JOURNAL OF
THE ASIATIC SOCIETY OF BANGLADESH
SCIENCE

ISSN 1016-6947

Vol. 47 | No. 2 | December 2021

THE ASIATIC SOCIETY OF BANGLADESH

THE ASIATIC SOCIETY OF BANGLADESH

Journal of the Asiatic Society of Bangladesh (Science)

Journal of the Asiatic Society of Bangladesh, Science is published twice a year (June and December comprising one volume) in English. Original research papers dealing with all branches of science with special reference to Asiatic studies by the members of the Society are published. Any non-member of the Society may publish a research paper if it is communicated by a member of the Society.

SUBSCRIPTION

Annual per volume:			Single issue:		
Inland	:	Tk. 500.00	Inland	:	Tk. 250.00
Foreign	:	US$ 40.00	Foreign	:	US$ 20.00

CORRESPONDENCE

All correspondence should be addressed to The General Secretary, The Asiatic Society of Bangladesh, 5 Old Secretariat Road (Nimtali), Ramna, Dhaka-1000, Bangladesh.
Phone : 9576391, E-mail : asbpublication@gmail.com, www.asiaticsociety.org.bd

PRINTED BY

SRL Printing Press
8/12 Babupura, Nilkhet, Dhaka-1205

JOURNAL OF
THE ASIATIC SOCIETY OF BANGLADESH
SCIENCE

Volume **47**, Issue **2**, December 2021
ISSN **1016-6947** eISSN **2408-8676**
Available at: https://www.asiaticsociety.org.bd/journals
https://www.banglajol.info/index.php/JASBS

Journal of the Asiatic Society of Bangladesh, Science
is indexed in the following online scholarly database:

JOURNAL OF
THE ASIATIC SOCIETY OF BANGLADESH
SCIENCE
(J. Asiat. Soc. Bangladesh, Sci.)

Vol. 47 **No. 2** **December 2021**

CONTENTS

THE ASIATIC SOCIETY OF BANGLADESH
Council 2020 & 2021

Guidelines to authors

The Journal of the Asiatic Society of Bangladesh publishes original research papers related to any field of sciences from anywhere in the world.

All manuscripts written in English and typed on one side of a good quality paper (A4) with one and a half space and 2.54 cm margins on all sides should be submitted in duplicate (one copy without identity of the authors) to the Editor. However, authors from overseas countries may submit soft copy of the paper. Regarding publication of the paper after review, the decision of the Editorial Board shall be final. All papers accepted by the Editorial Board are subjected to editorial modifications.

The manuscript of a full paper, preferably be limited within 12 typed pages (A4) including tables, figures, graphs, references, etc. For short communication it should not exceed five pages.

The manuscript should contain the following sub-titles in sequence: Title, Abstract, Key words, Introduction, Materials and Methods, Results and Discussion, Acknowledgements, if any, and References. In case of **'Short Communication'** no sub-titles are necessary.

Title: It should be brief and specific. The manuscript will have a separate title page giving name of the paper, authors name and address and a running head.

Abstract: It should not exceed 200 words containing the gist of results only.

Key words: Should not exceed 6 words and it should be after Abstract.

Text: The text of the article should be clear and precise. Introduction should be concise, precise and relevant to the study. Methods already published should be indicated by references. In case of modifications of a method give explicit descriptions. Results should be stated concisely and presented logically referring to tables and graphs. The same data should not be used both for the tables and for the graphs and/or figures. Simple data may be presented as a text instead of Tables and Figs. Each result should be followed by discussion or interpretation (in any case the Results and Discussion must not be separated) with appropriate reference(s). Discussion should deal with the obtained results and related results published nationally and internationally. Concluding remarks (without heading) must be given (that tally with the objective) in the last paragraph. The references in the text should be arranged chronologically.

Units: All measurements must be given in SI (International System) or SI-derived units.

Tables, Graphs and Figures: Number of tables, graphs and figures should be minimum. However, these should be typed separately. The graphs and figures should be drawn giving statistical analysis and properly labelled. The figures and graphs should be properly drawn with bold, solid lines so that these could be reduced up to half or less of the original. The photographs should be submitted on glossy papers or in JPEG format. Symbols in the graphs should be distinct and labels should be readable. Coloured photographs are also accepted.

References: In the text, references should be cited within brackets quoting author's surname and the year of publication in the appropriate place e.g. (Alva and Edwards 1990, Kabir 2005 and Khan *et al*. 2008). References should be arranged alphabetically according to author's surname at the end of the paper. Names of journals and books should be in italics giving edition, year of publication and name of the publishers.

Examples:

Alva, A.K. and D.G. Edwards. 1990. Response of lupin cultivars to concentration of Ca and Al in dilute nutrient solutions. *J. Pl. Nutr.* **13**: 57-76.

Amin, F.B., Z.N. Tahmida Begum and R. Mandal, 2011. Impact of potassium and zinc on growth of cyanobacteria in seasonally flooded rice field of Meghna floodplain. *J. Asiat. Soc. Bangladesh, Sci*. **37**(2): 251-255

Helyar, K.R. and W.M. Porter. 1989. Soil acidification, its measurement and processes involved. *In:* Robson, A.D. (ed.) 'Soil Acidity and Plant Growth', Academic press, pp. 61-101.

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

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

Khoiyangbam, R.S. and N. Gupta. 2012. Introduction to Environmental Science. Publ. The Energy and Resources Institute, New Delhi.

The author(s) must submit one computer composed hard copy of the revised paper along with the CD in MS Word version 8.

Final galley proofs, if possible, will be sent to authors. No alternations or additions in the text are desirable at this stage.

Off-prints

A contributor of each paper is entitled to get 10 off-prints free of cost.

Declaration

While submitting a paper the individual authors are to sign a declaration to the effect that (i) the work reported has been carried out by them and they prepared the manuscript, (ii) they take public responsibility for the contents of the paper, (iii) the paper has not been published before in any referred scientific journal or has not been submitted to such journal for publication.

Review of books

Books for review should be sent to the Editor in duplicate.

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 99-108, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57274

A COMPARATIVE STUDY ON NOISE POLLUTION LEVELS IN DHANMONDI AREA, DHAKA: A GEOSPATIAL ANALYSIS

MAHMUDA PARVIN*
Department of Environmental Science, Stamford University Bangladesh, Dhanmondi, Dhaka 1209, Bangladesh

Abstract

Noise pollution has been recognized as one of the most vital environmental pollutions that affecting urban area's quality of life. Sound levels at different points of the study area have been recorded and presented spatially by geostatistical analysis. A comparison has been made between the study area data in 2019 and that of 2021. In 2021 the noise level was significantly higher despite the Covid 19 pandemic. The comparative study showed that the noise level of the study area in 2021increased significantly. Noise level data in the sample points of the study area on Friday (holiday) were also collected and found that it was higher than that of even working days, especially in the evening.

Keywords: Noise pollution, Urban area, Environment, Interpolation method, Spatial distribution

Introduction

Nowadays, noise pollution has become a significant problem in Bangladesh. In most of the divisional headquarters, the sound levels are far above the acceptable level for human hearing. Industrialization and urbanization are increasing at rapid rates. Consequently, noise pollution in urban areas is increasing day by day. Noise created by different sources like an airplane flying over, the train passing through the densely populated areas , honking cars, loud music, construction, a barking dog, etc., are considered noise pollution. According to the World Health Organization (WHO), the levels of noise pollution in some cities are critical and are seriously harming human health and activity. Noise pollution and its effect on human health has been of great concern, especially in modern cities, and is recently considered a vital issue to be solved (Amurtha *et al.* 2016, Mahmud and Alsubaie 2016, Pirerra *et al.* 2010). Day and night noise polluters in large and developed cities are insidious. In 2010, Hong Kong Environmental Protection Department received 23,678 environmental complaints most of which were due to noise pollution (Jaecker-Cueppers, 2011).

*Corresponding author: E-mail: <mahmudaalam@yahoo.com>.

It is well established now that noise is a potential hazard to health, communication, workplaces, and enjoyable social life. Noise is becoming an indefensible interference imposed upon students' education, comfort, health, and the general human's quality of life.

Environmental noise pollution is increasing rapidly over the years due to the rapid increase in human activities such as transportation, industrialization, and urbanization (Hunashal and Patil 2012, Pathak *et al.* 2008). Some research groups have researched several cities of the world to study the harmful effects of environmental noise pollution on human health, comfort, and welfare (Alberola *et al.* 2005, Bhosale *et al.* 2010, Vidya *et al.* 2006).

Amin *et al.* (2014) studied the noise levels of some CNG stations at Sylhet at different times, and they found that noise levels were higher than the permissible noise levels. The temporal and spatial dynamics of urban traffic-induced noise pollution at various locations of Pabna at different times of the day were studied by Arifuzzaman and Razu (2015). They also found that noise levels of the study areas were also higher compared to the standard noise levels. The status of noise pollution at the major intersections in the Khulna metropolitan city was assessed by Sultana *et al.* (2020). It was reported that noise levels in diverse areas were higher than in commercial areas. Earlier noise levels at different locations of Dhaka city were studied by some research groups (Chowdhury *et al.* 2010, Riyad *et al.* 2020). But the noise level of Dhanmondi was not studied recently. This study attempts to assess the noise pollution of Dhanmondi, an important area of Dhaka city, established as residential area but over period turned to a mixed area of residential, commercial and others.

Objectives of the study: The objectives of the study comprise the following: (i) To assess the noise levels at different locations of the Dhanmondi area, (ii) To compare the noise levels of the study area based on time, locations, working hours, etc. (iii) To show the spatial distribution of noise levels of the study area.

Study area: Dhanmondi (ward DSCC 15), situated in Dhaka South City Corporation, was selected (Fig. 1). It is situated between 23°44´12´´ and 23°45´22´´ north latitudes and between 90°22´ and 90°23´ east longitudes. Noise levels at 40 sample points of the study area have been collected. These points were not selected at a specific distance from each other, instead it was measured around places like shopping mall, schools, hospitals, roadsides, commercial places, etc. The surrounding neighborhood is characterized by residential houses generally comprised of 4-5 floors. From Fig. 2, it was found that 8 sample points belonged to the residential zone, 7 sample points belonged to the mixed

zone, 7 sample points were in commercial area (Shopping mall, bank, other offices) and 3 sample points were in silent zone (Primary school, hospital) and 4 in recreational place (Abahoni playground, lake side park, etc.) and rest of the sample points belonged to roadside and road intersections. Many important organizations, offices, hospitals, educational institutions, residences, lakes etc. are situated in the study area. The major roads are important for urban and national connectivity and have all modern facilities. Fig. 2 showed the land use pattern of the study area with sample locations.

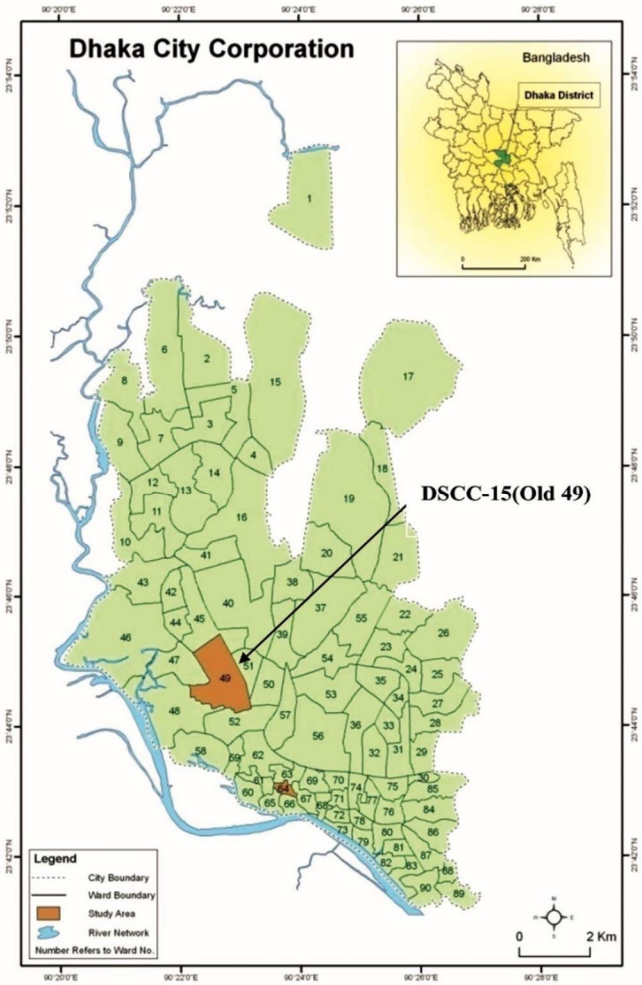


Fig. 1. Map of the study area, Dhanmondi, DSCC-15 (Old-49).

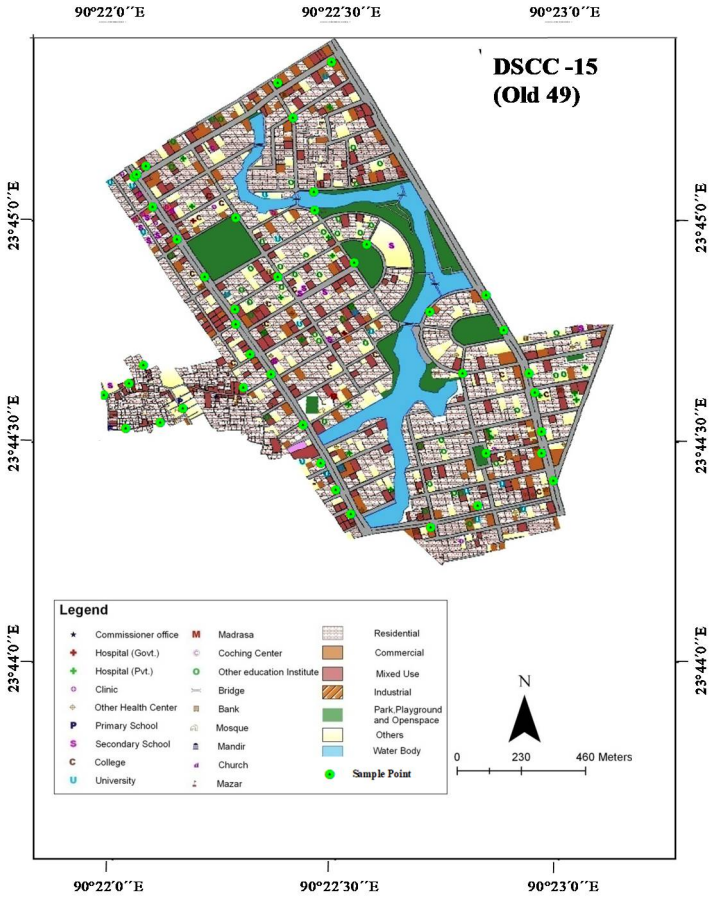


Fig. 2. Land use map of Ward DSCC-15 with sample locations.

