 55B instrument. The same procedure (without digestion) was followed for the analysis of water samples.

Plant analysis: A sub-sample weighing 0.5 g. was transferred into a dry clean digestion vessel. Five ml of HNO_3 was added and then the sample was allowed to stand for over night in a fume hood. In the following day, the vessels were placed on heating block and heating was continued for 2-4 hour as the temperature was slowly raised to 120^0 C. When brown fumes were observed, this step (by adding concentrated HNO_3) was repeated until no brown fumes were given off. There after the vessel was allowed to cool and 3 ml of 30% H_2O_2 was added. Again, the vessel was heated at 120^0C until the effervescence was minimal. After cooling, the digest was removed by filtration, by centrifugation, or by allowing the sample to settle.

Statistical analysis: The collected data were analyzed statistically following MSTAT-C program.

Results and Discussion

Yield and yield components: There was no significant variation in yield and yield components among the tested wheat varieties despite of arsenic contamination in the irrigation water and soil (Tables 2-6). In case of first year (2010-11), the experiment was conducted in Benerpota, Satkhira (AEZ 13) and Poranpur, Faridpur (AEZ 12). But arsenic content in soil (6.8 mg kg^{-1}) at Benerpota was much lower than the thresh hold level (20 mg kg^{-1}) (Duxbury and Zavala 2005) while STW irrigation water (0.14 mg L^{-1}) contains slightly higher arsenic than recommended safe level (0.10 mg L^{-1}). After completion of the first year trial, the location Benerpota was dropped for the second year trial because of the low arsenic content in soil. However, in case of second year (2011-12), the trail was conducted in highly arsenic contaminated areas like Sharsha and Chowgacha under Jessore (AEZ 11) in addition to Poranpur of Faridpur.

At Benerpota, Shatkhira during 2010-2011 the grain yield of the tested wheat varieties varied from 3.23 to 3.54 t ha^{-1} but this variation was statistically non-significant (Table 2). Nevertheless, numerically the highest grain yield (3.54 t ha^{-1}) was recorded from the variety, BARI Gom-21 (Shatabdi), which was followed by BARI Gom-24 (Prodip). Shatabi produced 4, 5 and 9% higher grain yield than Prodip, Bijoy and BARI Gom-26, respectively. Almost similar trend of result was observed in case of straw yield where yield varied from 3.05 to 3.48 t ha^{-1}.

Table 2. Performance of wheat varieties to arsenic contaminated soil and irrigation water at Benerpota, Satkhira during 2010-11.

Varieties	Plant height (cm)	Spike m^{-2}	Grains $spike^{-1}$ (no)	1000 grains weight (g)	Yield (t ha^{-1})	
					Grain	Straw
BARI Gom-21 (Shatabdi)	89.2	319	39.3	47.1	3.54	3.33
BARI Gom-23 (Bijoy)	88.7	310	40.0	47.3	3.36	3.11
BARI Gom-24 (Prodip)	89.5	311	41.8	48.2	3.41	3.48
BARI Gom-26	87.6	305	38.8	47.0	3.23	3.05
Level of significance	NS	NS	NS	NS	NS	NS
CV(%)	2.5	3.1	6.5	2.5	11.4	8.2

NS = Non significant

In case of Poranpur, Faridpur the highest grain yield (3.62 t ha^{-1}) was obtained from BARI Gom-24 (Prodip), which was followed by followed by BARI Gom-23 (Bijoy). The lowest grain yield (3.14 t ha^{-1}) was observed in BARI Gom- 26, which was almost similar to BARI Gom-21 (Shatabdi). Thus the variety, Prodip gave 4, 10 and 15% higher grain yield than Bijoy, Shatabdi and BARI Gom-26, respectively but such variation was statistically non-significant (Table 3). For the second year (2011-12) too, none of the tested five varieties gave significantly higher yield. Besides, numerically higher grain yield (3.41 t ha^{-1}) was obtained from BARI Gom-21 (Shatabdi) followed by Prodip (3.34 tha^{-1}). Almost similar trend of result was obtained from the straw yield but on an average, the straw yield was 5% lower than that of the grain yield (Table 4).

Table 3. Performance of wheat varieties to arsenic contaminated soil and irrigation water at Poranpur, Faridpur during 2010-11.

Varieties	Plant height (cm)	Spike m^{-2}	Grains $spike^{-1}$ (no)	1000 grains weight (g)	Yield (t ha^{-1})	
					Grain	Straw
BARI Gom-21 (Shatabdi)	87.0	317	42.3	47.6	3.28	3.42
BARI Gom-23 (Bijoy)	88.8	321	37.5	48.2	3.49	3.26
BARI Gom-24 (Prodip)	89.3	320	38.6.	47.9	3.62	3.47
BARI Gom-26	86.5	308	37.3	47.7	3.14	3.07
Level of significance	NS	NS	NS	NS	NS	NS
CV(%)	1.9	5.5	6.4	2.2	9.6	7.2

NS = Non significant

Table 4. Performance of wheat varieties to arsenic contaminated soil and irrigation water at Poranpur, Faridpur during 2011-12.

Varieties	Plant height (cm)	Spike m^{-2}	Grains $spike^{-1}$ (no)	1000 grains weight (g)	Yield (t ha^{-1})	
					Grain	Straw
BARI Gom-21 (Shatabdi)	87.4	293	38.8	47.0	3.41	3.06
BARI Gom-23 (Bijoy)	85.5	288	40.4	46.3	3.16	3.12
BARI Gom-24 (Prodip)	85.0	285	38.0	48.3	3.34	3.15
BARI Gom-25	85.2	284	38.7	46.0	3.20	3.24
BARI Gom-26	86.3	291	39.3	45.6	3.25	2.98
Level of significance	NS	NS	NS	NS	NS	NS
CV(%)	2.1	1.6	6.1	2.6	10.3	8.7

NS = Non significant

In case of Chowgacha, Jessore the grain yield of the tested wheat varieties ranged from 2.93 – 3.20 t ha^{-1} showing apparently higher result for Shatabdi but this variation was too small to be significant (Table 5).

At the second location, Sharsha under the same district, almost similar trend of result was observed. Numerically, the higher grain yield (3.23 t ha^{-1}) was obtained from Shatabdi followed by Prodip (3.18 t ha^{-1}) and BARI Gom-25 (Table 6).

Table 5. Performance of wheat varieties to arsenic contaminated soil and irrigation water at Chowgacha, Jessore during 2011-12

Varieties	Plant height (cm)	Spike m^{-2}	Grains $spike^{-1}$ (no)	1000 grains weight (g)	Yield (t ha^{-1})	
					Grain	Straw
BARI Gom-21 (Shatabdi)	87.7	289	44.7	46.0	3.20	2.95
BARI Gom-23 (Bijoy)	86.8	286	41.9	46.3	3.06	2.91
BARI Gom-24 (Prodip)	86.7	284	42.9	45.7	3.12	3.07
BARI Gom-25	87.4	288	43.6	45.7	2.93	3.16
BARI Gom-26	86.9	290	43.7	44.8	3.03	3.01
Level of significance	NS	NS	NS	NS	NS	NS
CV(%)	2.4	1.8	5.0	3.7	9.8	10.2

NS = Non significant

Table 6. Performance of wheat varieties to arsenic contaminated soil and irrigation water at Sharsha, Jessore during 2011-12.

Varieties	Plant height (cm)	Spike m^{-2}	Grains $spike^{-1}$ (no)	1000 grains weight (g)	Yield (t ha^{-1})	
					Grain	Straw
BARI Gom-21 (Shatabdi)	89.4	304	46.7	46.2	3.23	3.09
BARI Gom-23 (Bijoy)	86.9	295	43.6	43.7	2.96	3.02
BARI Gom-24 (Prodip)	86.2	296	44.3	46.0	3.18	2.92
BARI Gom-25	88.2	300	42.5	47.4	3.03	2.81
BARI Gom-26	87.1	304	43.4	46.7	2.91	2.70
Level of significance	NS	NS	NS	NS	NS	NS
CV(%)	2.6	2.7	3.3	4.2	8.7	7.5

NS = Non significant

Except for Benerpota, as shown in Table 2, the background level of total arsenic in soil was remarkably higher (28.5 – 36.4 mg kg^{-1}) than the thresh hold level (20 mg kg^{-1}) in addition to excessively higher content of arsenic (0.238 to 0.346 mg L^{-1}) in the adjacent STW irrigation water as compared to FAO permissible limit (0.10 mg L^{-1}). In spite of these, the tested wheat varieties gave static yield even if not up to their potential but still greatly higher than countries average (3.10 t ha^{-1}) from the major hot spots of arsenic polluted areas like Poranpur, Sharsha and Chowgacha. This result signified that there was no remarkable effect of arsenic contaminated irrigation water and soil on the yield of upland crop like wheat. Under oxidized situation, As^{+5} (arsenate) becomes the dominant fraction, which is 60 times less toxic than As^{+3} (arsenite) and that might be the major reason in favor of gaining non significant effect of arsenic contamination on the yield of wheat. These results are in agreement with the findings of Lambkin and Alloway (2003).

Arsenic content and uptake: There was no perceptible variation in arsenic content in wheat among the tested varieties within a particular location irrespective of root, straw and grain (Tables 7-11).

At Benerpota, arsenic content in root varied from 1.21 to 1.88 mg kg^{-1} where the highest (1.88 mg kg-1) was obtained from BARI Gom-26 followed by Bijoy and the lowest content was in Prodip. Similar trend of result was observed for the contents of arsenic in the straw and grain although they contain much lower arsenic than that of root. The variety, Prodip contains 0.043 and 0.028 mg kg^{-1} arsenic in straw and grain, respectively, which was lower than the other tested varieties (Table 7). Lower arsenic content (0.010-0.19 mg kg-1) in wheat grain was also found in India (Bhattacharya *et al*. 2010). The total (straw + grain) arsenic uptake was also highest (333 mg ha^{-1}) in BARI Gom-26 followed by Bijoy and the lowest (245 mg kg^{-1}) was in Prodip. The As content in grain was much lower than that of corresponding straw. The transfer coefficient of arsenic from

soil to above ground parts (straw + grain) of wheat varied slightly among the tested varieties. The highest transfer coefficient (0.0025) was recorded in BARI Gom-26, which means that 0.0025% of soil arsenic might have transferred to the grain and straw of wheat. However, the lowest transfer coefficient (0.0018) was found in Prodip.

Table 7. Arsenic content and uptake by wheat varieties at Benerpota, Satkhira during 2010-2011.

Variety	Arsenic content (mg kg^{-1})			Arsenic uptake (mg ha^{-1})			Transfer co-efficient
	Root	Straw	Grain	Straw	Grain	Total	
BARI Gom-21 (Shatabdi)	1.42	0.056	0.032	186.48	113.28	299.76	0.0022
BARI Gom-23 (Bijoy)	1.65	0.061	0.036	189.71	120.96	310.67	0.0023
BARI Gom-24 (Prodip)	1.21	0.043	0.028	149.64	95.48	245.12	0.0018
BARI Gom-26	1.88	0.068	0.039	207.4	125.97	333.37	0.0025

At Poranpur, arsenic content in root, straw and grain was much higher than the corresponding values of Benerpota. This might be due to higher level of As in soil and irrigation water in former than that of the latter. The variety, Prodip showed 3.35, 0.164 and 0.086 mg kg^{-1} arsenic in root, straw and grain, respectively which was lower than rest of the tested varieties (Table 8). The uptake of arsenic was also lowest (880.4 mg kg^{-1}) in Prodip, which resulted in the lower transfer coefficient (0.0015) in it. Similar trend of result (Table 9) was also observed in the second year (2011-12).

Table 8. Arsenic content and uptake by wheat varieties at Paranpur, Faridpur during 2010-2011.

Variety	Arsenic content (mg kg^{-1})			Arsenic uptake (mg ha^{-1})			Transfer co-efficient
	Root	Straw	Grain	Straw	Grain	Total	
BARI Gom-21 (Shatabdi)	3.41	0.168	0.092	574.56	301.76	876.32	0.0015
BARI Gom-23 (Bijoy)	3.48	0.176	0.112	573.76	390.88	964.64	0.0017
BARI Gom-24 (Prodip)	3.35	0.164	0.086	569.08	311.32	880.4	0.0015
BARI Gom-26	3.57	0.171	0.124	524.97	389.36	914.33	0.0016

Table 9. Arsenic content and uptake by wheat varieties at Paranpur, Faridpur during 2011-12.

Variety	Arsenic content (mg kg^{-1})			Arsenic uptake (mg ha^{-1})			Transfer co-efficient
	Root	Straw	Grain	Straw	Grain	Total	
BARI Gom-21 (Shatabdi)	3.53	0.172	0.096	526.32	327.36	853.68	0.0015
BARI Gom-23 (Bijoy)	3.44	0.174	0.105	542.88	331.8	874.68	0.0015
BARI Gom-24 (Prodip)	3.38	0.168	0.090	529.2	300.6	829.8	0.0015
BARI Gom-25	3.64	0.178	0.118	576.72	377.6	954.32	0.0017
BARI Gom-26	3.60	0.183	0.120	545.34	390	935.34	0.0016

In case of Chowgacha and Sharsha too, the arsenic content, uptake and transfer coefficient values were almost similar to that of Poranpur (Tables 10-11). However, the content and uptake values were narrowly higher for Chowgacha and Sharsha than Poranpur in most of the cases. This might be due to the lower transfer coefficient values in former than the later.

Table 10. Arsenic content and uptake by wheat varieties at Chougacha, Jessore during 2011-12.

Variety	Arsenic content (mg kg^{-1})			Arsenic uptake (mg ha^{-1})			Transfer co-efficient
	Root	Straw	Grain	Straw	Grain	Total	
BARI Gom-21 (Shatabdi)	3.48	0.186	0.102	548.70	326.40	875.10	0.0012
BARI Gom-23 (Bijoy)	3.56	0.178	0.098	517.98	299.88	817.86	0.0011
BARI Gom-24 (Prodip)	3.42	0.172	0.094	528.04	293.28	821.32	0.0011
BARI Gom-25	3.71	0.184	0.128	581.44	375.04	956.48	0.0013
BARI Gom-26	3.66	0.182	0.126	547.82	381.78	929.60	0.0013

Table 11. Arsenic content and uptake by wheat varieties at Sharsha, Jessore during 2011-12.

Variety	Arsenic content (mg kg^{-1})			Arsenic uptake (mg ha^{-1})			Transfer co-efficient
	Root	Straw	Grain	Straw	Grain	Total	
BARI Gom-21 (Shatabdi)	3.54	0.182	0.104	562.38	335.92	898.3	0.0014
BARI Gom-23 (Bijoy)	3.58	0.176	0.100	531.52	296	827.52	0.0013
BARI Gom-24 (Prodip)	3.40	0.169	0.090	493.48	286.2	779.68	0.0012
BARI Gom-25	3.68	0.186	0.120	522.66	363.6	886.26	0.0014
BARI Gom-26	3.62	0.180	0.123	513.00	357.93	870.93	0.0013

Generally, As concentration in roots was about 10 times higher than that in straw. This results suggest that arsenic usually is not distributed to the upper plant parts to a great extent rather mostly accumulates in root. This obtained result might be due to its lower mobility. Such absorption nature of As perhaps escapes the human being as well as cattle from the lethal poisoning. Martin *et al*. (1993) reported that uptake of arsenic by plants occurs primarily through the root system and the highest concentrations are reported in plant roots and tubers. Similar findings were observed by Kiss *et al*. (1992) and Tsutsumi (1980).

All the tested wheat varieties under this study appeared as promising and can be grown successfully in the arsenic affected areas. But BARI Gom-24 (*Prodip)* performed better compared with the other varieties in relation to arsenic content, uptake, biomass yield and transfer coefficient and thus can be regarded as arsenic tolerant to a considerable extent.

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LARVICIDAL EFFICACY OF SIX INSECTICIDES AGAINST CULEX QUINQUEFASCIATUS SAY (DIPTERA: CULICIDAE) LARVAE

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Abstract

Searching for potent larvicidal toxic effects of six synthetic organophosphate insecticides (Diazinon 60 EC, Solar 55 EC, Malathion 57 EC, Delathroit 40 EC, Parathrin 10 EC and Clorasid 20 EC) were evaluated in the laboratory against 3rd or 4th instar larvae of the mosquito species, *Culex quinquefasciatus* Say. The tested insecticides: Diazinon (Dizinol) 60 EC, Solar (Chloropyrics 50% + Cypermethrin 5%) 55 EC, Malathion (Sithion) 57 EC, Delathroit (Dimehoate) 40 EC, Parathrin (Cypermethrin) 10 EC and Clorasid (Chloropyrics) 20 EC showed LC_{50} values at application dosages 0.00250-0.05 ppm, 0.0001-0.0025 ppm, 0.00025-0.005 ppm, 0.0005-0.001 ppm, 0.0001-0.002 ppm and 0.00025-0.0025 ppm to be 8.609×10^{-3} ppm, 4.440×10^{-4} ppm, 9.094×10^{-4} ppm, 24.215×10^{-5} ppm, 4.797×10^{-4} ppm and 7.022×10^{-4} ppm respectively. Among the six insecticides, on the basis of LC_{50} and relative potency values, Delathroit 40 EC was the most toxic followed by Solar 40 EC > Parathrin 10 EC > Clorasid 20 EC > Malathion 57 EC > Diazinon 60 EC.

Key words: Larvicidal efficacy, Organophosphate insecticides, Toxicity, LC_{50}, *Culex quinquefasciatus* larva

Introduction

Mosquito control is necessary to prevent the transmission of mosquito-borne diseases and to protect people and livestock from their biting nuisance. But mosquito control is one of the major problems of the world in view of its ecology and vector behaviour. Effective mosquito control is often a complex and complicated task. The current mosquito control approach is based on synthetic insecticides. Insecticides especially organophosphorus and chlorinated hydrocarbons are extensively used as a control measure against the mosquitoes either as larvicides or as adulticides. The control of mosquito at the larval stage is necessary and efficient in integrated mosquito management. During the immature stage, mosquitoes are relatively less mobile, remaining more concentrated.

Several insecticides were tested in past against larvae of *Culex quinquefascatus, C. fatigans, C. pipiens, Aedes aegypti, Anopheles culifacies, An. stephensi, An. fluviatilis* and *An. gambiae* (Diptera : Culicdae) by Das *et al.* (1982), Verma and Rajvanshi (1983), Thavaselavam *et al.* (1993), Miyagi *et al.* (1994), Kalyanasundaran *et al.* (2003), Bansal and Singh (2006), Michaelakis and Koliopoules (2007), Kumar *et al.* (2010, 2011), Sarar *et al.* (2011) and Nkya *et al.* (2014) and at home by Begum and Mirdha (1975), Begum and Bhuiya (1983), Hossain *et al.* (1995), Shahjahan (1996), Ali *et al.* (1999), Zannat (2003) and Saha (2003).

The present study was undertaken to test the potency of some commercial insecticides i.e. Dizinon (Dizinol) 60 EC, Solar (Chlorpyrics 50% + Cypermethrin 5%) 55 EC, Malathion (Sithion) 57 EC, Delathroit (Dimethoate) 40 EC, Parathrin (Cypermethrin) 10 EC and Clorasid (Chloropyrics) 20 EC. In this investigation, toxic effects of the six synthetic organophosphorus insecticides were examined for their toxicity against the mosquito larvae *Culex quinquefasciatus* Say.

Materials and Methods

To study the toxic effect of six insecticides: Diazinon Dizinol) 60 EC, Solar (Chloropyrics 50% + Cypermethrin 5%) 55 EC, Malathion (Sithion) 57 EC, Delathroit (Dimethoate) 40 EC, Parathrin (Cypermethrin) 10 EC and Clorasid (Chloropyrics) 20 EC systematic short term bioassays were done in the Entomological research laboratory of Department of Zoology, Chittagong University. All the six insecticides were bought from the government-approved shop of Chittagong city. Larvae of the mosquito were collected by small hand sieve from drains and small stagnant water bodies of Chittagong University campus and reared in the laboratory in an aquarium containing stagnant water. The third or fourth instar larvae of *Culex quinquefasciatus* were sorted as experimental specimens. The experiments were conducted at 30 ± 2°C room temperature.

Before the final experiments, several preliminary screenings on different concentrations (ppm) of the insecticides were done. These preliminary experiments helped to ascertain the dose ranges for obtaining 1-99% mortality. The bioassays were run in a series of glass beakers each containing 500 ml of required concentration of the insecticide and run for a period of 24 hours. The different insecticide extracts in different doses were added to the beakers to determine the LC_{50} and LC_{90} values for *C. quinquefasciatus* larvae. Five concentrations of each extract were used in the final experiments. Ten *C. quinquefasciatus* larvae of third or fourth instars were released in each beaker and kept for 24 hours. Three replicates were done for each concentration. In each experiment a control was maintained in which the same number of mosquito larvae were released in same volume of tap water and was replicated in the same way. No food was supplied to the insects during the test period. All the beakers were netted on top.

Statistical analysis was done for the obtained data of the experiment. The dose concentrations were transferred to logarithms. Probit analysis was used to determine the LC_{50} and LC_{90} values of each insecticide. Values of LC_{50} and LC_{90} with 95% confidence intervals were analyzed in a computer based probit analysis programme. The regression equation was calculated from empirical probit, working probit, weighting probit, the values of which were taken from the tables given by Finney (1971). Expected probit was calculated from respective empirical probit. Values of chi square at 0.05 level and ANOVA- test at 0.01 and 0.05 level were calculated following Fisher and Yates (1963). The relative potency values were calculated by taking the highest LC_{50} value as unit.

Results and Discussion

Effects of the insecticides on Culex quinquefasciatus larvae: The effectiveness of Diazinon (Dizinol) 60 EC, Solar (Chloropyrics 50% + Cypermethrin 5%) 55 EC, Malathion

Table 1. Toxicities of the six experimental insecticides on *Culex quinquefasciatus* larvae exposed for 24 hours.

Solvents / Toxicity Parameters	Diazinon 60 EC	Solar 55 EC	Malathion 57 EC	Delathroit 40 EC	Parathrin 10 EC	Clorasid 20 EC
Dose range (ppm)	0.0025-0.05	0.0001-0.0025	0.00025-0.005	0.00005-0.001	0.0001-0.002	0.00025-0.0025
Mortality range (%)	13.33-96.67	10.00-96.67	13.33-93.33	10.00-93.33	13.33-93.33	13.33-96.67
Slope line values	0.76x+4.31	2.21x+3.60	1.79x+3.27	1.29x+2.98	1.94x+3.68	2.94x+2.51
Chi-square value	55.07	4.40	3.16	28.84	9.48	2.87
Degrees of freedom (χ^2)	4	4	4	4	4	4
P-value (χ^2)	P<0.05	P>0.05	P>0.05	P<0.05	P>0.05	P>0.05
ANOVA- value (Treatment)	213.99	62.89	448.28	120.98	134.30	46.00
Degrees of freedom (ANOVA- test) (Treatment)	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8
P-value (Treatment)	P<0.01<0.05	P<0.01<0.05	P<0.01<0.05	P<0.01<0.05	P<0.01<0.05	P<0.01<0.05
ANOVA- value (Replication)	7.11	0.44	20.99	0.99	6.00	0.390
Degrees of freedon (ANOVA- test) (Replication)	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8	F_1=4 F_2=8
P-value (Replication)	P>0.01 & P<0.05	P>0.01>0.05	P<0.01<0.05	P>0.01>0.05	P>0.01 & P<0.05	P>0.01>0.05
LC_{50} (ppm)	8.609×10^{-3}	4.440×10^{-4}	9.094×10^{-4}	24.215×10^{-5}	4797×10^{-4}	7.022×10^{-4}
Confidence limit (lower)	6.425×10^{-3}	3.388×10^{-4}	6.651×10^{-4}	18.156×10^{-5}	3.598×10^{-4}	5.788×10^{-4}
Confidence limit (upper)	11.342×10^{-3}	5.771×10^{-4}	12.240×10^{-4}	32.355×10^{-5}	6.360×10^{-4}	8.514×10^{-4}
LC_{90} (ppm)	38.450×10^{-3}	17.594×10^{-4}	46.855×10^{-4}	113.536×10^{-5}	22.146×10^{-4}	19.486×10^{-4}
Confidence limit (lower)	25.936×10^{-3}	12.168×10^{-4}	30.187×10^{-4}	74.239×10^{-5}	14.573×10^{-4}	14.620×10^{-4}
Confidence limit (upper)	72.840×10^{-3}	31.755×10^{-4}	98.103×10^{-4}	228.587×10^{-5}	44.694×10^{-4}	31.858×10^{-4}

(Sithion) 57 EC, Delathroit (Dimethoate) 40 EC, Parathrin (Cypermethrin) 10 EC and Clorasid (Chloropyrics) 20 EC insecticides were bioassayed upon *C. quinquefasciatus* larvae at various concentrations. Records in terms of mortality were taken at an interval of 24 hours of exposure to the test insecticides. No control mortality was seen to occur. The values of the dose ranges and mortality ranges, slope line values, Chi square and ANOVA values, LC_{50} and LC_{90} values with their confidence limits of the six insecticides are given in Table 1. Probit mortality lines of the six insecticides for the species are shown in Fig 1.

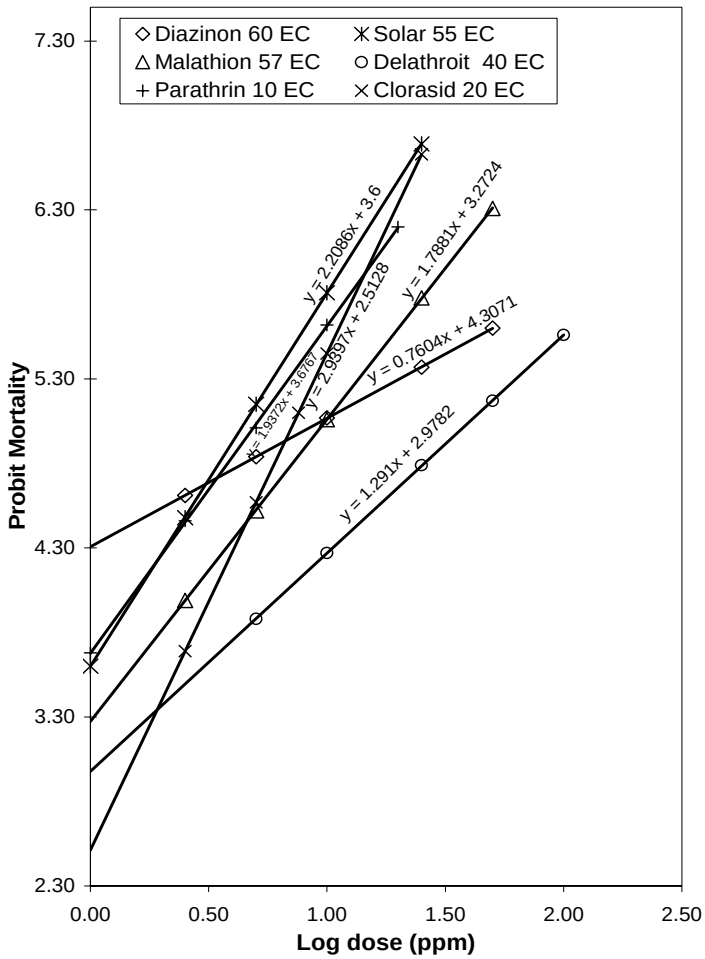

Fig 1. Regression lines for determining the LC_{50} of Diazinon 60 EC, Solar 55 EC, Malathion 57 EC, Delathroit 40 EC, Parathrin 10 EC and Clorasid 20 EC insecticides on *Culex quinquefasciatus* larvae after 24 hours of exposure.

Relative potency values of the six insecticides: The relative potency values of the six insecticides on *C. quinquefasciatus* larvae were calculated and are presented in Table 2.

Table 2. The LC_{50} and relative potency values of Diazinon 60 EC, Solar 55 EC, Malathion 57 EC, Delathroit 40 EC, Parathrin 10 EC and Clorasid 20 EC on *C. quinquefasciatus* larvae.

Insecticides	Extract	LC_{50} (ppm)	Relative Potency
Diazinon 60 EC	Distilled water	$8.6087\times10^{-3} = 86.087\times10^{-4}$	1.000
Solar 55 EC	Distilled water	4.440×10^{-4}	19.389
Malathion 57 EC	Distilled water	9.097×10^{-4}	9.463
Delathroit 40 EC	Distilled water	$24.215\times10^{-5} = 2.422\times10^{-4}$	35.544
Parathrin 10 EC	Distilled water	4.797×10^{-4}	17.946
Clorasid 20 EC	Distilled water	7.022×10^{-4}	12.259

From the Table 2 it is evident that amongst the six insecticides Delathroit 40 EC was the most toxic insecticide having low LC_{50} value ($2.422x10^{-4}$ ppm) and high relative potency value (35.544). The lowest toxic insecticide was Diazinon 60 EC having a high LC_{50} value ($86.087x10^{-4}$ ppm) and low relative potency value (1.000). Hence, from the relative potency values it is suggested that Delathroit 40 EC was 35 times more toxic than Diazinon 60 EC extract. The relative position of the six insecticides on the basis of their LC_{50} and relative potency values was in the order: Delathroit 40 EC > Solar 55 EC > Parathrin 10 EC > Clorasid 20 EC > Malathion 57 EC > Diazinon 60 EC. From the results it may be concluded that of the six tested insecticides Delathroit was the most toxic, followed by Solar, Parathrin, Clorasid, Malathion and Diazinon. A comparison of the relative potency values amongst the six insecticides is shown in Table 3.

The effects of the six insecticides (Diazinon 60 EC, Solar 55 EC, Malathion 57 EC, Delathroit 40 EC, Parathrin 10 EC and Clorasid 20 EC) were studied in a dose dependent manner. In the present study, analysis of the data showed that Delathroit 40 EC was most toxic at 0.001 ppm, whereas 0.00005 ppm was found to be the least toxic dose. Diazinon 60 EC, Solar 55 EC, Malathion 57 EC, Parathrin 10 EC and Clorasid 20 EC insecticides were highly toxic at 0.5 ppm, 0.0025 ppm, 0.005 ppm, 0.002 ppm and 0.0025 ppm respectively whereas 0.0025 ppm, 0.0001 ppm, 0.00025 ppm, 0.0001 ppm and 0.00025 ppm were found to be the least toxic doses respectively.

From the mortality data it was also observed that the mortality of the experimental mosquito larvae increased with the gradual increase of the dose concentrations of different insecticides. Different mortality within the concentrations used, ranged between 10 and 97 percent. The order of larvicidal activity or toxicity of the six insecticides on *C. quinquefasciatus* observed in the present study was: Delathroit 40 EC > Solar 55 EC > Parathrin 10 EC > Clorasid 20 EC > Malathion 57 EC > Diazinon 60 EC.

Table 3. Comparison of the relative potency values among the six insecticides.

Comparison between the insecticides	Relative potency
Diazinon 60 EC relative to Solar 55 EC	19.389
Diazinon 60 EC relative to Malathion 57 EC	9.463
Diazinon 60 EC relative to Delathroit 40 EC	35.544
Diazinon 60 EC relative to Parathrin 10 EC	17.946
Diazinon 60 EC relative to Clorasid 20 EC	12.259
Solar 55 EC relative to Malathion 57 EC	0.488
Solar 55 EC relative to Delathroit 40 EC	1.833
Solar 55 EC relative to Parathrin 10 EC	0.926
Solar 55 EC relative to Clorasid 20 EC	0.632
Malathion 57 EC relative to Delathroit 40 EC	3.756
Malathion 57 EC relative to Parathrin 10 EC	1.896
Malathion 57 EC relative to Clorasid 20 EC	1.295
Delathroit 40 EC relative to Parathrin 10 EC	0.505
Delathroit 40 EC relative to Clorasid 20 EC	0.345
Parathrin 10 EC relative to Clorasid 20 EC	0.683

The LC_{50} values and relative potency of the insecticides to the larvae as observed in the present investigation revealed that Delathroit 40 EC was the most toxic to the test larvae and was about thirty five times more toxic than Diazinon 60 EC. Solar 55 EC and Parathrin 10 EC also showed more or less same relative potency and were two times less potent than Delathroit 40 EC. Malathion 57 EC and Clorasid 20 EC showed more or less similar relative potency and were 3-4 times less potent then Delathroit 40 EC. The LC_{50} values were found to be 2.424×10^{-4}, 4.440×10^{-4}, 4.797×10^{-4}, 7.022×10^{-4}, 9.097×10^{-4} and 86.087×10^{-4} ppm for Delathroit 40 EC, Solar 55 EC, Parathrin 10 EC, Clorasid 20 EC, Malathion 57 EC and Diazinon 60 EC respectively. The relative potency of the insecticides to larvae of *C. quinquefasciatus* in order of decreasing toxicity was as follows: Delathroit 40 EC > Solar 55 EC > Parathrin 10 EC > Clorasid 20 EC > Malathion 57 EC > Diazinon 60 EC. Pal and Karla (1958) and Ramkrishnan *et al*. (1960) respectively observed LD_{50} values of Malathion as 0.032 ppm and 0.031 ppm on *Culex* sp. larvae. In the present test LC_{50} values of Malathion, 9.097×10^{-4} ppm indicated that the larvae of *C. quinquefasciatus* strain in Bangladesh is very susceptible than those tested by Pal and Karla (1958) and Ramkrishnan *et al.* (1960).

The dose ranges in the present findings were 0.0025-0.05 ppm for Diazinon 60 EC, 0.0001-0.0025 ppm for Solar 55 EC, 0.00025-0.005 ppm for Malathion 57 EC, 0.00005-0.001 ppm for Delathroit 40 EC, 0.0001-0.002 ppm for Parathrin 10 EC and 0.00025-0.0025 ppm for Clorasid 20 EC which were somewhat similar to the dose ranges found by Hossain *et al.* (1995) in case of Cypermethrin 10 EC (0.00006-0.00390 ppm), and Deltamethrin 2.5 EC (0.00006-0.00195 ppm) and Begum and Mirdha (1975) in case of Gusathion 20 EC (0.001-0.0001 ppm), Sumithion 50 EC (0.0002-0.0009 ppm), Lebaycid

50 EC (0.0004-0.0007 ppm), Folithion 50 EC (0.0007-0.0014 ppm) and Birlane 50 EC (0.002-0.010 ppm). The mortality range of the present observation was 10-97% which was more or less similar to the findings of Hossain *et al.* (1995) and Kumar *et al.* (2011) on *Culex quinquefasciatus* larvae, whereby mortality ranged from 0-100% with Cypermethrin 10 EC and Deltamethrin 2.5 EC and 8-100% with Propoxur and Bocide (Spinosad) respectively and Begum and Mirdha (1975) on *Culex fatigans* larvae whereby mortality ranged from 13-93% with Gusathion 20 EC.