In this densely populated city, certain important areas are being used for multi-dimensional purposes increasing noise pollution potentiality. Environmental Conservation Act-1995 (ECA'95) and Environmental Conservation Rules 1997 (ECR'97), (Rule 12, Schedule-4) categorize areas to point out standards of sound.

Methodology

In this study, the interpolation method was used for the study area's spatial distribution of noise levels. Several interpolation methods include linear interpolation, Inverse Distance Weighting (IDW), Natural Neighbor Inverse Distance Weighted (NNIDW), Spline and Kriging, etc. The spatial distribution of noise levels in Dhanmondi in the years 2019 and

2021 was done with the IDW method. Based on the noise levels behavior of the locations in the study area IDW method was selected for generating noise color contour. It is one of the most commonly used techniques with higher accuracy than other interpolation methods (Moteallemi *et al*. 2017). It weighs each point by the inverse of the distance after the reference point assigned for each measurement. It provides an exact weighted interpolated surface grid. Furthermore, IDW offers satisfactory results for predicting noise level maps.

The following equation can express the IDW interpolation formula:

$$x^* = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots\ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots\ldots + w_n}$$

where, x* is the unknown value at a location to be determined, w is the weight, and x is the known point value. The weight is an inverse distance of a point to each known point value used in the calculation. Simply the weight can be calculated using the following equation.

$$w_1 = \frac{1}{d_{ix^*}^{p}}$$

Data standardization: Several sound level data were taken at each location point with a VOLTCRAFT digital noise level meter SL-50. Then, they were averaged to get the final sound level value. The data were collected above 1.5 meters above the ground surface to avoid the noise generated by the wind condition. The data were averaged because a place's sound level varies due to different types of sources common in the study area, such as traffic signals, honking, crowd, etc.

Data analysis and interpretation: Arc GIS 10.4.1 software was used in data analysis and interpretation. Noise level contour map and surface were generated based on noise level data collected from the different points of the study area. Noise level color contours were produced using different intervals, which depict the spatial variation of noise. Bangladesh transverse mercator (BTM) projection system was used in this study.

Results and Discussion

Dhaka city is one of the most densely populated cities in the world. Dhanmondi which belongs to Dhaka South City Corporation, is a significant residential and commercial place. Many academic institutions, hospitals, clinics, and offices are situated in that area.

So, maintaining noise pollution to a certain limit is very important for the policy makers. Maximum acceptable noise level varies from place to place. Namely, noise levels at silent zone, residential and commercial areas are different. The standard values of noise level at different areas are presented in Table 1.

Table 1. Noise quality standards, by zone and time of day.

Zone Class	Limits in dB (decibel)	
	Daytime (6 am-9 pm)	Nighttime (9 pm-6 am)
Silent zone	45	35
Residential zone	50	40
Mixed(residential/commercial/industrial)zone	60	50
Commercial zone	70	60
Industrial zone	75	70

Source: Unnayan Shamannay, People's Report on Bangladesh Environment 2001.

Recently, the spatial distribution of noise levels in Ward DSCC 15 in the year 2007 was demonstrated by Parvin *et al*. (2016). It was found that noise levels of most of the points of the study area were found to be higher than the permissible limit. These data were used to compare the present research outcomes.

In November 2019 and in March 2021, the noise levels of the Ward DSCC 15 were measured during the periods of 8am - 10am, 12pm - 2pm and 5pm - 7pm of the working day. Despite having modern facilities and well-planned constructions, a similar type of distribution as of 2007 reported by Parvin *et al.* (2016) was observed. But the range of noise levels in 2019 and 2021werecomparatively higher.

On the working day of the year 2019, the noise level of the study area ranged from 69-85 dB in the morning, that of 2021 was 63 to 84dB (decibel) and the noise level ranged from 71 to 89 dB during the holiday (Fig. 3). All the noise level values were higher than the acceptable limits for roadside, residential area, near the hospital and in the commercial area. The high noise level occurs during the daytime as people travel to and from schools, markets, and workplaces (Ahmad and Khan 2003). The severities of noise pollutions were higher in the morning on Friday. The range is lower in 2021 compared to 2019 because of Covid 19. All educational institutes were closed. So, students' movements were not found.

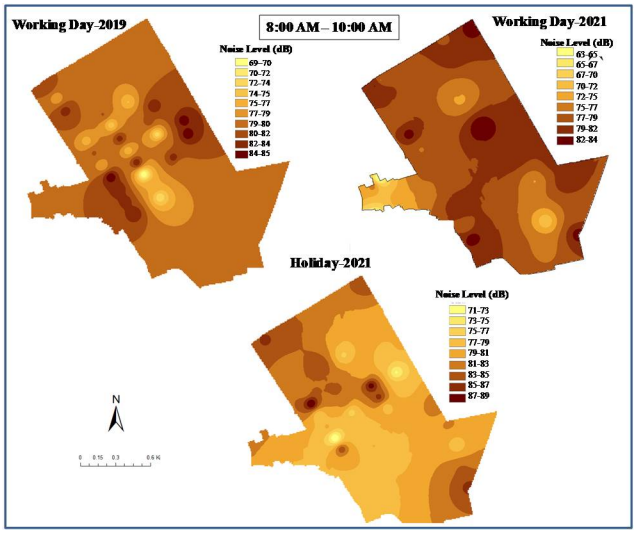


Fig. 3. Spatial distribution of noise levels in Ward DSCC 15 from 8:00 to 10:00am in 2019 and 2021.

The spatial distribution of noise levels of the study area from 12.00pm – 2.00pm in the years 2019 and 2021 is shown in Fig. 4.

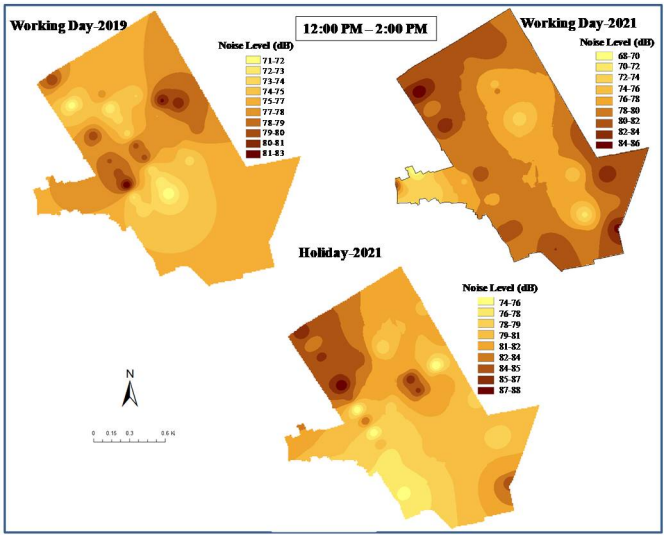


Fig. 4. Spatial distribution of noise levels in Ward DSCC 15 from 12:00 to 2:00pm in 2019 and 2021.

Fig.4 revealed that the noise levels in the study area were also higher than the acceptable limit during the working day in 2019 and 2021. In the noon, the noise level was slightly higher than that of 2019 though all the educational institutes were closed due to Covid 19 pandemic. The tendency was increasing in the study area day by day. In the noon (12 pm-2 pm), the noise level ranges in 2019 were 71- 83dB, and in 2021 were 68-86 dB and 74-88 dB on Friday, 2021. The lake area and adjacent residential area showed comparatively lower noise pollution. Landuse pattern map of the study area (Fig. 2) exhibits that the left side of the Satmosjid road (near Jigatola and Mitali road) are mostly covered by residential area. This area showed a relatively lower level of noise (77-79 dB) in 2019 (70-76 dB) in 2021 at noon, but that is also higher than the standard level for the residential area.

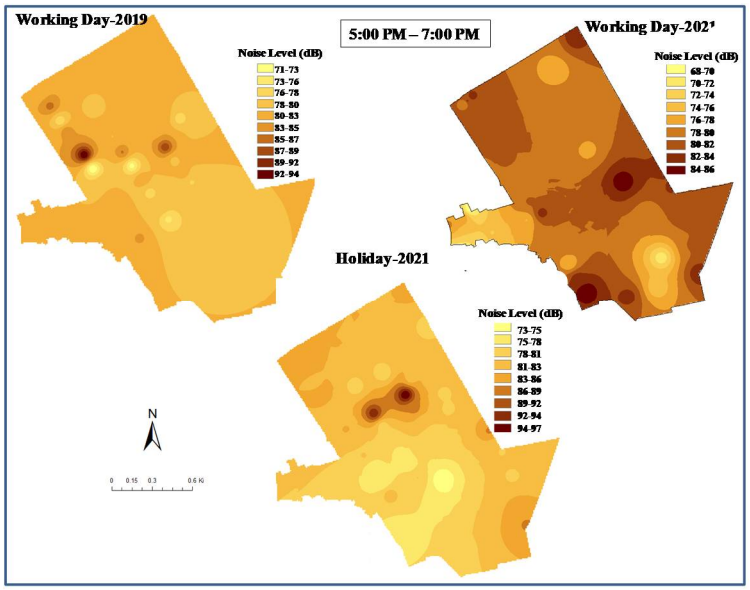


Fig. 5. Spatial distribution of noise levels in Ward DSCC 15 from 5:00 to 7:00 pm in 2019 and 2021.

An attempt was made to explore the noise level situation in the evening. From Fig. 5, it was found that the ranges of noise levels varied from 71-94 dB, 68-86dB, and 73-97 dB in the evening during the working day in 2019, 2021, and in holiday 2021, respectively. The severity was lower in 2021 than that of 2019 because of the closure of educational institutes due to the Covid 19 Pandemic. In the evening, the severity was higher on

holiday than a working day in 2021 in recreational places near Dhanmondi bridge, Rabindra Sorobar, Dhanmondi Women's complex etc. In the Ward DSCC 15, the noise level value is too high on Friday in the cross-section of road 16 and Satmosjid road (Commercial pace and diverse area). Most of the time, the value was higher than 80 dB. The north-western part of the study area always showed a noise level of higher than 80 dB because of increased recreational movements.

Conclusion

Noise levels of the Dhanmondi area in 2019 and 2021 at different periods have been measured and shown spatially by IDW interpolation methods. Noise levels of the study area in 2007 were collected from the literature. A comparative study has been carried out to explore the trend of increasing noise pollution. In 2007, the maximum noise level was 72 dB, whereas, in 2019 and 2021 the maximum noise level in the morning was 94 dB and 86 dB, respectively. Thus, noise pollution in the study area is increasing day by day. Sensitive institutions, e.g., schools and hospitals, should be located about 60 m away from the roadside. The Government of our country is concerned about this issue. Recently, some selected areas of Dhaka City have been declared as Silent Zone, and law enforcement agencies are working on it. Some motivational works and advertisements could be done to develop awareness among the mass.

References

Ahmad, A.J and J.A. Khan. 2003. Traffic noise control in the city. NED Engineering Horizons. XVI. 174.

Alberola, J., H. Flindell, and J. Bullmore. 2005. Variability in road traffic noise levels, European Commission environmental noise directive 2002/49/EC; *Off. J. Eur. Communities*. **189**: 12-25.

Amin, N., I. Sikhder., M.A. Zafor and M.A.I. Chowdhury. 2014. Assessments of noise pollution of two vulnerable sites of Sylhet city, Bangladesh. *Int. J. Water Res. Environ. Eng.* **6**(1): 112-120.

Amurtha, P.P., M. Sravani, K. M. Ashok, P. Sowmya, and S.P. Naga. 2016. Noise pollution and its impact on human health and social behavior using system approach-A case study in Kurnool city, India. *Civil Environ. Res.* **8**(7): 70-80.

Arifuzzaman, K. and S.M.H. Razu. 2015. Road traffic noise pollution: present scenario and potential noise attenuation strategy for Pabna Municipality, Bangladesh. *Int. J.* Adv. Res.**3**(4): 782-789.

Bhosale, B.J., P.M. Nalawade, S.P. Chavan and M.B. Mule. 2010. Studies on assessment of traffic noise level in Aurangabad city, India. *Noise Health*. **12**(48): 195-196.

Chowdhury. S.C, M.M. Razzaque and M.M. Helali. 2010. Assessment of noise pollution in Dhaka city. The 17th International conference on sound and vibration. Cairo, 18-22 July.

The Bangladesh Environment Conservation Act, 1995.

ECR. 1997. The Environment Conservation Rules, Government of the People's Republic of Bangladesh, Ministry of Environment and Forest. 205-207.

Jaecker-Cueppers, M. 2011. Urban Transport and Health, Module 5c, Division 44, Noise and its Abatement, a source book for policy maker, GIZ publication.

Hunashal, R.B. and Y.B. Patil. 2012. Assessment of noise pollution indices in the city of Kolhapur, *India. Procedia Soc.Behav. Sci*. **37**:448-457.

Mahmud, F.E-S. and A. Alsubaie. 2016. Study of Environmental noise pollution in the University of Dammam Campus. *Saudi. J. Med. Med. Sci.* **2**(3):178-184.

Moteallemi, A., B. Bina., M. Minaei. and S. Mortezaie. 2017. The evaluation of noise pollution at Samen district in Mshhad, Khorasan Razavi Province, Iran using geographic information system. *Int. J. Occup. Hyg*. **9**(4):179-185.

Pathak,V., B.D. Tripathi and V.K. Mishra. 2008. Evaluation of traffic noise pollution and attitudes of exposed individuals in working places. *Atmos. Environ*. **42**(16): 3892-3898.

Pirerra, S., E. Devalck and R. Cluydts. 2010. Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health. *Environ. Int*. **36** (5): 492-498.

Parvin, M., M.I. Hossain. andA.U. Khan. 2016. Spatial distribution of noise pollution in Dhaka City: a geo-statistical modelling, *Stamford J. Environ. Hum. Habitat*. **5**: 14-23.

Riyad, R.H., A. Amin. and M. Mazumder 2020. A study of noise pollution by traffic during peak and offpeak hour in Dhaka city. *Journal of Innovations in Civil Engineering and Technology*. **2**(2): 43-53.

Sultana, A., A.K. Paul and M.U. Nessa. 2020. The status of noise pollution in the major traffic intersection in Khulna metropolitan city in Bangladesh its possible effects on noise-exposed people.*Eur. J. Environ. Sci*. **1**(5): 1-8.

UnnayanShamannay, People’s Report on Bangladesh Environment. 2001. The University Press Limited (UPL).

Vidya, S.B., T. Nageswara and G. Rao. 2006. Noise pollution levels in Visakhapatnam city (India). *Environ. Sci. Eng.* **48**(2): 139-134.

(Revised copy received on 01.09.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 109-120, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57275

INCIDENCE, ABUNDANCE AND DAMAGE OF PAPAYA MEALYBUG IN SOUTHERN PART OF BANGLADESH AND ITS MANAGEMENT

M. M. H. KHAN AND M. N. HOSSAIN
Department of Entomology, Patuakhali Science and Technology University, Dumki, Patuakhali, Bangladesh

Abstract

The papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink, is a small hemipteran that attacks several genera of host plants, including economically important tropical fruits and ornamentals. A study was carried out at farmers' papaya garden and homestead areas of 8 locations *viz.*, Dumki, Bouphal, Dashmina, Patuakhali, Mirjagonj, Amtali, Kalapara and Kuakata of Patuakhali and Barguna districts of Bangladesh to observe the incidence, abundance, and damage potential of papaya mealybug, *Paracoccus marginatus* (Williams and Granara de Willink) from March to June 2019. An experiment consisting of seven treatments following randomized complete block design (RCBD) with three replications was conducted for controlling papaya mealybugs at Patuakhali Science and Technology University (PSTU) campus during March to June 2019. Results revealed that among 8 locations, the highest incidence of *P. marginatus* was recorded in June, and the lowest was in April. The maximum abundance of *P. marginatus* on leaves and fruits of the papaya plant was observed at Kolapara, and the lowest was at Amtali. The highest percent infested plants (65%) per location, infested leaves/plant (97%), and infested fruits/plant (47%) was recorded in Kolapara, and the lowest percent infestations (31, 18, and 11%, respectively) were in Amtali. Among all treatments, the removal of infested leaves with petioles and application of Nitro 505EC @ 1 ml/L of water (T_1) was the best approach for the management of papaya mealybugs. The removal of infested leaves with petioles + Biotap plus extra 95EC @ 0.2 g/L of water (T_3) could be used as 2nd choice for controlling papaya mealybugs. The results concluded that removal of infested leaves and the application of Nitro 505 EC at the rate of 1 ml/L of water might be used to control the papaya mealybug.

Keywords: Abundance, Incidence, Mealybugs, Papaya, *Paracoccus marginatus*

Introduction

The papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is a small polyphagous sucking insect pest and has a wide host range that attacks several genera of plant species, including many economically important vegetables, fruit, and ornamental plants, such as avocado, beans, cassava, citrus,

*Corresponding author: E-mail: <mohasin1965@pstu.ac.bd>

coffee, cotton, eggplant, frangipani, gardenia, hibiscus, mango, papaya, pea, sweet potato, tomato, and numerous weeds (Chellanppan *et al*., 2013; Cham *et al*. 2011; Tanwar *et al*., 2010; Miller and Miller 2002). A total of 50 plants species in 20 families were identified as the host of *P. marginatus* in Ghana in 2009 (Cham *et al*. 2011). Fourteen species of mealybugs were recorded in Bangladesh and attacked 103 host plants (Islam *et al.* 2017). *P. marginatus* is an invasive insect pest most probably believed to be native to Mexico or Central America (Tanwar *et al.* 2010; CABI, 2015). Walker *et al.* (2003) stated that *P. marginatus* was recorded from the 14 Caribbean countries. It has been reported to cause severe damages to horticultural and field crops (Muniappan *et al.*, 2008; Tanwar *et al*. 2010). Though it is a severe pest of papaya (Tanwar *et al.*, 2010; Bhawane *et al.*, 2011; Chellanppan *et al.* 2013) and have also reported in guava (Sakthivel *et al*. 2012), mulberry (Tanwar *et al*. 2010; Lalitha *et al*. 2015) as a host of papaya mealybug, *P. marginatus* in India. Population abundance is the number of individuals per unit area/plant where the number of organisms in a population changes over time due to various factors such as birth, death, immigration, and emigration (Norris *et al*. 2003). The abundance of insect populations is also governed by the availability of food resources (Borror and DeLong 1954). Papaya mealybug is most active in warm and temperature weather and the infestation appears on above ground parts on leaves, stems, and fruits as clusters of cotton-like masses with long waxy filaments. The immature and adult stages of *P. marginatus* suck the sap by inserting its stylets into the epidermis of the leaf, fruit, and stem and weaken it. While feeding, it injects a toxic substance into the leaves, resulting in chlorosis, plant stunting, leaves becoming crinkled, yellowish and withered causing early leaf and fruit drop, and ultimately death of plants. The honeydew excreted by the bug results in the formation of a black sooty mould which interferes in the photosynthesis process and causes further damage to the crops. Heavy infestations can render fruit inedible due to the buildup of thick white waxy coating (Tanwar *et al.* 2010).

Mealybugs can be controlled by removing mealybugs by rubbing or picking mealybugs from affected plants which is practicable in a low infestation. Pruning and destroying affected plant parts is particularly useful at the initial stage of infestation (Schulthess *et al*. 1997; Neuenschwander 2003). Satyanarayana *et al.* (2003) found that phosphamidon was significantly superior over the rest of the treatments, recording 80% mortality. Among the extracts, the highest percentage (68.50%) mortality was recorded from *Azadirachta indica* (Juss.) and the lowest (9.00%) from *Eucalyptus citridiora* Hook. Tanwar *et al*. (2010) worked on the incidence and damaging value of papaya mealybug and its management strategies. Recently papaya mealybug has become a serious problem for the production of healthy papaya and its yield reduction in the southern coastal region

of Bangladesh. So far, incidence and damages to papaya crops caused by *P. marginatus* in the southern part of Bangladesh have not yet been reported. Keeping this in view, studies were undertaken to monitor *P. marginatus* infestation on papaya in eight selected locations to know the incidence, abundance, and damage potential of papaya mealybug and find out suitable management approach against this papaya mealybug.

Methodology

Survey on the incidence, abundance and damage potential of mealybug on papaya: Studies were carried out in the farmers' field and homestead garden of Patuakhali and Barguna districts to collect data on the incidence, abundance and damage symptoms of mealybugs infesting papaya from September 2018 to June 2019. Eight locations viz., Dumki, Bouphal, Dashmina, Patuakhali, Mirjagonj, Amtali, Kalapara, and Kuakata were selected. Two villages from each location were selected considering papaya cultivation. A total of 80 plants taking five (5) papaya plants from each village were selected randomly. All the plant parts were carefully observed and recorded papaya mealybug population, its infestation and damage symptoms. The random selection and collection method was followed for the study providing every sampling unit an equal chance to be chosen. Every leaf was considered as a single sampling unit and a total of six leaves along with their twigs (two leaves each from lower, middle, and upper canopy) were sampled from randomly selected plants. Five plants were sampled randomly and considered as five replications from each location to avoid any errors. The leaves were cut with a sharp knife, placed in plastic sealed carry bags, and labeled with the date and locality of the collection. The samples thus collected were brought to the Entomology laboratory for sorting and population counts for mealybug for each plant. Later on these specimens were kept in glass jars and covered with muslin cloth on top for rearing the mealybug and were observed the presence of any natural enemies emerging from such infested specimens. Data on the number of infested and healthy plants per location, number of infested leaves per plant, number of fruits per plant were recorded through observation of individual plants in each location. Population abundance of *P. marginatus* was measured by counting the number of egg and immature groups under a stereo microscope.

Percentage of *P. marginatus* on the fruits and leaves was calculated by dividing the number of fruits/leaves attacked by the total number of fruits/leaves in each plant individual by:

$$P = \frac{n}{N} \times 1000$$

with P = percentage attack rate, n = number of infested fruits/leaves per plant, and N = total number of fruits/leaves per plant.

Effect of some control approaches for managing mealybug on papaya: An experiment was laid out in a randomized complete block design with 3 replications. Seven treatments *viz.*, T_1 = Removal of infested leaves with petioles + application of Nitro 505EC @ 1 ml/L of water, T_2 = Application of Nitro 505EC @ 1 ml/L of water, T_3 = Removal of infested leaves with petioles + Biotap plus extra 95EC @ 0.2 g/L of water, T_4 = Biotap plus extra 95EC @ 0.2 g/L of water, T_5= Removal of infested leaves with petioles + application of voliam flexi 300SC @ 0.5 ml/L of water, T_6 = Application of voliam flexi 300SC @ 0.5 ml/L of water and T_7= Untreated Control were used. Data were collected on the number of mealybugs per plant, leaf and fruit, the number of infested leaves and fruits/plant.

Data were analyzed by using WASP software following analysis of variance (ANOVA) and means were separated by CD (critical difference) values.

Results and Discussion

Damage symptoms: P. marginatus has only been recorded feeding on above-ground parts of its hosts, particularly on leaves and fruit. Papaya mealybug infestations are typically observed as clusters of cotton-like masses on the above-ground portion of plants. The papaya mealybug feeds on the sap of plants by inserting its stylets into the epidermis of the leaf, as well as into the fruit and stem. In doing so, it injects a toxic substance into the leaves. The result is chlorosis, plant stunting, leaf deformation, early leaf and fruit drop, a heavy honeydew building and death. Heavy infestations can render fruit inedible due to the buildup of thick white wax. The adult female is yellow and is covered with a white waxy coating. Heavy infestations by *P. marginatus* cause deformation of new growth, leaf yellowing, leaf curl and early fall of fruit. Fruit may become entirely covered by a layer of mealybugs and wax secretions (Plate 1).

Plate 1. Infestation and damage symptoms of *P. marginatus* on different parts of papaya plant at PSTU campus.

Incidence of the mealybug population: The incidence of the mealybug population (*P. marginatus*) per leaf of papaya plant on various dates of observations is shown in Fig. 1. The highest incidence of mealybugs per leaf was observed on 24 June followed by 10 June and 27 May, while the lowest incidence was on 15 April, followed by 29 April and 13 May. The incidence of mealybugs gradually increased with increasing temperature and time.

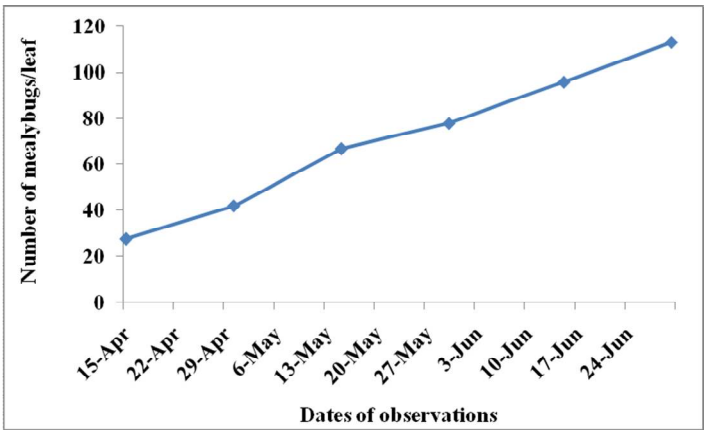


Fig. 1. Incidence of mealybug population (*Paracoccus marginatus*) per leaf of papaya plant at dumki upazila.

Abundance of P. marginatus on leaf and fruit of papaya plant: In the case of leaf, the highest number of papaya mealybugs was recorded in Kolapara (128 mealybugs/leaf), followed by Dumki (108), Dasmina (94), Bouphal (88) and Patuakhali (76) while the lowest number was at Amtali (42) followed by Kuakata (57) and Mirjaganj (61) (Fig. 2). A similar trend was also observed in the case of fruit where the highest number of mealybugs per fruit was recorded in Kolapara (82 mealybugs/fruit) followed by Dumki (73), Dasmina (62), and Bouphal (56), while the lowest number was in Amtali (28) followed by Kuakata (36), Mirjaganj (44) and Patuakhali (48) (Fig. 2).

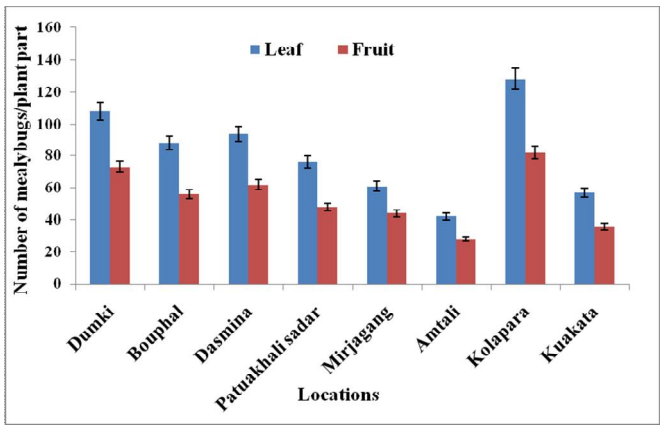


Fig. 2. Population abundance of *P. marginatus* on leaf and fruit of papaya plant in eight locations during April to June 2019.