The range of the LC_{50} values of the present finding with *C. quinquefasciatus* was 0.0086 (86.087×10^{-4}) ppm with Diazinon 60 EC to 0.00024 (2.422×10^{-4}) ppm with Delathriot 40 EC which was similar to the findings of Sarar *et al*. (2011) with Temephos (LC_{50} = 0.0079 mg/L or ppm), Kumar *et al*. (2011) with Propoxur (LC_{50} = 0.00013 ppm), Bansal and Singh (2006) with Alphamethrin (LC_{50} = 0.00021 mg/L or ppm), Kalyanasundaran *et al*. (2003) with Dursban (Chloropyrifos-ethyl) (LC_{50} = 0.00011 mg/L or ppm), Hossain *et al*. (1995) with Cypermethrin 10 EC (LC_{50} = 0.00034 ppm) and with Deltamethrin 2.5 EC (LC_{50} = 0.00029 ppm), Begum and Mirdha (1975) with Gusathion 20 EC (LC_{50} = 0.00033 ppm) and with Sumithion 50 EC (LC_{50} = 0.00038 ppm) on *Culex quinquefasciatus* and *Culex fatigans* larvae.

Results obtained from the present study clearly indicate that Diazinon 60 EC is least effective among the six insecticides tested. Under the consideration of above investigation, it is apparent that if we apply more insecticides at over dose, our environment will be polluted by these insecticides and the larvae will attain resistance.

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ASSESSMENT OF SOIL QUALITY OF COASTAL SHRIMP CULTURE POND AT CHAKARIA, COX'S BAZAR

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Abstract

The present study was carried out to find the status of different soil quality variables of coastal shrimp culture pond at different tidal marks of Chakaria, Cox'Bazar during the period from August 2012 to July 2013. The values of different soil quality variables such as sand, silt, clay, pH, organic matter, NO_2-N, PO_4-P, exchangeable K^+, Soil compactness, bulk density, particle density, porosity and Field water capacity fluctuated between 2.04-43.88%, 30.80-55.36%, 23.98-49.94%, 5.9-8.9, 1.62-9.95%, 4.01-9.92 µg/Kg, 1.14-3.50 µg/Kg, 0.82-1.74 meq/100g, 14.00-31.5 cm, 0.80-1.21 gcm^{-3}, 2.11-2.74 gcm^{-3}, 52.7-65.97% and 44.27-78.18% respectively. Significant differences ($p<0.05$) in the values of sand, silt, clay, bulk density, porosity, NO_2-N and field water capacity of soil of the culture ponds at tide marks were observed. Strong correlations between soil bulk density vs sand (0.863), field water capacity vs clay (0.845), field water capacity vs silt (0.797), exchangeable K^+ vs PO_4-P (0.787), porosity vs field water capacity (0.769) and porosity vs clay (0.705) were found at 0.01% level of significance.

Key words: Soil quality, Shrimp culture, Tidal marks, Correlation matrix

Introduction

Soil composed of mineral matter, water, air, organic matter and living community which vary from one area to another at different periods (Mishra 2000). Soil quality controls pond bottom stability, pH, plant nutrients and salinity of water essential for the progression of phytoplankton which are known as the base of food chain of the fish (Hill 1976 and Ekubo and Abowei 2011). Moreover, soil can hold the water providing various nutrients as natural feed for the cultivated shrimp (Boyd 1995 and Soewardi 2002) and serve as a biological sieved through the absorption of the carbon-based remains of food, fish excretions and algal metabolites (Townsend 1982). The excellence of overlying water is strongly affected by pond bottom soil quality (Singh 1982) and is considered as the "chemical laboratory" of the pond (Adams and Evans 1962). Heavier textured soils pose problems of enlargements of deep cracks when dry resulting leakage losses of water (Welch *et al.* 1977). Sometimes, accumulation and decomposition of the organic matter release organic substances, acids and dissolute minerals harmful for biota (Singh 1982). Due to decomposition of organic matter, soils and sediment become anaerobic inducing

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growth of micro-organisms. These micro-organisms produce ammonia, nitrite, ferrous iron, hydrogen sulfide, methane and other reduced compounds (Patrick *et al.* 1963) which can damage species (Boyd and Musig 1992) because their habitats are closely connected with the sediment. Generally produced ammonia stressed the cultured organisms slowing down feeding activity and growth (Rappaport and Sarig 1975, 1979, Ravch and Avnimelech 1978 and Ram *et al.* 1981) and mortality (Nix and Ingols 1981). Since Chakaria coastal area under Cox's Bazar district is being extensively used as aquaculture farms by the local community, majority of the farmers involved in aquaculture activities have no adequate knowledge on the soil quality of the ponds of the study area. Therefore the research was carried out to find the soil quality variables of culture ponds.

Materials and Methods

The study was conducted at Chakaria Upazila (21°55' 20"-21°34'30"N and 91°56' 20"-91°13'20"E) under Cox's Bazar District in the Division of Chittagong, Bangladesh from August 2012 to July 2013. The selected shrimp culture ponds situated at Chouarfari area under Chakaria Upazila are regularly flooded due to tidal effect.

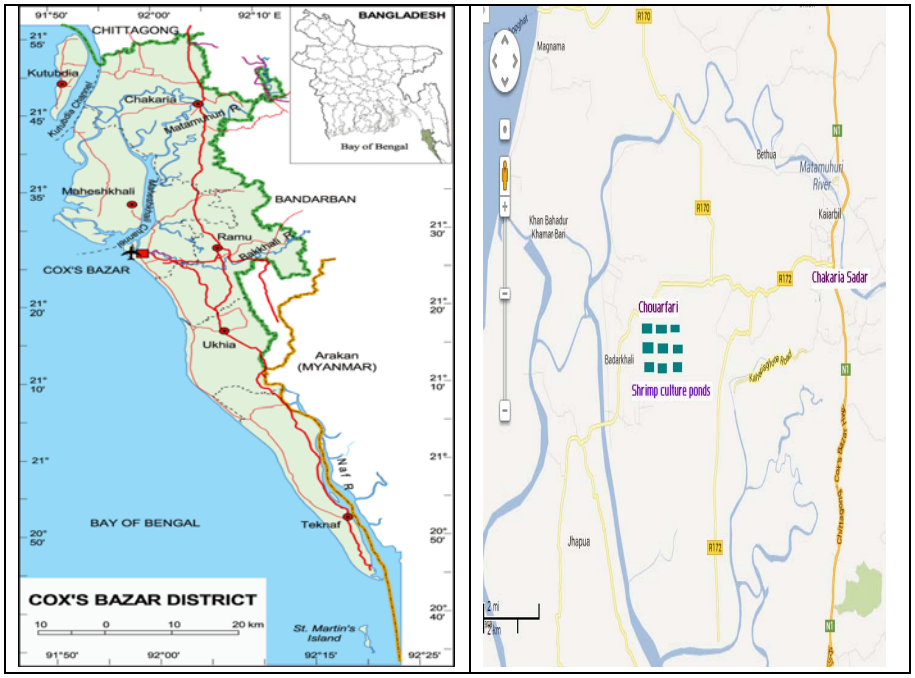

Fig 1. Map of Cox's Bazar District and Chakaria Upazila showing Chouarfari area.

Soil samples were collected from the study area by using transect method along with stratified random technique (Hale 2013). For soil sampling, three transects maintaining distances of 1km were placed at low tide, mid tide and high tide mark. Three culture ponds located in each transect were chosen maintaining an equidistance from one to another for the collection of soil sample. A hand held cylindrical corer (length: 30 cm, diameter: 3.7cm) was used for the collection of three replicated samples from each pond following 'S' shaped design.

The collected soil samples were air dried, powdered and passed through a 0.5mm mesh sieve. Before analysis, soil samples were finally dried in an oven at 105^0C for 24 hr. Soil pH and soil compactness were recorded in-situ condition. Soil pH was determined by soil pH meter. Other soil variables were analyzed at the Laboratory of Institute of Marine Sciences and Fisheries. The analysis for Exchangeable K^+ was done at Soil Resource Development Institute (SRDI). Soil organic matter (SOM) was measured by Walkey and Black wet oxidation method modified by Haq and Alam (2005).

Soil texture (% of sand, silt and clay) in the study area was analyzed by the hydrometer method described by Huq and Alam 2005, modified from Bouyoucos 1936. Phosphate-Phosphorus was determined by the method stated by Murphy and Riley (1961). Soil bulk density, field water capacity and soil particle density was determined by the method described by Huq and Alam 2005. Soil compactness was measured by the method described by Jones and Kunz (2004). Exchangeable K+ was determined by the method described by Peterson (2002). Soil sample was also collected by 5.3cm long and 1.9cm diameter plastic core for bulk density determination (Huq and Alam 2005).

Data analysis: One Way Analysis of Variance (ANOVA) test was performed to find out the significant ($p<0.05$) variation among different soil variables measured from different tidal marks in different seasons. A correlation matrix was executed to show the relationship among different soil variables.

Results and Discussion

The value (average ± SD) of different soil quality variables like texture, soil pH, Exchangeable K+, NO_2-N, PO_4-P, Soil organic matter, Bulk density, Particle density, Porosity, Field water capacity, Compactness of shrimp culture ponds situated at different tidal marks are presented in details in Table 1. The percentage of sand fluctuated between 6.17- 41.09 at the pond of different tide marks throughout the study period. The percentage of silt varied between 32.73- 51.47 and percentage of clay ranged between 25.08- 44.65 at the ponds of different tide marks. FAO (1985) reported that the soil of Ellisha Chakaria was mostly Silty Clay loam and Silty Clay. This is completely acquiesced with the mid tide mark and high tide mark soil texture of the present study.

Table 1. Soil quality variables of the study area.

	Low Tide Mark		Mid Tide Mark		High Tide Mark	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Parameter	Average ±SD	Average ±SD	Average ±SD	Average ±SD	Average ±SD	Average ±SD
Sand (%)	41.09±1.99	38.98±0.60	14.52±6.52	14.08±6.11	6.67±3.41	6.17±2.81
Silt (%)	32.73±1.53	35.93±1.01	51.47±1.44	48.39±2.07	51.26±4.42	49.19±5.51
Clay (%)	26.18±0.70	25.08±0.77	34.00±5.87	37.53±7.00	42.07±2.48	44.65±4.26
Textural Name	Loam		Silty clay loam		Silty clay	
Soil pH	7.61±0.74	6.71±0.18	8.46±0.39	6.23±0.16	8.58±0.18	6.22±0.20
Organic Matter (%)	4.81±1.39	4.84±1.15	6.59±1.61	6.51±1.21	4.99±1.24	6.32±1.62
Organic Carbon (%)	2.53±0.73	2.54±0.60	3.47±0.85	3.43±0.64	2.63±0.65	3.34±0.85
NO_2-N (µg/Kg)	7.1±0.80	9.1±0.56	6.19±0.79	7.11±0.78	5.35±0.76	6.35±0.12
PO4-P (µg/Kg)	1.71±0.51	2.74±0.31	2.26±0.56	3.11±0.34	1.38±0.17	2.62±0.15
K+ (meq/100g)	0.88±0.06	1.43±0.07	1.39±0.05	1.66±0.05	1.14±0.03	1.61±0.05
Soil compactness (cm)	21.61±3.39	19.67±3.3	21.56±4.69	21.00±5.2	25.00±3.96	23.61±5.27
Bulk Density (gcm^{-3})	1.05±0.15	0.99±0.06	0.90±0.08	0.87±0.06	0.85±0.02	0.83±0.02
Particle Density (gcm^{-3})	2.51±0.17	2.42±0.14	2.40±0.17	2.38±0.18	2.36±0.04	2.34±0.04
Porosity (%)	58.50±5.24	58.99±1.2	62.29±5.95	63.10±5.2	64.01±0.75	64.33±0.59
Field water capacity (%)	51.48±8.18	52.17±7.8	60.94±5.91	62.18±6.2	69.86±5.88	71.68±4.88
NO_2-N (µg/Kg)	7.1±0.80	9.1±0.56	6.19±0.79	7.11±0.78	5.35±0.76	6.35±0.12

The soil pH fluctuated between 6.22- 8.58 of the ponds of different tidal marks. Pond bottom soil pH can range from less than 4 to more than 9 but the best pH for pond soils is considered to be about neutral pH 7 (Boyd 1995). Maximum availability of soil phosphorus usually occurrs at about pH between 6 and 7.5 (CFA 1995). Most soil microorganisms, and especially soil bacteria, function best at pH 7 to 8 (Boyd 1995). Recommended level of soil pH for aquaculture is 7.5-8.5. The percentage of soil organic matter fluctuated between 4.81- 6.59 at the ponds of different tide marks (Table 1). The recommended value of organic matter ranged between 4.0–20.0% suitable for shrimp farming according to feasibility criteria (Poernomo 1992 and Widigdo 2002). In the present study organic matter was found to be within the optimum level. Organic matter was found to increase cation exchange capacity that helped in decomposition of dead algae in pond bottom, consume oxygen and release toxic gas: CO_2, H_2S, and NH_3 (Colt and Armstrong 1981, Boyd 1995 and Camargo *et al.* 2005.)

The Nitrite-Nitrogen fluctuated between 5.35 to 9.1 µg/kg at the ponds of different tide marks. According to Townsend (1982), optimum level of nitrite nitrogen is (5-10) µg/kg, which is similar to the nitrite-nitrogen of the present study. The Phosphate-Phosphorus varied between 1.38 to 3.11 µg/kg at the ponds of different tide marks. Optimum level of phosphate-phosphorus is (0.50-1.50) µg/kg suitable for aquaculture (Townsend 1982). In the present study, amount of phosphate-phosphorus was found to be above the optimum

level, which might be due to the deposition of phosphate into the soil which comes with tidal water. The exchangeable K+ fluctuated between 0.88 to 1.66 meq/ 100g at the ponds of different tide marks (Table 1). Exchangeable K+ at the range of (0.6-1.0) meq/100g is high and greater than 1.0 meq/100g. The Soil compactness fluctuated between 19.67 cm to 25 cm at the ponds of different tide marks. According to Municipality of central Saanich Resource Atlas, a clay layer at 20- 50 cm depth will restrict rooting, sub soiling at silty clay loam soil, which represents the compactness and it is similar to the present study. The percentage of soil bulk density fluctuated between 0.83 to 1.05 g cm^{-3} at the ponds of different tide marks. Bulk density of a mineral soil is normally between 1.0 and 1.6 g/ cm^3. Townsend (1982) reported that soils rich in organics and some friable clay may have a bulk density well below 1 g/cm^3 and this result is similar to the present study. The Soil particle density fluctuated between 2.34 to 2.51 g cm^{-3} at the ponds of different tide marks. According to Townsend 1982, the particle density of most mineral soil is in the range of 2.60 to 2.75 g cm^{-3}, which strongly supports particle density of the present study. The soil porosity ranged between 58.50 to 64.33% at these ponds. Total porosity values for unconsolidated materials lie in the range of 25%-70%. Porosity of silt is 35-50% and porosity of clay is 40-70% (Freeze and Cherry 1979). In the present study the porosity of soil is also in the range of 25-70%. The percentage of field water capacity varied between 51.48- 71.68 at these ponds. According to NRCCA (2010), the volumetric soil moisture content residual at field capacity is about 15 to 25% for sandy soils, 35 to 45% for loam soils, and 45 to 65% for silty clay loam soils and it can be more for silty clay and clay type soil. In the present study field capacity at mid tide mark and low tide mark are within the range of NRCCA (2010).

The interrelationship among soil variables found in the present study was measured at different significant levels. Significant positive correlations between soil bulk density vs sand (0.863), field water capacity vs clay (0.845), field water capacity vs silt (0.797), K+ vs PO_4-P (0.787), porosity vs field water capacity (0.769) and porosity vs clay (0.705) were observed at 1% level of significance. These results are similar to the results stated by NRCCA (2010). Moderate positive correlations were found between silt vs clay (0.541), silt vs porosity (0.542), organic matter vs silt (0.452), organic carbon vs silt (0.454). These results are similar to the results found by NRCCA (2010). Strong negative correlations were observed between field water capacity vs sand (-0.931), sand vs clay (-0.878), sand vs silt (-0.874), sand vs porosity (-0.698), silt vs bulk density (-0.741), clay vs bulk density (-0.792), bulk density vs porosity (-0.854), field water capacity vs bulk density (-0.821) at the level $p<0.05$. Rasool *et al* (2014) found the similar result between bulk density vs porosity.

Healthy and maximum growth of culture species in the coastal aquaculture pond depend mainly on the optimum level of sediment and water quality variables. Therefore the present result may help the local community for choosing a suitable culture pond for enhancing their aquaculture production in the Chouarfari area of Chakaria, Cox's Bazar.

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EFFECTS OF SELECTED TREATMENTS AND TECHNIQUES FOR THE RECLAMATION AND IMPROVEMENT OF CHERINGA ACID SULFATE SOIL UNDER RICE PRODUCTION IN THE COASTAL PLAIN OF COX'S BAZAR

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Abstract

Modified-Plain-Ridge-Ditch techniques (Tech 1: pyrite layer at top, jarosite layer at middle and top soil at the bottom of ridge; Tech 2: top soil at top, pyrite at middle and jarosite layer at the bottom of ridge) were used under field condition for the reclamation and improvement of the pre-leached Cheringa acid sulfate soil manipulated by basic slag (BS_{20} and BS_{30}: basic slag 20 and 30 t ha^{-1}) and aggregate size (A_{20} and A_{30}: aggregate sizes of soil less than 20 and 20-30 mm) treatments. The initial soil had very low pH (3.4), high ECe (1.6 S m^{-1}) and pyrite content (76 g kg^{-1}). Magnesium content (water soluble + exchangeable = 5.38 c mol kg^{-1}) of the soil was about 3 fold than that of Ca (1.71 c mol kg^{-1}), and Al content (9.22 c mol kg^{-1}) was highly toxic level. The pre- and post harvested soil data revealed that the properties of the soil was strongly ($p \leq 0.05$) influenced by the different treatments. The average soil data of all the treatments at post harvesting of rice cultivars were increased by 1.5 units for soil $pH_{(dry)}$ and 12 to 463% for the contents of N, P, Ca and Mg, while decreased the concentrations of Fe, Al, Na, Cl^- and SO_4^{2-} by 27 to 93% compared with the initial soil. The maximum growth and yield of rice grain (5.4 t ha^{-1}) were attained by the local cultivar Pizam compared with the high yielding variety BR 14 (5.1 t ha^{-1}) by the $A_{20}BS_{30}$ treatment in the ridges of the Tech 2. The lowest grain yields of 0.03 (BR 14) and 0.07 (Pizam) t ha^{-1} were recorded for the control plots (where no amendment was applied). The other treatments also resulted in a significant ($p \leq 0.05$) improved performance on plant production compared with the control.

Key words: Aggregate size, Basic slag, Growth performance, Modified-plain-ridge-ditch techniques, Reclamation, Improvement of acid sulfate soil

Introduction

Acid sulfate soils (ASSs) affect more than 100 million hectares (M ha) of land world-wide of which about 0.7 M ha occurs in the coastal areas where crop production is very low; somewhere the lands are unproductive, though the lands have high agricultural potential (Van Mensvoort and Dent 1998 and Khan 2000). Runoff and leachate from ASSs can adversely affect the aquatic communities, agricultural and engineering works and beneficial use of environment (Khan 2016). Crop production on salt-affected soils is

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adversely affected due to salt toxicity, nutritional imbalances, poor soil physical and chemical properties (Murtaza *et al.* 2011 and Khan 2015). In the ASS areas, massive fish kills and ulcerative diseases have been reported by several scientists (Lin and Melville 1994 and Sammut *et al*. 1996). Losses due to fish killing from such situations in the coastal plains of Bangladesh were about US$ 3.4 million during 1988-1989 (Callinan *et al*. 1993). Moreover, as the availability of land for growing crops is limited, it may become inevitable to utilize marginal and problem soils. Among the problem soils in Bangladesh, the ASSs have been causing severe environmental degradation (Khan 2016).

Conventional reclamation of ASSs through liming and flash leaching is not sustainable. Because, soil acidity produced by 1% oxidizable sulfur requires about 30 t of $CaCO_3$ ha^{-1} (van Breemen 1993). Usually ASSs contain 1-5% oxidizable sulfur and the use of more than 10 t lime ha^{-1} showed antagonistic effect on micronutrient levels as well as on the balance of basic cations in plants (Khan *et al*. 1994). Neutralization of ASSs with lime and/or leaching let to the deterioration of the soils, related ecosystems and to permanent soil acidification (Khan and Adachi 1999). Takai *et al*. (1992) reported that nutrient deficiency is an important factor when reclamation and improvement practices are performed in ASSs. Khan *et al*. (1994) reported the reclamation and improvement of ASSs require addition of materials rich in basic cations such as basic slag. The composition and use of basic slag were found to be harmless in Bangladesh since 1985 (Khan *et al*. 2006). Tri *et al*. (1993) revealed that construction of raised bed is the most important land management practices for ASSs. However, this practice has not achieved enough success. It's success depends on several factors of the soils, their position and environmental conditions (AARD and LAWOO 1992, Khan 2000). Construction of raised bed is important in sustainable reclamation and management practices of the soils. This type of reclamation of ASSs may be difficult but very essential due to the formation of acidity through the natural phenomenon of oxidation-reduction processes in the coastal soils (Khan 2015). Potential ASSs may have high pH like 6 to 7 under wet condition, but it does not mean that the soils are safe because at that situation it may create H_2S, Fe and some organic acid problems (Moore *et al*. 1990). Successful reclamation of the ASSs may result in the development of productive fields for crop growth. While poor soil reclamation may lead to creation of unfavorable soil conditions for crop growth and formation of actual ASSs, the real problem in the coastal tidal flat plain areas (Khan *et al*. 2007). With this background, the objectives of the present study were to evaluate the effects of basic slag, aggregate size and different techniques for the reclamation and improvement of ASS in relation to rice production.

Materials and Methods

Site condition: The experiment was conducted in a fallow land at Cheringa ASS occuring in the coastal old mangrove floodplain area in the Cox's Bazar district of Bangladesh. The site enjoys tropical monsoon climate and has three main seasons, namely, the

monsoon or rainy season, the dry or winter season and the pre-monsoon or summer season. The study site was once occupied for centuries by dense mangrove forest. Now about 95% of the areas have been cleared for agricultural cultivation. As a result, the potential ASSs have become actual ASSs with very poor yields. They generate H_2SO_4 that brings their pH from 6-7 to below 4, sometimes to as low as 2. This acid leaks into drainage and floodwaters, corrodes steel and concrete, and attacks clay liberating elements in toxic concentrations. Eight series of ASSs were studied in the field and among these the Cheringa ASS at Sarisabari was selected for further studies in relation to crop production.

Experimental design and field preparation: The experiment was set up in a completely randomized block design with three replications. There was an approximately 1.5 m wide and 1.0 m deep drain around the experimental field, about a 0.5 and 0.3 m boundary around each main plot and subplot, respectively for protecting the individual plot from the contamination of the treatments. The field of about 0.75 ha was divided into 12 main plots each having 10 x 5 m^2 size. In each main plot of plain or ridge, there were 6 subplots of 1 x 1 m^2 but there was no subplot in the ditch, which was about 10 x 5 m^2 wide and 0.4 to 0.6 m deep. The subplots of 1 x 1 m^2 were then used for individual treatment. These plots were irrigated mainly by using rainwater (yearly rainfall >4000 mm) collected from the local rain-fed channels through the irrigation pump. Pond water was also used for irrigation during the dry period. Saline water intrusion and drainage water were controlled through dikes and flap gates. Basic slag was collected from a steel industry and then grounded to less than 1 mm sizes in order to apply in the field. The rates of BS_{10} and BS_{20} (basic slag at 10 and 20 t ha^{-1}) were incorporated into the topsoil (depth: 0-20 cm) by broadcasting during ploughing. For in-situ neutralization of acidity arising from jarosite and pyrite layers in the modified-plain-ridge-ditch techniques (Fig. 1), the same doses of BS were incorporated into the subsoil (0.2-0.4 m) by using a soil slitter (5 cm diameter) at every 0.2 m of distance.

Modified-Plain-Ridge-Ditch Techniques

Plain: The area of each main plain (flood plain land) plot was 10 x 5 m^2 and the particle size of the plain plot soil was grounded manually into two aggregate sizes of about less than 20, and 20 to 30 mm (A_{20} and A_{30}). The grounded soils were then processed under the sun and open air for maximum oxidization within 2 days. The plain land was considered to reclaim by the application of flash leaching (5-7 times washing within a week: till the pH becomes >4.5 and lower ECe values) followed by the application of BS treatments. The drainage waters from the plain plots under the Modified-Plain-Ridge-Ditch techniques were disposed to the nearby ditches where the water was treated by BS as required to raise the water pH till 5.5.

Ridge: The ridge means raised bed of about 60 cm soil, stacked upon flood plain soil (plain land), which was made by raising different layers of soil through excavation and arranged as shown in the Fig. 1 (Tech 1 and Tech 2). These 60 cm high beds were

constructed to facilitate leaching of acids and salts of the soil. The area of the top of each ridge was 10×5 m^2 same as the size of plain land plot. Particle sizes of the bed materials were grounded manually into two aggregate sizes of A_{20} and A_{30}. These smaller sizes of aggregates were considered in order to understand the effects of oxidation of sulfidic materials and their quick drainage from this heavy-textured ASS. Each plot on the ridge of the different techniques were brought into flash leaching followed by the application of BS treatments as practiced for the plain plot. The drainage water was neutralized by the use of BS into the nearby ditches. The arrangements of soil layers in different techniques were - **Technique 1:** Top layer (surface soil) was extended to about 20 cm thick layer (1st layer: 0-20 cm) first onto the adjacent plots and was ground into different aggregate sizes

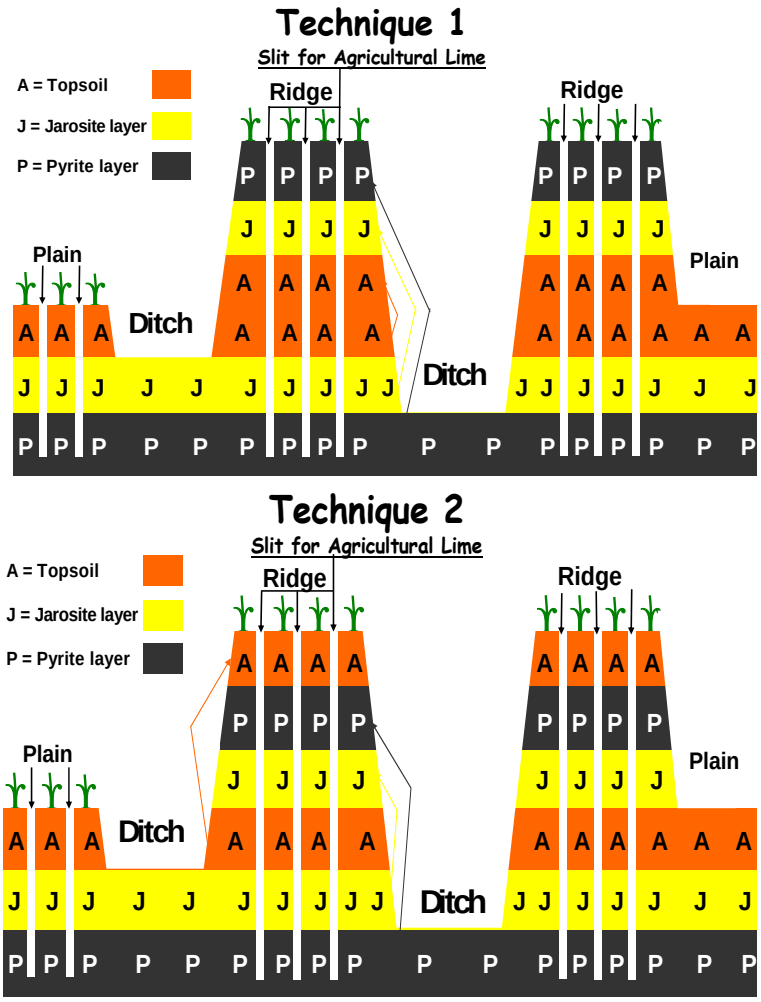

Fig 1. Modified-Plain-Ridge-Ditch techniques used in the field experiment for the reclamation and improvement of acid sulfate soil in relation to rice production.

(A_{20} and A_{30}) as per treatment requirement and was kept open to air for oxidation within 2 days. Then second layer (20-40 cm layer: sub surface soil with jarosite material) was extended to about 20 cm thick layer onto that processed first layer. The soils of the second layer was also ground to the desired sizes of aggregates and kept for oxidation for 2 days. Finally the third layer (40-60 cm layer: deeper soil containing pyrite material) was placed at the top of the previously stacked layers. This third layer was also considered for the preparation of different sizes of aggregates and the oxidation of 2 days. After that, the prepared 60 cm raised beds were taken under extensive leaching (5-7 times washing within a week) with rain and pond waters. Thereafter, the top soil of the ridge was subjected to the different rates of basic slag application as per treatments designed for the experiment. **Technique 2:** The preparation and processing of land such as aggregate size, duration of oxidation through air drying and experimental treatments were similar as those stated for Tech 1, except for the arrangement of soil layers. In the Tech 2, within the ridge (raised bed of 60 cm), the arrangement of soil layers was like as jarosite layer was placed at the bottom (3rd layer: 40-60 cm), then pyrite layer in the middle (2nd layer: 20-40 cm) followed by the surface soil on the top (0-20 cm) of the ridge.

Ditch: Adjacent to each ridge, there was a ditch of about 10 x 5 m^2 having a depth of about 0.6 m attributed to the excavation of soil for the preparation of ridges. These ditches were constructed as reservoir of acid drainage waters, where these acidic waters were neutralized by the use of basic slag during dry season. But during rainy season, these acidic wastes were automatically diluted by rain and/or controlled runoff waters. The pH level of the drainage waters was maintained to about pH 5.5 by the application of basic slag as per requirement.

Two varieties of rice (high yielding variety – HYV BR 14 and local Pizam) were planted in the Cheringa ASS in August 2004. The top soil (0-20 cm) in each plot (plain and ridge) was fertilized with N, P and K at the rates of 100, 80 and 60 kg ha^{-1} as urea, triple super phosphate (TSP) and MP, respectively as a basal dose. All the TSP and MP and one-third urea were applied just one day prior to transplantation where as the rest two-third of urea were applied as top dressing at two times after 30 and 60 days of transplantation. The plots were allowed to receive natural rain and pond waters whenever necessary to maintain favorable conditions (maximum saturated to field moist condition) for rice. Each plot of plain and ridge was divided into two equal parts for the transplantation of the two varieties of rice. Thirty day-old healthy and uniform seedlings were transplanted at the rate of four plants per hill. The distances between the hills were 15 cm. Pests were controlled by the use of insecticide, 'Nogos' whenever it required.

Soil analysis: The bulk samples obtained from the soil were stored for a couple of days under field-moist conditions (by putting the soil samples into polyethylene bags in an air-tied box) just prior to laboratory analyses, when the sub-samples were air-dried and crushed to 2 mm before analyses. Particle size distribution (Day 1965), Soil pH (Jackson 1973), for saturation extract of soil, the electrical conductivity (Richards 1954), water

soluble Na^+ and K^+ (flame photometry: Black 1965), water soluble SO_4^{2-} and Cl^- contents (Jackson 1973); Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} (atomic absorption spectrometry - AAS: Hesse 1971), organic matter content (Nelson and Sommers 1982), available N (1.3M KCl extraction, Jackson 1973), available P (0.002N H_2SO_4, pH 3 extraction, Olsen *et al*. 1954), Cation exchange capacity (Chapman 1965), exchangeable cations by flame photometry (Na^+, K^+) and AAS (Ca^{2+}, Mg^{2+},), Exchangeable Al^{3+} (1M KCl, Thomas 1982) and Fe^{3+} (1M CH_3COONH_4: pH 4.8, Black 1965) were followed for relevant analyses.

Results and Discussion

Pre- and post harvested soils: The Cheringa ASS (depth: 0-20 cm) showed a silty clay loam texture, initially low pH of 3.4, pyrite content of 76 g kg^{-1}, low base saturation (34%), high ECe (1.6 S m^{-1}), high exchangeable Fe^{3+} and Al^{3+} contents of 1.83 and 7.91 c mol kg^{-1}, respectively (Table 1). The contents of basic cations (Na^+, K^+, Ca^{2+} and Mg^{2+})

Table 1. Some selected properties of the initial Cheringa acid sulfate soil (depth: 0-20 cm) and the average soil (0-20 cm) data of all the treatments at post harvesting of the rice grown under field condition.

Soil properties	Initial soil	Post harvested soil	% IOC†
Textural class		Silty clay loam	
Bulk density (Mg m^{-3})	1.12	1.21	8
Moisture at Field Capacity (%)	49	51	4
Soil pH (Field, 1:2.5)	4.2	5.7	36
Soil pH (Dry, 1:2.5)	3.4	4.9	44
Soil pH (0.02 M $CaCl_2$, 1:2.5)	3.2	4.5	41
‡Pyrite content (g kg^{-1})	76	35	-54
ECe (S m^{-1})	1.6	0.38	-76
Organic Carbon (g kg^{-1})	21.3	21.8	2
Available N (1.3 M KCl: mM kg^{-1})	6.44	7.21	12
Avail. P (0.002N H_2SO_4, pH 3: mM kg^{-1})	0.11	0.25	127
CEC (1 M NH_4Cl: c mol kg^{-1})	19.1	19.8	4
Base saturation at pH 7.0 (%)	34.2	77.8	127
Exchangeable cations (1 M KCl)			
Sodium (flame photometer: c mol kg^{-1})	3.43	2.41	-30
Potassium (flame photomet.: c mol kg^{-1})	0.36	0.76	111
Calcium (AAS*: c mol kg^{-1})	0.95	5.35	463
Magnesium (AAS: c mol kg^{-1})	1.79	6.53	265
Aluminum (AAS: c mol kg^{-1})	7.91	0.53	-93
Iron (AAS: c mol kg^{-1})	1.83	0.91	-50
Water-soluble ions:			
Sodium (flame photometer: c mol kg^{-1})	3.11	2.21	-29
Potassium (flame photomet.: c mol kg^{-1})	0.26	0.44	69
Calcium (AAS¶: c mol kg^{-1})	0.76	3.22	324
Magnesium (AAS: c mol kg^{-1})	3.59	4.87	36
Aluminum (AAS: c mol kg^{-1})	1.31	0.26	-80
Iron (AAS: c mol kg^{-1})	0.43	0.57	33
Chloride (0.05N $AgNO_3$: c mol kg^{-1})	3.31	2.40	-27
Sulfate ($BaCl_2$: c mol kg^{-1})	4.06	2.63	-35

†IOC = Increased over control (initial value), ‡Pyrite (FeS_2) content was calculated from the total content of Fe {(Fe content/46.7) x 100, i.e. FeS_2 was considered to contain 46.7% Fe} in the acid sulfate soils. ¶AAS=Atomic Absorption Spectrophotometer.

in the initial soil were low to medium, while acidic cations (Al^{3+} and Fe^{3+}) were very high in relation to the amounts found elsewhere (Khan 2015). The pH value of the average soil data of all the treatments at post harvesting of rice was found to increase from 3.4 to 4.9, i.e. by 1.5 units higher compared with the control (i.e. initial value), while the ECe value of the soil was found to decrease to 0.38 S m^{-1} (76% decreased over control: Table 1). The contents of N, P, Ca and Mg in the average soil data at post harvesting were found to increase by 12 to 463% over control. The contents of exchangeable Al^{3+}, Fe^{3+}, Na^{+}, Cl^{-} and SO_4^{2-} in the soil were found to decrease by 27 to 93% over control (Table 1). The results also indicate that the physico-chemical properties of the ASS were strongly influenced by the application of leaching followed by basic slag and aggregate size treatments in different reclamation and management techniques.