Percentage of plant infestation by P. marginatus: The percentage of plant infestation by *P. marginatus* in 8 locations is presented in Fig. 3. It revealed that the highest percent (65%) infested plants per location was recorded in Kolapara followed by Dumki (58%), while the lowest percent (31%) was recorded at Amtali followed by Kuakata (36%).

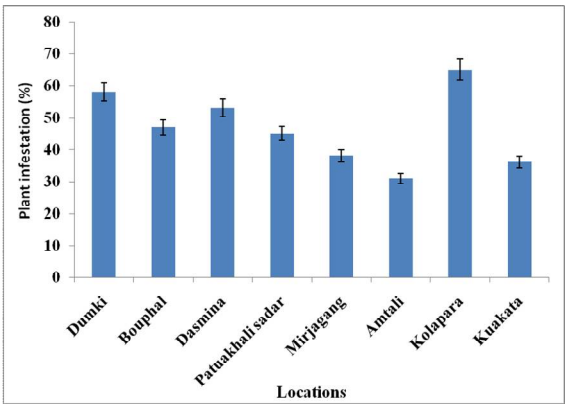


Fig. 3. Mean percentage of plant infestation by *P. marginatus* in eight locations.

Percentage of infested leaves per papaya plant: Percentage of infested leaves per plant by *P. marginatus* among 8 locations are shown in Fig. 4. The highest percent (97%) infested leaves per plant was recorded at Kolapara followed by Dumki (90%) while the lowest percent (18%) was recorded at Amtali followed by Kuakata (21%).

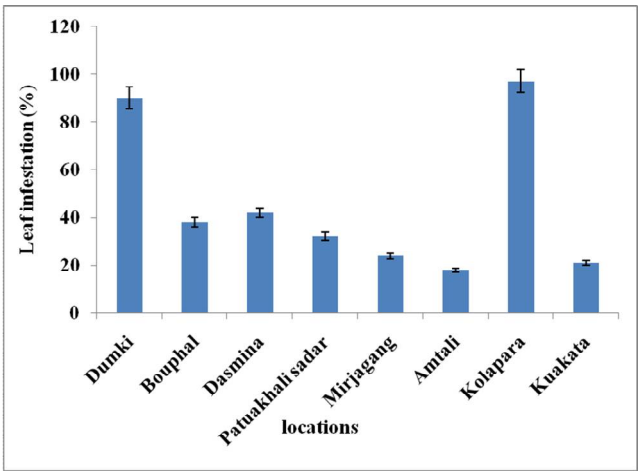


Fig. 4. Mean percentage of infested leaves per papaya plant by *P. marginatus* in eight locations.

Percentage of infested fruits per papaya plant: The percentage of infested fruit per plant by *P. marginatus* is shown in Figure 5. Among 8 locations, it was observed that the highest percent (47%) infested fruit per plant was recorded in Kolapara followed by Dumki (34%). In contrast. the lowest percent (11%) was recorded at Amtali followed by Kuakata (13%), Mirjaganj (15%) and Patuakhali Sadar (17%).

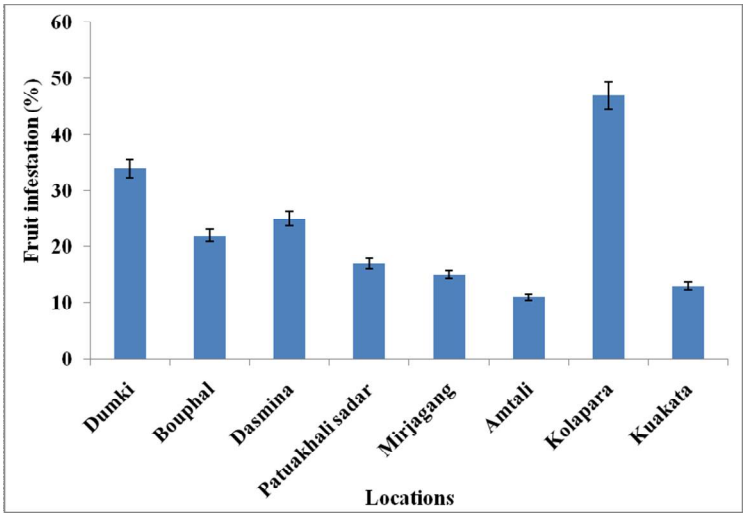


Fig. 5. Mean percentage of infested fruits per papaya plant by *P. marginatus* in eight locations.

Effectiveness of different treatments on mealybug infesting leaf and fruit: The effectiveness of different treatments on mealybug populations infesting leaves and fruits of papaya plants are presented in Table 1. The lowest number (0.82 mealybugs/leaf) of mealybugs per leaf was found in T_1 **(**Removal of infested leaves with petioles + application of nitro 505EC @ 1 ml/L of water) treated plants which were significantly different from T_6 (Application of voliam flexi 300SC @ 0.5 ml/L of water) treated plants (2.61 mealybugs/leaf) and T_7 (untreated control) (49.49 mealybugs/leaf) but statistically similar to T_2 (2.08), T_3 (0.99), T_4 (2.36) and T_5 (1.08) treated plants. The highest percent reduction (98.34%) of mealybugs population over control was recorded in T_1 treated plant followed by T_3 (98.00%) and T_5 (97.81%), while the lowest percent reduction was in T_6 (94.73%) followed by T_4 (95.23%) and T_2 (95.80%).

In the case of fruit, the lowest number (0.56 mealybugs/fruit) of mealybugs per fruit was found in T_1 **(**Removal of infested leaves with petioles + application of nitro 505EC @ 1 ml/L of water) treated plants which were significantly different from T_2 (1.86), T_4 (2.04),

T_6 (2.16 mealybugs/fruit) treated plants and T_7 (untreated control) (33.22 mealybugs/ fruit) but statistically similar to T_3 (0.74) and T_5 (0.94) treated plants. The highest percent reduction (98.31%) of mealybugs population over control was recorded in T_1 treated plant followed by T_3 (97.77%) and T_5 (97.17%), while the lowest percent reduction was in T_6 (93.50%) followed by T_4 (93.86%) and T_2 (94.40%).

Table 1. Effectiveness of different treatments on mealybug populations infesting leaf and fruit of papaya plant.

Treatments	Number of mealybugs/leaf	Reduction (%) over control	Number of mealybugs/fruit	Reduction (%) over control
T_1	0.82c	98.34	0.56d	98.31
T_2	2.08bc	95.80	1.86bc	94.40
T_3	0.99bc	98.00	0.74cd	97.77
T_4	2.36bc	95.23	2.04b	93.86
T_5	1.08bc	97.81	0.94bcd	97.17
T_6	2.61b	94.73	2.16b	93.50
T_7	49.49a	-	33.22a	-
CD values (5%)	1.674		1.261	
CV (%)	11.12		12.01	

Values are an average of three replications. CD = Critical difference value at 5 % level. Value having common letter (s) in a column does not differ significantly ($p > 0.05$).

T_1 = Removal of infested leaves with petioles + application of nitro 505EC @ 1 ml/L of water, T_2 = Application of Nitro 505EC @ 1 ml/L of water, T_3 = Removal of infested leaves with petioles + Biotap plus extra 95EC @ 0.2 g/L of water, T_4 = Biotap plus extra 95EC @ 0.2 g/l of water, T_5= Removal of infested leaves with petioles + application of voliam flexi 300SC @ 0.5 ml/L of water, T_6 = Application of Voliam flexi 300SC @ 0.5 ml/L of water and T_7 = untreated Control.

The present study's findings are supported by Khan *et al.* (2014) who stated that the infestation levels of papaya mealybug were varied in different seasons of the year, while high infestation was in March to June. Tairas *et al.* (2014) observed that the population abundance of *P. marginatus* in the dry season was higher (3226 individuals/plant) than in the rainy season, which counted 285 individuals/plant. The total population of *P. marginatus* was positively correlated with the level of attack on the fruit and leaves of papaya plants. In the dry season, the attack level on the fruit was 32 and 49% on the

leaves, while during the rainy season, the attack level was 11% on fruit and 15% on leaves. Due to the attack of *P. marginatus*, the leaves become crinkled, yellowish, and dried; the honeydew excreted by the bug and associated black sooty mould formation impairs photosynthesis efficiency of the affected plants. Papaya fruit can be heavily infested with mealybugs, becoming white and essentially inedible (Tanwar *et al.* 2010). Sandeep and Gurlaz (2016) observed 70% infestation on different plant parts of papaya. The papaya mealybug inserts its stylet into the epidermis of the leaf or the skin of fruit or stem and feeds on the plant sap. At the same time, it injects a toxic substance into the plant, which results in chlorosis, distortion, stunting, early leaf and fruit fall, the production of honeydew, sooty mould, and possibly the death of the plant (Walker *et al.* 2003). Infestation of *P. marginatus* appeared like masses of cottony growth on infested plant parts of papaya *viz.* stem, twigs, leaves, and fruits resulted in yellowing, drying, and stunting of the plants. Honeydew secretion by mealybug resulted in sooty mould development which was observed deposited on all the infested parts of papaya. These damage symptoms were supported by Sultana and Khan (2015). They reported that the percentage of leaf stalk infestation per plant was 88.89%, while the leaf area covered by papaya mealybug colonies was 45%. Colonies of *P. marginatus* excrete honeydew, which coats nearby plant surfaces. Sooty mould developed on honeydew blocks out air and light, impairs photosynthesis and reduces plant productivity. Heavy infestations of thin-skinned fruit crops such as papaya can make them unmarketable. *P. marginatus* causes significant damage to cassava in Central America, and can cause serious damage to papaya, other tropical fruit and ornamentals such as *Annona* and *Hibiscus* spp. (Miller and Miller 2002). Sultana *et al.* (2015) also reported that maximum temperature and relative humidity positively correlated with the mealybug population while rain negatively correlated. Wheel powder applied at the rate 5.0 g/L of water at 24, 48, and 72 hours after application provided effective control of the mealybug population in laboratory conditions. Likewise, three doses of Superior 505 EC effective in controlling mealybugs in laboratory conditions.

Conclusion

The incidence of mealybugs gradually increased with increasing temperature and time. The highest number of papaya mealybugs per leaf and fruit was found in Kolapara and the lowest in Amtali. The highest percentage of plant infestation by *P. marginatus* was in Kolapara. Considering the lowest number of mealybugs on leaves and fruits and the highest percent reduction of mealybugs over control, out of all treatments, T_1 (Removal

of infested leaves with petioles + application of nitro 505EC @ 1 ml/L of water) was the best management approach and T_3 (Removal of infested leaves with petioles + Biotap plus extra 95EC @ 0.2 g/L of water) could be applied as 2nd choice for controlling papaya mealybugs.

References

Bhawane, G.P., S.M. Gaikwad, A.B. Mamlayya and S.R. Aland. 2011. Invasion of papaya mealybug, in Assam. *The Bioscan.* **6**(3): 471-474.

Borror, D.J. and D.M. DeLong. 1954. An Introduction to the Study of Insects. Publ. Holt, Rinehart & Winston, New York. pp. 1030.

Cham, D., H. Davis, D. Obeng-Ofori and E. Owusu. 2011. Host range of the newly invasion mealybug species *Paracoccus marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) in two ecological zones of Ghana. *Res. Zool.* **1**(1): 1-7.

Chellanppan, M., L. Lawrence, P. Indhu, T. Cherian, S. Anitha and T. Jimcymaria. 2013. Host range and distribution pattern of papaya mealybug, *Paracoccus marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) on selected Euphorbiaceae hosts in Kerala. *J. Trop. Agric.* **51**(1-2): 51-59.

Islam, K.S., M.R. Ali, M. A. Hossain, F.M. Aminuzzaman, M.J. Ullah, M.F. Alam, S. Saha and K.M.A.A. Mahamud. 2017. Pest risk analysis of mealybug spp. in Bangladesh. Strengthening Phytosanitary Capacity in Bangladesh Project. Plant Quarantine Wing, DAE, Khamarbari, Farmgate, Dhaka-1205. 28 p.

Khan, M.A.M., M.J.H. Biswas, K.S. Ahmed and S. Sheheli. 2014. Outbreak of *Paracoccus marginatus* in Bangladesh and its control strategies in the fields. *Progress. Agric.* **25**: 17-22.

Lalitha, N., S.M.V. Kumar, A.K. Saha and S.N. Kumar. 2015. Report of papaya mealybug, *Paracoccus marginatus* in mulberry in West Brngal. *Current Biotica.* **9**(1): 82-85.

Miller, D.R. and G.L. Miller. 2002. Redescription of *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Coccoidea: Pseudococcidae), including descriptions of the immature stages and adult male. *Proc. Entomol. Soc. Wash.* **104**: 1-23.

Muniappan, R., B.M. Shepard, G.W. Watson, G.R. Carner, G. Sartiami, A. Rauf and M.D. Hmming. 2008. First report of papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Coccoidea: Pseudococcidae) in Indonesia and India. *J. Agric. Urban Entomol*. **25**(1): 37-40.

Neuenschwander, P. 2003. Biological control of cassava and mango mealybugs. In Biological Control in IPM Systems in Africa. Neuenschwander, P., Borgemeister, C and Langewald. J. (Editors). CABI Publishing in association with the ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA) and the Swiss Agency for Development and Cooperation (SDC). pp. 45-59. ISBN: 0-85199-639-6.

Norris, R.F., E.P.C. Chen and M. Kogan. 2003. Concept in Integrated Pest Management. New Jersey, USA: Prentice Hall.

Sakthivel, P., P. Karuppuchamy, Kalyanasundaram and T. Srinivasan. 2012. Host plants of invasive papaya mealybug, *Paracoccus marginatus* (Williams and Granara de Willink) in Tamil Nadu. *Madras Agric. J.* **99**(7-9): 615-619.

Sandeep, S. and K. Gurlaz. 2016. Record of papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink and its natural enemies on papaya, guava, grapes and plumeria in Punjab. *Pest Manage. Hort. Ecosyst.* **22**(1): 45-50.

Satyanarayana, C., R.K.Y. Babu and M. Manjunatha. 2003. Preliminary studies on botanicals against *Maconellicoccus hirsutus* (Green). *Insect Environ.* **9**(3): 114- 115.

Schulthess, F., P. Neuenschwander and S. Gounou. 1997. Multi-trophic interactions in cassava, Manihot esculenta, cropping systems in the subhumid tropics of West Africa. *Agric. Ecosyst. Environ.* **66** (3): 211-222.

Sultana, I., M.M.H. Khan and M.H. Rahman. 2015. Incidence of guava mealy bug, *Ferrisia virgata* ckll and its management. *Bangladesh J. Entomol.* **25**(2): 13-22.

Sultana, I. and M.M.H. Khan. 2015. Host range, damage extent and morphometrics of mealybug spp. (Hemiptera: Pseudococcidae). *Bangladesh J. Entomol*. **25**(2): 67-75.

Tairas, W., M. Tulung, J. Pelealu and S.J. Rondonuwu. 2014. Study on population abundance of papaya mealybug (Paracoccus marginatus Williams & Granara de Willink) in the North Minahasa Regency of North Suawesi Province, Indonesia. *Int. J. Sci. Eng. Res.* **5**(3): 961-964.

Tanwar, R. K., P. Jeyakumar, and S. Vennila. 2010. Papaya mealybug and its management strategies. Technical Bulletin 22. National Centre for Integrated Pest Management, New Delhi. 1-20 pp.

Walker, A., M. Hoy and D. Meyerdirk. 2003. "Papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Coccoidea: Pseudococcidae)," EENY-302. Featured Creatures. The Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Services, University of Florida, Gainesville, FL, USA.

(Revised copy received on 07.09.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 121-136, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57276

SYSTEMATICS OF MODERN BENTHIC FORAMINIFERAL ASSEMBLAGES FROM THE DELTAIC MANGROVE ECOSYSTEM OF SUNDARBANS

TUMPA SAHA[1] AND SUBROTA KUMAR SAHA[2*]

[1]*Beach Sand Mineral Exploitation Center, Bangladesh Atomic Energy Commission, Kalatoli, Cox's Bazar-4700, Bangladesh*

[2]*Department of Geology, University of Dhaka, Dhaka-1000, Bangladesh*

Abstract

The contemporary intertidal foraminifera and estuarine environment information were collected from the four sites adjoining the deltaic mangrove environment in the Sundarbans. The marsh zones of the south-western coastal region of Bangladesh were examined for modern benthic foraminifera and to expound on the relationship of the foraminiferal assemblages with the environment. Due to high inaccessibility and remoteness, the taxonomic study of foraminifera and its depositional environment remains largely overlooked in the Sundarbans of Bangladesh. This study includes a detailed survey of depositional environment of these fluvio-deltaic to shallow marine sediments. The seventeen species belonging to fourteen genera representing nine families were recorded from surficial sediment of supratidal, intertidal, and dune environment of Kotka, Jamtala, Kochikhali, and Dimer char area. In the present study, these foraminiferal assemblages are characterized calcareous and agglutinated foraminifera. The Kotka beach is recognized as *Nonionina* assemblage zone, Jamtala beach designated as *Ammonia* assemblage zone, Kochikhali as *Nonionina* assemblage zone and Dimer char as *Rosalina-Nonionina-Nonionella* assemblage zone. The deposition of foraminifera is restricted to Sundarbans' low to high marsh zone.

Keywords: Mangroves, Intertidal foraminifera, Depositional environment, Sediment texture.

Introduction

Sundarbans, the mangrove ecosystem, is situated in the southernmost part of the Ganges-Brahmaputra-Meghna (GBM) delta. Late Holocene deposits of the GBM river system formed the riverine delta which is extended across coastal parts of India (West Bengal) and Bangladesh (Stanley and Hait 2000). The fresh water of the Ganges distributaries system and the saline water of the Bay of Bengal make a transition zone in this mangrove ecosystem. Various abiotic factors such as coastal geomorphology, temperature, salinity, tidal amplitude and duration, dissolved oxygen, and nutrients govern the environmental

*Corresponding author: <mail: sks@du.ac.bd>.

setting of the mangrove ecosystem. Competition, space and food supply are also included in the biotic factors of this ecosystem. In time and space, such macro-level environmental factors of mangroves changes (Ghosh *et al.* 2014). These changes are well reflected in the distribution of foraminifera. Reconstruction of paleo-environmental conditions may be established by understanding the development of mangrove communities in recent times. This ecosystem consists of various species of fauna and flora. A large number of distributaries of the Ganges and Brahmaputra rivers flow through this ecosystem. A complex network of estuaries, beaches, tidal creeks, tidal inlets, mudflats, sandflats and mangrove swamps exists in this tide-dominated wetland (Mitra *et al.* 2009). With a high tidal range, high rainfall and high annual sediment load of several rivers debouching sediments into the region makes the study area environmentally dynamic.

Foraminifera constitutes the most diverse group of shelled microorganisms in the modern oceans (Gupta 1999). They are the most ancient and abundant fossils. Also the most efficient rock builders, that's why they are geologically significant (Flint 1899). Sen *et al*. (2016), in their investigation of benthic foraminifera, noted 15 species from southeast Sundarbans of India. The study area is highly inaccessible because of its geographic location. Moreover, this forest is a water-logged jungle where tigers and other wild animals thrive and intersected by numerous river channels and creeks. So, the taxonomy of modern foraminifera and their distribution in the estuaries of the south-west coastal region of Bangladesh was largely overlooked.

The present research' main objective of the was to systematically describe the recorded foraminiferal species and determine the bio-assemblage constituents and prepare assemblage zone for the overall study area, characterize modern benthic foraminifera, their distribution, assemblage patterns from four sampling sites and investigate the south-western coastal margin of Bangladesh.

Materials and Methods

Regionally, the study area covers the South-western coastal margin of Bangladesh. The study area had been chosen for its uniqueness and then to get something new because the micropaleontology of that area was completely unexplored and unknown.

The sampling sites cover an area of almost 16-17 km extending west to east and represent the coastal environments of the Sundarbans forest. The study area belongs to four sampling sites, Kotka ($21^0 51'24''$N, $89^0 46'16''$E), Jamtala ($21^0 50'49''$N, $89^0 49'01''$E),

Kochikhali ($21^0$51′55″N, $89^0$50′12″E) and Dimer char ($21^0$51′04″N, $89^0$51′01″E) of the Sundarbans of Bangladesh (Fig. 1).

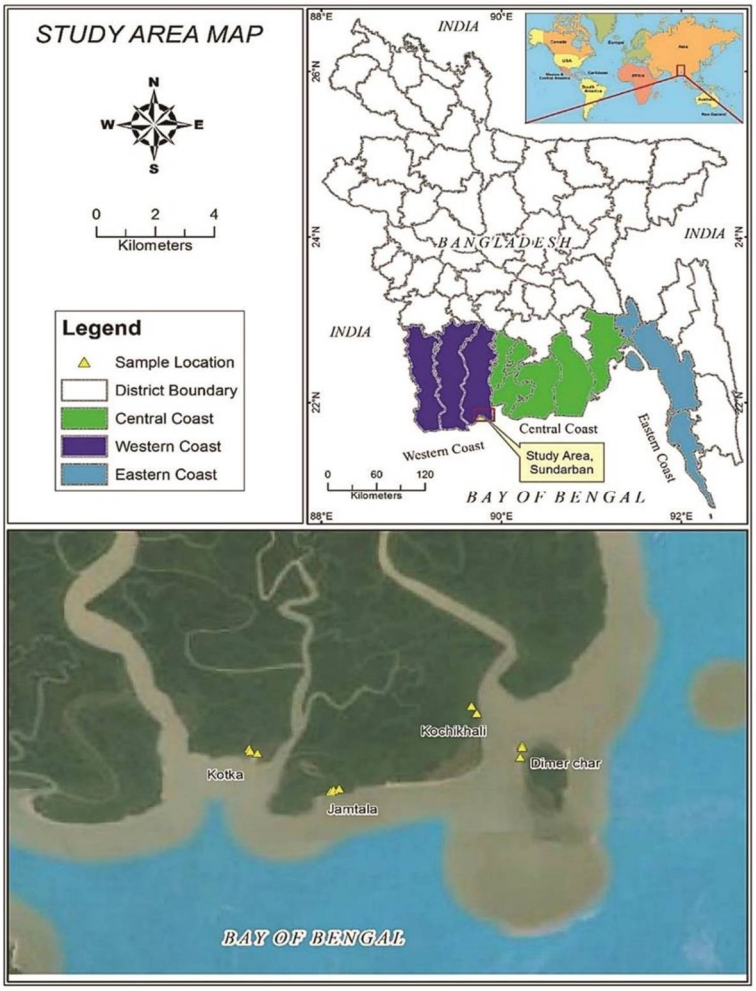


Fig. 1. Location Map of Study area highlighting sampling points.

This area selection is important because there is no such micro-paleontological research in the south-western coastal area of Bangladesh. All samples were carried out during low tide as the water regressed; thereby, the intertidal zone was exposed. From these sections, samples were collected at depth about 0.5-1m using a hand auger and scrapper. The collected samples were labeled and preserved in sample bags.

The collected samples were washed carefully to remove the unwanted fraction of materials like clay and silt, dried in an oven at 100ºC temperature for 30-40 minutes, and 100gm of samples were weighted from oven dry samples for each and every location. Then, the samples were sieved for 15 to 20 minutes, and the samples were stored in individual packets after labeling the mesh number and retained weight.

After picking under a binocular microscope, foraminifera was placed on a gridded tray, observed under Leica EZ4E microscope (Leica Corporation) at 35X magnification, and bright-field images were captured using cellSens software (Leica). In order to accurately identify foraminifera species based on morphological features, some representative samples sent to Jadavpur University, India for Scanning Electron Microscopy (SEM).

Systematic paleontology

Taxonomic identification from Order to the Genus level was followed after Loeblich and Tappan (1988), Cushman (1933) and revised and uptodated by using some literature to identify upto species level (Akimoto *et al.* 2002, Barker 1960, Wells 1985, Nomura and Seto 1992, 2002, Kathal *et al.* 2000, Khare *et al.* 2007, Dey *et al*. 2007, 2012, Devi and Rajshekhara 2009, Ghosh 2012, Gehrels and Newman 2004, Edwards *et al.* 2004, Culver and Horton 2005, Javaux and Scott 2003, Horton and Edwards 2006 and Hawkes *et al.* 2010). The Foraminifera shells were identified based on the shape of the test, the number of chambers, nature of coiling, wall composition, type of aperture, etc.

Order: Rotaliida

Superfamily: Rotaliacea

Family: Rotaliidae Ehrenberg, 1839

Subfamily: Ammoniidae Saidova, 1981

Genus: *Ammonia* Brunnich, 1772

Ammonia aoteanna (Plate 1: a, b)

Morphological Description: Test biconvex with low trochospiral coil, spiral side evolute, umbilical side involute and may have large umbilical plug surrounded by umbilical fissure, wall calcareous, and coarsely perforate.

Observed Location: Jamtala and Kotka beach, Sundarbans.

Ammonia beccarii (Plate 1: c, d)

Morphological Description: *Ammonia beccarii* has resembles morphological features with *Ammonia aoteanna,* except both surfaces are ornamented by pillars, and the umbilical side has transverse ridges.

Observed Location: Dimer char, Jamtala beach, Kochikhali and Kotka beach in the Sundarbans.

Ammonia tepida (Plate 1: e, f)

Morphological Description: *Ammonia tepida* has similar in morphological features with *Ammonia aoteanna* except for final whorl with deeply incised umbilical, radial and intraseptal spaces, sutural fissures straight or branching and appear on the umbilical side; wall calcareous, optically radial, primarily bilamellar, moderately perforate.

Observed Location: Jamtala beach, Sundarbans.

Genus: *Asterorotalia* Hofker, 1950

Asterorotalia trispinosa (Plate 1: g, h)

Morphological Description: Test flattened, low trochospiral to the nearly planispiral coil of two whorls, eight to ten chambers in the final whorl, sutures slightly depressed, chambers on umbilical side separated by deeply incised sutures with granulose to spinose borders; wall calcareous, perforate, optically radial, the surface of spiral side smooth between the numerous inflational knobs and pustules.

Observed Location: Dimer char, Jamtala beach and Kotka beach in the Sundarbans.

Superfamily: Discorbacea

Family: Rosalinidae Reiss, 1963

Genus: *Rosalina* d'Orbigny, 1826

Rosalina sp. (Plate 1: i, j)

Morphological Description: Test trochospiral, planoconvex to concavo-convex, on the umbilical side chambers, are subtriangular; wall calcareous, with organic inner lining and surface smooth.

Observed Location: Jamtala beach, Sundarbans.

Rosalina bradyi (Plate 1: k, l)

Morphological Description: Test trochospiral where the depressed sutures are oblique and curved back at the periphery, on the umbilical side chambers are subtriangular and strongly overlapping; wall calcareous.

Observed Location: Dimer char, Kochikhali, and Kotka beach in the Sundarbans.

Order: Lituolida

Superfamily: Rzehakinacea Cushman

Family: Rzehakinidae Cushman

Genus: *Miliammina* Heron-Allen and Earland, 1930

Miliammina fusca (Plate 1: m, n)

Morphological Description: Test elongate ovate, with quinqueloculine arrangement; wall relatively thick, very finely agglutinated on an organic base; aperture at the end of the chamber, rounded to semilunate.

Observed Location: Jamtala beach, Sundarbans.