The post harvested soil data (Fig. 2) of pH, exchangeable K^{+}, Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} contents were found to be affected significantly ($p \leq 0.05$) by the application of basic slag and aggregate size treatments in different techniques. The application of $A_{20}BS_{30}$ attained the highest value of soil pH of 5.6 in the Tech 1 and 5.8 in the Tech 2 during post harvesting followed by the $A_{20}BS_{20}$ (pH 5.2 in Tech 1 and 5.3 in Tech 2: Fig. 2) treatment. The contents of exchangeable Al^{3+} and Fe^{3+} during post harvesting were found to decrease sharply by the treatments and the decrements were more pronounced in the soil of the ridges of the techniques (Fig. 2). The highest amount of exchangeable Al^{3+} of 7.91 c mol kg^{-1} was recorded for the control plots, while this value decreased to 0.18 for Tech 1 and 0.11 for Tech 2 by the $A_{20}BS_{30}$ preceded by the $A_{30}BS_{30}$ and $A_{20}BS_{20}$ treatments. The decrease was more pronounced with the Tech 2. Among the treatments, the application of BS ranked first followed by the aggregate size treatments and techniques for the increments of soil pH and nutrient status of the soil which might be due to basic nature of BS (pH 9.6) as well as its release of some elements mainly Ca, Mg, etc. into the soils. The results agreed well with the findings of some researches. Of them, Khan (2002) reported that the acid sulfate soils released a very large amount of Al, e.g. 10 mM L^{-1}, while a very low concentration of Al can be hazardous. Concentrations of 1 to 2 mM Al L^{-1} are toxic to most crops and about 2 mM Al L^{-1} is toxic for rice. Fishes are most susceptible and fish death occur at 0.5 mM Al L^{-1}. Standard and potable water mostly range between 0.05 and 1.5 mM Al L^{-1} (Sittig 1994). Khan *et al*. (2006) reported that the application of basic slag in ASSs significantly increased soil pH, Ca and Mg and decreased Na, Fe and Al concentrations over time.

Tiller production: The maximum numbers of tillers/hill of 19 and 17 for BR 14 and 20 and 18 for Pizam were recorded by the application of $A_{20}BS_{30}$ in the Tech 1 and Tech 2, respectively and followed by the treatments of $A_{20}BS_{20}$ (Fig. 3). The effects of the treatments in the soil in relation to the production of tillers were: Tech 2 > Tech 1; BS_{30} > BS_{20} and A_{20} > A_{30} (Fig. 3). In most cases, the productions of tillers by the two rice cultivars were found to be significant ($p \leq 0.05$) by the application of basic slag and aggregate size treatments and techniques. Most of the treatments were found to exert

more positive effects in increasing the tiller production on the soil at the ridges of both the techniques and the effect was more pronounced under Tech 2 (Fig. 3). Khan et al. (1996) also observed almost similar effects by the application of basic slag for the vegetative growth of rice cultivated in two saline-acid sulfate soils.

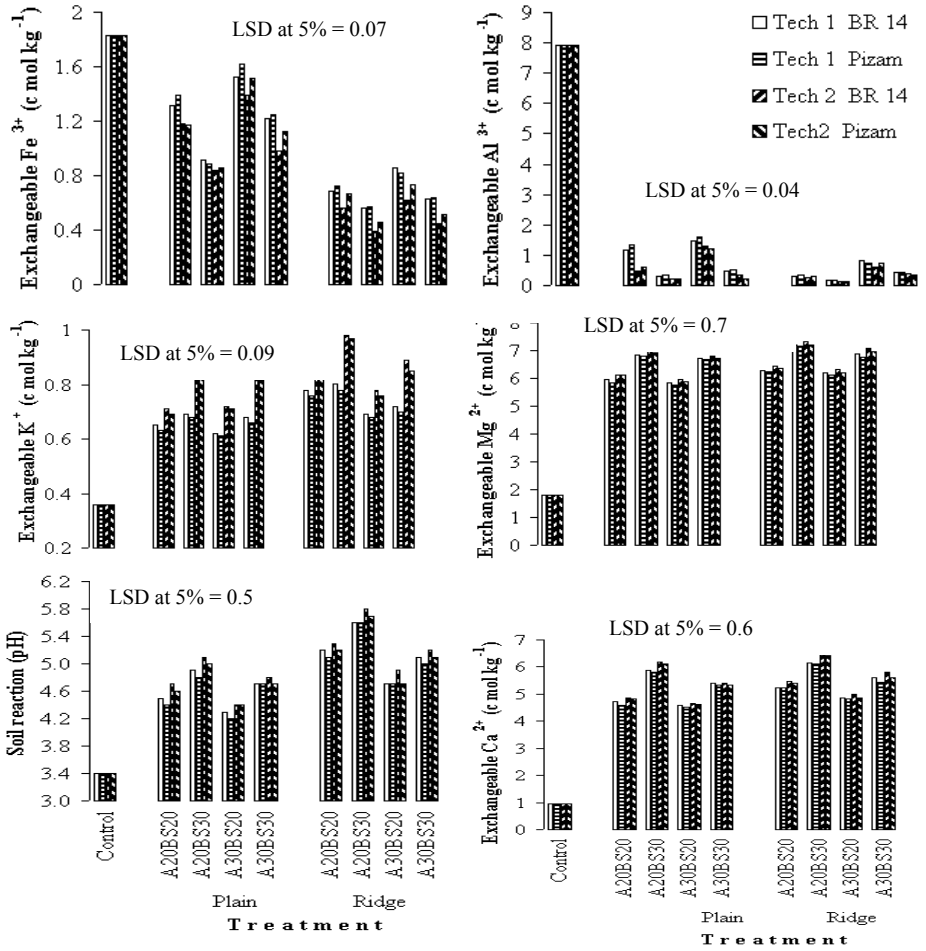

Fig. 2. Influence of different techniques, basic slag (BS) and aggregate size (A) treatments on the selected properties of soil studied under field condition.

Yield performance of rice: The straw and grain yields of the rice cultivars grown under the midified-plain-ridge-ditch techniques in the Cheringa ASS were found to increase significantly ($0 \leq 0.05$) by the different treatments and the improvement was more pronounced with the Tech 2 (Fig. 3). This might be due to the less requirement of the basic slag regarding neutralizing the acidity in the soil under Tech 2. In the Tech 1, the oxidized layer required more amount of basic slag in increasing pH level (5 to 6) for optimum crop growth. The lowest quantities of straw and grain yields were recorded by

the control treatment. Fageria and Baligar (1999) reported that rice was the most tolerant among the tested crops and produced the maximum dry matter at the pH of 4.9. The present data show that on average pH value ranged from 3.4 to 5.8 (Fig. 2), where the higher rate of BS_{30} was found to increase the soil pH at the highest level that resulted the maximum yield of rice under both the techniques. The highest yields of grain and straw were recorded for the local Pizam (grain: 5.4; straw: 5.5 t ha^{-1}) followed by the HYV BR 14 (grain: 5.1; straw: 5.0 t ha^{-1}) by the treatment of $A_{20}BS_{30}$ in Tech 2 > Tech 1 (Fig. 3).

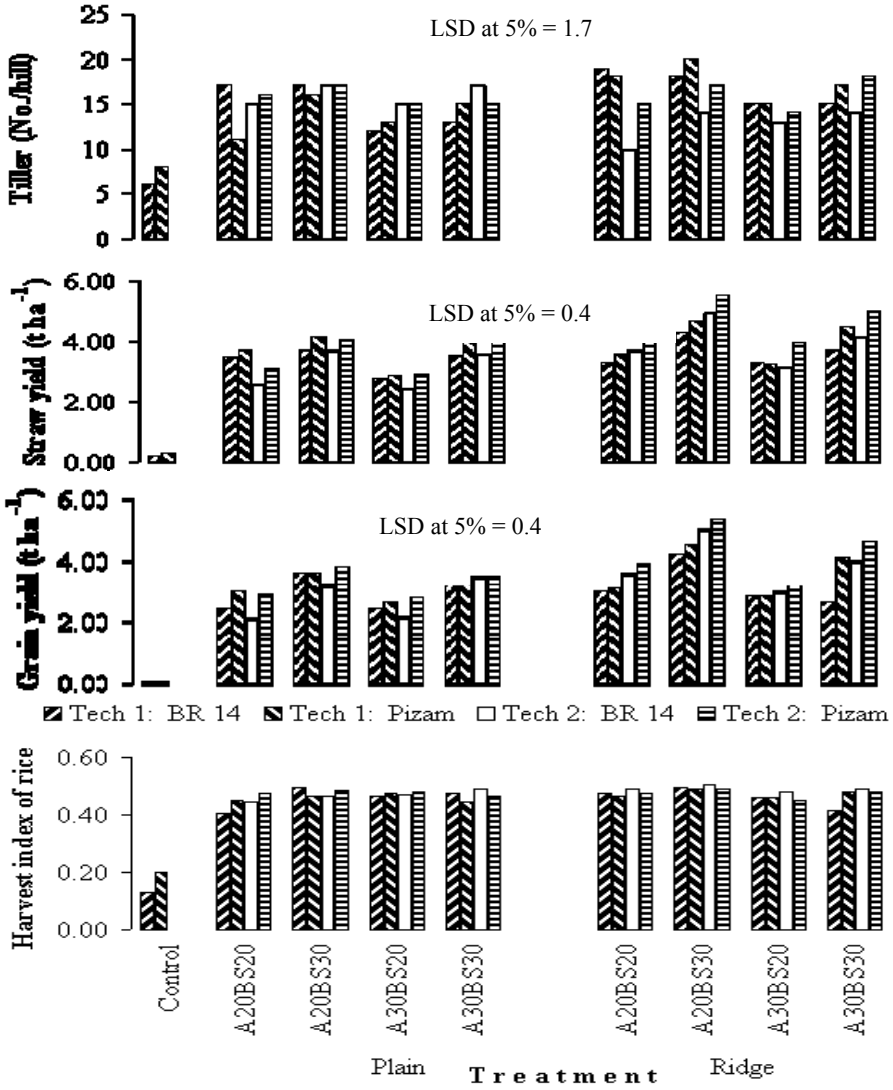

Fig. 3. Influence of different techniques, basic slag (BS) and aggregate size (A) treatments on the growth and yield performance of rice grown in acid sulfate soil under field condition.

The sizes of soil aggregates also influenced the growth of rice in presence of basic slag treatments. The A_{20} aggregated soils mostly yielded the highest production of rice which might be due to the maximum oxidation of pyrite, release of Al and acid from the soil. This in turn helped to increase the pH levels (Fig. 2) resulting in better availability of plant nutrients in the soil. Westerhof (1998) revealed that exchangeable bases and CEC had positive correlation, while exchangeable Al was negatively correlated with the amount of soil in the micro-aggregate and primary particle fractions. The plain lands which have the similar aggregate sizes and treatments failed to obtain expected production of rice. The general trends of the treatments on the yield of rice were observed almost similar to $A_{20}BS_{30} > A_{30}BS_{30} > A_{30}BS_{20} > A_{20}BS_{20}$ in the ridges for both the rice cultivars and the techniques.

Apart from the treatments and techniques, the average grain yield increments of rice were about 12% higher for the local Pizam compared with the HYV BR 14 rice. The HYV rice failed to give better yield under present condition of soil salinity and acidity. But the local Pizam cultivar showed better growth and yield performance due to its better tolerance/adaptive capability to the salinity, acidity or other environmental hazards. The harvest indexes of rice grown on the studied soil were also the best in the treatment of $A_{20}BS_{30}$ followed by $A_{20}BS_{20}$ under both the Tech 2 and Tech 1, respectively (Fig. 3). Anderson *et al*. (1987) also reported that the long-term use of calcium silicate slag was beneficial for the growth of sugarcane, rice and rice-sugarcane rotation crops grown on Everglades Histosols. The application of basic slag was reported to be effective due to the increase in the soil pH and release of some elements such as Ca and Mg into the growing media as well as the large amount of Si, which is beneficial to rice growth (Khan *et al*. 1996). The effect of a smaller aggregate size (A_{20}), compared with a larger (A_{30}) size was more effective for rice production, which might be due to the maintenance of relatively more favorable conditions associated with the initial fast waste out of acidity and salinity (Khan *et al.* 2006).

The application of BS_{30} ranked first, followed by the $A_{20} > A_{30}$ for the reclamation and improvement of the soil under Tech 2. The significant ($p \leq 0.05$) positive improvements of growth, yield of rice and soil properties were more pronounced under Tech 2 than that of Tech 1 under the modified-plain-ridge-ditch system. Application of basic slag and aggregate size treatments in different techniques not only increased soil pH, but also improved ionic balance between Ca and Mg and remarkably decreased the Fe and Al contents in the soil.

The use of modified-plain-ridge-ditch techniques and the different sizes of aggregates were found to be contributed for the physico-chemical amendments of the soil as well as improved rice production. The application of basic slag in the ASS was an effective measure, which can be used at a reasonable price and improved the growth and yields of the rice cultivars, but was also beneficial to the surrounding environment. However, for a cost benefit analysis of these treatments in relation to acid neutralizing capacity for a long time

in different fields, further studies on different soils and crops under variable climatic conditions should be carried out.

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EFFECTS OF BOTANICALS AGAINST ANTHRACNOSE AND BLIGHT DISEASES OF HOUTTUYNIA CORDATA THUNB

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Abstract

Anthracnose and blight were recorded on *Houttuynia cordata* Thunb. during April 2013 to December 2013. The isolated fungi from the symptomatic plants were identified as *Alterneria alternata* (Fr.) Keissler and *Colletotrichum gloeosporoides* (Penz.) Sacc. Ethanol leaf extracts of five plants viz.,*Azadirachta indica* L., *Citrus limon* L., *Datura metel* L., *Sennaalata* L. and *Tagetes erecta* L.were evaluated against the pathogenic fungi *A. alternata* and *C. gloeosporoides* at 5%, 10% and 20% concentrations *in vitro*. *A. indica* recorded as good inhibitor against the test fungi followed by *C. limon*, S. *alata*, *D. metel* and *T.erecta*. *In vivo* treatment also showed that *A.indica* is the most effective in controlling diseases at 10% concentration. The plants treated with *A. indica* were fresh and healthy up to one month of observation.

Key words: Anthracnose, Blight, *Houttuynia cordata*, Botanicals

Introduction

The plant *Houttuynia cordata* Thunb., the single species in the genus *Houttuynia* belonging to the family Saururaceae is a traditional medicinal herb. It is known as "Chameleon Plant" and its local name is "Aistya Gachh". This plant is mainly native to Japan, Korea, Southern China and Southeast Asia. It is widely distributed in the tropical Himalaya from Garwhal to Sikkim, Assam, Khasia Mountains. It mostly grows in hilly areas with providing moist and shady places. In Bangladesh it is found in Sylhet and Narail districts.

Houttuynia is herbaceous perennial plant which grows up to 50 cm tall. The leaves are simple, alternate, broadly ovate-cordate, 6.0 x 5.8. Flowers are white, bisexual and grow usually in summer (May-June). The plant grows well in moist to wet soil and even slightly submerged in water in partial or full sun (Ahmed *et al*. 2009).

The herb has a decayed, fishy smell to which its name refers, inspite of the fact it is eaten by the Chineseas as a salad. Its ethnobotanical uses considered for poisoned sores (furuncles), infectious skin diseases, piles, malaria, snakebite and other ailments. It is used as an antipyretic and detoxicant and is frequently used to treat pulmonary infections. It is antitumorous and is a special medicine for lung cancer (Smith and Stuart 1973}.

Remarkable research findings are available on medicinal properties of the plant in abroad (Wang 1994, Dong *et al*. 1998, Zhu 1998 and Ahmed *et al.* 2009*)*. But little information

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is available regarding the fungal diseases of the plant in home and abroad (Azad and Shamsi 2011and Zheng *et al.* 2011).Previously it was reported that symptoms appeared on leaves of *H. cordata*from September 2007 to November 2009 in Dangyang County, Hubei, China and the crop area affected estimated to be over 600 ha per year. Rhizome yield was reduced by 20% on average, with up to 70% yield losses in some fields during the autumn growing season (Zheng *et al.* 2011).So far there is no report available regarding the control of the diseases of *H. cordata*.Present research was undertaken to find out a suitable ecofriendly management of the diseases of this important herbal medicinal plant.

Materials and Methods

Leaves of *H.cordata* plants showing anthracnose and blight symptoms were collected from experimental field plots of Botanical Garden, Curzon Hall campus, Dhaka University, during April to December 2013.

The fungi were isolated from samples following the "Tissue Planting" method on PDA medium and "Blotter" method (CAB 1968).Identification of the isolates was determined following the standard literatures (Ellis 1971, 1976, Sutton1980, Ellis and Ellis 1998 and Barnett and Hunter 2000).

Pathogenicity test of the isolated fungi: All the isolated fungi were tested for their pathogenic potentiality following "Detached leaf technique"(Azad and Shamsi 2011) and "Spraying of spore suspension" method (Shamsi *et al*. 2003).The pathogenic fungi screened from "Detached leaf assay"were selected for net house experiment.Healthy plants of *H. cordata* were selected for pathogenicity test. The overall experiment was conducted in net house of Botanical Garden, Curzon Hall campus, Dhaka University. Plants were grown in 12 inch earthen pot containing sterilized soil for 6 weeks. Five plants were transplanted in each pot. Three replications were maintained for each treatment with five pots per replication. Test fungi were grown on PDA medium for 7-10 days. Spore suspension of each of the pathogenic fungus at the rate of 10^4 spores/ml concentration was sprayed on healthy plants using hand sprayer. Inoculated plants were covered by perforated polythene bags to avoid contamination and to maintain humidity. Symptoms were recorded and fungi were re-isolated to fulfill Koch's postulate.

Plant extract used in the experiment and their preparation: *Azadirachta indica, Citrus limon, Datura metel, Senna alata* and *Tageteserecta* were selected for the experiment.Hundred gms of collected plant materials were washed in sterile distilled water. Then the plant materials were chopped into small pieces.Stock solution of an extract of each plant was individually prepared using sterile water and chopped leaf material (1:1 w/v)in a clean blender. The mass of a plant part were squeezed through three folds of fine cloth. The supernatants were filtered through Whatman filter paper No.1 and the filtrate was collected in 250 ml Erlenmeyer flasks. 5%, 10% and 20%

concentrations were prepared from stock solution (2014) following Shamsi *et al*. and evaluated against two pathogenic fungi following poison food techniques (Grover and Moore 1962).

Fifteen ml of autoclaved PDA medium supplemented with 5%, 10% and 20% ethanol plant extracts were separately poured into Petri plates from lest tubes, allowed to cool and solidify. The Petri plates containing media devoid of the extract but with same amount of distilled water served as control. After complete solidification of the medium, 5mm disc of seven day old culture of each test pathogen was inoculated in the centre of the Petri plates with solidified PDA medium. The plates were incubated at 25± 2 ^{0}C for seven days.After incubation the colony diameter was measured in mm (Singh and Tripathi 1999). For each treatment three replications were maintained. The fungitoxicity of the extracts in terms of percentage inhibition of mycelial growth (I) was calculated using the formula: Percent inhibition = C - T / C X 100, where C = Average increase in mycelial growth in control plate and T = Average increase in mycelial growth in treatment plate.

Application of plant extracts in controlling anthracnose and blight of H. cordata: *Houttuynia cordata* was grown in 12 inch earthen pot containing sterilized soil for 6 weeks. Five plants were transplanted in each pot. Three replications were maintained for each treatment. Ethanol leaf extracts of five selected plants were screened in laboratory against test fungi. Among them *A.indica* showing complete inhibition of radial growth of the fungi at all the concentrations used were selected for controlling disease in net house experiment.Ethanol leaf extract of the plant at 10% concentration was sprayed on healthy plants by hand sprayer. Control plants were washed with distilled water. All the plants were covered by perforated polythene bags for 48 hours to avoid contamination. The experiment was conducted in net house of Botanical garden, Curzon Hall, Campus, DU. These pots were observed for one month in August 2013.

Measurement of disease severity: Disease severity were estimated by the following formula:

$$\text{Severity} = \frac{\text{Sum of all Ratings}}{\text{No. of observation} \times \text{Highest Rating}} \times 100$$

For visual estimation of severity, 0-9 point scale was used for rating of all foliar diseases studied (PDI=McKinney's Index, Ghos *et al.* 2009).
No infection – 0, 0 – 10% leaf area infected – 1, 10 – 20% leaf area infected – 2, 20 – 30% leaf area infected – 3, 30 – 40% leaf area infected – 4,40 – 50% leaf area infected – 5, 50 – 60% leaf area infected – 6, 60 – 70% leaf area infected – 7, 70 – 80% leaf area infected – 8, 80 – 90% or more leaf area infected – 9.

Results and Discussion

Anthracnose and blight were recorded on *H. cordata* leaf during April to December 2013 (Plate 1).

Seven fungal species were isolated from 18 examined samples of *H. cordata* belonging to 6 genera. The isolated 7 fungi namely *Alterneria alternata, Aspergillus fumigatus, Aspergillus niger, Colletotrichum gloeosporioides, Curvularia lunata, Pestaliopsis guepini*and, *Rhizopus stolonifer* were tested for their pathogenic potentiality. The results revealed that *A. alternata* and *C. gloeosporioides* produced symptoms on *H. cordata.* Zheng *et al*. (2011) first reported leaf spot of *H. cordata* caused by *A. alternata* from China.

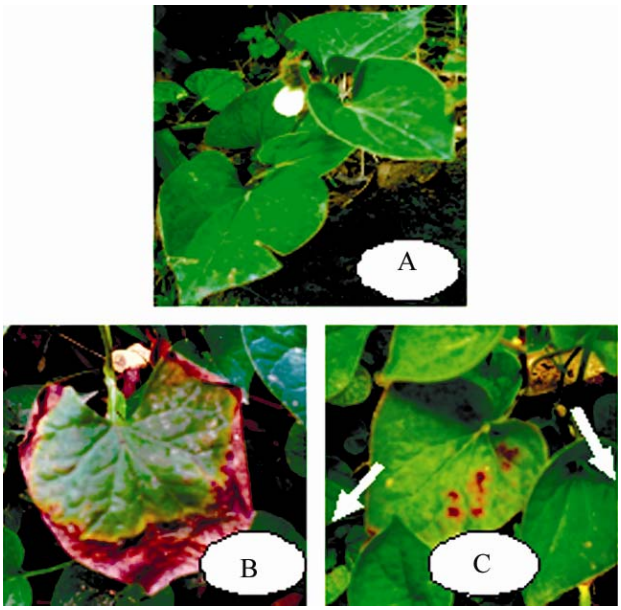

Plate 1. *Houttuynia cordata*: A. Healthy plants. B. Plants showing anthracnose and C. blight symptoms.

Azad and Shamsi (2011) recorded two types of symptoms (Anthracnose and leaf spot) on *H. cordata* and 17 species of fungi in their experiment. Among these 3 fungal species of *Colletotrichum* were found to be pathogenic to the plant. Result of present study slightly differs from previous result reported by Azad and Shamsi (2011).

Considerable research has been carried out and scientists successfully controlled plant pathogenic fungi with plant extract. These are safe and suitable biological control agents against fungal plant pathogens (Misher and Das 1992, Singh and Tripathi 1999, Varma and Dubey 1999 and Sharmin and Shamsi 2013).Common and locally available plants with antimicrobial activity viz., *A. indica, C. limon, D. metel, S. alata,* and *T.erecta* were selected in this experiment. Ethanol leaf extract of the plants at 20%, 10% and 5% concentrations were evaluated on radial growth of the two pathogenic fungi *A. alternata* and *C. gloeosporioides* of *H. cordata.*Results of the experiment are presented in Figs. 1 and 2.

Effect of plant extracts on radial growth of *Alterneria alternata in vitro*:Ethanol extracts of five angiospermic plants were used in this experiment. Among the selected plants *A. indica* showed 100% inhibition of radial growth of the fungus at all concentrations used. Exclusively at 20% concentration other plant extracts showed 100% inhibition of radial growth of test fungus. *Citrus limon* and *S. alata*also showed 100% inhibition of radial growth of the fungus at 10% concentration.. Whereas *D. metel* and *T. erecta* were capable of 68.57% and 58.18% radial growth inhibition of test fungus at the same concentration. *Citrus limon, T. erecta, S. alata* and *D.metel* showed 57.89%, 50%, 42.42% and40% inhibition of radialgrowth of the test fungus at 5% concentration (Fig.1).

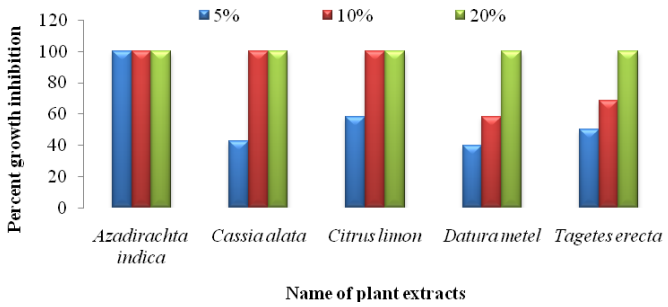

Fig. 1. Effect of plant extract on the radial growth of *Alternaria alternata* at different concentrations.

Effect of plant extracts against radial growth of *Colletotrichum gloeosporioides in vitro*: *Azadirachta indica* showed 100% inhibition of radial growth of test fungus at all concentrations used. Similar result was observed in case of *A. alternata*. Rest of the plant extracts showed 100% inhibition of radial growth of the fungus at 20% and 10% concentrations, respectively. *Datura metel,C. limon, T. erecta* and *S. alata* were capable of 76.39%, 69.23%, 60.38%, and 36.67% inhibition of radial growth of the fungus at 5% concentration (Fig. 2). Efficacy gradients indicates that *A. indica* and *C. limon* were the best inhibiting agent against the radial growth of *A. alternata* and *C. gloeosporioides* the causal agents of blight and anthracnose of *H. cordata.*

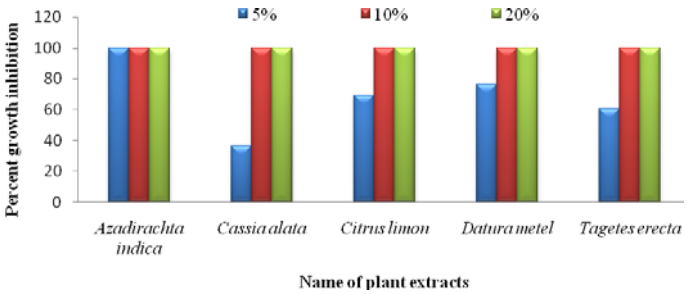

Fig. 2. Effect of plant extracts on the radial growth of *Colletotrichum gloeosporioides* at different concentrations.

Effectof plant extracts in controlling diseases of *Houttuyniacordata*: Extract of *Azadirachta indica* at 10% concentration was sprayed over the plants in net house. After one month of application, the treated plants did not show infection. Moreover, plant height and leaf size increased more than control plants. On the other hand control plants gradually showed symptoms with the application of fungi. Plants became shorter compared to treated plants. Disease severity was recorded on control (untreated plants) at (0-9) DS scale during development of symptom. Highest disease severity 8 was recorded at the end of 4thweek followed by DS 5 at the end of 3rd week, DS 2 was recorded at the beginning of 2nd week.At the end of first week plants were apparently healthy.Up to one month of observation treated plants remained symptomless (Tables 1, 2 and Plate 2).

Plate 2. *Houttuynia cordata*: A. Infected plants (Control); B: Plants treated with *Azadirachta indica* at 10% concentration.

Table 1. Effect of *A. indica* extract on plant height and leaf size of *H. cordata*.

Control plants			*A. indica* treated plants		
Plant height	leaf length	width (cm)	plant height	leaf length	width (cm)
16.5	5.4	3.7	21.0	6.0	4.5

Mean calculated from 25 plants examined.

Table 2. Disease severity recorded on untreated control plants of *H. cordata* in August 2013.

DI	1	weeks Disease severity 2	3	4
0	0			
1		2		
2				
3				
4			5	
5				
6				
7				
8				8
9				

Mean calculated from 25 plants examined.

Exploitation of naturally available chemicals from plants, which retards the reproduction of undesirable microorganisms, would be a more realistic and ecologically sound method for plant protection and will have a prominent role in the development of future commercial and safe fungicide for crop protection strategies, with special reference to control the fungal plant diseases.Present research is a new addition in the field of Plant Pathology.

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PLANT DIVERSITY OF DHAKA UNIVERSITY CAMPUS, BANGLADESH

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Abstract

The present article focuses the status of plant diversity of Dhaka University campus. A total of 541 plant species have been recorded from the campus area. These species are assigned to 117 families. For each species local name, scientific name, family and habit have been provided. Species presentation in the families varied from 1 to 26. 47% species belongs to 16 families and 53% species belongs to others 101 families. Euporbiaceae is the largest family in the Dicotyledon having 26 species whereas Liliaceae is the largest family in Monocotyledon having 18 species. Among the recorded species, 37% are represented by herbs, 29% by trees, 21% by shrubs, 11% by climbers, 2% by epiphytes and 0.2% by parasites. Plant species recorded in the campus categorized into different purpose groups. The result showed that 59% plant species represented by native species whereas 41% plant species represented by exotics. The survey spotted the presence a number of threatened species of Bangladesh in the gardent of the campus. Such species are *Corypha taliera, Podocarpus nerifolia, Mangifera sylvatica, Willoughbia edulis, Hydnocarpus kurzii, Gloriosa superva, Entada redii, Hedychium coccinium* and *Vandopsis gigantea*.

Key words: Plant diversity, Dhaka University, Campus

Introduction

Plant diversity is essential base of most of our terrestrial ecosystem. We all including animals are totally dependent on plant diversity directly or indirectly for not only food energy but also for all necessity of daily life. Globally, tens of thousands of species of higher plants and several hundred lower plants are currently used by humans for a wide variety of purposes as food, fuel, fiber, oil, herbs, spices, industrial crops and as forage and fodder for domesticated animals. Approximately, 25000-30000 plant species have been used by the people of tropical countries and up to 25000 species have been used in traditional medicines (Heywood 1993). In addition, many thousands of species are grown as ornamentals in parks, public and private gardens, as avenue trees and for shade and shelter. Another important role of plant diversity is the provision of ecosystem services including clean environment, the protection of watersheds, stabilization of slopes, improvement of soils, moderation of climate and the provision of a habitat for much of our wild fauna. Currently, plant diversity of the world has been facing tremendous

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amount of threats from humanity. The threats posed by human are urbanization, commercial agriculture, tree plantations, logging and wood extraction, mining and transportation, pollution, over harvesting, tourism, biological invasion, exotic monoculture plantations. Some natural events and disasters also have an impact on the plant diversity in different habitats.

Survey and documentation of plant resources of campus area of different Universities have already been done in Bangladesh (Sultana *et al*. 2013, Alam and Pasha 1999, Uddin and Pasha1999, Begum and Zaman 1984, Islam and Zaman 1984 and Anon 1999). The survey of plant diversity is very much important because it provides baseline information for comparison after modification of the habitats and to monitor changes in biodiversity overtime. Survey results are useful to determine the presence of rare, threatened, exotics, natives, pest and medicinal plant species. Currently the survey results have also been used to investigate the potential impact of planned developments and to inform management programs to make decision for biodiversity conservation. No such plants survey and documentation works are found for DU campus. Such document of plant resources is essential for students, faculty members and other enthusiastic persons who fascinated for plants. That is why in the present study an attempt has been made to survey and document plant species growing and planted in the Dhaka University campus area.

Materials and Methods

Dhaka University (DU) is located in between 23° 43□ N and 90° 23□ E at the centre of the capital city Dhaka of Bangladesh. The campus area is now fall under three thanas including Shahabag, New market and Farmgate. Overa 90% area is under shahabag thana. On the first day of July 1921 the University of Dhaka opened its doors to students with Sir P.J. Hartog as the first Vice-Chancellor of the University. The University was set up in a picturesque part of the city known as Ramna. The total area of the campus is about 600 acres of land. (http://www.du.ac.bd/main_menu/the_university/about). The campus area of DU is the refuge centre of both native and exotic plant species. The dominant component of plant diversity is trees of different species associated with shrubs, herbs and climbers. In each year plantation programs have been done by different hall authorities and arboriculture centre. Botany Department of DU has been introduced many ornamental, rare and important medicinal plant species in the campus in form of mini garden. Same plantation work has also been done by the faculty of pharmacy for their research purposes. Plant environment of DU campus area has been maintained by the arboriculture centre (under the leadership of the Department of Botany, DU).

In order to collect data, all corners of Dhaka University Campus including different halls and institutes have been visited over a couple of years (2012 to 2015). Observations on the campus environment were made in all the seasons to identify plants. Images of all observed plants with either flowers or fruits have been taken. Special efforts were given to find species of conservation concern including invasive, threatened, endemic and rare.

Maximum identification was done at the observation sites and in case of confusion in identity, fertile plant specimens have been collected (Hyland 1972, Balick *et al.* 1982 and Alexiades 1996). Species identification has been done by consulting different Floras (Uddin and Hassan 2004, Siddiqui *et al.* 2007c and Ahmed *et al.* 2008a, 2008b, 2009b, 2009c, 2009d and 2009e). The updated nomenclature of the species has been followed (Siddiqui *et al.* 2007 and Siddiqui *et al.* 2007c and Ahmed *et al.* 2008a, 2008b, 2009b, 2009c, 2009d and 2009e). Threatened categories of plants have been confirmed with the help of Khan *et al.* (2001) and Ara *et al.* (2013). Some noxious exotic plant species have also been determined comparing with the reports of Hossain and Pasha (2004) and Akter and Zuberi (2009). Families have been determined according to Cronquist (1981).

Results and Discussion

In the present survey of Dhaka University campus, a total of 541 plant species has been recorded. These species are assigned to 117 families. For each species local name, scientific name, family and habit are provided (Table 1). Species presentations in the families varied from 1 to 26. Calculation showed that 47% species belongs to 16 families and 53% species belongs to others 101 families. Euporbiaceae is the largest family in the Dicotyledon having 26 species whereas Liliaceae is the largest family in Monocotyledon having 18 species. The most dominant families are Euphorbiaceae, Asteraceae, Fabaceae, Liliaceae, Orchidaceae, Apocynaceae, Caesalpiniaceae, Arecaceae, Moraceae, Zingiberaceae, Verbenaceae, Rubiaceae, Mimosaceae, Malvaceae, Araceae and solanaceae (Fig. 1). Among the species, 37% are represented by herbs, 29% by trees, 21% by shrubs, 11% by climbers, 2% by epiphytes and 0.2% by parasites (Fig. 2). Plant species recorded in the campus are categorized into different purpose groups. Among the groups ornamental category attained maximum plant species followed by medicinal, wild, timber and fire wood (Fig. 3). This is due to the aesthetic desire of the campus view.