Order: Miliolida

Suborder: Miliolina

Superfamily: Miliolacea

Family: Miliolidae

Genus: *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina akneriana (Plate 1: o, p)

Morphological Description: Exterior of the test is composed of three chambers, with early chamber quinqueloculine depending on the degree of overlap of successive chambers, the later ones making 120 degrees angle to each other; wall calcareous, imperforate, porcelaneous; aperture ovate typically with a bifid tooth.

Observed Location: Jamtala beach, Sundarbans.

Order: Lituolida

Superfamily: Lituolacea

Family: Haplophragmoididae Maync, 1952

Subfamily: Haplophragmoidinae Maync, 1952

Genus: *Haplophragmoides* Cushman, 1910

Haplophragmoides canariensis (Plate 1: q, r)

Morphological Description: Test planispirally enrolled, involute to slightly evolute, bi-umbilicate, wall thin, finely to coarsely agglutinated, exterior smoothly finished; aperture elongate equatorial silt at the base of the apertural face.

Remarks: It is commonly found in the high marsh area.

Observed Location: Dimer char, Jamtala beach, Kochikhali and Kotka beach in the Sundarbans.

Order: Rotaliida

Family: Anomalinidae

Genus: *Anomalinella*

Truncatulina rostrata (Plate 1: s, t)

Morphological Description: Early-stage test in trochoid but in adult stage test is planispiral; nine to ten gradually enlarging chambers in the final whorl, sutures gently curved, limbate, periphery angular, carinate; wall calcareous, sutures and keels imperforate; aperture ventral.

Remarks: The subgenus *Preanomalinella* was described as slightly trochoid in the early stage and had a slightly asymmetrical aperture, but both features are present in the type species of *Anomalinella sp. A. rostrata* hence are regarded as congeneric.

Observed Location: Jamtala beach, Sundarbans.

Order: Trochamminida

Superfamily: Trochamminacea

Family: Trochamminidae

Subfamily: Trochammininae

Genus: *Trochammina*

Trochammina inflata (Plate 2: a, b)

Morphological Description: Test free, trochospiral, wall agglutinated, imperforate, aperture an interio-marginal, umbilical-extra umbilical arch with narrow bordering lip.

Observed Location: Jamtala beach and Kotka beach in the Sundarbans.

Order: Trochamminida

Superfamily: Trochamminacea

Family: Trochamminidae

Subfamily: Jadammininae Saidova, 1981

Genus: *Jadammina* Bartenstein and Brand, 1938

Jadammina macrescens (Plate 2: c, d)

Morphological Description: Test free, a flattened trochospiral that tends to be nearly planispiral in the adult, chambers increasing gradually in size as added, sutures radial to slightly curved; primary aperture a low interiomarginal equatorial silt.

Observed Location: Jamtala beach and Kotka beach in the Sundarbans.

Order: Rotaliida

Superfamily: Rotaliacea

Family: Elphidiidae Galloway, 1933

Subfamily: Elphidiinae Galloway, 1933

Genus: *Elphidium* de Montfort, 1808

Elphidium lessonii (Plate 2: e, f)

Morphological Description: Test large, lenticular, planispirally enrolled, involute or partially evolute, may have an umbilical plug on each side, seven to twenty chambers in the final whorl, periphery carinate; wall calcareous, optically radial, finely perforate.

Observed Location: Dimer char, Jamtala beach, Kochikhali and Kotka beach in the Sundarbans.

Order: Rotaliida

Superfamily: Rotaliacea

Family: Elphidiidae Galloway, 1933

Subfamily: Elphidiinae Galloway, 1933

Genus: *Cribroelphidium* Cushman and Bronnimann, 1948

Cribroelphidium vadescens (Plate 2: g, h)

Morphological Description: Test planispiral and involute with rounded noncarinate periphery, about eight to eleven slightly inflated chambers in the final whorl, slightly depressed, umbilicus with boss; wall calcareous, perforate but apertural face smooth, optically radial, bilamellar with septal flaps; aperture multiple and may also have areal openings.

Observed Location: Jamtala beach, Kochikhali and Kotka beach in the Sundarbans.

Order: Rotaliida

Superfamily: Nonionacea

Family: Nonionidae Schultze, 1854

Subfamily: Nonioninae Schultze, 1854

Genus: *Haynesina* Banner and Culver, 1978

Nonionina germanica Ehrenberg, 1840 (Plate 2: i, j)

Morphological Description: Test planispiral, at least in the adult, involute, biumbilicate, about eight to ten chambers per whorl, chamber wall bend inward posteriorly and fuse to the preceding septal face; wall calcareous, perforate, optically radial but morphologically granular calcite, tubercles prominently developed around the aperture; primary aperture a low and symmetrical interiomarginal arch but obscured by abundant surface pustules.

Observed Location: Dimer char, Jamtala beach, Kochikhali and Kotka beach in the Sundarbans

Order: Rotaliida

Superfamily: Nonionacea

Family: Nonionidae Schultze, 1854

Subfamily: Nonioninae Schultze, 1854

Genus: *Nonionella* Cushman, 1926

Nonionella miocenica Cushman, 1926 (Plate 2: k, l)

Morphological Description: Test slightly compressed in a low trochospiral coil, periphery rounded, spiral side partially evolute around an umbilical boss, umbilical side involute, chambers numerous, broad and low, whorls progressively enlarging and may produce a flaring test, chambers with a flaplike projection overhanging the umbilicus, sutures curved, depressed; wall calcareous, aperture a small interiomarginal and nearly equatorial arch.

Observed Location: Dimer char, Jamtala beach and Kotka beach in the Sundarbans.

Order: Rotaliida

Superfamily: Nonionacea

Family: Nonionidae Schultze, 1854

Subfamily: Nonioninae Schultze, 1854

Genus: *Nonionellina* Voloshinova, 1958

Nonionellina sp (Plate 2: m, n)

Morphological Description: Test trochospiral in the early stage, later nearly planispiral, involute, chambers enlarging rapidly as added, with an inflated basal lobe on the umbilical side, biumbilicate but umbilici small and inequal, open throughout growth and not covered with chamber lobes, periphery subangular to rounded; wall calcareous, finely perforateS; primary aperture a low interiomarginal and equatorial arch.

Observed Location: Dimer char and Kochikhali in the Sundarbans.

Discussion

Through this study, 17 species, 14 genera representing 9 families of foraminifera were identified. According to their origin, the identified species are benthic in origin. The most significant and remarkable genera are *Nonionina, Nonionella, Ammonia, Elphidium, Rosalina, Haplophragmoides, Jadammina, Trochammina, Cribroelphidium, Asterorotali a.*

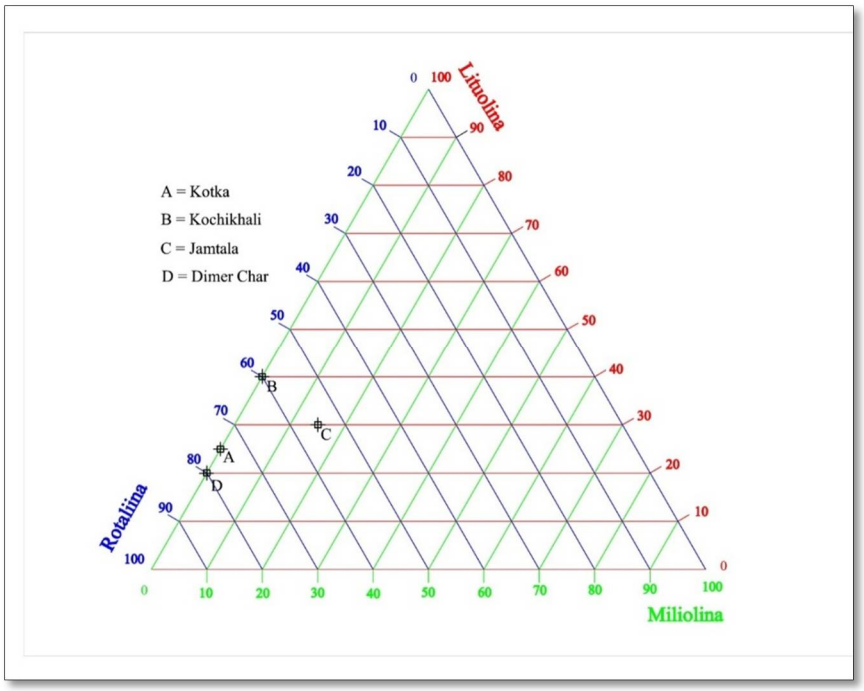


Fig. 2. Ternary plot characterizing sampling sites based on observed suborder of forams.

Quinqueloculina, Miliammina etc. Among the three major suborders, Rotaliina comprises the highest number of foraminifera. The suborder Lituolina contains a fair amount of forams. Mainly, Rotaliina and Lituolida cover the whole Kotka, Kochikhali and Dimer char and only Jamtala contains a little amount of forams of suborder Miliolina containing only 1 species namely *Quinqueloculina akneriana.* The ternary plot can show the relative abundance based on the percentage of the observed suborders of foraminifera, and it characterizes sampling sites.

Based on the tidal sequence, the Sundarbans is recognized as high, middle and low marsh zone. Based on the frequency of occurrence of an individual species in samples from a particular location, the relative abundance curves of species are prepared for four study sites.

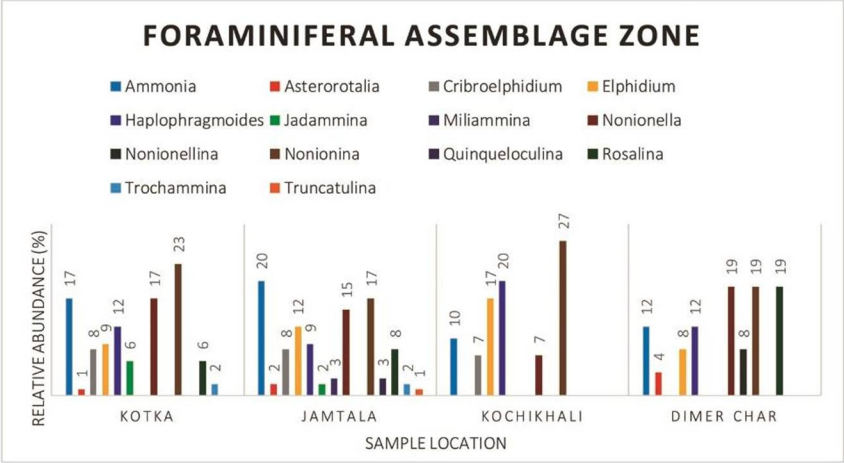


Fig. 3. Foraminiferal assemblage zones for the study area.

From Fig. 3, Kotka beach can be recognized as *Nonionina* assemblage zone, Jamtala beach designated as *Ammonia* assemblage zone. In contrast, Kochikhali can be demarcated as the *Nonionina* assemblage zone and Dimer char as the *Rosalina-Nonionina-Nonionella* assemblage zone.

In the present research, calcareous taxa such as *Nonionina germanica, Nonionella miocenica, Ammonia beccarii, Elphidium lessonii, Rosalina bradyi, Cribroelphidium vadescens etc.* found most based on their relative abundance. According to Murray (1999, 2006), *Ammonia* and *Elphidium* are frequently dominant modern foraminiferal assemblages in the lower zone of estuaries. Based on the determination of high marsh

assemblages, the pioneer works of many scientists have depicted the distribution patterns of modern saltmarsh agglutinated foraminifera, they established their utility already in assessing paleo sea level. Agglutinated foraminifera such as *Haplophragmoides canariensis, Jadammina macrescens, Trochammina* inflate, Miliammina fusca, etc. have been identified in the study area. Finally, both calcareous and agglutinated foraminifera are abundant in the middle marsh zone.

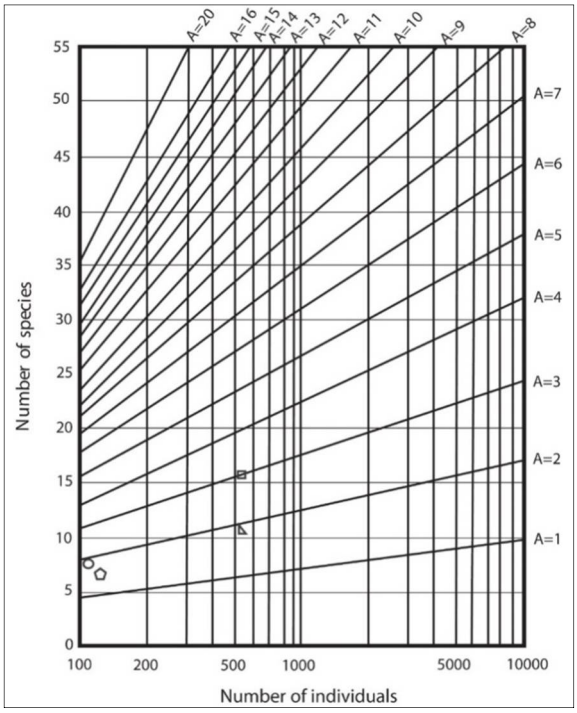


Fig. 4. Diversity index (A) of the Sundarban foraminiferal assemblage (symbol code: *triangle* - Kotka; *square* - Jamtala; *pentagon* - Kochikhali and *circle* - Dimer Char).

In Kotka, calcareous foraminiferal assemblages *Nonionina, Nonionella, Ammonia* are abundant and characterize Kotka beach as a low marsh zone of depositional environments. The abundance of calcareous *and* agglutinated foraminifera characterized Jamtala as the middle marsh zone of deposition. Finally, in Kochikhali and Dimer char, the calcareous foraminiferal assemblages like *Nonionina germanica, Elphidium lessonii, Rosalina bradyi, Ammonia beccarii, Cribroelphidium vadescens, Nonionellina* sp. dominate in low marsh zone and agglutinated foraminiferal assemblage

Haplophragmoides canariensis is dominant in high marsh zone (Gupta 1999, Murray 1999b, Ghosh 2014). So, Kochikhali and Dimer char are demarcated as low to high marsh zone of depositional environments.

Foraminiferal assemblages are low diverse in Sundarban and Kotka and Jamtala contain 11 and 16 species, respectively. Kochikhali and Dimer char are diverse in nature and include 7 and 8 species, respectively. So, both zones suggest that the foraminifera decrease from low to high marsh zone (Fig. 4).

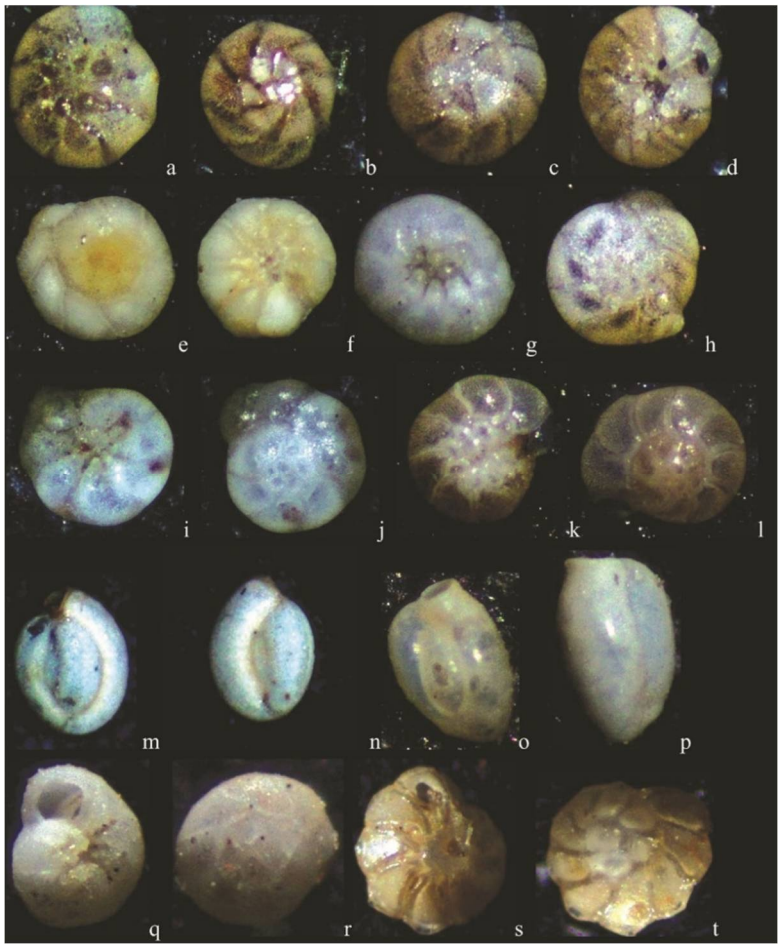


Plate 1: a, b *Ammonia aoteana*, c. d *Ammonia beccarii*, e. f *Ammonia tepida*, g, h. *Asterorotalia trispinosa*, i, j. *Rosalina* sp., k, l. *Rosalina bradyi*, m, n. *Miliammina fusca*, o, p. *Quinqueloculina akneriana*, q, r. *Haplophragmoides canariensis*, s, t. *Truncatulina rostrata*.

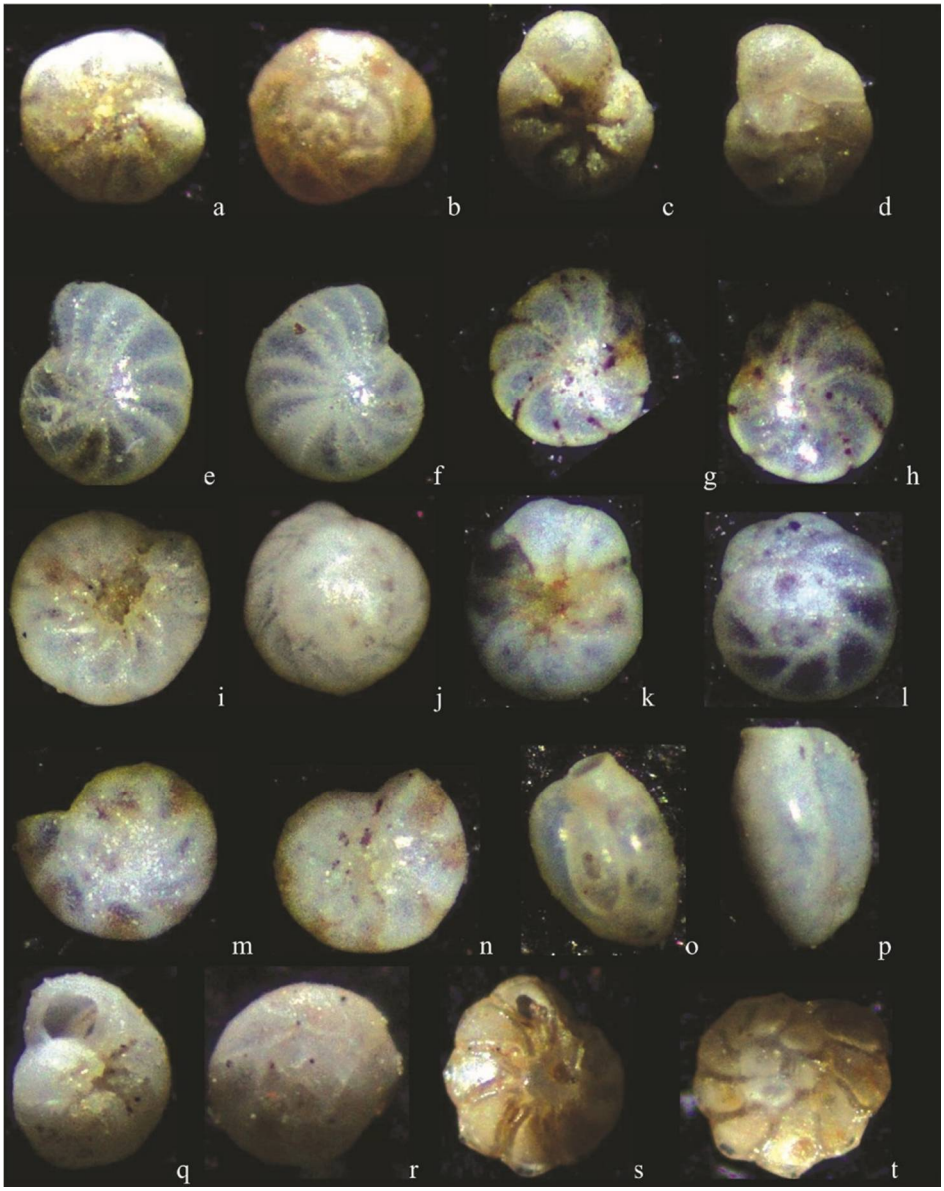


Plate 2: a, b *Trochammina inflata,* c, d. *Jadammina macrescens,* e, f. *Elphidium lessonii,* g, h, *Cribroelphidium vadescens,* i, j. *Nonionina germanica,* k, l. *Nonionella miocenica,* m, n. *Nonionellina* sp. o, p, *Quinqueloculina akneriana.* q, r, *Haplophragmoides canariensis,* s, t. *Truncatulina rostrata.*

Conclusion

The marsh areas of Sundarban are influenced by a multitude of factors comprising monsoon, meso-tidal range, and biotic effects. These environmental factors have a marked effect on foraminiferal assemblage and mangrove vegetation. The present integrated study of foraminifera and vegetation distinguishes the high and low marsh zones: a) High Marsh: Foraminifera- Trochammina inflata, Miliammina fusca, and Haplophragmoides canarienses; b) Low marsh: Foraminifera-Ammonia beccarii, Haynesina germanica, Rosalina bradyi and Elphidium sp. Saltmarsh foraminifera differentiates the high and low marsh zone, and paleo-environment of the study area has been identified. Numerous environmental factors influence and these factors take prominent attributes on foraminiferal assemblages. The dominance of high marsh foraminifera like *Haplophragmoides canariensis, Jadammina macrescens, Trochammina inflata and Miliammina fusca* is a distinguished feature, and in fact, *Jadammina* and *Trochammina* are confined to mangrove habitats (Murray 2006). This research aimed to create a thorough study of benthic foraminifera from remote, inaccessible, and unexplored Sundarbans of Bangladesh. This foraminiferal dataset may provide a better understanding of sea level rise in the south-western coastal region of Bangladesh.

References

Akimoto, K.M. 2002. Atlas of Holocene benthic foraminifers of Shimabara bay, Kyushu, Southwest Japan. *The Kagoshima Univ. Mus. Mon*. **2**: 1-112.

Culver, S.J. and B.J. Horton. 2005. Infaunal marsh foraminifera from the outer banks, North Carolina, U.S.A. *J. Foram. Res*. **35**(2): 148-170.

Cushman, J.1. 1933. Foraminifera their classification and economic use. *Special Publication.* No. 4. Cushman Laboratory for Foraminiferal Research.

Devi, G.S. and K.P. Rajshekhara. 2009. Intertidal Foraminifera of Indian coast-a scanning electron photomicrograph-illustrated catalogue. *J. Threatened Taxa*. **1**(1):17- 36.

Dey, M., D. Ganguly, S.K. Mandal, T.K. De and T.K. Jana. 2007. Foraminiferal calcium carbonate pump response to temporal changes of carbon dioxide systems in the Sundarban mangrove environment North East coast of Bay of Bengal India. *Amer. Geophys. Union*. V. **114**: 32-45.

Dey, M., Ganguly, D., Choudhury, C., Majumder, N. and Jana, T.K. 2012. Intra-annual variation of modern foraminiferal assemblage in a tropical mangrove ecosystem in India. *Wetlands*. **32**(5): 813-826.

Edwards, R.J. 2004. Surface distributions of salt-marsh foraminifera from Connecticut, USA: modern analogues for high-resolution sea level studies. *Marine Micropaleontology*. **51**(1-2): 1-21.

Flint, J.M. 1899. Recent Foraminifera: A descriptive catalogue of specimens dredged by the US Fish Commission Steamer Albatross. Smithsonian Institution. United States National Museum.

Gehrels, W.R. and S.W.G. Newman. 2004. Salt-marsh foraminifera in Ho Bugt, western Denmark, and their use as sea-level indicators. *Geografisk Tidsskrift-Danish J. Geogr.* **104**(1): 97-106.

Ghosh, A. 2012. Estuarine Foraminifera from the Gulf of Cambay. *J. Geolog. Soc. India.* **80**(1): 65-74.

Ghosh, A. 2014. Marsh foraminiferal assemblages in relation to vegetation in Sunderban, India. *J. Geol. Soc. India.* **84**(6): 657-667.

Gupta, B. K. 1999a. Systematics of modern Foraminifera. In Modern foraminifera. Springer, Dordrecht. pp. 7-36.

Gupta, B.K. 1999b. Foraminifera in marginal marine environments. In Modern foraminifera. Springer, Dordrecht. pp. 141-159.

Hawkes, A.D. 2010. The application of intertidal foraminifera to reconstruct coastal subsidence during the giant Cascadia earthquake of AD 1700 in Oregon, USA. *Quaternary International.* **221**(1-2):116-140.

Horton, B.P. 2006. Quantifying Holocene sea level change using intertidal foraminifera: lessons from the British Isles. *Departmental Papers (EES).* **50**: 1-97.

Javaux, E.J. 2003. Illustration of modern benthic foraminifera from Bermuda and remarks on distribution in other subtropical/tropical areas. *Palaeontologia Electronica.* **6**(4): 29-57.

Kathal, P.K. 2002. Taxonomy, distribution patterns and ecology of recent littoral foraminifera of the east coast of India. *Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen.* 115-160.

Khare, N. C. 2007. An overview of foraminiferal studies in nearshore regions off eastern coast of India, and Andaman and Nicobar Islands. *Indian Jour. Mar. Sci.* **36**: 288-300.

Loeblich, A. R. and Tappan, H. 1988. Foraminiferal Genera and their Classification. Van Nostrand Reinhold, New York Google Scholar.

Mitra, A.G. 2009. Observed changes in water mass properties in the Indian Sundarbans (northwestern Bay of Bengal) during 1980–2007. *Curr. Sci.* **97**(10): 1445-1452.

Murray, J.W. 1999a. Natural dissolution of modern shallow water benthic foraminifera: taphonomic effects on the palaeoecological record, *Jour. Palaeogeography, Palaeoclimatology, Palaeoecology.* **146** (1-4): 195-209.

Murray, J.W. 1999b. Taphonomic experiments on marginal marine foraminiferal assemblages: how much ecological information is preserved*? Jour. Palaeogeography, Palaeoclimatology, Palaeoecology.* **149**(1-4): 183-197.

Murray, J.W. 2006. Ecology and applications of benthic foraminifera. Cambridge University Press.

Sen, A.G. 2016. Modern benthic foraminiferal assemblages from the world's largest deltaic mangrove ecosystem, the Sundarbans. *Marine Biodiversity.* **46**(2): 421-431.

Stanley, D.J. and A.K. Hait. 2000. Holocene depositional patterns, neotectonics and Sundarban mangroves in the western Ganges-Brahmaputra delta. *J. Coastal Res.* **16**(1): 26-39.