Origin status of campus plants was tried to explore in the present study. The result showed that 59% plant species are native species whereas 41% plant species are exotics (Fig. 4). Rising tendency of exotics in the campus area is the challenge for future native flora conservation and ecofriendly environment to encourage wildlife diversity. The survey finally spotted the presence of a number of threatened species of Bangladesh in the garden of the campus. Such species are *Antigonon leptopus, Corypha taliera, Rauvolfia serpntina, Andrographis paniculata, Mangifera sylvatica, Willuoghbia edulis, Podocarpus nerefolia, Hydnocarpus kurzii, Gloriosa superva, Entada redii, Hedychium coccinium* and *Vandopsis gigantea*. Observation during survey revealed that the campus area dominated by a good number of tree species. These are Samanea *saman* (Rain tree), *Swietenia mahagoni* (Mahogani), *Polyalthia longifolia* (Debdaru), *Lagerstroemia speciosa* (Jarul), *Cocos nucifera* (Coconut), *Hopea odorata* (Telsur), *Delonix regia* (Krishnachura) and *Masua ferae* (Nageshwar). Rare occurrence of the tree species are *Butea monosperma* (Polash), *Cassia fitula* (Sonalu), *Bombax ceiba* (Shimultula),

Table 1. Plant species with scientific name, bangla name, family and habit.

Name	Bangla name	Family	Habit
Ablemoschus esculentus (L.) Moench	Vandi	Malvaceae	Herb
Ablemoschus moschatus Medic.	Mushakdana	Malvaceae	Herb
Abroma augusta (L.) L.f.	Ulatkamble	Sterculiaceae	Shrub
Abrus precatorius L.	Roti	Fabaceae	Climber
Acacia moniliformis Griseb.	Akash moni	Mimosaceae	Tree
Acalypha hispida Burm.f.	Bara hatisur	Euphorbiaceae	Shrub
Acalypha indica L.	Muktajuri	Euphorbiaceae	Herb
*Acampe papillosa (*Lindl.) Lindl.	Porgasha	Orchidaceae	Epiphyte
Acampe rigida (Buch.-Ham. ex J. E. Sm.) P.F. Hunt	Porgasha	Orchidaceae	Epiphyte
Achyranthes aspera L.	Upathlenga	Amaranthacea	Herb
Adansonia digitata L.	Manky bread	Malvaceae	Tree
Adenanthera pavonina L.	Roktachandon	Mimosaceae	Tree
Adhatoda zeylanica Medikus	Basak	Acanthaceae	Shrub
Aegle marmelos (L.) Corr.	Bel	Rutaceae	Tree
Aganosma dichotoma (Roth) K. Schum	Malatilata	Apocynaceae	Climber
Agave americana L.	Senchuri tree	Agavaceae	Shrub
Agave cantula Roxb.	Century plant	Agavaceae	Shrub
Ageratum conyzoides L.	Fulkuri	Asteraceae	Herb
Alangium salviifolium (L.f.) Wangerin	Ankora	Allangiaceae	Tree
Albizia lebbeck (L.) Benth. & Hook.	Koroi	Mimosaceae	Tree
Albizia procera (Roxb.) Benth.	Sadakoroi	Mimosaceae	Tree
Albizia richardiana (Voigt.) King & Prain	Gagan shiris	Mimosaceae	Tree
Alcea rosea L.	Hollyhock	Malvaceae	Shrub
Allamanda cathartica L.	Kalkephul	Apocynaceae	Climber
Allamanda nerifolia Hook. f.	Harkara	Apocynaceae	Climber
Allium tuberosum Rottler ex Spreng.	Sadapiaz	Liliaceae	Herb
Alocasia esculenta (L.) Schott	Mankachu	Araceae	Herb
Aloe vera (L.) Burm.f.	Alovera	Aloaceae	Herb
Alpinia calcarata (Haworth) Rosc.	Tara	Zingiberaceae	Herb
Alpinia zerumbet (Pers.) Burtt. & Smith	Tara	Zingiberaceae	Herb
Alstonia scholaris (L.) R. Br.	Chatim	Apocynaceae	Tree
Alternanthera philoxeroides (Mart.) Griseb	Helencha	Amaranthaceae	Herb
Alternanthera sessilis (L.) R. Br. ex Roem &Schult	Chanchishak	Amaranthaceae	Herb
Amaranthus spinosus L.	Kantanotey	Amaranthaceae	Herb
Amaranthus tricolor L.	Denga	Amaranthaceae	Herb
*Amaranthus viridis*L.	Noteshak	Amaranthaceae	Herb
Amomum dealbatum Roxb.	Bonelachi	Zingiberaceae	Herb
Amorphophallus bulbifer (Roxb.) Blume	Ol kachu	Araceae	Herb

Contd.

Name	Bangla name	Family	Habit
Ampelygonum microcephalum (D. Don) Hassan	Madhusilum sak	Polygonaceae	Herb
Ampelygonum salarkhanii Hassan	Girishobhan sak	Polygonaceae	Herb
Ananas comosus (L.) Merr.	Anaros	Bromiliaceae	Herb
Andrographis paniculata (Burm.f.) Wall.ex Nees	Kalomegh	Acanthaceae	Herb
Annona reticulata L.	Nona Ata	Annonaceae	Tree
Annona squamosa L.	Shorifa	Annonaceae	Tree
Antigonon leptopus Hook. *et* Arn.	Anantalata	Polygonaceae	Climber
Antirrhinum majus L.	Sanipati	Scrophulariaceae	Herb
Aquilaria agallocha Roxb.	Aagar	Thymeliaceae	Tree
Araucaria juniper	Monky puzzle tree	Araucariaceae	Tree
Areca catechu L.	Supari	Arecaceae	Shrub
Argyreia nervosa (Burm.f.) Boj.	Guguli	Convolvulaceae	Climber
Arides odorata Lour.	Porgasha	Orchidaceae	Epiphyte
Aristolochia tagala Cham.	Ishwarmul	Aristolochiaceae	Climber
Artabotrys hexapetalus (L.f.) Bhandari	Kanthalichampa	Annonaceae	Climber
Artocarpus altilis (Park.) Fosberg	Breadfruit tree	Moraceae	Tree
Artocarpus chaplasha Roxb.	Chapalish	Moraceae	Tree
Artocarpus heterophyllus Lamk.	Kanthal	Moraceae	Tree
Artocarpus lakoocha Roxb.	Deua	Moraceae	Tree
Arundina graminifolia (D.Don) Hochr.	Gassphul	Orchidaceae	Herb
Asclepias curassavica L.	Moricha	Asclepiadaceae	Shrub
Asparagus racemosus Willd.	Satamuli	Liliaceae	Climber
Averrhoa belimbi L.	Belimbi	Averrhoaceae	Shrub
Averrhoa carambola L.	kamranga	Averrhoaceae	Tree
Axonopus compressus (Sw.) P.	Dhakagass	Poaceae	Herb
*Azadirachta indica*A. Juss.	Neem	Meliaceae	Tree
Baccaurea ramiflora Lour.	Lotkon	Euphorbiaceae	Tree
Bacopa monnieri (L.) Pennell	Brammi	Scrophulariaceae	Herb
Bambusa tulda Roxb.	Bans	Poaceae	Shrub
Barringtonia acutangula (L.) Gaerth.	Hizol	Lecythidacae	Tree
Bauhinia acuminate L.	Sadakanchan	Caesalpiniaceae	Shrub
Bauhinia purpurea L.	Rakta kanchan	Fabaceae	Tree
Bauhinia variegate L.	Lalkanchan	Caesalpiniaceae	Tree
Beloperone guttata (Wall.) Brandegee	Chingri Gach	Acanthaceae	Herb
Berrya cordifolia (Willd.) Burrett	Chavandalai	Tiliaceae	Tree
Bixa orellana L.	Jafran	Bixaceae	Shrub
Blumea lacera (Burm.f.) DC.	Kukurmuta	Asteraceae	Herb
Boerhaavia diffusa L.	Punarnova	Nyctaginaceae	Herb
Bombax ceiba L.	Shimultula	Bombacaceae	Tree
Borassus flabellifer L.	Tal	Arecaceae	Shrub
Bouea oppositifolia (Roxb.) Meissner	Mailam	Anacardiaceae	Tree

Contd.

Name	Bangla name	Family	Habit
Bougainvillea glabra Choisy	Bagan bilas	Nyctaginaceae	Climber
Brownea coccinea Jacq.	Supti	Caesalpiniaceae	Tree
Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Bercht & presl	Rajghanta	Solanaceae	Shrub
Brunfelsia latifolia Benth.	Brunfesia	Solanaceae	Shrub
Bryophyllum daigremontianum (Hamet & Perr.) A. Berger	Patharkhuchi	Crassulaceae	Herb
Bryophyllum pinnatum (Lamk.) Oken	Patharkuchi	Crassulaceae	Herb
Bulbophyllum lilacinum Ridl.	Porgasha	Orchidaceae	Epiphyte
Butea monosperma (Lmak.) Taub.	palash	Fabaceae	Tree
Caesalpinia pulcherima (L.) Swartz	Radhachura	Caesalpiniaceae	Shrub
Caesalpinia sappan L.	Bakam	Caesalpiniaceae	Shrub
Cajanus cajan (L.) Millsp.	Arhor	Fabaceae	Shrub
Calendula officinalis L.	kalendula	Asteraceae	Herb
Caliandra emarginata Benth.	Chotobetmara	Mimosaceae	Shrub
Callistemon citrinus (Curtis) Skeels	Bottlebrush	Myrtaceae	Tree
Calotropis gigantean (L.) R. Br.	Akanda	Asclepiadaceae	Shrub
Calotropis procera (Ait.) R. Br.	Akanda	Asclepiadaceae	Shrub
Camellia sinensis (L.)O. Kuntze	Cha	Theaceae	Shrub
Campanumoea lancifolia (Roxb.) Merr.	Atosigede	Campanulaceae	Herb
Campsis radicans (L.) Seem	Kolkephul	Bignoniaceae	Climber
Canna indica L.	Kolabati	Canaceae	Herb
Cardiospermum halicacabum L.	Phutka	Sapindaceae	Climber
Careya herbacea Roxb.	Tendupata	Lecythidaceae	Tree
Careya sphaerica Roxb.	Kumvi pata	Lecythidaceae	Tree
Carica papaya L.	Pepe	Caricaceae	Shrub
Carissa carandas L.	Karomsa	Apocynaceae	Shrub
Caryota urens L.	Caryota	Arecaceae	Shrub
Cassia alata L.	Dadmardon	Caesalpiniaceae	Shrub
Cassia bakeriana Craib	Golapi Sonalu	Caesalpiniaceae	Tree
Cassia fistula L.	Bandar lati	Caesalpiniaceae	Tree
Cassia hirsuta L.	Shapadaru	Caesalpiniaceae	Herb
Cassia roxburghii DC.	Lal-golapi sonalu	Caesalpiniaceae	Tree
Casuarina littoralis (Salisb.) L.A.S.Johnson	Jhau	Casuarinaceae	Tree
Cauroupita guinensis	Nagalingam	Lecythridaceae	Tree
Ceiba pentandra (L.) Gaertn.	Tula	Bombacaceae	Tree
*Celosia cristata*L.	Morogphul	Amaranthacea	Herb
Centella asiatica (L.) Urban	Thankuni	Apiaceae	Herb
Cestrum nocturnum L.	Hasnahena	Solanaceae	Shrub
Chlorophytum nepalens (Lindl.) Baker	Klorolax	Liliaceae	Herb
Chrysalidocarpus lucubensis Becc.	-	Arecacaeae	Shrub
Chrysalidocarpus lutescens (Bory) H. Wendl.	-	Arecacaeae	Shrub
Chrysanthemum morifolium Ramat	Chandramollica	Asteraceae	Herb
Chrysopogon caeculatus (Retz.) Trin.	Premkanta	Poaceae	Herb

Contd.

Name	Bangla name	Family	Habit
Chukrasia tabularis A. Juss.	Chikrasi	Meliaceae	Tree
Cinnamomum camphora (L.) J. Presl	karpur	Lauraceae	Tree
Cinnamomum tamala Nees& Eberm.	Tejpata	Lauraceae	Tree
Cinnamomum verum J. S. Presl	Darchini	Lauraceae	Tree
Cissus Quadrangularis L.	Harjoralota	Vitaceae	Climber
Citrus aurantifolia (Christm. & Panzer) Swingle	Lebu	Rutaceae	Shrub
Citrus maxima (Burm.) Merr.	Batabi	Rutaceae	Tree
Clausena heptaphylla (Roxb.) Wight & Arn. ex Steud.	Panbilas	Rutaceae	Shrub
Cleome gynandra L.	Hurhuria	Capparaceae	Herb
Cleome hassleriana Chodat	Nunirleta	Capparaceae	Herb
Cleome rutidosperma DC.	Begunehurhurey	Capparaceae	Herb
Clerodendrum chinense (Osbeck) Mabberley	Chandana bhat	Verbenaceae	Herb
Clerodendrum thomsonae Balf. f.	Bleeding heart	Verbenaceae	Climber
Clerodendrum viscosum Pers.	Bhat	Verbenaceae	Herb
Clinogyne dichotoma (Roxb.) Salisb. ex Benth	Sheetalpat	Marantaceae	Herb
Clitoria ternatea L.	Aparajita	Fabaceae	Climber
Cocos nucifera L.	Narikel	Arecaceae	Shrub
Codiaeum variegatum (L.) A. Juss.	Patabahar	Euphorbiaceae	Shrub
Coffea Arabica L.	Coffi	Rubiaceae	Shrub
Coleus amboinicus Lour.	Kolius	Lamiaceae	Herb
Coleus scutellarioides (L.) Benth.	Kolius	Lamiaceae	Herb
Colocasia esculenta (L.) Schott	Kachu	Araceae	Herb
Commelina benghalensis L.	Kanchira	Commelinaceae	Herb
Congea tomentosa Roxb.	Kongia	Verbenaceae	Climber
Corchorus capsularis L.	Pat	Tiliaceae	Herb
Coreopsis tinctoria Nutt.	Shonalipata	Asteraceae	Herb
Corypha taliera Roxb.	Talipalm	Arecaceae	Shrub
Cosmos bipinnatus Cav.	Cosmos	Asteraceae	Herb
Crinum amoenum Roxb.	Gangkachu	Liliaceae	Herb
Crinum asiaticum L.	Barakanur	Liliaceae	Herb
Crinum defixum Ker-Gawl.	Sukhdarshan	Liliaceae	Herb
Crinum latifolium L.	Sukhdarshan	Liliaceae	Herb
Crossandra infundibuliformis (L.) Nees	Gobbi	Acanthaceae	Shrub
Croton bonplandianus Baill.	Croton	Euphorbiaceae	Herb
Curculigo orchioides Gaertn.	Talmuli	Liliaceae	Herb
Curculigo recurvata Dryand.	Talmuli	Liliaceae	Herb
Curcuma longa L.	Halud	Zingiberaceae	Herb
Curcuma zedoaria (Christm.) Rosc.	Shadi	Zingiberaceae	Herb
Cuscuta reflexa Roxb.	Sarnalata	Cuscutaceae	Parasite
Cycas pectinata Buch.-Ham.	Cycad	Cycadaceae	Shrub
Cycas revolute Thunb.	Sago Cycad	Cycadaceae	Shrub

Contd.

Name	Bangla name	Family	Habit
Cymbidium aloifolium (L.) Sw.	Porgasha	Orchidaceae	Epiphyte
Cynodon dactylon (L.) Pers.	Durba	Poaceae	Herb
Cyperus distans L. f.	Panimalanga	Cyperaceae	Herb
Cyperus rotundus L.	Muthagass	Cyperaceae	Herb
Dalbergia sissoo Roxb.	Sissu	Fabaceae	Tree
Datura metel L.	Dutra	Solanaceae	Shrub
Delonix regia Rafin.	Krishna chura	Fabaceae	Tree
Dendrobium aphyllum (Roxb.) Fischer	Porgasha	Orchidaceae	Epiphyte
Dendrobium lindleyi Steud.	Porgasha	Orchidaceae	Epiphyte
Dendrophthoe falcate (L. f.) Etting	Phorolla	Loranthaceae	Parasite
Desmodium triflorum (L.) DC.	Kidaliya	Fabaceae	Herb
Dianthus caryophyllus L.	Jatasalpar	Caryophyllaceae	Herb
Dianthus chinensis L.	Chinasalpar	Caryophyllaceae	Herb
Didymosperma gracilis Hook. f.	-	Arecaceae	Shrub
Dieffenbachia seguine (Jacq.) Schott	Segubet	Araceae	Herb
Dillenia indica L.	Chalta	Dilleniaceae	Tree
Dimocarpus longan Lour.	Asphal	Sapindaceae	Tree
Dioscorea belophylla (Prain) Voigt ex Haines	Suprialu	Dioscoreaceae	Climber
Dioscorea bulbifera L.	Matialu	Dioscoreaceae	Climber
Diospyros blancoi A. DC.	Beelati Gab	Ebenaceae	Tree
Diospyros malabarica (Desr.) Kostel.	Deshi Gab	Ebenaceae	Tree
Diospyros Montana Roxb.	Bon gab	Ebenaceae	Tree
Dipterocarpus turbinatus Gaertn.	Garjon	Dipterocarpaceae	Tree
Dracaena spicata Roxb.	Dracena	Agavaceae	Shrub
Duranta repens L.	Katamehdi	Verbenaceae	Shrub
Eclipta alba (L.) Hassk.	Keshoraj	Asteraceae	Herb
Eichhornia crassipes (Mart.) Solms	Kachuripana	Pontederiaceae	Herb
Elaeis guineensis Jacq.	Pum oil	Arecaceae	Shrub
Elaeocarpus floribundus Blume	Jolpai	Elaeocarpaceae	Tree
Entada rheedii Spreng.	Gila	Mimosaceae	Climber
Ephedra sinensis	Ephedra	Ephedraceae	Shrub
Eranthemum pulchellum Andre.	Shukh murali	Acanthaceae	Shrub
Eriobotrya japonica (Thunb.) Lindl.	Lokat	Rosaceae	Tree
Erythrina indica Lamk.	Mandar	Fabaceae	Tree
Erythrina suberosa Roxb.	Mandar	Fabaceae	Tree
Erythrina variegate L.	Mandar	Fabaceae	Tree
Eucalyptus camaldulensis Dehnhardt	Eucalyptus	Myrtaceae	Tree
Eupatorium ayapana Vent.	-	Asteraceae	Climber
Eupatrium triplinerva M.Vahl.	Ayapan	Asteraceae	Herb
Euphorbia antiquorum L.	Katagach	Euphorbiaceae	Herb
Euphorbia cotinifolia L.	Tamat	Euphorbiaceae	Shrub
Euphorbia hirta L.	Dudhia	Euphorbiaceae	Herb
Euphorbia milii Des.	Katamukut	Euphorbiaceae	Shrub
Euphorbia nerifolia L.	Mansasij	Euphorbiaceae	Herb
Euphorbia nivulia F. Ham.	Patranuli	Euphorbiaceae	Shrub

Contd.

Name	Bangla name	Family	Habit
Euphorbia pulcherima Willd. ex Klotz	Lalpata	Euphorbiaceae	Shrub
Euryale ferox Salisb.	Makhna	Nymphaeaceae	Herb
Evolvulus nummularius (L.) L.	-	Convolvulaceae	Herb
Excoecaria agallocha L.	Geoa	Euphorbiaceae	Tree
Ficus benghalensis L.	Bat	Moraceae	Tree
Ficus benjamina L.	Pakur	Moraceae	Tree
Ficus elastic Roxb. ex Hornem	Indian rabber	Moraceae	Tree
Ficus hispida L. f.	Dumur	Moraceae	Tree
Ficus pumila L.	Latabot	Moraceae	Climber
Ficus racemosa L.	Jagdumur	Moraceae	Tree
Ficus religiosa L.	Ashwatha bot	Moraceae	Tree
Ficus rumphii Blume	Gai Aswathwa	Moraceae	Tree
Filicium decipiens (Wight & Arn.) Thw.	Fern tree	Sapindaceae	Tree
Fragaria vesca L.	Stawberry	Rosaceae	Herb
Galphimia gracilis Hort. ex Bartl.	Rain of gold	Malpighiaceae	Shrub
Garcinia cowa Roxb. ex DC.	Kao	Clusiaceae	Tree
Garcinia Morella (Gaertn.) Desr.	Tomal	Clusiaceae	Tree
Garcinia xanthochymus Hook. f. ex T. Anders.	Dayphal	Clusiaceae	Tree
Gardenia augusta (L.) Merr.	Gondaraj	Rubiaceae	Shrub
Geodorum citrinum Jack.	Bhuifor	Orchidaceae	Herb
Gerbera aurantifolia Sch.-Bip.	Gerbera	Asteraceae	Herb
Gerbera viridifolia Sch.-Bip.	Gerbera	Asteraceae	Herb
Globba multiflora Wall. ex Baker	Shukh globba	Zingiberaceae	Herb
Globba orixensis Roxb.	Jhansi globba	Zingiberaceae	Herb
Gloriosa superb L.	Ulatchandal	Liliaceae	Climber
Glycosmis pentaphylla (Retz.) A. DC.	Motkila	Rutaceae	Shrub
Glyricidia maculate H. B. & K.	Basantamanzuri	Fabaceae	Tree
Gmelina arborea Roxb.	Gamari	Verbenaceae	Tree
Gmelina philippensis Cham.	Jhep gamari	Verbenaceae	Climber
Gomphrena globosa L.	Botamphul	Amaranthacea	Herb
Grevillea robusta A. Cunn. ex R. Br.	Silver Oak	Proteaceae	Tree
Grewia tiliifolia Vahl.	Rakta kussum	Tiliaceae	Shrub
Gustavia insignis Willd. ex O. Berg.	Bugflies	Lecythidaceae	Tree
Haemanthus mutliflorus Martyn ex Willd.	Agniglock	Liliaceae	Herb
Hedychium coccineum Buch. - Hum. ex Smith	Sagor pakhi	Zingiberaceae	Herb
Hedychium coronarium Koen.	Dolon chapa	Zingberaceae	Herb
Helianthus annuus L.	Surjamukhi	Asteraceae	Herb
Helianthus debilis Nutt.	Shasapati mukhi	Asteraceae	Herb
Heliconia latispatha Benth.	Haludkakramoni	Heliconiaceae	Herb
Heliconia metallica Planch. & Linden ex Hook.	Swaraga pakhi	Heliconiaceae	Herb
Heliconia psittacorum L. f.	Tiathuti	Heliconiaceae	Herb

Contd.

Name	Bangla name	Family	Habit
Heliconia rostrata Ruiz & Pavon	Chingrinomi	Heliconiaceae	Herb
Heliotropium indicum L.	Hatisur	Boraginaceae	Herb
Hemerocallis fulva L.		Liliaceae	Herb
Heritiera fomes Buch. – Hum.	Sundari	Sterculiaceae	Tree
Hertiera littoralis (Dryand.) Ait.	Sundari	Sterculiaceae	Tree
Hevea brasiliensis (Willd. ex A. Juss.) Muell. – Arg.	Rabar	Euphorbiaceae	Tree
Hibiscus mutabilis L.	Jaba	Malvaceae	Shrub
Hibiscus rosa-sinensis L.	Jaba	Malvaceae	Shrub
Hibiscus schizopetalus (Mast.) Hook. f.	Jaba	Malvaceae	Shrub
Hibiscus syriacus L.	Jaba	Malvaceae	Shrub
Holarrhena pubescens Wall. ex G. Don	Kurchi	Apocynaceae	Tree
Hopea odorata Roxb.	Telsur	Dipterocarpaceae	Tree
Houttuynia cordata Thunb.	Aistya nagini	Saururaceae	Herb
Hoya parasitica (Roxb.) Wall. ex Wight	Chera pata	Asclepiadaceae	Climber
Hydnocarpus kurzii (King) Warb.	Chalmugra	Flacourtiaceae	Tree
Hydrangea macrophylla (Thunb.) Serin	Hydrangea	Hydrangeaceae	Herb
Hyptis sauveolens (L.) Poit.	Tokma	Lamiaceae	Herb
Impatiens balsamina L.	Doparti	Balsamiaceae	Herb
Impatiens chinensis L.	Dupatra	Balsamiaceae	Herb
Imperata cylendrica (L.) P.Beauv.	Uluchan	Poaceae	Herb
Ipomoea aquatic Forssk.	Kalmi	Convolvulaceae	Herb
Ipomoea batatas (L.) Lamk.	Misteealu	Convolvulaceae	Climber
Ipomoea fistulosa Mart. ex Choisy	Dolkolmi	Convolvulaceae	Herb
Ipomoea indica (Burm. f.) Merr.	Deshi kalmi	Convolvulaceae	Climber
Ipomoea purpurea Roth	Beguni kalmi	Convolvulaceae	Climber
Ipomoea quamoclit L.	Gatephul	Convolvulaceae	Climber
Ixora chinensis Lamk.	Rangon	Rubiaceae	Shrub
Ixora coccinea L.	Rangan	Rubiaceae	Shrub
Ixora rosea Siams.	Rangan	Rubiaceae	Shrub
Jacaranda mimosifolia D. Don.	Jekeranda	Bignoniaceae	Tree
Jasminum auriculatum Vahl	Jui	Oleaceae	Climber
Jasminum gradiflorum L.	Chameli	Oleaceae	Climber
Jasminum multiflorum (Burm. f.) Andr.	Chameli	Oleaceae	Climber
Jasminum sambac (L.) Ait.	Bali	Oleaceae	Climber
Jatropha curcas L.	Baghverenda	Euphorbiaceae	Shrub
Jatropha gossypifolia L.	Jatropa	Euphorbiaceae	Shrub
Jatropha integerrima Jacq.	Jayati	Euphorbiaceae	Shrub
Justicia gendarussa Burm. f.	Jagathmordan	Acanthaceae	Shrub
Kaemperia rotunda L.	Buichapa	Zingiberaceae	Herb
Kalanchoe blossfeldiana V. Poelln.	Lalpatharkuchi	Crassulaceae	Herb
Kalanchoe laciniata (L.) Pers.	Himsagar	Crassulaceae	Herb
Khaya anthotheca (Welw.) C.DC.	Lambu	Meliaceae	Tree
Kigelia africana (Lam.) Benth.	Sausage tree	Bignoniaceae	Tree
Kyllinga brevifolia Rottb.	Mraa-shey	Cyperaceae	Herb

Contd.

Name	Bangla name	Family	Habit
Laffa cylindrica M.Roem.	Dundul	Cucurbitaceae	Climber
Lagerstroemia macrocarpa Wall.	Betuajarul	Lythraceae	Tree
Lagerstroemia speciosa (L.) Pers.	Jarul	Lythraceae	Tree
Lagerstroemia thorelli Gagnep.	Jarul	Lythraceae	Tree
Lagerstromia indica L.	Pink Cheri	Lythraceae	Shrub
Lannea coromandelica (Houtt.) Merr.	Bhadi	Anacardiaceae	Tree
Lantana camara L.	Lantana	Verbenaceae	Herb
Laportea interrupta (L.) Chew	Lalbichuti	Urticaceae	Herb
*Lawsonia inermis*L.	Mehedi	Lythraceae	Shrub
Leea macrophylla Roxb. ex Hornem.	Haustikorna	Leeaceae	Herb
Lemonia acidissima L.	Kaudbel	Rutaceae	Tree
Leonurus sibiricus L.	Roktodron	Lamiaceae	Herb
Leucaena leucocephala (Lamk.) de Wit	Epilepil	Mimosaceae	Tree
Leucas lavandulaefolia Smith	Dandakalash	Lamiaceae	Herb
Licuala grandis H. Wendl.	Kurujpata	Arecacaeae	Shrub
Limnocharis flava (L.) Buchen. In Bremen	Letuce pana	Limnocharitaceae	Herb
Litchi chinensis Sonn.	Lichu	Sapindaceae	Tree
Litsea glutinosa (Lour.) Robinson	Menda	Lauraceae	Tree
Litsea monopetala (Roxb.) Pers.	Huaria	Lauraceae	Tree
Livistona chinensis R. Br.	China tokopata	Arecacaeae	Shrub
Lobelia radicans Thunb.	Radhika lobel	Campanulaceae	Herb
Lonicera japonica Thunb.	Modhu lonicera	Caprifoliaceae	Climber
Macaranga peltata (Roxb.) Muell. – Arg.	Bora	Euphorbiaceae	Tree
Madhuca indica Gmel.	Mohua	Sapotaceae	Tree
Magnolia grandiflora L.	Udaychampa	Magnoliaceae	Tree
Magnolia pterocarpa Roxb.	Dulichampa	Magnoliaceae	Tree
Malpigia coccigera L.	Kanta malphigia	Malpigiaceae	Shrub
Malvaviscus arboreus Cav.		Malvaceae	Shrub
Mangifera indica L.	Aam	Anacardiaceae	Tree
Mangifera sylvatica Roxb.	Uriam	Anacardiaceae	Tree
Manihot esculenta Crantz	Kasava	Euphorbiaceae	Shrub
Manilkara zapota (L.) P. van Royen	Sofeda	Sapotaceae	Tree
Mansoa alliacea (Lamk.) A.H. Gentry	Rasun lata	Bignoniaceae	Climber
Maranta arundinacea L.	Arrarot	Marantaceae	Herb
Melia sempervirens (L.) Sw.	Gora neem	Meliaceae	Tree
Mellettia peguensis Ali	Millettia	Fabaceae	Tree
Melocanna baccifera (Roxb.) Kurz	Mulibans	Poaceae	Shrub
Melotia corchorifolia L.	Tikiokra	Sterculiaceae	Herb
*Memecylon edule*Roxb.	Enjan	Melastomaceae	Shrub
Mesua nagassarium (Burm. f.) Kosterm	Nageshor	Clusiaceae	Tree
Michelia champaca L.	Sharna chapa	Magnoliaceae	Tree
Millingtonia hortensis L. f.	Akash Neem	Bignoniaceae	Tree
Mimosa diplotricha C. Wright ex Sauv.	Lazzabati	Mimosaceae	Herb

Contd.

Name	Bangla name	Family	Habit
Mimosa pudica L.	Lazzabati	Mimosaceae	Herb
Mimusops elengi L.	Bakul	Sapindaceae	Tree
Mirabilis jalapa L.	Sandhyamalati	Nyctaginaceae	Herb
Molineria recurvate (Dryand.) Herbert.	Sati pata	Liliaceae	Herb
Momordica cochinchinensis (Lour.) Spreng.	Kakrol	Cucurbitaceae	Climber
Moras alba L.	Tut	Moraceae	Tree
*Morinda angustifolia*Roxb.	Rong gash	Rubiaceae	Shrub
Moringa oleifera Lamk.	sajina	Moringaceae	Tree
Murraya koenigii (L.) Spreng.	Karipata	Rutaceae	Shrub
Murraya paniculata (L.) Jack	Kamini	Rutaceae	Tree
Musa paradisiacal L.	Kach kola	Musaceae	Herb
Musa sapientum L.	kola	Musaceae	Herb
Mussaenda frondosa L.	Nagaboli	Rubiaceae	Shrub
Mussenda erythrophylla Schum. & Thonn.	Lalmussenda	Rubiaceae	Shrub
Mussenda glabra Vahl	Mussenda	Rubiaceae	Herb
Nelumbo nucifera Gaertn.	Padma	Nelumbonaceae	Herb
Neolamarkia cadamba (Roxb.) Bosser	Cadam	Rubiaceae	Tree
Nephelium lappaceum L.	Rambuthan	Sapindaceae	Tree
Neptunia oleracea Lour.	Panilazzabati	Mimosaceae	Herb
Nerium oleander L.	Roktakarobi	Apocynaceae	Shrub
Nicotiana plumbaginifolia Viv.	Botamak	Solanaceae	Herb
Nyctanthes arbor-tristis L.	Shephaly	Oleceae	Shrub
Nymphaea capensis Thunb.	Nil-shapla	Nymphaeaceae	Herb
Nymphaea rubra Roxb. ex Andr.	Lalshapla	Nymphaeaceae	Herb
Ocimum americanum L.	Ramtulsi	Lamiaceae	Herb
Ocimum basilicum L.	Babuitulsi	Lamiaceae	Herb
Ocimum tenuiflorum L.	Kalotulsi	Lamiaceae	Herb
Oplismenus burmanii (Retz.) P. Beauv.	Jabridurba	Poaceae	Herb
Opuntia dillenii Haw.	Phanimanasa	Cactaceae	Herb
Oroxylum indicum (L.) Kurz	Thona	Bignoniaceae	Tree
Oxalis corymbosa DC.	Golapiamrul	Oxalidaceae	Herb
Oxalis latifolia H. B. & K.	Amrul	Oxalidaceae	Herb
Paederia foetida L.	Gandhaveduli	Rubiaceae	Climber
Pancratium verecundum Ait.	Gor-rashun	Liliaceae	Herb
Pandanus foetidus Roxb.	Keya	Pandanaceae	Shrub
Passiflora coccinea Aublet	Laljhumko lata	Passifloraceae	Climber
Passiflora edulis Sims	Tankfal	Passifloraceae	Climber
Passiflora suberosa L.	Mela jhumka	Passifloraceae	Climber
Pavetta indica L.	Kathchapa	Rubiaceae	Shrub
Pedilanthus tithymaloides Poit.	-	Euphorbiaceae	Herb
Peltophorum pterocarpum (DC.) K. Heyne	Halud krishnachura	Caesalpiniaceae	Tree
Pentas lanceolata (Forssk.) Deflers	Pentus	Rubiaceae	Herb
Peperomia pellusida (L.) H.B. & K.	Peperomia	Peperomiaceae	Herb
Persea Americana P. Mill.	Avocado	Lauraceae	Tree

Contd.

Name	Bangla name	Family	Habit
Petra volubilis L.	Nilmonilota	Verbenaceae	Climber
Phaius tankervillii (Banks ex L'Her.) Blume	Tankaphai orchid	Orchidaceae	Herb
Phlogacanthus thyrsiformis Roxb. ex D.J. Mabberley	Rambashak	Acanthaceae	Shrub
Phlox drummondii Hook.	Phlox	Polygalaceae	Herb
Phoenix sylvestris Roxb.	Khejur	Arecaceae	Shrub
*Pholidota pallida*Sensu Holttum	Porgasha	Orchidaceae	Epiphyte
Phyllanthus acidus (L.) Skeels	Orbori	Euphorbiaceae	Tree
Phyllanthus emblica L.	Amloki	Euphorbiaceae	Tree
Phyllanthus niruri L.	Bhuaimla	Euphorbiaceae	Herb
Phyllanthus reticulates Poir.	Sitki	Euphorbiaceae	Shrub
Physalis minima L.	Potpoti	Solanaceae	Herb
Pilea microphylla (L.) Leibm.	Latamaricha	Urticaceae	Herb
Pinus caribaea Morelet	Pine	Pinaceae	Tree
Pinus kesiya Royle ex Gordon	Pine	Pinaceae	Tree
Piper betle L.	Pan	Piperaceae	Climber
Piper chaba Hunter	Chui	Piperaceae	Climber
Piper longum L.	Pipul	Piperaceae	Herb
Piper nigram L.	Goalmorich	Piperaceae	Climber
Pithecellobium dulce (Roxb.) Benth	Khaibabla	Mimosaceae	Tree
Pitunia hybrid Hort. ex Vilm.	Pitnia	Solanaceae	Herb
Plumbago capensis Thunb.	Nilcheeta	Plumbaginaceae	Herb
Plumbago zeylanica L.	Chita	Plumbaginaceae	Herb
Plumeria alba L.	Gorurchampa	Apocynaceae	Tree
Plumeria obtuse L.	Katgolap	Apocynaceae	Tree
Plumeria rubra L.	Katgolap	Apocynaceae	Tree
Podocapus neriifolius D. Don	Banspata	Podocarpaceae	Tree
Pogostemon parviflorus Benth.	Nugpachuli	Lamiaceae	Herb
Polyalthia longifolia (Sonn.) Thw.	Debdaru	Annonaceae	Tree
Polyalthia penduriformis	Debdaru	Annonaceae	Tree
Pongamia pinnata (L.) Pierre	Koroj	Fabaceae	Tree
Portulaca grandiflora Hook.	Chotoluinna	Portulacaceae	Herb
Pothos scandens L.	Sunat	Araceae	Climber
Pouzolzia zeylanica (Linnaeus) Bennett	Cylonizolzi	Urticaceae	Herb
Premna bengalensis C.B. Clarke	Pakihara	Verbenaceae	Tree
Premna esculenta Roxb.	Lalongpata	Verbenaceae	Shrub
Psidium araca Raddi	Tokpeara	Myrtaceae	Shrub
Psidium Chinense Lodd. ex Loud.	Chinese peara	Myrtaceae	Shrub
Psidium guajava L.	Peara	Myrtaceae	Tree
Psilotrichum ferrungineum (Roxb.) Moq. – Tand.	Putishak	Amaranthaceae	Herb
*Pterocarpus indicus*Willd.	Padauk	Fabaceae	Tree
Pterygota alata (Roxb.) R. Br.	Buddhu narikel	Sterculiaceae	Tree
Ptychosperma macarthurii (Becc. ex Rader Macher) H. Wendl.	Arhtar palm	Arecacaeae	Herb
Punica granatum L.	Dalim	Punicaceae	Shrub

Contd.

Name	Bangla name	Family	Habit
Putranjiva roxburghii Wall.	Zeaputa	Euphorbiaceae	Tree
Quisqualis indica L.	Madhurilata	Combretaceae	Climber
Rauvolfia tetraphylla L.	Bara chadar	Apocynaceae	Shrub
Rauwolfia serpentine (L.) Benth. ex Kurz	Sarpagandha	Apocynaceae	Herb
Ravenala madagascariensis J.F. Gmel.	Panthpadap	Strelitziaceae	Herb
Rhaphidophora aurea (Linden & Andr) Birdsey	Money plant	Araceae	Climber
Rhaphidophora pertusa (Roxb.) Schott	Tusafido	Araceae	Climber
Rhapis excels Henry ex Rehder	Gurital	Arecacaea	Shrub
Rhynchostylis retusa (L.) Blume	Porgasha	Orchidaceae	Epiphyte
Ricinus communis L.	Bherenda	Euphorbiaceae	Shrub
Rivina humilis L.	Raivina	Phytolaccaceae	Herb
Rosa alba L.	Sadagolap	Rosaceae	Shrub
Rosa centifolia L.	Pink golap	Rosaceae	Shrub
Rosa chinensis Jacq.	Kantagolap	Rosaceae	Shrub
Rosa damascenes Mill.	Golap	Rosaceae	Shrub
Roystonia regia O.F. Cook	Royel pum	Arecaceae	Shrub
Ruellia malacosperma Greenm.	Malaghatni	Acanthaceae	Herb
Ruellia tuberose L.	Chatpoty	Acanthaceae	Herb
Salvia splendens Sellow ex Roem. & Schult	Shumo salvia	Lamiaceae	Herb
Samanea saman (Jacq.) Merr.	Rain tree	Mimosaceae	Tree
Santalum album L.	Chandan	Santalaceae	Tree
Sapindus danura (Roxb.) Voigt	Sapindus	Sapindaceae	Shrub
Sapindus saponaria L.	Ritha	Sapindaceae	Tree
Saraca indica L.	Ashok	Fabaceae	Tree
Scoparia dulcis L.	Bondhane	Scrophulariaceae	Herb
Senna siamea (Lamk.) Irwin & Barneby	Minjori	Caesalpiniaceae	Tree
Senna surattensis (Burm.f.) Irwin & Barneby	Suratisena	Caesalpiniaceae	Shrub
Senna tora (L.) Roxb.	Terasena	Caesalpiniaceae	Herb
Sequoia sempervirens (D. Don) Endl.	Redwood tree	Cupressaceae	Tree
Sesamum indicum L.	Til	Pedaliaceae	Herb
Sesbania grandiflora (L.) Poir.	Bakful	Fabaceae	Shrub
Sida cordifolia L.	Bala	Malvaceae	Herb
Sida rhombifolia L.	Kureta	Malvaceae	Herb
Smilax perfoliata Lour.	Kumarilata	Smilacaceae	Climber
Smilax zeylanica L.	Kumarilata	Smilacaceae	Climber
Solanum melongena L.	Begun	Solanaceae	Herb
Solanum nigrum L.	Titbegun	Solanaceae	Herb
Solanum sissymbrifolium Lamk.	Kanta begun	Solanaceae	Herb
Solanum torvum Swartz	Gotabegun	Solanaceae	Shrub
Spathiphyllum wallisii Regel	Shanto lily	Araceae	Herb
Spathodea campanulata Beauv.	Pakhiful	Bignoniaceae	Tree
Spathoglottis plicata Blume	Kantaglotis	Orchidaceae	Herb

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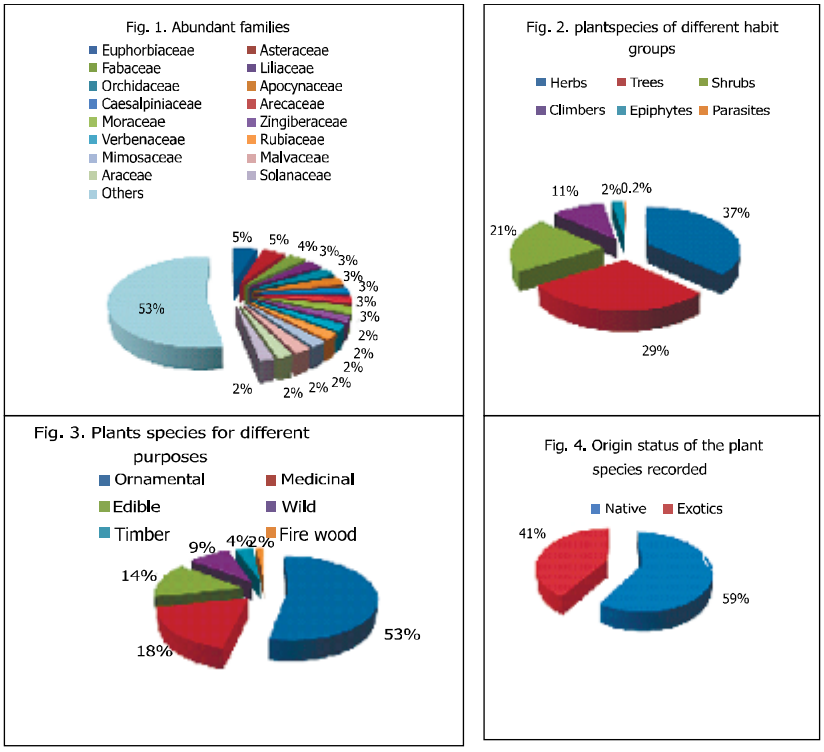
Name	Bangla name	Family	Habit
Spilanthes acmella auct. Non L., Thw.	Marhatitiga	Asteraceae	Herb
Spondias pinnata (L.f.) Kurz	Amra	Anacardiaceae	Tree
Stemona tuberose Lour.	Lalguranialu	Stemonaceae	Climber
Sterculia foetida L.	Jonglibadam	Sterculiaceae	Tree
Sterculia villosa Roxb. ex Smith	Udal	Sterculiaceae	Tree
Stereospermum personatum (Hassk.) Chatterjee	Parul	Bignoniaceae	Tree
Streblus asper Lour.	Shewra	Moraceae	Tree
Strelitzia reginae Ait.	Sarger pakhi	Strelitziaceae	Herb
Strychnos nux-vomica L.	Nuxvom	Loganiaceae	Tree
Swietenia macrophylla King	Mehegoni	Meliaceae	Tree
Swietenia mahagoni Jacq.	Mehegoni	Meliaceae	Tree
Swintonia floribunda Griff.	Civit	Anacardiaceae	Tree
Synedrella nodiflora (L.) Gaertn.	Relanodi	Asteraceae	Herb
Syngonium macrophyllum Engl.	Baroslatakachu	Araceae	Climber
Syngonium podophyllum Schott	Podolata kachu	Araceae	Herb
Syzygium aqueum (Burm.f.) Alston	Jambo	Myrtaceae	Tree
Syzygium cumini (L.) Skeels	Kalo-jam	Myrtaceae	Tree
Syzygium jambos (L.) Alston	Golap-jam	Myrtaceae	Tree
Syzygium samarangense (Blume) Marr. & Perry	Jamrul	Myrtaceae	Tree
Tabernaemontana corymbosa Roxb. ex Wall.	Tagor	Apocynaceae	Shrub
Tabernaemontana divaricata (L.) R. Br. ex Roem. & Schult.	Tagor	Apocynaceae	Shrub
Tacca chantrieri Andr.	Tacca	Taccaceae	Herb
Tacca integrifolia Ker- Gawl.	Tacca	Taccaceae	Herb
Tacca plantaginea (Hance) Drenth	Tacca	Taccaceae	Herb
Tagetes erecta L.	Gada	Asteraceae	Herb
Tagetes patula L.	Gada	Asteraceae	Herb
Tamarindus indica L.	Tetul	Caesalpiniaceae	Tree
Tectona grandis L. f.	Segun	Verbenaceae	Tree
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Arjun	Combretaceae	Tree
Terminalia bellirica (Gaertn.) Roxb.	Bohera	Combretaceae	Tree
Terminalia catappa L.	Katbadam	Combretaceae	Tree
Terminalia chebula Retz.	Horitaki	Combretaceae	Tree
Tetrastigma angustifolium (Roxb.) Planch.	Sarupati lata	Vitaceae	Climber
Theobroma cacao L.	Coco	Byttneriaceae	Shrub
Thevetia peruviana (Pers.) K. Schum.	Haldekarobi	Apocynaceae	Shrub
Thuja orientalis (L.) Franco	Thuja	Cupressaceae	Shrub
Thunbergia erecta (Benth.) T. Anders.	Nilghanta	Acanthaceae	Shrub
Tinospora cordifolia (Willd.) Hook.f. & Thoms.	Gulancha	Menispermaceae	Climber
Tinospora crispa (L.) Hook.f. & Thoms	Gulancha	Menispermaceae	Climber

Contd.

Name	Bangla name	Family	Habit
Tithonia tagetiflora Desf.	Arora	Asteraceae	Herb
Toona ciliate M. Roem.	Toon	Meliaceae	Tree
*Torenia fournieri*Lind. ex tourn.	-	Scrophulariaceae	Herb
Trema orientalis (L.) Blume	Jibon	Ulmaceae	Tree
Tridax procumbens L.	Tridara	Asteraceae	Herb
Triumfetta rhomboidea Jacq.	bonokra	Tiliaceae	Herb
Tropaeolum majus L.	Tropaeolum	Tropaeolaceae	Herb
Typhonium trilobatum (L.) Schott	Ghetukachu	Araceae	Herb
Uraria crinita (L.) Desv. ex DC.	Diangleja	Fabaceae	Herb
Uraria picta (Jacq.) Desv. ex DC.	Sankarjata	Fabaceae	Herb
Urena lobata L.	Bonokra	Malvaceae	Herb
Urginea indica (Roxb.) Kunth	Beach piaz	Liliaceae	Herb
Vanda tassellata (Roxb.) Hook.f. ex G.Don	Porgasha	Orchidaceae	Epiphyte
Vanda teres (Roxb.) Lindl.	Porgasha	Orchidaceae	Epiphyte
Vandopsis gigantean (Lindl.) Pfitz	Porgasha	Orchidaceae	Epiphyte
Vanilla parishii Reichb.f.	Vanila	Orchidaceae	Climber
Vernonia patula (Aiton) Merrill	Saravarnon	Asteraceae	Herb
Vitex negundo L.	Nishinda	Verbenaceae	Shrub
Vitex trifolia L.f.	Neelnishinda	Verbenaceae	Shrub
Vitis vinifera L.	Angur	Vitaceae	Climber
Wedelia chinensis (Osbeck) Merr.	Bhimraj	Asteraceae	Herb
Wedelia trilobata (L.) A.S. Hitech.	Wadella	Asteraceae	Herb
Willoughbeia edulis Roxb.	Lotaam	Apocynaceae	Climber
Wrightia coccinea (Roxb.) Sims	Pallam	Apocynaceae	Tree
Xanthium indicum Koen.ex Roxb.	Ghagra	Asteraceae	Herb
Xanthosoma violaceum Schott	Dudkachu	Araceae	Herb
Zanthoxylum rhetsa (Roxb.) DC.	Bajna	Rutaceae	Tree
Zephyranthes candida (Lindl.) Herbert	Sada gahsful	Liliaceae	Herb
Zephyranthes minuta (Kunth) D. Dietr	Golapi gashful	Liliaceae	Herb
Zephyranthes tubispatha (L'Her.) Herbert ex Traub	Holde gashful	Liliaceae	Herb
Zingiber montanum (Koen.) Dietr.	Bonada	Zingiberaceae	Herb
Zingiber officinale Rosc.	Ada	Zingiberaceae	Herb
Zingiber zerumbet (L.) Smith	Ekangi	Zingiberaceae	Herb
*Zinia elegans*Jacq.	Zinia	Asteraceae	Herb
Zinia pauciflora L.	Zinia	Asteraceae	Herb
Ziziphus mauritiana Lamk.	Boroi	Rhamnaceae	Tree
Ziziphus oenoplia (L.) Mill.	Bonboroi	Rhamnaceae	Shrub
Ziziphus rugosa Lamk.	Bonboroi	Rhamnaceae	Shrub

Diospyros malabarica (Deshigab), *Garcinia cowa* (Kao), *Baccaurea ramiflora* (Lotkon), *Sterculia villosa* (Udal), and *Sterculia foetida* (Basketbadam) were also observed. The oldest trees in the campus mainly are *Samanea saman* (Rain tree), *Albizia rechardiana* (Rajkoroi), *Polyalthia longifolia* (Debdaru), *Hopea odorata* (Telsur), *Ptercarpus indica* (Padauk), *Mangifera indica* (Aam), *Petrigota alata* (BuddaNarikel), *Cocos nucifera*

(Narikel), *Swietenia mahagoni* (Mahogany), *Tamarindus indica* (Tamarind), *Roystenia regia* (Royal palm) and *Diospyros malabarica* (Dehsigab). Some plants in the campus play an important role to promote biodiversity by providing resting, nesting and feeding sites. Most noteworthy species is *Hopea odorata* that provides resting and nesting sites for kites whereas *Litsea glutinosa, Butea monosperma and Ficus benghalensis* provide feeding sites to a good number of native birds. The DU campus also serves as refuge center for many rare, exotic and threatened species (Plate 1).



The present floristic survey in the campus is very preliminary in nature. Record of 541species in a small land of DU campus is the indication richness in one component of diversity. However, extensive and intensive survey may increase the total number of species in the campus area. The individual representation in the species is very unequal. This is because of preference in the choice to select individuals for plantation. Long term study is needed to make distribution map of all tree species in the campus using GIS techniques. It is very difficult to make sound conclusion based on the present results. DU campus can be served as the refuge centre for the threatened plants of Bangladesh.

Plate 1. Some rare, exotic and threatened species planted and growing in DU campus.

As the area is protected, priority should be given on native threatened plant species during plantation. Presence of exotic plant species in the campus area is the challenge for future natural environment of campus. Gradually exotic replacement can be done by planting native multipurpose plant species. Some first growing soft wood trees are found in the campus area. Such species creates hazard to students and public life during natural disasters and even causes of death. Immediate management plan should be taken for those species. If necessary, cutting, treming, dressing and even replacement can be done. To increase the aesthetic view of the campus, plant species with different flowering times should be planted. Plant taxonomist should be involved in the management committee to look after the plant diversity in the campus.

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EFFECTS OF NAA AND DIFFERENT NITROGEN LEVELS ON NUTRIENT UPTAKE BY BARI GOM-26 (TRITICUM AESTIVUM L.)

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Abstract

An experiment was conducted to evaluate the effects of NAA (0, 25, 50 ppm) at varying nitrogen levels (0, 50, 75, 100 % of the recommended dose) on nitrogen (N), phosphorus (P) and potassium (K) uptake by shoot and root and percentage of total NPK uptake by BARI Gom-26 at flowering and grain filling stage. Application of NAA at varying nitrogen levels had significant effect on P and K uptake by shoot and root at both stages, whereas, the N content of shoot at flowering stage and of root at the grain filling stage were non-significant.At both the stages, K content of root increased following all the treatments. At flowering and grain filling stage, P content of root and shoot increased and decreased due to different treatments. The maximum percentage of total NPK uptake was recorded from K followed by N and P respectively at both stages. In majority cases there was a decreasing trend in percentage uptake of N and P at grain filling stage compared with flowering stagewhereas, the trend was almost reverse in case of K. The N content of grain increased following all the treatments, the maximum being due to 25 ppm NAA in combination with 75 % N-fertilizer. Only decrease in P content of grain was recorded when 25 ppm NAA without any N-fertilizer was applied. In case of K content, 50 ppm NAA without any N-fertilizer resulted the only decrease. The highest nitrogen use efficiency (NUE) by total plant was also recorded from 50 ppm NAA in combination with 50 % N-fertilizer at flowering stage, whereas, from 25 ppm NAA in combination with 75 % N-fertilizer at grain filling stage.

Key words: BARI Gom-26, NAA, Nitrogen levels, Foliar application, Nutrient uptake

Introduction

Intensive high yield agriculture is largely dependent on addition of fertilizers, especially industrially produced nitrogenous one as it is the major factor limiting yield of crops including wheat(Tilman*et al*. 2002 and Andrews *et al*. 2004). Farmers generally use excess fertilizer for better production. Chemical fertilizers often have low use efficiency and plants cannot uptake all the nutrients beyond its capacity. There must be a balance between nitrogen use efficiency and optimal crop productivity. Currently about 30-50 % of applied nitrogen fertilizer is taken up by crops and the remainder accumulates in excess in terrestrial and aquatic ecosystems and in the troposphere(Smil 1999 and Cassman*et al*. 2002). These excessnitrogen also reduce farmers' profits, as optimal yields

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are not achieved. On the other hand, plants that efficiently absorb and use nutrients greatly enhance the overall efficiency of applied fertilizers, reducing cost of inputs and preventing loss of nutrients to ecosystem (Baligar*et al*. 2001). As a result, lowering fertilizer input and maximizing nitrogen use efficiency (NUE) needs due attention all over the world. Naphthalene acetic acid (NAA), a synthetic growth regulator at appropriate concentration is known to affect growth, development and other physiological and biochemical processes of cereal crops (Sing and Gill 1985, Jahan and Adam 2011, 2013 and 2014). But,reports regarding the effect of NAA on nutrient content and uptake by cereal crops are meager (Adam *et al*. 2012). Application of NAA in combination with various nitrogen levels can play important role in reducing production cost of crops as well as balance use for better results both commercially and environmentally. Thus an experiment was carried out to investigate the effects of NAA in combination with varying nitrogen levels on the nutrient content and uptake by BARI GOM-26.

Materials and Methods

A field experiment was carried out at the Botanical garden of the University of Dhaka during November 2014 to March 2015. Seeds of BARI Gom-26 were collected from BARI (Bangladesh Agricultural Research Institute), Joydebpur, Gazipur. Itis a high yielding, heat tolerant variety recommended for Rabi season and was released in 2010. The experimental soil was analyzed and high levels of phosphorus and low levels of nitrogen and potassium were recorded(Fertilizer Recommendation Guide 2012). Cow-dung, TSP, MP and gypsum were applied as basal dose during land preparation. The experiment was laid out in RCBD with five replications. There were three concentrations of NAA *viz*.G_0= without NAA, G_1=25 ppm NAA and G_2= 50 ppm NAA, and four levels of N-fertilizer *viz*. F_0= without any N-fertilizer, F_1= 50 % of the recommended dose, F_2= 75 % of the recommended dose and F_3= full recommended dose of N-fertilizer (urea). As such there were 12 treatment combinations. Two-thirds of the urea was used as basal and the rest one-third was applied at 25 days after sowing. Seeds were sterilized with 0.05 % calcium hypochlorite solution and were sown on November 8, 2014. Plant to plant distance was 10 cm. Thinning was done at the age of 18 days.Weeding was done fortnightly starting from the age of 18 days.Irrigations were also done as per the necessity. Treatments were applied as foliar spray at the age of 30 days. Dry shoot and root were crushed and then used for the determination of Nitrogen (N), phosphorus (P) and potassium (K) content at flowering and grain filling stages whereas, those of grain were determined after harvest. The N, P and K contents of shoot, root and grain were determined by micro-Kjeldalh's method, vanadate-molybdate yellow color method and flame photometer respectivelyas modified by Huq and Alam (2005). Uptake of NPK of shoot and root and nitrogen use efficiency were calculated using the formula of Nyborg*et al*.(1995). Data were analyzed statistically(Steel *et al*. 1997) and treatment means were compared by LSD test at 5 % level of significance.

Results and Discussion

Results presented in Table 1 show that application of NAA at varying nitrogen levels had significant effect on P and K uptake by shoot and root at flowering and grain filling stages. However, N content of shoot at the flowering stage and root at the grain filling stage were non-significant. The N content of root at the flowering stage and that of shoot and root at the grain filling stage increased due to all the treatments. The maximum N content of root at the flowering and grain filling stage was due to 50 % N-fertilizer (without NAA) and 25 ppm NAA in combination with 75 % N-fertilizer respectively. Highest N content of shoot at the flowering and grain filling stage was due to 50 ppm NAA in combination with 50 % N-fertilizer and 25 ppm NAA in combination with 75 % N-fertilizer respectively. At both the stages, K content of root increased following all the treatments. Maximum K content of root recorded at the flowering and grain filling stages was due to 75 % N-fertilizer (without NAA) and 25 ppm NAA in combination with 75 % N-fertilizer respectively. Both increase and decrease in P content of root and shoot at the flowering and grain filling stage were recorded due to different treatments. However, maximum P content of root due to 25 ppm NAA in combination with 75 % N-fertilizer was recorded only in case of root at the flowering stage. The favorable effect of NAA in enhancing the nutrient uptake was reported in cotton (Patel 1992), in fenugreek (Purbey and Sen 2007), in green gram (Rahman and Venkatrama 2006) and in rice (Adam *et al*. 2012). Increased and decreased uptake of N, P and K due to application of different nitrogen levels in wheat were also reported by Chaturvedi (2006), Kumbhar*et al*. (2007) and Laghari*et al*. (2010). Thus, the results are in agreement with the findings of previous workers.However, no reports are available on N, P and K uptake by wheat following application of NAA in combination with nitrogen levels.

Findings of this investigation also indicated that the maximum percentage uptake was recorded from K followed by N and P respectively in both the stages (Fig.1). This findings also showed a decreasing tendency in percentage N and P uptake in most cases of grain filling stage compared to flowering stage. However, reverse trend was found in case of K uptake where, percentage uptake of K was recorded higher in grain filling stage except two treatments (G_0F_3, G_1F_0). At the flowering stage, treatment means varied significantly in case of percentage P uptake, whereas, at the grain filling stage, significant variations were observed in case of percentage N uptake. The reason for decreasing percentage uptake of N and P at grain filling stage might be due to the transport of N and P into developing seed(Chapin and Wardlaw 1988). The consistently increased percentage uptake of K by BARI Gom-26 up to grain filing stage might be due to the fact that K maintains water balance and promotes energy generation which is required for moving nutrients in the plant and uptake of other nutrients. Jones *et al*. (2009) also

Table 1. Effects of NAA at varying nitrogen levels on N, P and K uptake by shoot and root of BARI Gom-26 at two different stages.

Treatments	Flowering stage						Grain filling stage					
	Shoot			Root			Shoot			Root		
	N	P	K	N	P	K (mg/plant)	N	P	K	N	P	K
G_0F_0	31.07	12.47 c-g	49.98 de	0.67 h	0.24 g	0.04 c	19.19 h	17.28bc	80.38 d-g	1.67	0.37 f	0.05 i
G_0F_1	35.2	18.29 ab	92.22 ab	2.83 a	0.33 d	0.05 c	36.91 c-h	10.60 cd	126.45abc	3.19	0.55 b	0.33 d-i
G_0F_2	35.71	8.07 f-i	71.31 a-e	2.03 a-f	0.21 hi	0.19 a	41.11 b-g	10.00 cd	137.17 a	2.33	0.41 e	0.53 c-g
G_0F_3	46.47	21.15 a	92.20 abc	2.75 ab	0.36 e	0.05 c	49.34 b-e	16.35bcd	79.74 d-g	3.55	0.53 b	0.55 cde
G_1F_0	37.23	11.46 c-i	73.85 a-e	1.18 e-h	0.28 ef	0.04 c	31.09 e-h	9.64 cd	63.84 g	2.00	0.48 c	0.17 hi
G_1F_1	33.09	12.43 c-h	53.56 de	1.31 d-h	0.22 gh	0.10 b	57.91 ab	15.31bcd	97.36 a-g	4.08	0.49 c	0.54 c-f
G_1F_2	43.18	16.57 abc	78.55 a-d	2.65 abc	0.41 a	0.06 bc	71.52 a	12.92bcd	124.08 a-d	4.59	0.44 d	1.34 a
G_1F_3	39.45	15.06 bcd	41.45 e	1.21 e-h	0.15 j	0.08 bc	55.42 abc	27.70 a	122.8 a-f	3.02	0.41 e	0.63 cd
G_2F_0	20.16	6.83 i	41.44 e	0.69 h	0.17 j	0.10 b	25.55 fgh	8.63 d	76.73 d-g	2.01	0.38 f	0.08 hi
G_2F_1	55.94	14.52 b-e	98.77 a	2.09 a-e	0.40 ab	0.10 b	53.96 a-d	16.69bcd	135.92 ab	3.49	0.92 a	1.23 ab
G_2F_2	43.07	12.96 b-f	57.79 b-e	2.32 a-d	0.27 ef	0.05 c	33.09 e-h	11.25bcd	96.76 a-g	3.24	0.30 g	0.40 d-h
G_2F_3	31.57	11.43 c-i	64.37 a-e	1.89 a-g	0.29 e	0.19 a	43.28 b-f	21.38 b	122.83 a-e	3.26	0.44 d	0.79 c
CV (%)	31.57	32.26	33.84	46.51	30.66	61.93	48.96	44.07	28.86	42.02	32.14	79.55
LSD (0.05)	NS	5.44	34.99	1.03	0.02	0.04	20.77	10.37	50.90	NS	0.02	0.34

*Means in a vertical column followed by same letter do not differ significantly at 5 % level.

reported that very little of the accumulated K is used for grain filling in wheat. However, the overall NPK uptake by both shoot and root increased considerably at grain filling stage.

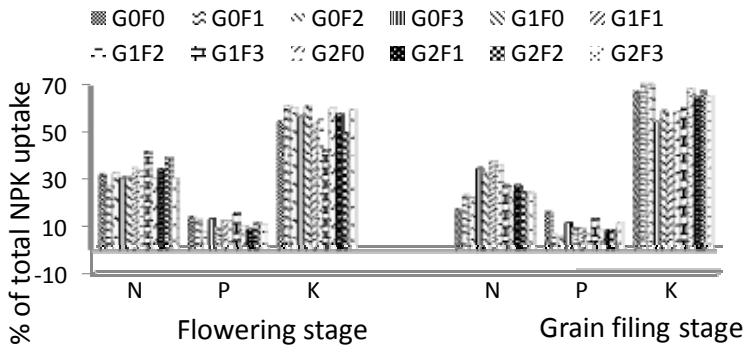

Fig 1. Comparative analysis on percentage of total NPK uptake by BARI Gom-26 at two different stages ($LSD_{0.05}$ for percentage P of total NPK uptake at flowering stage is 3.97 and percentage N of total NPK uptake at grain filling stage is 9.38).

With two exceptions the N, P and K contents of grain were found to increase following all the treatments (Table 2). The N content of grain increased following all the treatments and the maximum was due to 25 ppm NAA in combination with 75 % N-fertilizer (Table 2). Only decrease in P content of grain was due to 25 ppm NAA without any N-fertilizer. Results also showed that K content of grain increased due to all the treatments except 50 ppm NAA without N-fertilizer.None of the value was found significant.Increase in N, P and K contents of grain following NAA application was also reported in different plants *viz.* rice (Adam *et al*. 2012), fenugreek (Purbey and Sen 2007) and maize (Akter 2010).

Table 2. Effects of NAA at varying nitrogen levels on NPK contents (%) of grain of BARI Gom-26 at harvest.

Treatments	N	P	K
G_0F_0	2.091	0.286	0.094
G_0F_1	2.304	0.316	0.172
G_0F_2	2.219	0.315	0.191
G_0F_3	2.404	0.315	0.250
G_1F_0	2.205	0.284	0.133
G_1F_1	2.276	0.446	0.289
G_1F_2	2.432	0.506	0.270
G_1F_3	2.404	0.436	0.211
G_2F_0	2.276	0.291	0.074
G_2F_1	2.233	0.504	0.270
G_2F_2	2.304	0.522	0.133
G_2F_3	2.205	0.412	0.231
CV (%)	45.19	6.67	43.97
LSD (0.05)	NS	NS	NS

Nitrogen use efficiency (NUE) was not influenced by any definite treatment in case of shoot and root where, the maximum values were obtained from different treatments in both the stages (Table 3). Significant variations were observed in case of root at flowering stage and shoot at grain filling stage. At the flowering stage, maximum NUE of shoot and that of total plant were recorded from 50 ppm NAA in combination with 50 % N-fertilizer. However, at the grain filling stage, maximum NUE of shoot and that of total plant were recorded from 25 ppm NAA in combination with 75 % N-fertilizer. This result indicates that lower concentration of NAA with relatively higher dose of N-fertilizer is more efficient in enhancing NUE. This finding is in agreement with the findings of Akinrinde (2006).

Table 3. Effects of NAA at varying nitrogen levels on nitrogen use efficiency (mg N/mg N) of BARI Gom-26 at two different stages.

Treatments	Flowering			Grain filling		
	shoot	root	Total plant	shoot	root	Total plant
G_0F_0	-	-	-	-	-	-
G_0F_1	0.017	0.009 a	0.026	0.072 d	0.006	0.078
G_0F_2	0.013	0.004 bc	0.017	0.060 d	0.002	0.062
G_0F_3	0.031	0.004 bc	0.035	0.062 d	0.004	0.066
G_1F_0	-	-	-	-	-	-
G_1F_1	0.008	0.003 bc	0.011	0.158 ab	0.010	0.168
G_1F_2	0.033	0.006 ab	0.039	0.167 a	0.008	0.175
G_1F_3	0.017	0.001 c	0.018	0.074 d	0.003	0.077
G_2F_0	-	-	-	-	-	-
G_2F_1	0.102	0.006 ab	0.108	0.142 abc	0.008	0.150
G_2F_2	0.033	0.005 abc	0.038	0.038 d	0.005	0.043
G_2F_3	0.001	0.003 bc	0.004	0.049 d	0.003	0.052
CV (%)	23.12	72.46	19.64	59.23	88.50	59.08
LSD (0.05)	NS	0.004	NS	0.066	NS	NS

*Means in a vertical column followed by same letter do not differ significantly at 5 % level

The higher uptake of N, P and K may have resulted from higher yield and production of higher dry matter. The increased uptake of NPK and NUE due to use of lower doses of N-fertilizer in combination with NAA might be the result of stimulatory effect of NAA in absorbing these nutrients by BARI GOM-26.

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FIRE HAZARD IN READYMADE GARMENT FACTORIES AND ITS IMPACTS ON WORKERS IN DHAKA METROPOLITAN AREA, BANGLADESH

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Abstract

Mirpur *Thana*, located in the northwestern part of Dhaka Metropolitan Area (DMA) is one of the most affected areas of fire in the RMG factories due to a large number of factories are operating in this area. Fire in the RMG sector has become a very common event in the recent years and causing colossal damage of lives and properties. The ultimate victims of fire in the factories are RMG workers because they become dead and injured and their livelihood held back. The present study based on the primary field investigation (including open ended questionnaire interview with a total of 70 workers), key informant interviews attempts to identify workers' opinions on fire hazard issues and to understand the consequences, of how these problems become linked with the workers' issue.

Key words: Fire hazard, Readymade garment factory, Dhaka Metropolitan Area, Garment workers, Weighted average index

Introduction

Fire is an important phenomenon from the very beginning of human civilization and the present world could not beg to be excused the essentiality of fire. Fire often becomes disastrous for human lives and habitat when it can spread accordingly if no effective measures are taken. Fire hazards have been frequently occurring events in the urban as well as in rural areas due to an increasing number of people getting involved in the economic, industrial and other activities (IRW 2012). Major fire hazards in the Readymade Garment (RMG) industries have occurred in different countries of the world and a large number of people have died inhumanly. This made the RMG workers more vulnerable as well as to become more practical to tackle the situations. The garment sector plays an important role in the economic development of Bangladesh. The sector accounts for 81 percent of total export earnings of the country. It employs directly around 3.6 million people, and 80 percent are women (BGMEA 2016). The garment sector currently consists of 5600 factories of various sizes, although around 3,500 are under operation (Muhammad 2011). The dirty secret of the steady growing RMG sector of Bangladesh is that the underpaid workers are treated as disposable objects (Claeson 2012). Many RMG factories fail to follow the most basic standards of health and safety issues of the workers. The rapid growth of the factories has led to the conversion of many buildings, built for other purposes, and ultimately used as garment factories. These are

often built-up without the required permits and standards from the concerned authorities. Many factories have constructed unauthorized floors or have increased the workforce and machinery beyond the safe capacity of the building. Many factories continue their operations at day and night in order to meet production targets. The establishment of factories or the conversions of residential or commercial buildings into garment factories has often been done as quickly and as cheaply as possible, which results in widespread safety problems including faulty electrical circuits, unsafe buildings, inadequate emergency exits and inadequate firefighting equipments (Clean Clothes Campaign 2012). RMG sector is facing lot of problems in the recent time in the entire world. At least 289 workers were trapped and died in a factory fire in Karachi, Pakistan on September 11, 2012 (ILO 2012). Local trade union leaders have reported that the factories do not follow the regulations and continue their operation without the required permission and registration. Most of the exit doors remain locked, reportedly to prevent theft. There were no fire exits and windows were barred. Surviving workers reported that stairs and exit ways were blocked with piles of finished merchandise (Claeson 2012). The recent major fire incident which occurred in Tazreen Fashions Ltd. could be recognized the largest fire tragedies in the history of RMG sector of Bangladesh. This factory located at Nischintopur in Ashulia, in the outskirts of DMA. The total number of deaths were 111 (ASK 2012) and more than 300 workers were injured (AMRC 2013). After the occurrence of major accidents in this sector, a lot of accidents are still happening in this sector of many countries of the world, e.g. China, India, Italy, Pakistan, Russia etc. The RMG workers, the driving force of economy in Bangladesh, are playing significant role in the growing production of this sector. Their safety issues are not considered always. Hence, they are exploited and deprived from the legitimate rights. Fires became a major problem in Bangladesh's garment industry for more than two decades and these caused the deaths and injuries of hundreds of workers over the years (Hossain 2014). They work hard for the development of factory and owners, but corporate greed often spoils their lives and hopes. They also work hard for the development of country's economy but they get very little in return. There are rules and regulations for the protection of the workers safety and rights but these are not implemented. The RMG workers lead a miserable life in the metropolitan areas with their limited earnings. Government, Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and the international buyers are emphasizing on fire safety issue of this sector. They are adapting various measures to improve the fire safety practices and these have certainly reduced the fire incidents and losses significantly (Wadud *et al.* 2013).

Materials and Methods

The main objective of the study to assess the present condition of fire hazards in the RMG factories of DMA. The study analyses various factors such as not following rules and regulations, unplanned factory building, limited compliances, inadequate fire fighting equipments, negligence of the authority and workers' ignorance etc. which are

worsening the existing situation to make the RMG sector more vulnerable for fire hazard. Moreover, this study focuses on the impacts on the workers due to fires in the RMG sector. Most of the RMG industries are located in the urban area or vicinity to urban area in Bangladesh. The garment industries grew in DMA remarkably in the last few years. The present study area is Mirpur (Sub-district) *Thana* which is under DMA (Fig. 1). There are 120 factories which are located in Mirpur *Thana* (BBS 2010). There are few factories which are operating their production without permission of the concerned authority. Thus, the study area was selected based on the location of factories, presence of large number of factories and workers. In order to conduct the study, Mirpur *Thana* area was selected based on the following considerations:

a) Significant numbers of garment factories are located and substantial numbers of workers are working in this area in compare to the other parts of the capital Dhaka.

b) The factories of the study area are affected by fires in the last few years and the numbers of casualties are mentionable.

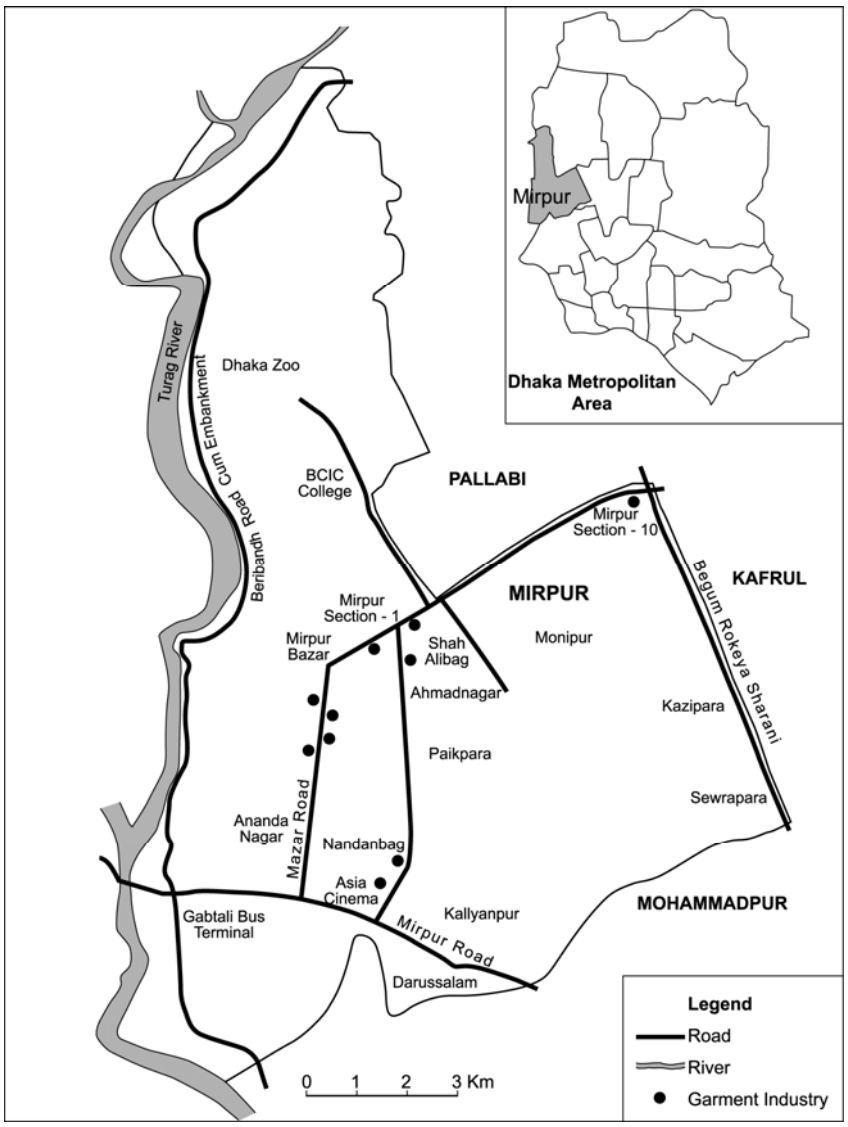
c) This area is not a recognized industrial zone, but lot of industries established in a scattered way without considering the problems of the surrounding communities and environment.

d) The area is termed as 'Mixed Area' of DMA, combining both the planned and informal types (Ahmed *et al.* 2014) and is considered mainly a residential area, and also simultaneously used for commercial and industrial purposes (Haq *et al*. 2012).

For this study, the required data and information were collected from both primary and secondary sources. About 51,232 workers are engaged in RMG sector in Mirpur *Thana* (BBS 2010). The primary data were gathered through a survey conducted on 70 RMG for the purposes of the study. Many of them are the victims of fires in the factory and few of them have observed the accident, from 10 factories of the study area (Fig. 1). Furthermore, 10 key informants (KIs) such as fire safety specialists, fire fighters, academicians, researchers, NGO personnel, workers' leaders etc. were interviewed to get in depth information on various issues which are related with the fire in the RMG factories. Secondary sources of information were published and unpublished research works relevant to the theme of the study. These include books, journal articles, research reports, document of the government offices, NGO documents, conference proceedings, government laws and regulations, locally published news paper reports and maps etc.

Weighted Average Index (WAI) analysis combines choice weights and question weights to produce a single index for all responses. It has been used to analyze various types of social scaling including various steps for effective fire hazard control, fire impacts on the workers, workers' opinion regarding the authority's steps (Table 1). A five point scale used to determine agreements, perceptions of the quality or performance, degree of satisfaction, and level of development in terms of fire risk. The scale represents

very high, high, moderate, low and very low with respective weights such as 1.0, 0.8, 0.6, 0.4 and 0.2. Basically, it assesses the results from the question score analysis and computes a weighted average of those results using the question weights.



Source: Modified from Banglapedia 2012

Fig. 1: Location of surveyed garment factories in Mirpur thana.

Table 1. The WAI for Assessing the Level of Workers' Issues.

Workers' issues	Very low	Low	Moderate	High	Very high
Various steps for effective fire hazard control	0.0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.0
Fire impacts on the workers	0.0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.0
Workers' opinion regarding the authority's steps	0.0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.0

In WAI the score of each item is calculated by the following formula:

$$WAI=\frac{fVL(W_1)+fL(W_2)+fM(W_3)+fH(W_4)+fVH(W_5)}{N}$$

Where,

WAI=Weighted Average Index W_1= 0.2

fVL= frequency of very low W_2=0.4

fL = frequency of low W_3=0.6

fM= frequency of moderate W_4=0.8

fH= frequency of high W_5=1.0

fVH= frequency of very high

N=total number of items

Results and Discussion

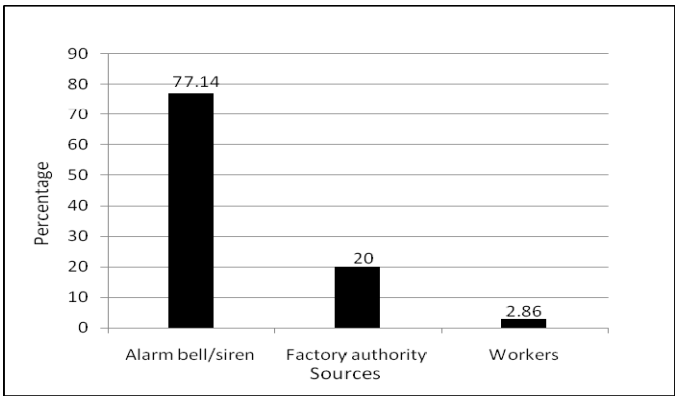
Causes of Fires in the Garment Factory: Fires occurred in the garment factories due to various reasons. The highest percentage of workers mentioned the main cause of fire is electric short circuit, whereas the lowest percentage of respondents opined as the overheating. The figures were 100 percent and 8.57 percent respectively. Low quality electric apparatus and improper checking of electric apparatus are propagating the problems. Excessive heat in the boiler of the factory, explosion occurs and subsequently fires broke out in the factory and this was mentioned by 44.29 percent workers. Flammable materials are stored in the factory without considering the danger of fire and this reason was mentioned by 37.14 percent workers. Transformer explosion became one of the major causes of fire in the factory which was reported by 24.29 percent workers. Only 24.29 percent respondents demonstrated that canteen kitchen is a source of fire in factory (Table 2). The workers also reported other causes such as friction of machinery, smoking in the factory, sabotages, lack of caution, bad housekeeping etc. as the causes of fires in the factories.

Table 2. Causes of fires in the garment factory.

Causes of fire	Frequency	% of respondents (N. 70)
Electric short circuit	70	100.0
Boiler explosion	31	44.29
Storage of flammable materials	26	37.14
Transformer explosion	20	28.57
Canteen kitchen	17	24.29
Overheating	8	8.57
Others	15	21.43
Total	187	

Source: Field Survey, 2014. Note: Multiple choices have been considered.

Fire Alarm in the RMG Factories: A fire alarm is a message to the occupants in a factory to be alert about forthcoming fire which may cause enormous damages and casualties. Majority of the workers (77.14 percent) are informed about the fire of the factory through the fire alarm bell or siren (Fig. 2). Among the workers, 20% mentioned that they are informed by the factory management authority to leave the working place due to fire. Sometimes the workers are conveyed the alarm by their colleagues also but very few respondents (2.86 percent).



Source: Field Survey, 2014
Fig. 2. Fire Alarm Sources in the Surveyed Factories.

More than half of the workers (52.9 percent) knew how to operate the fire alarm in the factory and the exact location of fire alarm switches. On the other hand, many respondents (47.1 percent) reported that they do not know the exactly how to operate the switch and its specific location (Table 3). The workers mentioned that due to lack of proper orientation by the factory management many of them cannot operate the alarm system.

Table 3. Whether the Workers Know How to Operate the Fire Alarm.

Fire alarm operation	Frequency	Percentage
Know	37	52.9
Do not know	33	47.1
Total	70	100.0

Source: Field Survey, 2014

Majority of the respondents (92.9 percent) mentioned that the fire alarm systems of the factory are enough loud and clear at present (Table 4). The workers could hear fire alarm loudly and clearly from the entire factory. A very few respondents (4.3 percent) reported that they could hear the alarm from their working area but not clearly. A very few respondents claimed that the alarm systems are not loud and clear in the factory due to the problematic alarm systems.

Table 4. Pattern of Fire Alarm System in the Factory.

Fire alarm system	Frequency	Percentage
Loud and clear	65	92.9
Loud but not clear	3	4.3
Not loud nor clear	1	1.4
Do not know	1	1.4
Total	70	100.0

Source: Field Survey, 2014.

Participation of the Workers in Fire Drill: Fire drill is supposed to be held in a garment factory in quarterly basis i.e. once in every quarter of a year (GoB 2003), but it is not holding in many non-compliant factories at all. Around 43 percent workers illustrated that there is no fire drill in their factory. However, all the factory managers reported that they arrange fire drills regularly. Many respondents (48.5 percent) informed that they participated in the fire drill regularly in their respective factory. Few respondents (8.6 percent) mentioned that they did not participate in the fire drill for a single time (Table 5).

Table 5. Types of Participation of the Workers in Fire Drill.

Participation in fire drill	Frequency	Percentage
There is no fire drill	30	42.9
Participated regularly	34	48.5
Never participated in fire drill	6	8.6
Total	70	100.0

Source: Field Survey, 2014.

The workers (44.3 percent) have enough confidence to face the fire hazard in the factories but they seek more supports from the factory authorities. Among them, 35.7 percent reported that they have a little confidence and 8.6 percent have somewhat confidence to step forward when fire may erupt. Only 11.4 percent workers do not have any confidence at all to fight against the fire in the factories (Table 6).

Table 6. Workers' confidence level to fight against fire.

Level of confidence	Frequency	Percentage
Not confidant at all	8	11.4
A little confidant	25	35.7
Somewhat confidant	6	8.6
Very confidant	31	44.3
Total	70	100.0

Source: Field Survey, 2014

Evacuation of Workers in the RMG Factories: The evacuation time is important because it indicates how much a factory authority and the workers are prepared to leave a fire

affected site. Various factors are associated with the evacuation processes in a garment factory building, for instance number of workers, number of floors of the building, size and number of the staircases, occupants' density in the staircase, and evacuation from several floors simultaneously and counter flow of fire fighters (Kobes *et al*. 2010). It is assumed that the fire exits will be used when the doors are open and the distance of main gates is more than the distance of fire exits. A worker must be able to escape from the factory building to a safe place within 2.5 minutes. It takes around 30 second to burn and 90 seconds to full blaze of the flammable materials in the factory. One person can go away 18 meter in one minute when fire happens. The highest percentage of workers mentioned that it takes less than 5 minutes to evacuate the whole factory whereas the lowest percentage of workers opined that 10 to 14 minutes are required for evacuation. The figures were 52.8 percent and 12.9 percent successively (Table 7). However, 34.3 percent respondents told that it takes 5 to 9 minutes to reach a safe place during fire by all.

Table 7. Evacuation Time of the Factory.

Evacuation time	Frequency	Percentage
Less than 5 minutes	37	52.8
5 to 9 minutes	24	34.3
10 to 14 minutes	9	12.9
Total	70	100.0

Source: Field Survey, 2014.

All the workers are evacuated from the factory building following the warning. Most of the workers (94.3 percent) of the surveyed factories followed the fire alarm frequently and only 5.7 percent of the respondents reported that they are confused to follow the warning (Table 8). This evacuation drill usually arranged suddenly without informing the workers so that they can evacuate immediately. However, recent fires in this sector created more awareness among the workers to follow the fire warning properly.

Table 8. Whether the Workers Follow Fire Warning in the Factory.

Fire warning	Frequency	Percentage
Frequently	66	94.3
Irregularly	4	5.7
Total	70	100.0

Source: Field Survey, 2014.

Safe evacuations are the most important aspect of fire safety mechanism. It is important to escape from the engulfing fire and follow the evacuation systems. The majority respondents (61.43 percent) expressed their concerns regarding the number of exit gates because the numbers of evacuees are higher during the emergency period (Table 9). Congested escape routes obstruct the normal flow of evacuation during a fire

significantly which is told by 54.29 percent of workers. Many factories do not have emergency evacuation plan which was reported by 42.86 percent workers. Around 39 percent respondents mentioned about the negligence of the factory management during evacuation. Long travel distances often become responsible for more panic and risk of the causalities of the workers and it was reported by 25.71 percent of the respondents.

Table 9. Problems during the Evacuation.

Problems	Frequency	% of total respondents (N.70)
Inadequate exit gates	43	61.43
Congested escape routes	38	54.29
Do not have emergency evacuation plan	30	42.86
Do not follow emergency evacuation plan	27	38.57
Long traveling distance	18	25.71
Total	156	

Source: Field Survey, 2014. Note: Multiple choices have been considered.

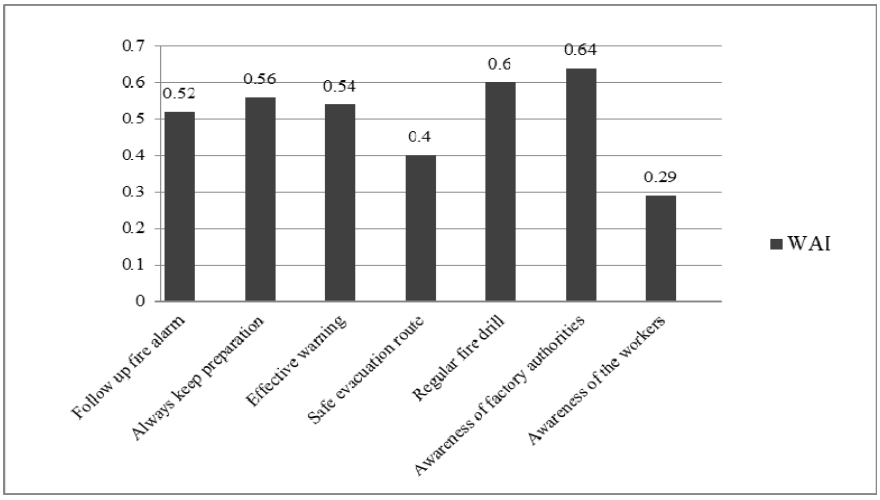
Majority of workers (97.1 percent) reported that they know the emergency exits while only 2.9 percent are not confirming about the emergency gates. The emergency exits are usually located behind the factory buildings. These gates remained locked in most of the time and often been clogged by the products of the factories.

Measures to Control Fire Hazard: The present study tried to explore the various measures by the workers for effective fire control in the factories. It is observed that 18.6 percent and 45.7 percent respondents reported on follow up fire alarm as very high and high level respectively (Table 10). In the case of always keep preparation, 17.1 percent and 28.6 percent of the respondents opined as very high and high successively. The WAI results of follow up fire alarm and always keep preparation are 0.52 and 0.56 accordingly which indicated the medium level of preparedness. In case of effective warning, 45.7 percent of the respondents mentioned as moderate of level preparedness and the WAI value in this regard is 0.54 i.e. the level of preparedness was moderate. Safe evacuation route is considered as low level of preparedness. Regular fire drill is taken as very high, high and moderate level of preparedness by 22.9 percent, 22.8 percent and 42.9 percent of the respondents respectively. The WAI result of fire drill was 0.60 i.e. the level of preparedness is moderate. In addition, 10 percent and 22.8 percent of the respondents mentioned awareness of the factory authority as very high and high level of measures accordingly and the WAI value was 0.64 that indicated high level of preparedness for fire control in the factories. The workers mentioned the awareness level of them as low and the WAI value was 0.29 only i.e. the degree of significance was low (Fig. 3).

Table 10. Workers' Steps for Effective Fire Hazard Control.

Preparedness	Degree					WAI N=70	Remark
	VH	H	M	L	VL		
Follow up fire alarm	13 (18.6)	32 (45.7)	25 (35.7)	0 (0.0)	0 (0.0)	0.52	M
Always keep preparation	12 (17.1)	20 (28.6)	16 (22.9)	18 (25.7)	4 (5.7)	0.56	M
Effective warning	10 (14.3)	15 (21.4)	32 (45.7)	10 (14.3)	3 (4.3)	0.54	M
Safe evacuation route	5 (7.1)	10 (14.3)	17 (24.3)	23 (32.9)	15 (21.4)	0.40	L
Regular fire drill	16 (22.9)	21 (30.0)	10 (14.3)	12 (17.1)	11 (15.7)	0.60	M
Awareness of factory authorities	7 (10.0)	16 (22.8)	30 (42.9)	15 (21.4)	2 (2.9)	0.64	H
Awareness of the workers	1 (1.4)	4 (5.7)	25 (35.7)	22 (31.4)	7 (10.0)	0.29	L

Source: Field Survey, 2014.
Note: VH=very high, H=high, M=moderate, L=low, VL=very low.
Note: The figure within the bracket indicates the percentage.
Note: WAI value VH=0.81-1.0, H=0.61-0.8, M=0.41-0.6, L=0.21-0.4, VL=0.0-0.2.



Source: Field Survey, 2014

Fig. 3. Degree of satisfaction of the workers associated with fire control.

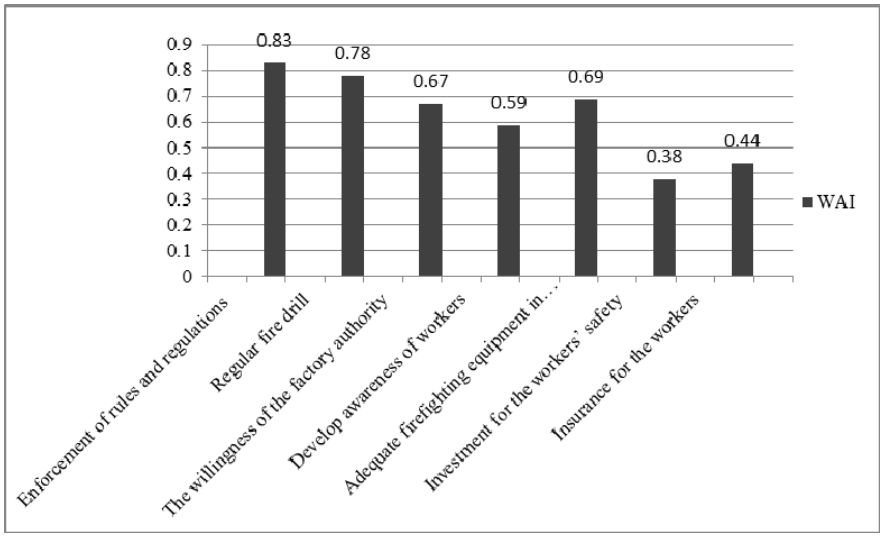
However, workers emphasized on various measures which should be taken by the factory authority to control fire in the garment factories. Around 54 percent workers mentioned that strict enforcement of the rules and regulations was considered as very high. Moreover, 22.9 percent and 12.9 percent of the respondents reported that enforcement of rules and regulations as high and moderate respectively (Table 11). The WAI result is

0.83 which showed that the importance of enforcement of rules and regulations was very high. In the case of fire drill, 44.3 percent of the workers mentioned regular fire drill as very high. The WAI result indicated the regular fire drill measures as high also. The willingness of the factory authorities is considered as high also and the WAI value was 0.67.

Table 11. Measures of Factory Authorities to Control Fire.

Measures	Degree						WAI N=70	Remark
		VH	H	M	L	VL		
Enforcement of rules and regulations	38 (54.3)	16 (22.9)	9 (12.9)	5 (7.1)	2 (2.9)		0.83	VH
Regular fire drill	31 (44.3)	20 (28.5)	5 (7.1)	12 (17.1)	2 (2.9)		0.78	H
The willingness of the factory authority	18 (25.7)	20 (28.6)	13 (18.6)	7 (10.0)	12 (17.1)		0.67	H
Develop awareness of workers	12 (17.1)	18 (25.7)	10 (17.3)	15 (21.4)	15 (21.4)		0.59	M
Adequate firefighting equipment in place	24 (34.3)	12 (17.1)	12 (17.1)	18 (25.7)	4 (5.7)		0.69	H
Investment for the workers' safety	8 (11.4)	0 (0.0)	7 (10.0)	17 (24.3)	38 (54.3)		0.38	L
Insurance for the workers	7 (10.0)	3 (4.3)	13 (18.6)	22 (31.4)	25 (35.7)		0.44	M

Source: Field Survey, 2014.
Note: VH=very high, H=high, M=moderate, L=low, VL=very low.
Note: The figure within the bracket indicates the percentage.
Note: WAI value VH=0.81-1.0, H=0.61-0.8, M=0.41-0.6, L=0.21-0.4, VL=0.0-0.2.



Source: Field Survey, 2014.

Fig. 4. Workers' opinions regarding fire control measures in the factories.

In case of awareness level of the workers, the WAI result was 0.59 which indicates as medium level measures. Furthermore, 34.3 percent of the workers reported the importance of adequate firefighting equipment and the WAI value was 0.69 which represented as high. Many of the workers (54.3 percent) focused less on the investment for the workers' safety and the WAI value was 0.38 which indicated as low level measures.

Therefore, the insurance for the workers was reported as very high by 10 percent workers, and the WAI value was 0.44 which was considered as the medium level measures. Group insurance scheme covers to claim up from 100,000 Tk. and 125,000 Tk. for death and permanent total disablement respectively (MoLE 2013). In this study, 54.3 percent workers reported that they are included in the insurance schemes, whereas 32.9 percent workers mentioned that they are not under the insurance schemes. On the other hand, 12.9 percent mentioned that they did not know about the persisting insurance schemes of the factory authority (Table 12). In fact, the compliant factories prefer to adapt insurance schemes for the workers while the non-compliant factories always try to avoid the issue.

Table 12. Whether the Workers Have Life Insurance.

Life insurance	Frequency	Percentage
Yes	38	54.2
No	23	32.9
Don't know	9	12.9
Total	70	100.0

Source: Field Survey, 2014.

The Ultimate Victims of Fire: Approximately 77 percent of the workers illustrated that the worst sufferers of factory fire were the workers and the staffs (Table 13). Among them, 18.57 percent mentioned that factory owners will be affected. The owners usually invest a huge amount of money for the establishment of the factory and take loan from the financial institutions. Hence, if any accident happened to the factory, the owners become loan defaulters. If they want to restore the factory and business, they have to take more loans from the financial institutions. Financial institutions often become the indirect victims of factory fires also.

Table 13. The Worst Sufferer of Fire Hazard.

Worst sufferer	Frequency	Percentage
Workers and staffs	54	77.14
Factory owners	13	18.57
Financial institutions	3	4.29
Total	70	100.0

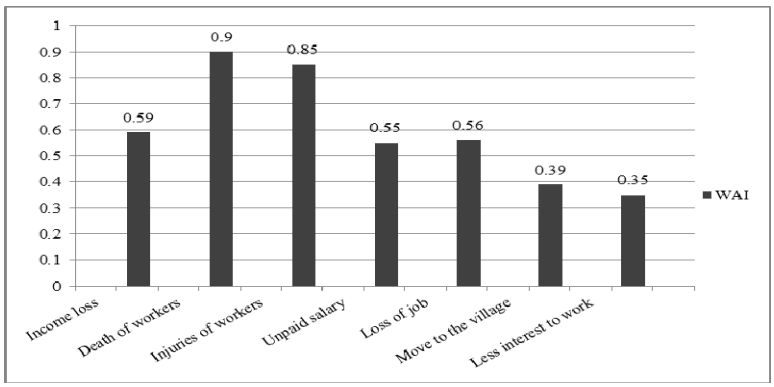
Source: Field Survey, 2014.

The fire accidents in the RMG sector have various direct impacts on workers. The majority of the respondents mentioned income loss of the workers due to fire, and 11.4 percent, 28.6 percent and 22.9 percent of the respondents reported their income loss was very high, high and moderate level respectively. In case of income, the WAI result was 0.59 that proved the income loss of the respondents was moderate. In case of death of workers, 56.8 percent of the workers mentioned very high and 31.4 percent reported as high. The WAI result of death of the workers is 0.90 which indicated the significant impacts on the workers. In case of injuries of the workers 41.4 percent and 47.1 percent reported as very high and high successively and the WAI result was 0.85 which indicated very high impact on the workers also (Table 14).

Table 14. Fire Impacts on the Workers.

Fire impacts on workers	Degree					WAI N=70	Remark
	VH	H	M	L	VL		
Income loss	8 (11.4)	20 (28.6)	16 (22.9)	13 (18.6)	13 (18.6)	0.59	M
Death of workers	41 (58.6)	22 (31.4)	7 (10.0)	0 (0.0)	0 (0.0)	0.90	VH
Injuries of workers	29 (41.4)	33 (47.1)	6 (8.6)	2 (2.9)	0 (0.0)	0.85	VH
Unpaid salary	12 (17.1)	10 (14.3)	9 (12.9)	27 (38.6)	12 (17.1)	0.55	M
Loss of job	14 (20.0)	11 (15.7)	10 (14.3)	18 (25.7)	17 (24.3)	0.56	M
Move to the village	0 (0.0)	3 (4.3)	15 (21.4)	29 (41.4)	23 (32.9)	0.39	L
Less interest to work	2 (2.9)	1 (1.4)	14 (20.0)	14 (20.0)	39 (55.7)	0.35	L

Source: Field Survey, 2014.
Note: VH=very high, H=high, M=moderate, L=low, VL=very low Note: The figure within the bracket indicates the percentage.
Note: WAI value VH=0.81-1.0, H=0.61-0.8, M=0.41-0.6, L=0.21-0.4, VL=0.0-0.2.



Source: Field Survey, 2014.

Fig. 5. Degree of satisfaction about fire impacts on workers.

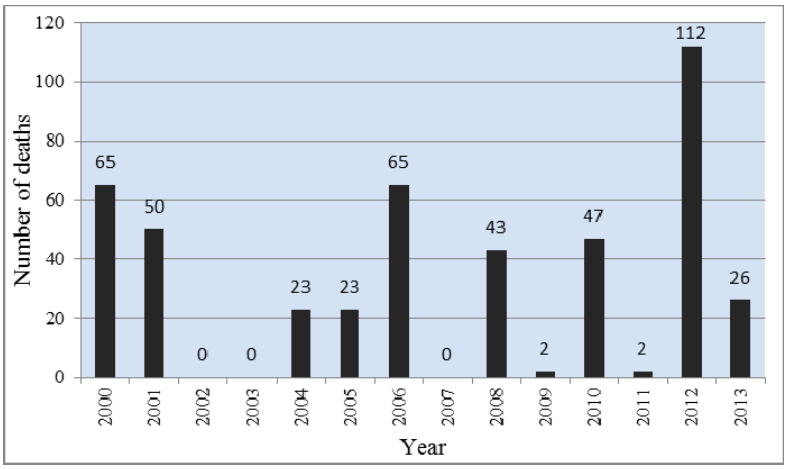
Furthermore, the WAI results of unpaid salary and loss of job indicated as 0.55 and 0.56 accordingly; these are medium level impacts on the workers. In addition, the WAI values regarding the move to the village and less interest to work were 0.39 and 0.35 respectively which indicated as low level impact on workers (Fig. 5). According to Bangladesh Fire Service and Civil Defense (BFSCD), around 1833 fire accidents occurred in the RMG industries between 2000 and 2013 in entire Bangladesh. The highest numbers of accidents occurred in 2007 and the numbers were 326 (Table 15). The total damages occurred due to the fire from 2000 to 2013 is around Tk. 540 crores (1 crore=Tk. 10 million) while the BFSCD authority saved about Tk. 18,264 crores worth property from fire over the period of time.

Table 15. Casualties and Damages in RMG sector of Bangladesh from 2000 to 2013.

Year	Number of accidents	Damages (in Tk.)*	Property saved (in Tk.)*	Number of injured	Number of deaths
2000	99	13,27,26,200	18,66,34,310	145	65
2001	67	15,16,35,000	18,40,01,898	176	50
2002	78	7,66,02,209	35,33,45,607	-	-
2003	102	4,81,99,017	21,89,66,167	-	-
2004	108	19,63,89,270	24,44,70,260	50	23
2005	76	88,51,09,150	118,09,62,396	130	23
2006	73	42,86,12,108	341,59,01,112	536	65
2007	326	4,16,33,389	58,36,94,181	-	-
2008	89	46,66,65,000	186,83,25,000	209	43
2009	293	99,11,40,867	377,99,60,890	150	02
2010	222	74,53,89,418	337,06,68,741	153	47
2011	175	16,69,85,732	121,08,37,202	64	02
2012	97	98,00,38,670	166,65,19,640	459	112
2013	28	9,0000000**	-	312	26
Total	1833	5401126030	182642870404	2384	458

Source: BFSCD, 2014 and compiled by author. * 1 US$ = Tk. 80. ** by single accident.

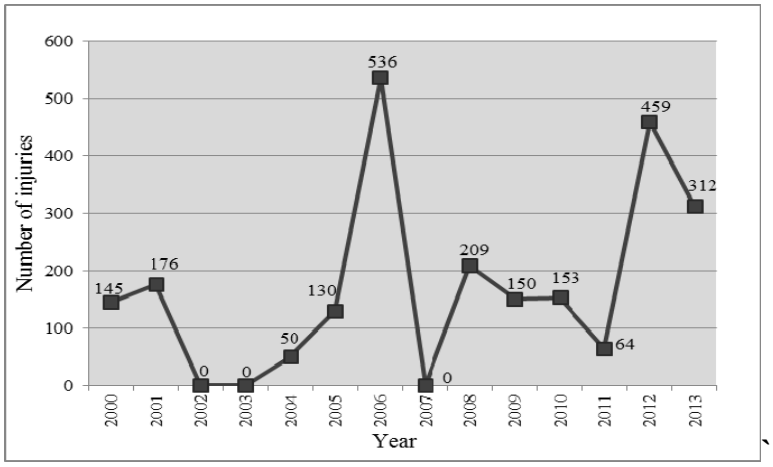
According to the BFSCD authority, nearly 150 workers died due to fire accidents in garment factories between 1990 and 2000. The death toll was much higher and may exceed 250 (Gain 2009). The numbers of injured and dead workers were 2384 (Fig. 6) and 458 (Fig. 7) successively from 2000 to 2013.



Source: BFSCD, 2013 and compiled by author

Fig. 6. Number of deaths due to fire in RMG factories from 2000 to 2013.

The casualties and damages also occurred in the RMG sector in the past when the numbers of factories were less. However, the accidents of this sector are recorded and reported more in the recent years.



Source: BFSCD, 2013 and compiled by author

Fig. 7. Number of injuries due to fire in RMG factories between 2000 and 2013.

The readymade garments industry acts as the backbone of our economy and as a catalyst for the development of our country (Hassan 2014). Bangladesh needs to work forward to be a country of compliant RMG factories specified in the laws without making any delay. Fires in the RMG sector causing colossal damages of lives and properties over the period of time. In the compliant factories, effective measures are taken over to control fire while

in the non-compliant factories the workers repercussions are more regarding the fire safety and other issues, and less measures are taken by the factory management. The majority of the workers have limited knowledge regarding the existing rules and regulations for fire hazard control in the factories. Hence, they should follow the fire alarm properly. In addition, Accord and Alliance, are legally binding among the different international organizations and local stakeholders, are also taking various steps to control fire in the factories. Thus, all the activities should be conducted in a coordinated way to ensure fire, building and electrical safety of the factories as well as for the well being of workers. There are adequate laws and codes on fire prevention and safety measures but the only problem is lack of proper implementation. Moreover, proper monitoring is a big challenge for this large number of factories. There are also rules and regulations in the factory level to control fire and a few are followed by the factory authorities and workers. The main focuses of existing regulations should be ensured on workers' safety and good working environment. The workers must be informed regarding the existing rules and regulations of fire in the factories and should be encouraged to go after. The existing rules and regulations regarding factory fire should be standard and necessary amendments are essential. Regular participation in fire drill and safe evacuation are prerequisite for the workers to escape from the fire. Furthermore, factory workers and management should be more aware to avoid the dreadful fires in the factories. Despite repeated demands from concerned groups, governments and BGMEA of past and present hardly had taken any practical actions to safe-guard the workers from the engulfing hazardous conditions. However, in the recent years the monitoring and inspections have been increased by the factory authorities. BGMEA is also carrying out different activities to mitigate fire in the factories. Therefore, it is the responsibility of all of us to maximize the safety of this industry which has given our economy a strong balance, ensured jobs for millions of people, especially for women, lifted them from the deep hole of chronic poverty and ensured them a dignified life.

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SOME ASPECTS OF BIOLOGY OF THE BAR-EYED GOBY GLOSSOGOBIUS GIURIS (HAMILTON 1822) (PERCIFORMES: GOBIIDAE) FROM NETRAKONA

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Abstract

The investigation was conducted on some aspects of biology viz. morphometrics, meristics, length-weight relationship and coefficient of condition of the Bar-eyed goby *Glossogobius giuris.* The mean of total length (TL) (94.42 ± 18.52 mm), standard length (SL) (73.13 ± 3.45mm), pre-dorsal length (PDL) (28.8 ± 7.32mm), head length (HL) (23.9 ± 4.87mm), snout length (SnL) (8.15 ± 1.9 mm) and height of body (HB) (14.17 ± 3.29mm) were determined.The relationships between the total length and other body parameters were found to be positively correlated and highly significant. The fin formula is D_1.6; D_2.1/9-10; P_1.17-21; P_2.1/5; A.1/9; C.17. The length-weight relationships of combined sex of *G. giuris* were determined as Log TW = -4.802 + 2.857 Log TL. The coefficient of conditions from the *ko* of combined sex and from the *kc* of combined sex was determined as 0.834 ± 0.132 and 0.827 ± 0.027, respectively. *Kn* values of combined sex were found to be 1.001 ± 0.156.

Key words: Bele, *Glossogobius giuris*, Morphometrics, Length-weight relationship, Coefficient of correlation

Introduction

The gobies (Family Gobiidae), a very prominent element in the fish fauna of Bangladesh, is a diversified group occurring in temperate and tropical zones throughout the world.They are mostly small, carnivorous, bottom-dwellers living along the shores of the bay, estuaries and river mouths and also in streams, lakes and swamps.The commonest of all the gobies in Bangladesh is the Bar-eyed goby, *Glossogobius giuris* (Hamilton 1822), locally known as Bele or Bailla. Bele occurs in esturine and freshwaters throughout Bangladesh (Rahman 1989). The species is distributed to East Coast of Africa, India, Pakistan, Ceylon, Burma, the Phillipines, China, Japan and New Caledonia (Srivastava 1968). *G. giuris* is somewhat hardy, but it can not survive in muddy water for long. The species is a good sport on rod and line with a bait of small prawn. Bele is highly esteemed as food and one of the varieties found in both freshwater and brackish water, largely caught and eaten (Bhuiyan 1964).

The morphometric and meristic characters of fishes and their relationships are used in taxonomy to prepare keys for identification in the fishery science. They are also helpful in differentiating stocks or subspecies. The morphometry of many fishes have been determined in India and used in taxonomy (Ganguly *et al.*1959, Prakash and Verma 1982, Tandon *et al.* 1993, Chunder 1997 and Mehta and Bapat 1977). Some works on the morphometry of some fishes have also been published in Bangladesh (Shafi and Quddus 1974, 1975, Azadi *et al.* 1992, Azadi and Naser 1996, Azadi *et al.* 1999 and Saha and Saha 2010, 2011).

The purpose of the length-weight analysis is to describe mathematical relationship between length and weight, primarily so that one may be converted into other and of condition factors to measure the variation from the expected weight for length of individual fish or groups of fishes as indication of relative robustness, plumpness or fatness, degree of well-being etc. (Le Cren 1951). Determination of ponderal index helps in the conversion of length into weight and vice versa (Doha 1970). Works on length-weight relationship and condition factor of freshwater small fishes have been done by Saha and Saha (2010, 2011).

Breeding of *G. giuris* has been studied (Le Cren 1951, Bhowmick 1965, Doha 1974, Haque 1983 and Saha & Saha 2009). But no study has been conducted on morphometrics, meristics, length-weight relationship and condition factors of *G. giuris* from Bangladesh.This type of study may have practical value in culture, management and further development of fishery relating to this fish species in Bangladesh.

Therefore, an investigation was conducted to determine some aspects of biology viz. morphometrics, meristics, length-weight relationship and coefficient of condition of the Bar-eyed goby *G. giuris* from Netrakona during the tenure from February 2004 to January 2005.

Materials and Methods

The samples of Bele for the present work were collected once a month from February 2004 to January 2005 from the fishermen of three fish markets of Netrakona district town. A total number of 299 individuals of Bele was collected for the study period. After collection, the fishes were preserved in 10% formalin.The samples were labelled monthwise in plastic jar and kept in the fisheries Laboratory. Different lengths of fishes were measured in the nearest mm by means of a measuring board fitted with a centimeter scale and the weights were recorded by means of a sensitive Pan balance (TG 928A, capacity 200g, China) in g. For fin formula, Rahman (1989) was followed.

Size frequency distribution: The size frequency distribution was calculated for each length group of 11.0 mm class interval by Peterson Polygon method. Statistical formulae were used to establish mathematical relationship between the total length and other lengths (Snedecor 1956 and Simpson *et al.*1960). The total length (TL) and total eight (TW) relationship of these fishes were determined by using the logarithmic transformation of the formula: W = aL (Le Cren 1951), where W = weight, L = length, a is a constant and an xponent. Values for a and n were found empirically.The value of the coefficient of condition (k) was calculated from the cube law equation W = KTL$^3 \times 10^5$ or $K = \frac{TW \times 10^5}{TL^3}$, where TW = total weight, TL = total length, and K = the factor of proportion.

Results and Discussion

Morphometrics

Size frequency distribution: The data on size frequency distribution of 306 individuals of males and females of Bele are presented in Fig. 1. The specimens were grouped into 12 size groups of 11.0 mm class intervals. Minimum number of male was found in one size group 125-136 mm while no male was found in five size groups viz. 136-147 mm, 147-158 mm, 158-169 mm, 169-180 mm and 180-191 mm. Maximum number of male was recorded in one size group (92-103 mm). On the other hand, minimum number of female was found in two size groups (136-147 mm and 180-191 mm) while maximum number of female was observed in 92-103 mm size group. Females were absent from three size groups (147-158 mm, 158-169 mm and 169-180 mm). According to Saha and Saha (2011), minimum number of male (132-138 mm and 138-144 mm size group) and female (150-156 mm and 156-162 mm size group) of *Nandus nandus* occurs in 2 size groups. Saha and Saha (2011) also reported that the highest number of male and female was available in 96-102 mm and 102-108 mm size groups, respectively in beel water of Netrakona.

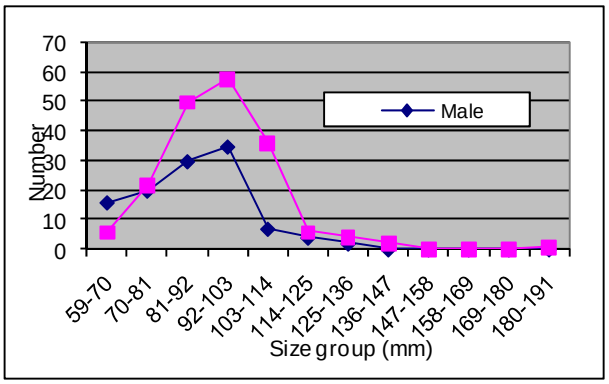

Fig.1. Size frequency distribution of male and female of Bele, *Glossogobius giuris* sampled from Netrakona.

Estimation of lengths: The total length (TL) of male individuals of *G. giuris* attained the range from 59 mm to 135 mm with the mean of 89.14 ± 14.77 mm. In females, it varied from 63 mm to 190 mm with an average of 97.67 ± 19.8 mm and in combined sex, the average being 94.42 ±18.52 mm. Information on maximum total length of *G. giuris* are achieved from different workers viz. 350 mm (Munro 1955), 170 mm (Bhuiyan 1964), 108-152 mm (Srivastava 1968), 450 mm (Day 1878) and 292 mm (Rahman 1989) from home and abroad.

The standard length (SL) of males attained the variation from 46 mm to 107 mm with the mean of 70.1 ± 12.03 mm. In females, it ranged from 50 mm to 152 mm with an average of 75.03 ± 13.92 mm and in combined sex, the mean being 73.13 ± 13.45 mm.

The head length (HL) of male *G. giuris* ranged from 14 mm to 35 mm with the mean of 22.67 ± 4.47 mm. In females, it varied from 15 mm to 50 mm with the mean of 24.68 ± 4.95 mm and in combined sex, the mean calculated to be 23.9 ± 4.87 mm.

The pre-dorsal length (PDL) of males showed a range from 19 mm to 38 mm with the average of 27.12 ± 5.07 mm. In females, it varied from 19 mm to 61 mm with the mean calculated 29.8 ± 8.23 mm and in combined sex, the average being 28.8 ± 7.32 mm.

The snout length (SnL) of males ranged from 2.5 mm to 13 mm with the mean of 7.71 ± 1.83 mm. In females, it varied from 05 mm to 15 mm with the mean of 8.42 ±1.9 mm and in combined sex, the mean calculated to be 8.15 ± 1.9 mm.

The height of body (HB) of males was found to range from 08 mm to 22 mm with the mean of 13.18 ± 2.97 mm. In females, it varied from 09 mm to 34 mm with an average of 14.74 ± 3.34 mm and in combined sex, the average calculated to be 14.17 ± 3.29 mm.

The total weight (TW) of male individuals of *G. giuris* was found to be 01.6 g to 23 g with the mean of 6.48 ± 3.58 g. In females, it varied from 1.8 g to 55.8 g with an average of 9.62 ± 8.91 g and in combined sex, the mean being 8.48 ± 7.56 g.

Total length (TL) and standard length (SL): Scattered diagram (Fig. 2) of total length and standard length of Bele (*G. giuris*) exhibits a positive and linear relationship between them. The coefficient of correlation is highly significant (r = 0.90). Saha and Saha (2011) determined the coefficient of correlation (r = 0.982) of *Nandus nandus* between total length and standard length which closely correlates with the present report.The relationships between the total length (TL) and standard length (SL) can be expressed by the following relations:

Log SL= -592+0.7877Log TL

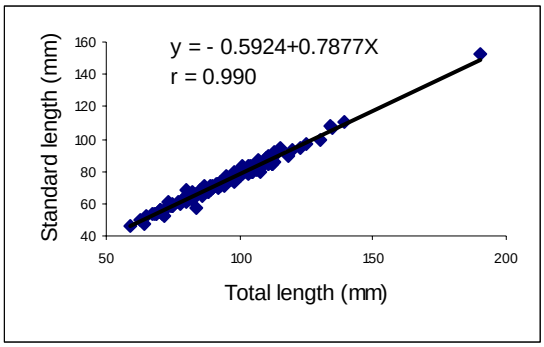

Fig. 2. Relationship between total length and standard length of Bele, *Glossogobius giuris*.

Total length (TL) and head length (HL): The relationships between total length and head length of Bele are linear, positive and highly significant (r = 0.962) between them. The coefficient of correlation (r = 0.962) between total length and head length of Bele shows maximum similarity with the finding (r = 0.951) of Saha and Saha (2011) who worked on *Nandus nandus* from Netrakona.The relationships between the total length (TL) and head length (HL) can be expressed by the following relations (Fig. 3):

Log HL = -2.0318+0.2772 Log TL

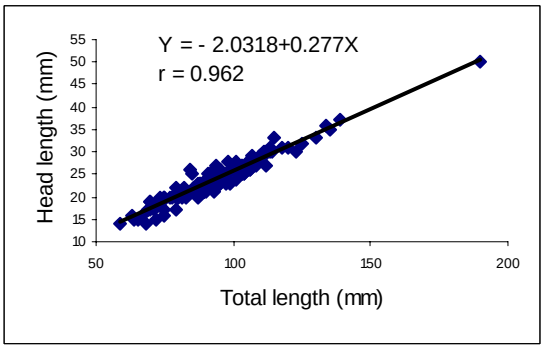

Fig.3. Relationship between total length and head length of Bele, *Glossogobius giuris.*

Total length (TL) and snout length (SNL): Scattered diagram (Fig. 4) of total length and snout length hints a positive and linear relationship between them. The coefficient of correlation was r = 0.882, which was strong and highly significant.The coefficient of correlation (r = 0.891) recorded by Saha and Saha (2011) closely coincides with this finding. The relationships between total length (TL) and snout length (SnL) were expressed by the following relations:

Log SnL = -4.4497+0.1297 Log TL

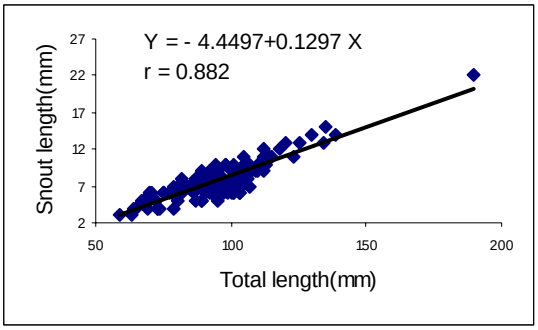

Fig.4. Relationship between total length and snout length of Bele, *Glossogobius giuris.*

Total length (TL) and pre-dorsal length (PDL): Scattered diagram of total length and pre-dorsal length of Bele (*G. giuris*) exhibits a positive and linear relationship between them (Fig. 5). The coefficient of correlation is highly significant (r = 0.90). The coefficient of correlation (r = 0.888) of *Nandus nandus* by Saha and Saha (2011) showed resemblance with the present study. The relationships between the total length (TL) and pre-dorsal length (PDL) were expressed by the following relations:

Log PDL = 1.8462+0.3233 Log TL

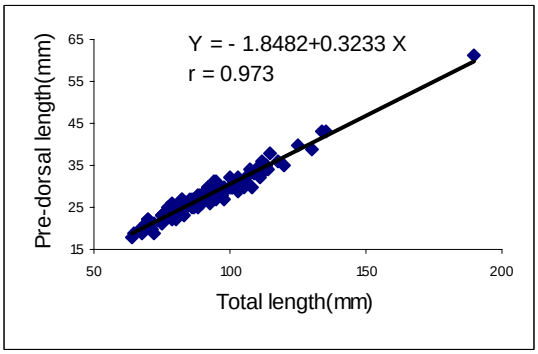

Fig. 5. Relationship between total length and pre-dorsal length of Bele, *Glossogobius giuris.*

Total length (TL) and height of body (HB): The relationships between total length and height of body of Bele are linear, positive and highly significant (Fig. 6). The correlation coefficient is 0.924. The coefficient of correlation (r = 0.839) of *Nandus nandus* (Saha and Saha 2011) is in conformity with this observation.The relationships between the total length (TL) and height of body (HB) were expressed by the following relations:

Log HB = -4.4205+0.1997 Log TL

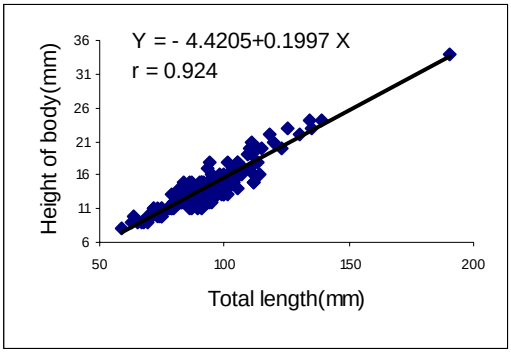

Fig.6. Relationship between total length and height of body of Bele, *Glossogobius giuris.*

Meristics: The lateral line of *Glossogobius giuris* is complete. Ist dorsal fin with 6 unbranched rays; 2nd dorsal fin with 1 unbranched and 9-10 branched rays; Pectoral fin with 17-21 branched rays; Pelvic fin with 1 unbranched and 5 branched rays; Anal fin with 1 unbranched and 9 branched rays; Caudal fin with 17 branched rays of *Glossogobius giuris* were determined. According to Rahman (1989), the fin formula is D_1.6; D_2.1/8-9; P_1.18-20; P_2.6 (1/5); A.1/8-9. Bhuiyan (1964) showed the fin formula of *G. giuris* as B.iv; D_1.6; D_2.9-10; A.9-10; V.6; C.17; L.l.32-34; L.tr.8/9 from Dacca.

The fin formula of Bele (*G.giuris*) from Netrakona stands as follows: D_1. 6; D_2. 1/9-10; P_1.17-21; P_2.1/5; A.1/9; C.17.

Length-weight relationship: The length-weight relationships for 306 individuals of Bele, *Glossogobius giuris* ranging in size from 59.0 mm to 190.0 mm and in total weight from 1.6 g to 55.8 g throughout the study period were determined. The length-weight relationships of male, female and combined sex were determined as Log TW = -4.704 + 2.811Log TL, Log TW = -4.910 + 2.909 Log TL and Log TW = -4.802 + 2.857 Log TL, respectively (Figs. 7-9). It is evident from Figs. 7- 9 that the weights bear a curvilinear relationship with the total length. Doha (1974) determined the equation from length-weight relationship of *G. giuris* as Log W= -4.657+2.816 log L from Mymensingh water which is in conformity with this study. Saha and Saha (2011) calculated the equations from the length-weight relationship of the freshwater percid fish, *Nandus nandus* as Log W=5.274+3.23 Log L in male, Log W=4.538+2.89 Log L in female and Log W= 4.751+2.39 Log L in combined sex from Netrakona.

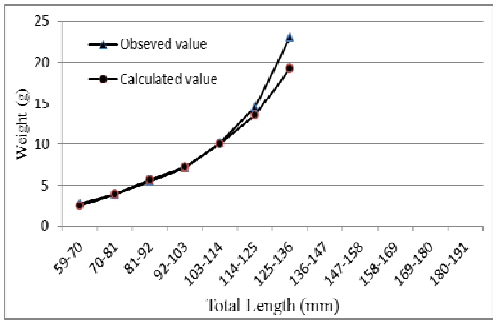

Fig.7. Relationship between total length and total weight in male *Glossogobius giuris.*

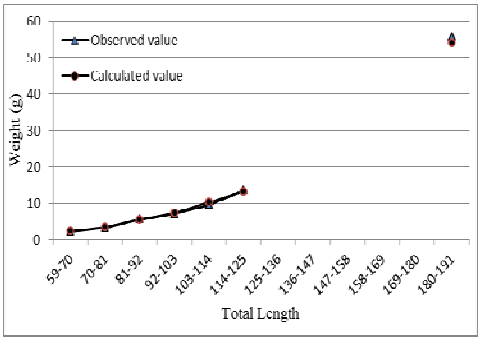

Fig.8. Relationship between total length and total weight in female *Glossogobius giuris*.

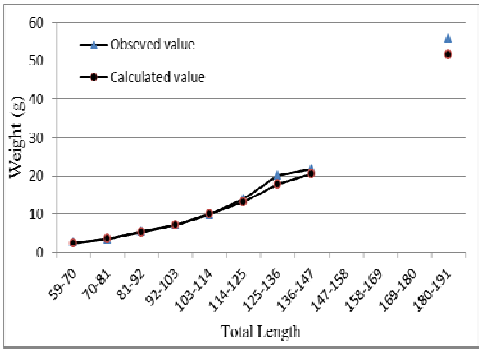

Fig.9. Relationship between total length and total weight in combined sex of *Glossogobius giuris.*

Coefficient of condition from the observed value (ko): The coefficient of condition from the observed value of *Glossogobius giuris* of male was found to range from 0.7906-0.8489 with an average of 0.8206; in case of female, it was 0.8274-0.9740 with the mean of 0.8697 and in combined sex, the mean and the range were 0.8564 and 0.8165-0.9042, respectively (Figs. 10, 11 and 12). Doha (1974) estimated the condition factor (*K*) of

Glossogobius giuris as 0.784-1.338 with the mean of 0.9991 which is in conformity with the present finding.

Coefficient of condition from the calculated value (kc): The coefficient of condition from the calculated value of *Glossogobius giuris* of male was estimated as 0.7522-0.8891 with the mean of 0.8564; in case of female, it varied from 0.8060-0.9234 with the mean of 0.8689 and in combined sex, it was found to range from 0.8411-0.8682 with an average of 0.8558 (Figs. 10-12).

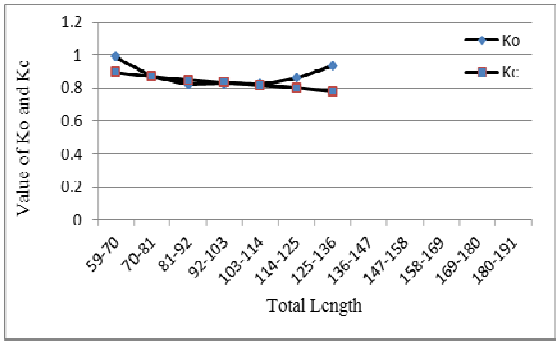

Fig. 10. Relationship between total length (TL) and coefficient of condition for observed weight (*Ko*) and calculated weight (*Kc*) in male *G. giuris.*

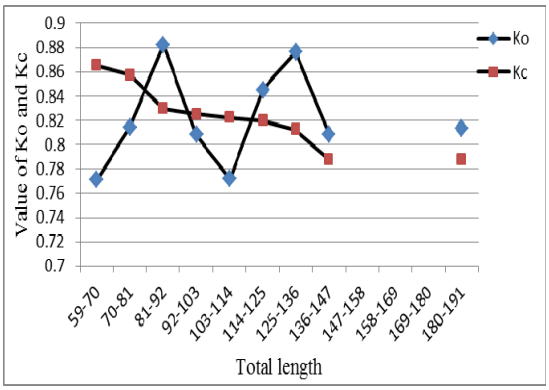

Fig.11. Relationship between total length (TL) and coefficient of condition for observed weight (*Ko*) and calculated weight (*Kc*) in female *G. giuris.*

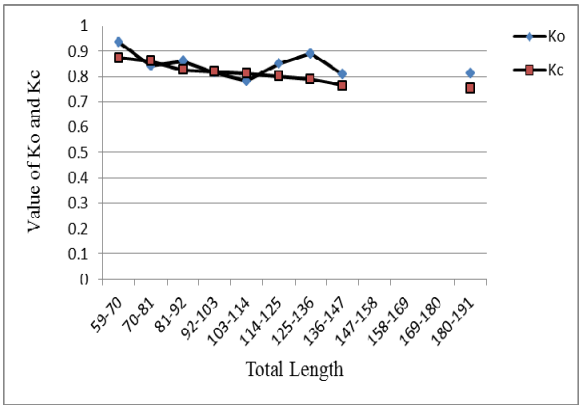

Fig.12. Relationship between total length (TL) and coefficient of condition for observed weight (*Ko*) and calculated weight (*Kc*) in combined sex of *G. giuris.*

Relative coefficient of condition (Kn): The relative coefficient of condition (*Kn*) of *Glossogobius giuris* of male was found to be 0.9402-1.1071 with the mean of 1.0006; in case of female, it ranged from 0.919-1.125 with the mean of 1.0035; in combined sex, the range was 0.960-1.057 with an average of 1.0002 (Fig. 13). Doha (1974) determined the mean of *Kn* of *G. giuris* as 0.9993 with a range of 0.903-1.117 which shows similarity with the present work. However, the *Kn* values shows dispersion in all the sex groups of freshwater fishes (Rahman 1990 and Saha & Saha 2010, 2011) which is in agreement with the present study.

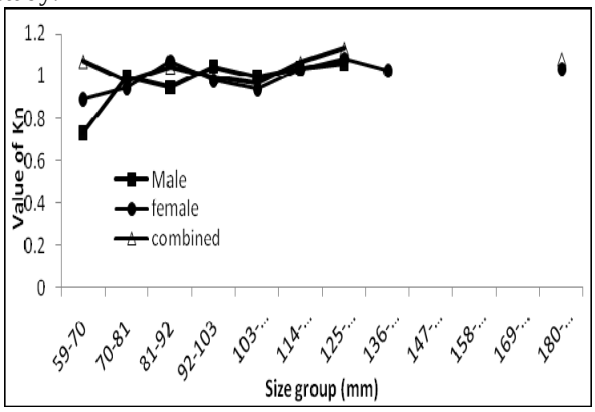

Fig.13. Relationship between total length and relative coefficient condition *(Kn)* for male, female and combined sex of *G. giuris.*

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OPTIMIZING PLANT DENSITY AND WEED CONTROL TECHNIQUES IN YIELD ENHANCEMENT OF MUNGBEAN

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Abstract

Field experiment was carried out at the Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to investigate the effect of plant density and weed control techniques on yield enhancement of mungbean. The experiment consisted of two factors *viz.* plant densities and weed control. Plant densities were 30 cm×continuous (D_1), 30 cm×5 cm (D_2), 30 cm×10 cm (D_3) and 30 cm×15 cm (D_4) arranged in the main plot. Weed control techniques were no weeding (W_0), two hand weeding at 15 and 30 DAS (W_1), Topstar 80 WP @ 75 g ha^{-1} as pre-emergence at 3 DAS (W_2) and Whip Super 9 EC @ 750 ml ha^{-1} at 15 and 30 DAS as post-emergence herbicide (W_3) arranged in the sub plot in a split plot design. Results showed that both plant density and weed control techniques significantly influenced most of the parameters studied. It was observed that application of pre and post emergence herbicide controlled weeds effectively compared to other weed control techniques whereas weed population and weed biomass were less in 30 cmx10 cm plant density. Considering yields, combination of 30 cm×10 cm plant density with application of Topstar 80 WP (D_3W_2) attributed to highest seed yield (1.47 t ha^{-1}), stover yield (1.94 t ha^{-1}) and biological yield (3.41 t ha^{-1}) of mungbean.

Key words: Plant density, Pre emergence herbicide, Post emergence herbicide

Introduction

Mungbean (*Vigna radiata* L.) belonging to family Fabaceae, is an important pulse crop of Bangladesh. It ranks third in protein content and fourth in area and production (MoA 2014). It also plays significant role in sustaining crop productivity by fixing nitrogen through rhizobial symbiosis and adding crop residues (Sharma and Behera 2009). Mungbean is a cheap source of easily digestible dietary protein which contains 24.7% protein, 0.6% fat, 0.9 fiber and 3.7% ash (Potter and Hotchkiss 1997). However, yield of mungbean is very poor (1.04 t ha^{-1}) as compared to many mungbean growing countries of tropical and sub-tropical regions of the world.

One of the reason of poor yield of mungbean is not to maintaining proper planting density which is a pre-requisite for obtaining higher yield (Rafiei 2009). Plant density affects the plant growth as well as grain yield in mungbean (Jahan and Hamid 2004). Plant density not only is defined in terms of number of plants per unit area but also in

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terms of arrangement of plants on the ground (Kaulm and Singh 2002). The optimum density favors the plants to grow well through efficient utilization of solar radiation and nutrients and thus increase grain yield of mungbean (Miah *et al*. 1990).

Another important factor responsible for low yield of mungbean is weed infestation. It competes with crop for space, nutrients, water and light and reduces yield of crop (Pandey and Mishra 2003). Weed crop competition commences with germination of the crop and continues till its maturity where emergence, growth, flowering and pod setting stages of mungbean are greatly hampered by weed. Weed infestation at these stages causes low pod setting and ultimately reduces grain yield of mungbean. This indicates that yield enhancement of mungbean can be possible by controlling weed to tolerable level. Yield improvement resulting from weeding has also been reported in mungbean by many researchers (Kumar and Kairan 1990 and Musa *et al*. 1996). However, information on plant density and weed control in yield improvement of mungbean is very scarce. Therefore, the study was undertaken to find out the effect of plant density and weed control techniques on yield enhancement of mungbean.

Materials and Methods

The field experiment was conducted in medium fertile soil at Sher-e-Bangla Agricultural University (90º33´ E longitude and 23º77´ N latitude), Dhaka, Bangladesh during April to June, 2014. The pH value of the soil was 5.60. A modern variety of mungbean, BARI Mung-6 was used as plant material for the present study. The experiment was carried out with four plant population densities *viz*. 30 cm×continuous (D_1), 30 cm×5 cm (D_2), 30 cm×10 cm (D_3) and 30 cm×15 cm (D_4) in the main plot and four weed management methods *viz.* no weeding (W_0), two hand weeding at 15 and 30 DAS (W_1), Topstar 80 WP @ 75 g ha^{-1} as pre-emergence at 3 DAS (W_2) and Whip Super 9 EC @ 750 ml ha^{-1} at 15 and 30 DAS as post-emergence herbicide (W_3) in the sub plot in a split plot design. All the intercultural operations were done as per necessity of the crop. Data related on weed parameters, yield contributing characters and yield were collected and subjected to analyze statistically and analysis of variance was done with the help of computer package MSTAT-C. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez 1984).

Results and Discussion

Weed parameters : Weeds grow everywhere and interfere the normal growth and development of crop plants. Weed population at 20 and 40 DAS varied significantly due to different plant density under the present trial (Table 1). At 20 and 40 DAS, the maximum weed population (7.67 m^{-2}) were recorded in D_4 (30 cm×15 cm) and (14.00 m^{-2}) in D_1 (30 cm×continuous), respectively. On the other hand, the minimum weed

population (6.08 m^{-2}) was observed in D_1 (30 cm×continuous) treatment and (11.50 m^{-2}) in D_3 treatment, at 20 and 40 DAS, respectively. In general, the lesser the space available, result is the minimum weed population. An increasing trend of weed biomass was observed with decreasing plant density D_4 (30 cm×15 cm) in this experiment at both sampling dates. It might be due to increasing weed competition in lower plant populations which favored to increase weed biomass.

Table 1. Effect of plant density and weed control techniques on weed population and weed biomass of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Weeds population (m^{-2})		Dry weight of weed biomass (g m^{-2})	
	20 DAS	40 DAS	20 DAS	40 DAS
Plant density				
D_1	6.08 c	14.00 a	3.92 b	4.88 b
D_2	6.58 b	12.67 b	3.95 b	4.92 b
D_3	7.00 b	11.50 c	3.93 b	4.91 b
D_4	7.67 a	12.58 b	4.21 a	5.24 a
SE	0.142	0.108	0.029	0.024
Weed control techniques				
W_0	15.92 a	26.58 a	4.72 a	6.46 a
W_1	3.92 bc	7.92 c	3.81 b	4.54 b
W_2	4.00 b	7.00 d	3.72 b	4.47 b
W_3	3.50 c	9.25 b	3.77 b	4.48 b
SE	0.158	0.219	0.040	0.048
CV (%)	8.00	5.98	6.92	5.61

Weed population and weed biomass showed a significant relationship with weed control techniques (Table 1). Application of pre and post emergence herbicides controlled weeds successfully and weed biomass was least in case of herbicide treated plots. On the other hand, highest weed biomass was recorded from no weeding (W_0) due to severe weed infestation which supports the findings of Naeem *et al.* (2000) who reported that weed density decreased significantly for different weed management as compared to control. Weed population and weed biomass (g m^{-2}) had significant effect on various combinations of planting density and weed control techniques (Table 2). Lower plant density combined with no weeding resulted in maximum weed population and weed biomass. Contrary, herbicidal treatments combined with optimum plant density performed better over other treatment combinations. This might be due to minimum space availability by the weed species combined with herbicide application which controlled them successfully and results in minimum number of weed population and weed biomass.

Table 2. Interaction effect of plant density and weed control techniques on weed population and weed biomass of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Weed population (m^{-2})		Dry weight of weed biomass (g m^{-2})	
	20 DAS	40 DAS	20 DAS	40 DAS
D_1W_0	15.33 b	28.33 a	4.81 a	6.65 a
D_1W_1	3.33 de	9.33 de	3.69 d-f	4.34 f-h
D_1W_2	3.33 de	8.00 ef	3.62 d-f	4.30 f-h
D_1W_3	2.33 e	10.33 d	3.58 ef	4.22 gh
D_2W_0	16.33 a	27.33 ab	4.68 a	6.33 b
D_2W_1	3.67 cd	7.33 fg	3.69 d-f	4.44 e-h
D_2W_2	3.33 de	6.67 fg	3.73 c-e	4.52 d-g
D_2W_3	3.00 de	9.33 de	3.68 d-f	4.40 f-h
D_3W_0	15.33 b	24.33 c	4.58 a	6.28 b
D_3W_1	4.00 cd	7.67 f	3.86 b-d	4.60 c-f
D_3W_2	4.67 c	6.00 g	3.44 f	4.15 h
D_3W_3	4.00 cd	8.00 ef	3.84 b-e	4.59 c-f
D_4W_0	16.67 a	26.33 b	4.79 a	6.58 ab
D_4W_1	4.67 c	7.33 fg	3.98 bc	4.78 cd
D_4W_2	4.67 c	7.33 fg	4.09 b	4.90 c
D_4W_3	4.67 c	9.33 de	3.99 bc	4.72 c-e
SE	0.922	0.438	0.080	0.097
CV (%)	8.00	5.98	6.92	5.61

Yield contributing characters: Significant variations were observed in case of yield contributing characters due to different plant density and weed control techniques (Table 3). Maximum number of pods plant^{-1} (18.92), number of seeds pod^{-1} (12.23) and 1000-seed weight (45.36 g) was recorded from 30 cm×10 cm (D_3) which was attributed due to the lesser competition within the plant populations and higher dry matter partitioning to the sink. On contrary, increasing planting density showed least values in case of yield contributing parameters of mungbean than others. This result supports the findings of Zaher *et al.* (2014) who observed the similar trend of yield attributes with increasing planting density. Present study also revealed that application of Topstar 80 WP (W_2) resulted in highest number of pods plant^{-1} (18.82), number of seeds pod^{-1} (12.17) and 1000-seed weight (44.74 g) which was due to weed free condition of the field that supported proper growth and development of the mungbean plants (Table 3). The result is in agreement with the findings of Akter *et al*. (2013). Considering interaction of plant density and weed control, it was evident that plant density of 30 cm×10 cm combined with Topstar 80 WP (D_3W_2) was the best treatment combination for all the yield contributing parameters of mungbean than rest of the others (Table 4).

Table 3. Effect of plant density and weed control techniques on yield contributing attributes of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000-seeds (g)
Plant density			
D_1	15.02 c	10.63 c	41.17 b
D_2	17.47 b	11.70 b	42.54 ab
D_3	18.92 a	12.23 a	45.36 a
D_4	17.63 b	11.83 b	44.39 a
SE	0.163	0.09	0.83
Weed control techniques			
W_0	13.72 c	10.38 b	40.92 b
W_1	18.63 a	12.02 a	44.12 a
W_2	18.82 a	12.17 a	44.74 a
W_3	17.87 b	11.81 a	43.68 a
SE	0.188	0.119	0.565
CV (%)	4.76	3.56	4.51

Table 4. Interaction effect of plant density and weed control techniques on yield contributing attributes of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000-seeds (g)
D_1W_0	12.03 h	10.07 e	40.06 d
D_1W_1	16.40 e	10.97 d	42.97 b-d
D_1W_2	16.17 e	10.80 de	40.63 d
D_1W_3	15.47 ef	10.67 de	41.02 d
D_2W_0	14.43 fg	10.63 de	42.81 b-d
D_2W_1	18.63 cd	12.07 bc	42.13 cd
D_2W_2	18.90 b-d	12.27 a-c	42.95 b-d
D_2W_3	17.90 d	11.83 c	42.28 cd
D_3W_0	14.57 fg	10.50 de	40.34 d
D_3W_1	20.50 a	12.80 ab	46.50 ab
D_3W_2	20.63 a	12.90 a	48.35 a
D_3W_3	19.97 ab	12.70 ab	46.26 ab
D_4W_0	13.83 g	10.33 de	40.47 d
D_4W_1	18.97 b-d	12.27 a-c	44.90 a-c
D_4W_2	19.57 a-c	12.70 ab	47.01 a
D_4W_3	18.13 d	12.03 bc	45.18 a-c
SE	0.375	0.238	1.129
CV (%)	4.76	3.56	4.51

Yield and harvest index : Results of this study indicated that yield of mungbean showed significant variation due to various plant densities (Table 5). The highest seed yield (1.36 t ha^{-1}), stover yield (1.75 t ha^{-1}), biological yield (3.11 t ha^{-1}) and harvest index (43.86 %) was recorded from 30 cm×10 cm (D_3). Increasing or decreasing plant density from 30 cm×10 cm (D_3) decreased yield of mungbean. Optimum planting density ensured higher dry matter production which attributed the increasing seed and stover yield compared to

other treatments. Kabir and Sarkar (2008) also reported that 30 cm×10 cm produced the highest seed yield in case of mungbean. Similarly Zaher *et al.* (2014) recorded the highest biological yield (3964 kg ha^{-1}) of mungbean by 30 cm row spacing.

Weeds compete with crop plants for the limited resources available in the crop field. Completely weed free condition allows plants to utilize those resources solely and results in better yield in respect of seed and stover compared to weedy check (control). Results revealed that various weed control techniques controlled weeds differently and showed a highly significant variation among the treatments (Table 5). Results revealed that application of pre emergence herbicide Topstar 80 WP (W_2) controlled weeds completely and produced maximum seed yield (1.39 t ha^{-1}), stover yield (1.85 t ha^{-1}) biological yield (3.24 t ha^{-1}) and harvest index (43.87%) over manual weeding and post emergence herbicide.

Table 5. Effect of plant density and weed control techniques on the yield of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Plant density				
D_1	1.13 c	1.56 c	2.69 c	42.04
D_2	1.26 b	1.65 b	2.91 b	43.36
D_3	1.36 a	1.75 a	3.11 a	43.86
D_4	1.33 a	1.70 ab	3.02 a	43.84
SE	0.016	0.024	0.032	0.427
Weed control techniques				
W_0	1.06 c	1.36 d	2.41 d	42.77
W_1	1.34 ab	1.78 b	3.12 b	42.84
W_2	1.39 a	1.85 a	3.24 a	43.87
W_3	1.30 b	1.67 c	2.97 c	43.61
SE	0.022	0.026	0.033	0.629
CV (%)	6.04	5.48	3.94	5.04

This might be due to the initial weed control by pre emergence herbicide which promoted plant growth effectively as weeds failed to establish properly at later (Chowdhury *et al.* 2014). Other treatments failed to control weeds successfully and severe weed infestation interfered the normal physiological processes of plants and ultimately seed and stover yield decreased drastically. Chattha *et al.* (2007) observed a significant increase (50%) in seed yield of mungbean due to chemical weed control at 2-3 leaf stage of weeds plus hand weeding at 50 DAS.

The interaction effect of plant density and weed control techniques varied significantly for yield of mungbean (Table 6). It was observed that herbicidal treatments combined with planting density performed better than rest of the other treatment combinations.

Minimum planting density coupled with herbicide (30 cm×10 cm treated with Topstar 80 WP) produced the highest seed yield (1.47 t ha^{-1}), stover yield (1.94 t ha^{-1}) and biological yield (3.41 t ha^{-1}). These were possible because of minimization of competition between intra and inter plant species provided by herbicide application and lesser plant density.

Table 6. Interaction effect of plant density and weed control techniques on the yield of BARI mug-6, Mean ± SE (n=3). Values labelled with different low case letters are significantly different at *P<0.05* by DMRT.

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
D_1W_0	1.02 c	1.28 d	2.30 f	44.27
D_1W_1	1.16 c	1.71 bc	2.86 d	40.27
D_1W_2	1.29 b	1.84 ab	3.13 bc	41.33
D_1W_3	1.04 c	1.42 d	2.47 ef	42.27
D_2W_0	1.05 c	1.36 d	2.40 ef	43.62
D_2W_1	1.32 ab	1.81 a-c	3.13 bc	42.26
D_2W_2	1.35 ab	1.79 a-c	3.13 bc	42.98
D_2W_3	1.33 ab	1.66 c	2.99 cd	44.59
D_3W_0	1.08 c	1.36 d	2.44 ef	44.52
D_3W_1	1.45 a	1.86 ab	3.32 ab	43.83
D_3W_2	1.47 a	1.94 a	3.41 a	43.13
D_3W_3	1.44 ab	1.84 ab	3.28 ab	43.94
D_4W_0	1.08 c	1.44 d	2.52 e	43.07
D_4W_1	1.42 ab	1.74 bc	3.16 bc	44.99
D_4W_2	1.43 ab	1.85 ab	3.29 ab	43.64
D_4W_3	1.37 ab	1.76 bc	3.14 bc	43.65
SE	0.044	0.053	0.067	1.258
CV (%)	6.04	5.48	3.94	5.04

From the results it may be concluded that sowing of mungbean at 30 cm×10 cm plant density and application of Topstar 80 WP as pre-emergence herbicide would be the best practice for yield enhancement of mungbean. Further study should be undertaken to know whether pre-emergence herbicide affects soil microorganisms or not.

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POST-HARVEST QUALITY LOSS OF SMALL INDIGENOUS FISH SPECIES IN SYLHET REGION: ENSURE QUALITY UP TO CONSUMER LEVEL

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Abstract

The present study was designed to investigate the post-harvest quality loss of locally captured Small Indigenous Species (SIS) based on existing marketing system in Sylhet region. A total of 20 fish harvesters, 30 fish handlers (involve in sorting, loading and unloading, transporting, receiving at market), 10 depot owners, 10 auctioneers, 5 aratders was interviewed and 10 markets were visited to collect data about post-harvest activities and marketing of SIS from some areas of Sylhet and Sunamgonj district from July 2015 to December 2015. At harvesting places (100%) fish were the best quality (defect point <2). Fish sold in early market (7am – 9 am) were also acceptable (defect point <2 to <3) in terms of quality. After harvesting rough handling (15%), compactness (3%), delay icing (10%), no icing (45%), marketing process (15%) and transportation (7%) lead to loss of a major proportion of total quality. On the basis of defect point average freshness quality of SIS were found <2 at harvesting places, <2 to <3 in landing center, during sorting, <2 to <3 during transportation and <2 to< 4 at market which were results from different activities associated with SIS handling and marketing.

Key words: Small indigenous species (SIS), Post-harvest quality loss, Quality, Ice, Defect point

Introduction

In Bangladesh, fisheries sector contributes an important role in socio-economic cultural setting, rural employment and food security. About 60% of the animal protein intake in Bangladesh comes from fish. The average per-capita consumption of fish in Bangladesh is between 20 and 25 kg, while the world average is 13 kg (DoF 2012). In terms of inland captured fishery, Sylhet region is one of the richest areas of fish production. In this region, fishes are captured from different resources, such as haors, beels, rivers and flood plains etc. Fishes play an important role to meet up the protein demand of this area and also contribute to the economy of the country. Among the captured fishes, small indigenous species (SIS), which grows to a size of 25 cm (Hossain and Afroze 1991) takes important part of the total catch. These small indigenous fish species are demandable fish item for their taste. In terms of economic and nutritional aspects these SIS are good resources of protein to low income group people. On the other hand, SIS

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has high nutritive value in terms of protein, vitamins, and minerals (Thilsted *et al*. 1997). After harvested in large quantity from the haor area SIS are sold in the local and other markets. Quality of the harvested SIS fishes landed for consumption is lost during harvesting and post-harvest handling (Hossain *et al*. 2012) due to ignorance and/or negligence of the people during harvest, distribution, processing and trade (Nowsad 2004), preservation methods, transportation methods, availability of ice during transportation and selling period etc. All the activities related to the loss of quality also result in serious economic loss of fishermen, middlemen, fish traders and finally consumers. The current study was designed to investigate the quantitative and qualitative changes of small indigenous fishes after harvesting, in different stages of marketing, as well as to evaluate the present status of SIS harvesting, handling, processing, preservation and marketing related to quality of fish and to recommend some appropriate means to maintain quality of SIS/fish.

Materials and Methods

The study was conducted in two districts namely Sylhet and Sunamgonj, where Sylhet Sadar and Sunamgonj Sadar, the main survey areas in respect of adjacent landing sites, local fish markets were taken under investigation. Data were mainly collected from the fishermen, fish harvester, fish handler and fish traders on the basis of questionnaired interview. Direct observation of landing center, marketing channel, distribution, icing facilities, distance from the landing center, and handling were taken under consideration. The middlemen, aratdars, wholesalers involved in supply, distribution and marketing of fish were selected from whole-sale market (Arot) and retail market for the study. The data were collected over six months from July to December, 2015. The entire situation of the distribution channel of fish including SIS (Hossain *et al*. 2012) from haor to retailer level was also studied.

Assessment of post- harvest quality loss of SIS in different stages of harvesting, marketing and distribution channel was done according to the modified method of (Nowsad 2010). The method was based on Fish Loss Assessment and Control Tool originally developed by Torry Research Institute, UK (Sakaguchi 1994). To assess the quality of harvested SIS at different stages of distribution channel, at first sensory defect point with numerical scores employed in a sensory analysis was done by using Table 1 (modified based on Howgate *et al.*1992). General grading of fish obtained through the analysis of defect points (DP) is presented in Table 2.

Table 1. Attributes and defect points for quality assessment of wet fish.

Attributes	Defect	Defect points	Grade
1. Odour of neck when broken	a) Natural odour	1	Acceptable
	b) Faint or sour odour	5	Reject
2. Odour of gills	a) Natural odour	1	Excellent
	b) Faint sour odour	2	Good
	c) Slight moderate sour odour	3	Acceptable
	d) Moderate to strong sour odour	5	Reject
3. Colour of gills	a) Slight pinkish red	1	Excellent
	b) Pinkish red to brownish	2	Good
	c) Brown or grey	3	Acceptable
	d) Bleached colour, thick yellow slime	5	Reject
4. General appearance	a) Full bloom, bright, shining, iridescent	1	Excellent
	b) Slight dullness and loss of bloom	2	Good
	c) Definite dullness and loss of bloom	3	Acceptable
	d) Reddish lateral line, dull, no bloom	5	Reject
5. Slime	a) Usually clear, transparent and uniformly spread	1	Excellent
		2	Good
	b) Becoming turbid, opaque and milky	5	Reject
	c) Thick sticky, yellowish or green colour		
6. Eye	a) Bulging with protruding lens, transparent eye cap	1	Excellent
		2	Good
	b) Slight cloudy of lens and sunken	3	Acceptable
	c) Dull, sunken, cloudy	5	Reject
	d) Sunken eyes covered with yellow slime		
7. Consistency of flesh	a) Firm and elastic	1	Excellent
	b) Moderately soft and some loss of elasticity	2	Good
		3	Acceptable
	c) Some softening	5	Reject
	d) Limp and flabby		

Table 2. Grading of fish on the basis of the defect points.

Grade	Average DP	Comments
a	< 2	Excellent/highly acceptable
b	2 to < 3	Good/acceptable
c	3 to < 4	Poor/can be accepted with care
d	4 to 5	Bad/should be rejected

Results and Discussion

Most of the harvested fishes were excellent in quality during harvesting. Fresh SIS (Table 3) were available in all markets depending on proper handling, preservation, distance from harvesting areas and communication status of the harvested area. The small freshwater fishes are more susceptible to spoilage due to their comparative small size and vulnerability of constituent proteins and lipids (Nowsad 2004). Since the quality loss of

fish was not understood at least up to 50% of deterioration by common organoleptic means (Sakaguchi 1990), consumers generally took it without any complain on quality. Different activities related to quality loss of SIS are presented in Table 4. Quality loss of SIS at different stages of marketing is shown in Fig. 1.

Table 3. Some SISs which are normally found in Sylhet region.

Scientific name	Bangla name	Fishbase name
Ailia coila	Kajuli,Baspata	Ganjeti cailia
Amblypharyngodon mola	Mola, Moa	Mola carplet
Anabas testudineus	Koi	Climbing perch
Botia dario	Bou, Rani	Bengal loach
Chanda nama	Namachanda	Elongate glass-perchlet
Chanda ranga	Chanda	Indian glassy fish
Channa punctatus	Taki	Spotted snakehead
Clarias batrachus	Magur	Walking catfish
Colisa fasciata	Khalisa	Banded gourami
Corica soborna	Kachki	Ganges river sprat
Esomus danricus	Darkina	Flying barb
Glossogobius giuris	Bele	Tank goby
Gudusia chapra	Chapila	Indian rivershad
Heteropneustes fossilis	Shingi	Stinging catfish
Lepidocephalus guntea	Gutum	Guntea loach
Macrognathus aculeatus	Tara Baim	Lesser spiny eel
Mastacembelus pancalus	Guchi	Barred spiny eel
Mystus tengara	Buzuri Tengra	Pyjama catfish
Mystus vittatus	Tengra	Striped dwarf catfish
Nandus nandus	Meni	Gangetic leaffish
Notopterus notopterus	Pholi	Bronze featherback
Ompok pabda	Pabda	Pabdah catfish
Puntius sophore	Jatpunti	Pool barb
Puntius ticto	Tit Punti	Ticto barb
Osteobrama cotio	Dhela	-
Salmostoma bacaila	Chela	Large razorbelly minnow
Xenentodon cancila	Kakila	Freshwater garfish

Harvesting methods had an important role in quality assessment of fish. For selling the fish in the morning markets most of the harvesting operation started at about 4.30 am to 5 am. Fishes which were marketed within one or two hours after harvesting were found to be excellent and fishermen got more prices. Traditional system with mass catch made the small fishes much vulnerable to organoleptic changes shortly after death resulting reduction of price of the fishes. Fixed net were generally used to harvest SIS of fishes from shallow water. In the summer season especially in day time water became hot ultimately affecting the freshness and spoilage rate of the SIS. Hot water temperatures rapidly enhanced the spoilage rate of fish that were accumulated in the net. Nowsad *et al.* (2010) also reported that fishes were hardly washed with clean water immediately after

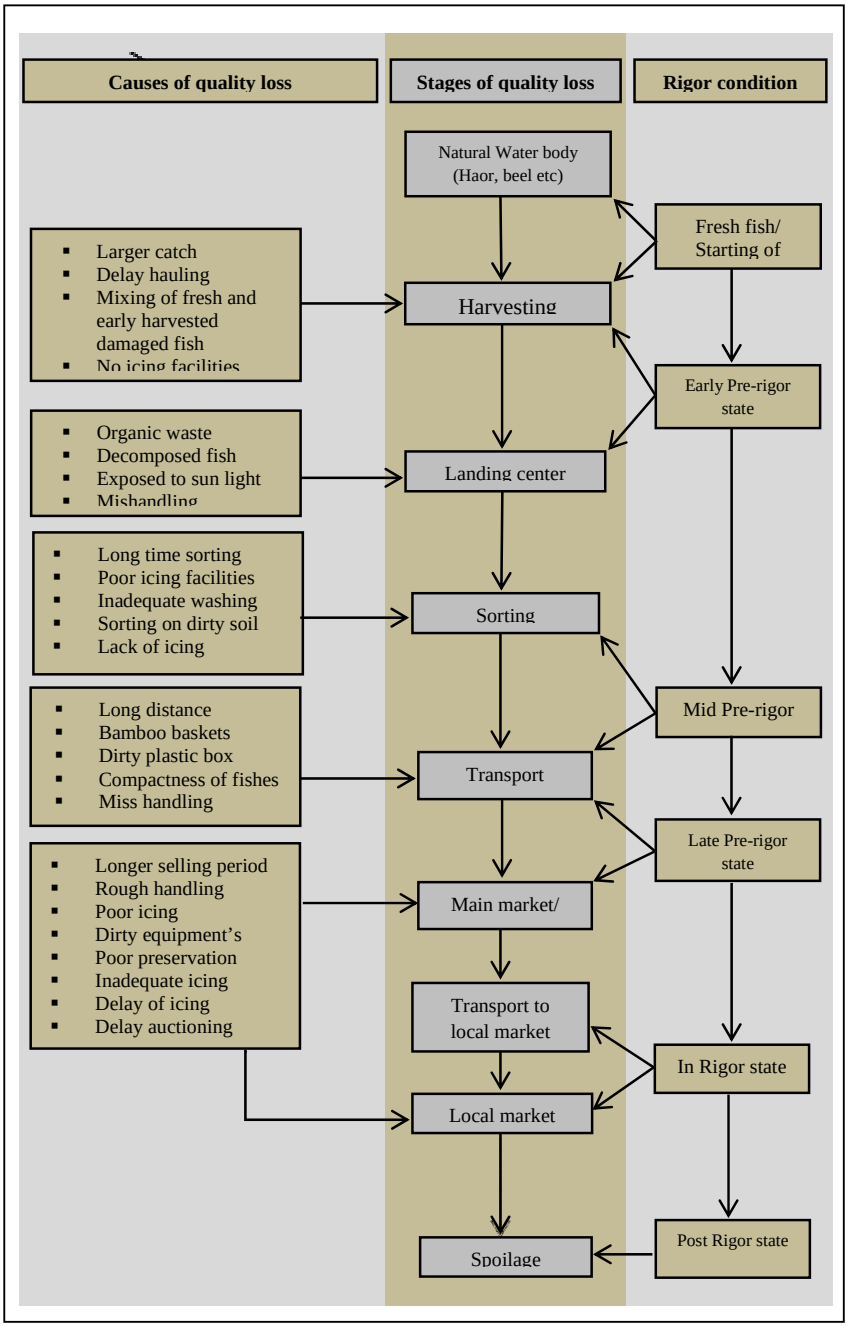

Fig.1. Flow chart of quality loss of SIS at different stages of marketing.

harvest. Sometimes engine oil of boat mixed with fish are preserved without ice. There was no icing facility for the harvested fish.

Boats were unloaded for first auctioning and also for sorting of mixed SIS catch even with large fishes. Sometimes bank near harvesting place was used as first landing and auctioning place. Generally local fishermen were associated with the unloading of the harvested fish. They hurried during unloading the boat. Smaller fishes especially SIS are more susceptible to physical damage if rough handling is done. Workers were found standing on the fish mass when unloaded. These bad practices created pressure on the top to lower part of the harvested fishes. Traditional bamboo made baskets and plastic boxes are used to unload fish from boat. In some cases human waste, duck waste, cow dung, dead animal body and other organic debris were observed where boats were unloaded. If organic debris was mixed with the catch accidentally or intentionally or unintentionally fish became more susceptible to bacterial decomposition. There was no facility of purchasing ice near temporary auctioning center (Hossain *et al.* 2012). Sorting after harvesting was done to separate fishes according to its value, price and size etc. Fish which are marketed immediately after landing remains better in quality. Lengthy sorting operations causing long time exposure to sunlight caused quality losses of fishes. Sometimes washing was done by dirty water, where as clean and contaminated free water was rarely used. Although, these activities did not affect the initial qualities but ultimately increased the load of spoilage bacterial population.

Distance was a factor for ensuring quality of small fishes. If communication was better it would require delivering the harvested fish within short time. However, not only the distance, proper transportation with necessary equipment is also required. It was observed that bamboos made baskets were mainly used. According to Hossain *et al*. (2012) mainly bamboo baskets wrapped in by polythene sheet and recently invented metallic box were used to transport the fish. Recently plastic made baskets are also used. Due to use of bamboo made baskets physical damage of fish as well as bacterial contamination also occurred. No ice was used during transportation of fish. Bamboos made baskets was mainly arranged in one by other vertically with full of fishes. Hossain *et al*. (2012) also reported that these were not properly washed after using and were kept in a contaminated place.

When harvested fishes were brought in a right way at early morning from water bodies were found fresh and excellent. Hossain *et al*. (2012) also reported that fish with extra respiratory organ like Baim (*Mastacembelaus armatus*), Taki (*Channa puntatus*), Gotchi (Macrognathus *aculeatus*), Gutum (*Lepidocephalichthys guntea*), Tengra (*Mystus bleekeri*) and Shing (Heteropneustes *fossilis*) were in quit fresh condition. In many cases during auctioning period icing was not done, but after completion of the auctioning the fish sellers use ice for high priced fish and avoid icing for the low priced fish. Nowsad (2004) observed the quality losses due to unavailability of suitable ice-box and ignorance of fishers on adequate handling, icing and freezing of fish.

In arat, washing, cleaning and icing of fish were hardly seen but sorting was regularly done. Again in the retail market washing, cleaning, sorting, grading and poor icing were done. Hossain *et al*. (2012) reported that to give fresh look to the fishes sprinkling water frequently over the fish was practiced.

After auctioning certain amount of fishes were marketed to other fish market of Sylhet region. In this case, quality depends on the proper handling, icing and also on preservation period. Generally the fishes which were sold at the afternoon were observed poor in quality in relation to defect point (Fig. 2) except very recent harvested fishes. Ice was available in most large markets of the Sylhet region except some small local markets.

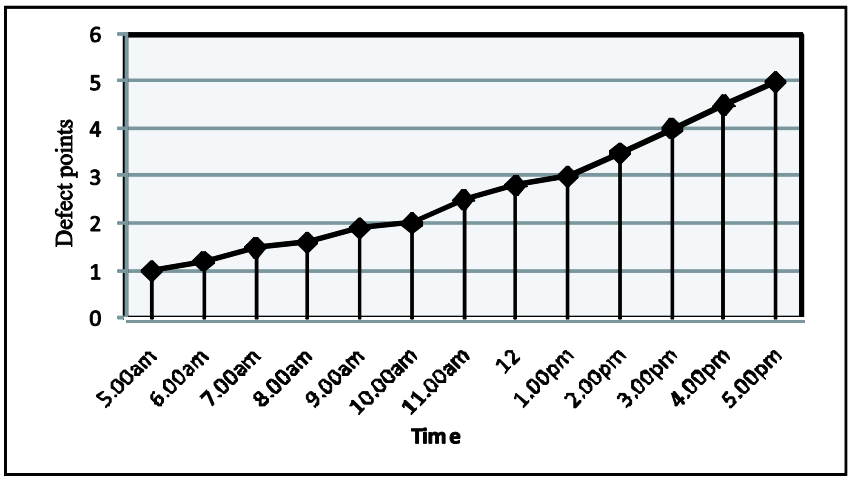

Fig. 2. Changes in defect point with relation to storage time.

In the present study it was found that quality of fishes was deteriorated due to delay in storage time (Fig.2). Major activities related to overall quality (Fig. 3) were lost due to no icing (45%), delay icing (10%), rough handling (15%) marketing process activities (15%), compactness (7 %) and transportation (3%). Range of defect point was between <2 to <4 (Table. 5). Some scientists also observed post-harvest fish losses at different stages of distribution chain from capture to consumption in the country. Huge loss of fish due to very poor or no preservation facilities in Mymensingh area was identified by Hossain *et al.* (2002). Hossain and Afroze (1991) and Hossain *et al.* (2002) observed that for inadequate handling and preservation (icing, chilling, and freezing) or storage facilities for farmed Indian major carps, the retail fish traders suffered huge economic loss in terms of low price offered for quality deterioration

Table 4. Different activities related to quality loss of SIS.

Quality assessment Activities	Frequency of activities (% of unit practice)								
	During harvesting	After harvesting	Landing after harvesting	First sorting after harvesting	Transportation from landing center/ From market	In Market			
						Receiving	Sorting	Auctioning	Packaging
Washing of fish	Not done	Only 5%	0%	0%	-	35%	-	-	-
Compactness of fish	90%	-	-	-	100%	100%	-	90%	95%
Standing on fish	85%	90%	-	-	80%	-	-	-	-
Rough handling	90%	95%	95%	90%	80%	100%	100%	100%	100%
Mixing of fresh and spoilage fish	70%	80%	90%	100%	0%	40%	80%	20%	10%
Sorting according to quality	5%	3%	3%	45%	1%	20%	10%	10%	-
Mixing with dirty materials	90%	90%	90%	100%	10%	5%	10%	5%	20%
Icing facilities	0%	0%	0%	0%	2%	2%	1%	20%	85%
Use of ice box	0%	0%	0%	0%	1%	1%	0%	1%	10%
Use of bamboo made baskets	20%	95%	95%	100%	75%	90%	95%	90%	85%
Use of effective holding baskets, plastic baskets	5%	10%	10%	20%	35%	20%	20%	20%	40%
Flake ice used	0%	0%	0%	0%	0%	0%	0%	10%	55%
Facilities for live fish	0%	1%	1%	5%	10%	2%	5%	10%	-
Exposed to open environment/ sun light	-	29%	40%	80%	10%	-	55%	60%	70%
Physical damage due to handling activities	20%	30%	10%	20%	90%	70%	80%	70%	60%
Possibility of higher bacterial contamination	100%	100%	100%	100%	100%	100%	100%	100%	100%
Handler knowledge about quality maintenance	10%	10%	5%	0%	1%	5%	1%	1%	1%

Table 5. Freshness quality of fish at different points.

Defect point	Quality of fish at different point				
	Quality at harvest	Quality at landing	Quality at sorting	Quality at transportation	Quality at market
< 2	100%	100%	95%	95%	80%
2 to < 3	0%	0%	2%	2%	10%
3 to < 4	0%	0%	2%	3%	8%
4 to 5	0%	0%	1%	0%	2%
Range of defect points	< 2	< 2 to < 3	< 2 to < 3	< 2 to < 3	< 2 to <4

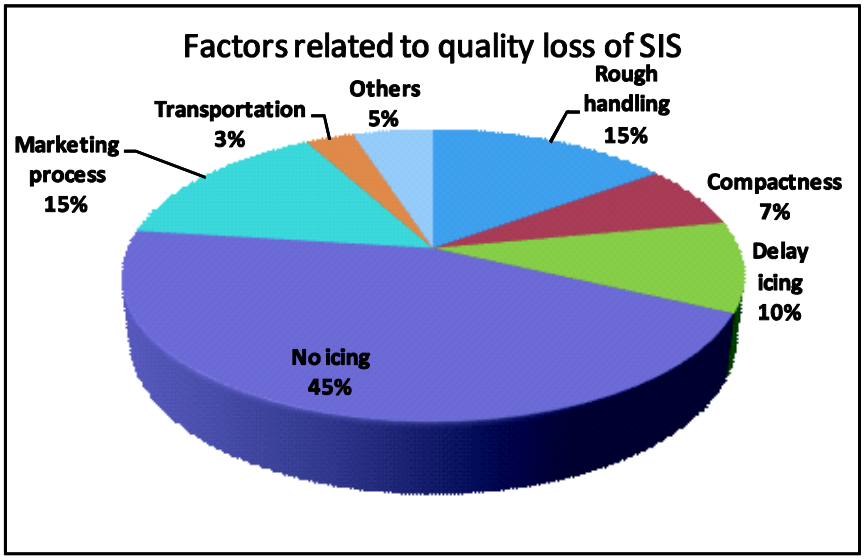

Fig. 3. Major activities related to overall quality loss (in percentages).

Some recommendations to ensure better quality of sis after harvesting: Small Indigenous Species of fishes are more popular in present market condition. Some recommendations are mentioned to ensure better quality of SIS depending on the existing situation and problems that are faced by the fishermen, sellers and customers.

1. Training of harvesters, fishermen about "Good Harvesting Practices" can be introduced. Fishermen should be trained up about some basic knowledge of harvesting technology so that it would be helpful to ensure the better quality of fish.

2. Some fixed landing centers should be established near harvesting areas with concrete made platform or temporary modified system (using of polythene on soil to perform the sorting), washing system and icing facilities.

3. In most of the areas where SIS is harvested have no icing facilities. To maintain the quality of fishes icing is indispensable. It is true that to ensure the icing facilities in every

place is very difficult but in some cases it is possible. In this case insulated van can be used for transportation.

4. Bamboos made baskets are commonly used for handling and transportation. Use of plastic boxes is not yet popular. In this case plastic boxes or insulated boxes can be used to carry the SIS as well as to maintain the better quality.

5. In the fish markets mishandling during harvesting, transportation, auctioning which is related to quality loss should be avoided.

6. Proper sanitation practices by the handlers in all cases through harvesting to marketing must be introduced to mitigate the above mentioned problems.

7. A time schedule can be maintained for selling of fish. Morning fish markets would be better for selling of fish to reduce the quality loss. Since most of the harvested fishes are brought at market before 9 am, so it is evident that fish which are sold before 10 am is better in quality. Beside this, a temporary based morning fish market (duration 2 to 3 hours) can also be established near the landing center and harvesting area which would ensure better quality of fish for the local consumers and reduce transportation cost, loss of quality during transportation.

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--Short communication

NEW RECORD OF MONOCHAETIA KARSTENII VAR. GALLICA (STEY.) SUTTON ON BRASSICA NAPUS L. FROM BANGLADESH

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Ananamorphic fungus, namely *Monochaetiakarstenii* var. *gallica* (Stey.) Sutton has been recorded for the first time for Bangladesh. This is the first record of association of this species withanthracnose disease infected leaves of *Brassica napus* L.

Brassica napus L. is an annual or biennial herbaceous plant that belongs to the Brassicaceae family. It is known as mustard, rape, rapeseedand oilseed rape. *B. napus* is an important oilseed crop in the world. It is the second largest oil crop after soybean and occupies 13% seed oil production of the world. Its use has been documented in Europe since the 13th century and has been grown 2000 BC in India mainly for its use as oil for lamps (Zafar *et al.* 2015). Its seed contain 40-50% oil and 36-40% protein in meal (Amin and Khalil 2005). Diseases play an important role in lowering rapeseed yield in the country. Rapeseed is attacked by more than 27 fungal diseases, of which alternaria black spot (*Alternaria brassicicola*), anthracnose (*Colletotrichum gloeosporioides*), black leg or stem canker (*Leptosphaeria maculans*), Cercospora leaf spot (*Cercospora brassicicola*), downy mildew (*Peronospora parasitica*), damping-off (*Rhizoctina solani* and *Fusarium* spp.), leaf blight (*A.brassicae*), leaf spot (*Phyllosticta brassicae*), sclerotinia stem rot (*Sclerotinia sclerotiorum*), Southern blight (*Sclerotium rolfsii*) are considered as major diseases. These diseases cause serious yield loss of mustard. Among these diseases anthracnose of leaf is one of the most serious diseases of *B.napus* L.

Anthracnose infected leaves of *Brassica napus* were collected from the Botanical Garden of Dhaka University and fungi were isolated from the samples following "Tissue plantingmethod" on PDA (Potato Dextrose Agar) medium (CAB 1968). Isolated fungi were identified based on morphological characteristics observed under acompound microscope following standard literatures (Ellis 1971, 1976, Sutton1 1982 and Barnett and Hunter 2000).

The isolated fungi were *Alternaria* sp., *A. brassicicola*, *Colletotrichum gloeosporioides*, *Curvularia* sp., *Fusarium* sp. and *Monochaetia karstenii* var. *gallica* (Stey.) Sutton.

Monochaetiakarstenii var. gallica (Stey.) Sutton, Can. J. Bot. **47**: 2091 (1969) (Plate 1) Colonies white, cottony on PDA medium. Mycelia immersed, septate,

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branched, pale brown to hyaline. Acervulus black, numerous, circular or linear. Dehiscence irregular. Conidiophores mostly cylindrical, straight, hyaline. Conidia mostly 4 euseptate, apical and basal cell hyaline, median cells brown, cell wall dark brown, smooth, continuous or constricted at the septa, 17-21 × 5-5.6 µm. Apical appendage 11-14µm long, basal appendage 1-3 µm long.

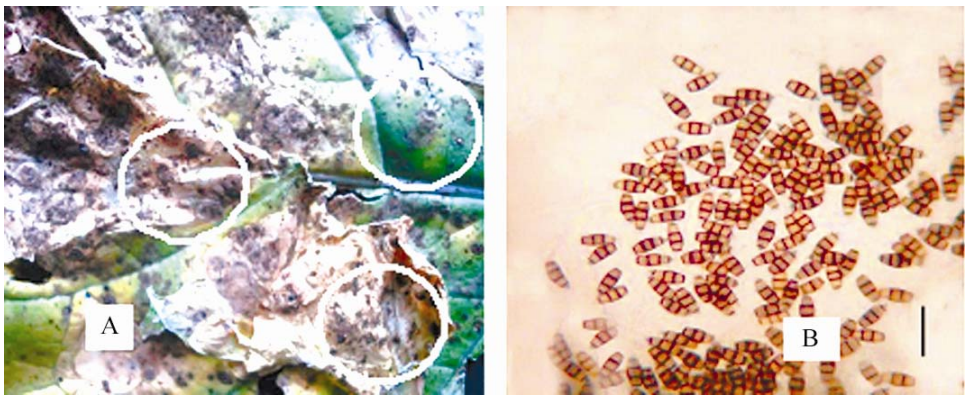

Plate 1. *Brassica napus*: A. Leaves showing anthracnose symptom with mycelial mat and acervuli. B. Conidiophores and conidia of *Monochaetia karstenii*var. *gallica* within acervuli (Bar = 50 µm).

Specimen examined: On anthracnose infected leaves of *Brassica napus* L., Botanical Garden, University of Dhaka, S. Shamsi 3051, 15 February 2016.

Based on these morphological characteristics, the fungus was identified as *Monochaetiakarstenii* var. *gallica*. The fungus is new record for Bangladesh.

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