(Revised copy received on 16.09.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 137-147, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57277

LABORATORY-BASED CYTOLOGICAL AND BIOCHEMICAL PROFILE OF CEREBROSPINAL FLUID FOR CHILDREN WITH ACUTE BACTERIAL MENINGITIS IN BANGLADESH

MOHAMMAD ZAKERIN ABEDIN[1,3*], LAILA JARIN[2] AND DONALD JAMES GOMES[3]

[1]*Department of Microbiology, School of Biomedical Science, Khwaja Yunus Ali University, Sirajganj, Bangladesh.*

[2]*Department of Microbiology, Lab Aid Medical Centre Gulshan Ltd, Dhaka, Bangladesh.*

[3]*Department of Microbiology, University of Dhaka, Dhaka, Bangladesh.*

Abstract

An attempt was made to analyze the cerebrospinal fluid (CSF) for a cytological and biochemical profile to identify etiological agents from children with suspected acute bacterial meningitis. The cerebrospinal fluid (CSF) samples from 371 suspected meningitis cases were examined, and the highest bacterial meningitis was found in 52(14.0%) cases in this study. Among a total of 371 samples of CSF, 272(73.3%) were crystal clear, 52(14.0%) were moderately turbid, 47(12.7%) highly turbid. The total leukocyte cell count of the CSF was proportionate to the turbidity. In the case of crystal clear CSF's, total leukocyte counts (TLC) were normally ranging from <5 to 45 per mm^3 with predominant lymphocytes. Moderately turbid fluid showed 46 to 500 cells per mm^3 and highly turbid fluid showed from 501 to more than 10,00 cells/mm^3. In the latter cases, differential counts demonstrated polymorphonuclear predominance. In addition, about 100% (52 cases) of positive and 12.5% (40/319) of negative cases had CSF protein concentration >100 mg/dL. CSF protein concentration greater than 100 mg/dl and sugar level below 40 mg/dl were considered as suspected bacterial meningitis in this study. Surprisingly, the C-Reactive Protein (CRP) values were found to be >40 mg/dL in both culturally positive and negative cases. Most of meningitis positive cases showed increased total cell counts as well as protein concentration, and decreased serum sugar concentrations.

Keywords: Cytological patterns, Biochemical profile, Acute bacterial meningitis

Introduction

Bacterial meningitis continues to be a significant cause of mortality and morbidity in neonates and children throughout the world. Casualty in both developed and developing

*Corresponding author: <zakerin.du2016@gmail.com>.

countries of bacterial meningitis range from 4.5% and 15-50%, respectively. The percentage of mortality cases are near 100% in untreated people, and up to 40% of youngsters get fitting anti-infection treatment in developing nations (Salih *et al.* 1991).

After admission to the medical clinics, all happens within 72 hours; CSF protects the cerebrum from the sudden change in stable substance, pressure, and also maintains it and expels cerebral metabolism waste materials (McGing and Kelley 2009). CSF is the most significant part of evaluation for the laboratory diagnosis of meningitis. Bacteria, mycobacteria, and fungal diseases are created from CSF variations that may incredibly encourage conclusion and direct introductory treatment. All patients with acute bacterial meningitis ought to be performed the fundamental investigations of CSF include cell count, measurement of pressure, differential count of WBC, glucose, protein levels, Gram's stain properties, and cultural characteristics (Greenlee *et al.* 2009).

The composition of CSFs is liable for trademark changes in the meninges of meningitis patients by the infection of different pathogens that leads to changes in physiological and anatomical conditions of meninges. The expanded relocation of polymorphonuclear (PMN) leukocytes and leakage of protein into the CSF due to loss of trustworthiness of cerebral vessels and integrity of the blood-brain barrier. The standard CSF value is 0-5 leukocytes/mm^3, for the most part lymphocytes, however, in neonates, cell check is up to 30/mm^3 (Collee *et al.* 1996). A preponderance of neutrophils (WBC >500/mm^3) and monocytes (WBC >100/mm^3) is normal for a bacterial and viral meningitis respectively that is an impressive example cover is frequently found (Venkatesh *et al.* 2000).

Recognize bacterial meningitis (glucose <40 mg/dl) from aseptic meningitis (glucose are normally unaltered) by the level of CSF glucose (Mace 2008). The physiological activity of the choroid epithelium and utilization by bacterial pathogens and leukocytes leads to diminished CSF glucose (Watson *et al.* 1995). The count of white blood cells (>7500 cells/mm^3) and estimations of glucose (<10 mg/dL) levels are separated from chemical meningitis (Forgacs *et al.* 2001).

The blood-CSF barrier of CSF excludes a large amount of proteins. Protein accessing the CSF essentially arrives at the CSF by transport inside pinocytotic vesicles navigating delicate endothelial cells (McGing and Kelley 2009). The proteins level is more than 200 mg/dL of profoundly critical for acute bacterial meningitis showing interruption of the blood-cerebrum or the blood-CSF boundary (Mace 2008). In this investigation, we planned to study the profiling of cytological and biochemical parameters from cerebrospinal fluid from suspected bacterial meningitis in children in Bangladesh.

Material and Methods

Study Population: The study was done for one year, from August 2010 to August 2011. The 371 individuals with suspected meningitis in children were included. The children were clinically diagnosed with bacterial meningitis by physicians.

Sampling Sites: Samples were collected from different hospitals and diagnostic centers located in Dhaka city, Bangladesh, including Popular Diagnostic Center Ltd. and Central Hospital Ltd. After collection, the physical appearances of the CSF were noted. They were grouped according to their turbidity as crystal clear, moderately turbid, and highly turbid CSF. The cerebrospinal fluids (CSFs) were processed within one hour of gathering in the research facility. The samples were handled utilizing Gram staining, cell count, and Latex Agglutination Test (LAT) and biochemical analyses.

Analysis of TLC and DLC: In this study, a Neubauer counting chamber method and Wright's staining were used for cytological analysis of total leucocytes count (TLC), and differential leukocytes count (DLC) was done on the CSF specimen before centrifugation of the samples. Greater than 500 cells/mm^3 was significant for bacterial meningitis.

Estimation of CSF Protein and Glucose: CSF protein and glucose concentrations were determined by using the Vistors-250 System (USA). CSF protein concentration greater than 100 mg/dl and sugar level below 40 mg/dl were considered as suspected bacterial meningitis in this study.

Estimation of C-Reactive Protein (CRP): Cerebrospinal spinal fluids CRP level was estimated by using CRP latex agglutination kit (Chrono Lab, UK). On the provided slide, a drop of CSF was mixed with latex CRP reagent, and agglutination reaction was seen after 2 minutes. The presence of agglutination was considered a positive test. CRP level >40 mg/dl in CSF was taken as significant.

Latex Agglutination Test (LAT): The LAT was performed to identify the bacterial antigens of *Haemophilus influenzae* (HI), *Streptococcus pneumoniae* (SPN), *Neisseria meningitidis* (NM), and *Escherichia coli* (EC) using a Wellcogen Test- card latex agglutination (Thermo Fisher Scientific, USA) according to manufacturer's guidelines.

Data Analysis: The data obtained were analyzed by SPSS version 20 and Excel 2016. Descriptive statistics and chi-square tests were done to check the statistical significance.

Results and Discussion

Cerebrospinal fluid samples (n = 371) were aseptically drawn from different children with associated cases of bacterial meningitis patients aged between 2 months and 12

years from different hospitals and diagnostic centers in Dhaka city, Bangladesh. Most of them came from low income families. They were the victims of malnutrition and were suffering from several different diseases due to deficiencies of vitamins. Among the 371 patients, 63% (234/371) were male, and 37% (137/371) were females. Considering the positive cases, there was a slight predominance of males than females with a ratio of 1.7:1.

Latex Agglutination Test: Depending on the meningeal pathogen, latex agglutination has shown good sensitivity in detecting the antigens of common meningeal pathogens. The Latex agglutination test (LAT) method is one of the rapid tests for analysis of bacterial meningitis from CSF specimens. In this investigation, the LATs were positive for 14.0% (52/371) of CSFs (Table 1). In this LAT analysis, 50% (26/52) was *Streptococcus pneumoniae* followed by *Haemophilus influenzae* type b 21.1% (11/52), *Neisseria meningitides* 15.4% (8/52), and least of *Escherichia coli* K1 13.5 (7/52), that has also been observed by other studies (Shrestha *et al.* 2015).

Table 1. Latex agglutination test results from CSF by Wellcogen test- card.

Detected bacterial pathogens	Number of isolates	Percent
Streptococcus pneumoniae	26	50.0%
Haemophilusinfluenzae type b	11	21.1%
Neisseria meningitides	8	15.4%
Escherichia coli K1	7	13.5%
Total	52	100%

*Gr**am Staining Technique**:* The precipitate of a CSF sample is used for microscopy using Gram staining reaction for the preliminary identification of the organism. After staining, bacteria were found in 48 (12.9%) cases. No Gram- positive rod bacteria were found in any sample. The microorganisms found were Gram-negative cocci, Gram negative coccobacilli, Gram- positive cocci, and Gram -negative bacilli (rod- shaped) (Table 2).

Table 2. Morphology and staining properties of bacteria found in the CSF.

Morphology	Staining property	Number of isolates	Frequency (%)
Cocci (*Streptococcus pneumoniae*)	Gram- Positive	23	48.0
Coccobacilli *(Haemophilus influenzae type b)*	Gram -Negative	10	20.8
Cocci (*Neisseria meningitides)*	Gram -Negative	8	16.6
Rods (Escherichia coli)	Gram -Negative	7	14.6
Total		48	100%

Cytological Profile: The total numbers of leucocytes in the cerebrospinal fluid were counted as soon as the samples were brought to the laboratory. The crystal clear CSF showed 0-45 cell/mm^{3}and moderately turbid CSF showed 46-500 cells/mm^3. The highly turbid CSF was collected from cases of acute bacterial meningitis. In the latter cases, as great increases in the number of leucocytes were found with the range of 501 to >1000 cells/mm^3.The total number of leucocytes counted from different CSF is given in table (Table 3).

Table 3. Total leucocyte Cells (TLC) and positive cases (N=52) within analyzed samples.

	Total CSF samples (N=371)		Positive cases (N=52)	
TLC (cells/mm^3)	Frequency (N)	Percentage (%)	Frequency (N)	Positive rate (%)
<5-45	272	73.3	2	3.85
46-500	52	14.0	9	17.30
501- >1000	47	12.7	41	78.85

Most meningitis- positive cases showed increased total leuckocyte cell counts (TLC) and proteins and decreased serum sugar concentration. 78.85 % (41/52) of positive cases showed that TLC was higher than 501/mm^3, but 17.3% (9/52) and 3.85.0% (2/52) of positive cases showed that TLC was higher than 46/mm^3, and less than 45/mm^3, respectively. 73.30% (272 cases) showed that TLC was 0-45/mm^3, and within the cases, only 2 cases showed positive meningitis patients (Fig. 1).

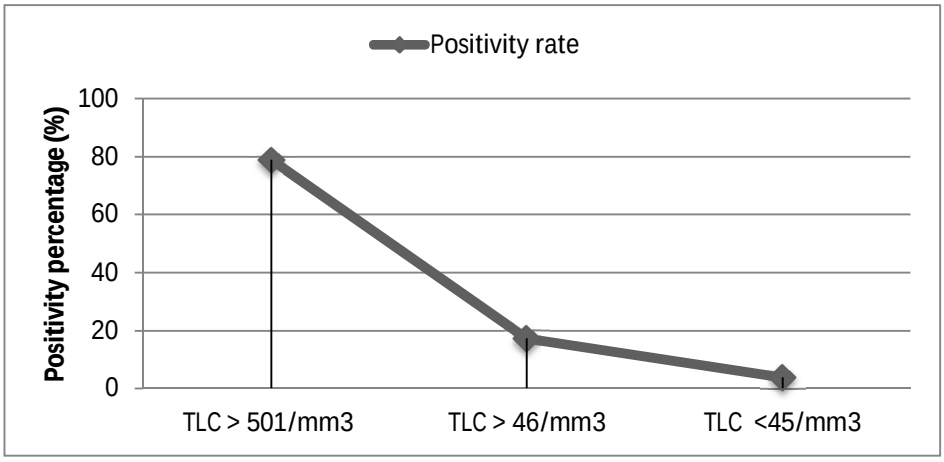


Fig. 1. Percentage of growth and TLC (Total Leukocyte cell) between TLC 0-100/mm^3 and TLC >100/mm^3

In our analysis, 41/52 of cloudy CSFs are affirmed acute bacterial meningitis cases. A few (2 cases) CSF is colorless, and only 9 samples of CSF are moderate turbid, additionally positive for bacterial meningitis. The color of the CSF to demonstrate infection could be deceiving, focusing on the need to utilize additional research facility indicative strategies. It is commonly acknowledged that WBC count >1000/mm^3 is responsible for an individual of bacterial meningitis.

The WBC ≥ 100/ mm^3 of the CSF is a more noteworthy rate were affirmed as bacterial meningitis individuals, which is steady with the standard portrayal of speculated bacterial contamination and, along these lines, a helpful trademark to survey the nearness of bacterial meningitis where culture offices are not accessible (Almeida *et al.* 2019).

In our study, total leukocyte count (TLC), protein and glucose more prominent than the normal range of 10 to >1000 cells/mm^3, 315 mg/dL, and 22.5 mg/dL, respectively, and with overwhelming neutrophils are observed among the 52 positive bacterial meningitis cases as observed by Pandey *et al.* (2015). Most studies, particularly expanded all out protein, increased white blood cells with neutrophils, and decreased glucose from CSF, and the nearness of countless PMN leukocytes and Gram staining is performed for microscopic organisms from CSF sediment that results in acute bacterial meningitis. Similar studies were also observed by other researchers (Dubos *et al.* 2008).

The total count of cells, glucose, total protein, and lactate levels were studied in cerebrospinal fluids. The pleocytosis of primarily polymorphic leukocytes is mainly due to bacterial meningitis occurring exemplary anomalies of CSF arrangement include low CSF to blood glucose proportion, low glucose focus, and raised protein levels. These variations are consistently missing within neonates. At 6% of cases in CSF with *S. agalactiae* bacterial meningitis were investigated within one hundred forty-six children (Johansson *et al.* 2015).

The CSF white blood cells tally was low, and the median was 6 cells/mm^3 and a territory amount of 0–90 000/mm^3, interquartile range of 2–15/mm^3. In the microbiologically confirmatory analysis of bacterial meningitis, CSF white blood cells tallies of more than 21 cells/ mm^3 had an affectability of 79% and explicitness of 81%. The concentrations of CSF glucose and protein varied from 0 to 198 mg/dL (median, 20 mg/dL) and 0.4 to 19.6 g/L (median, 2.7 g/L), respectively; microbiological culture-demonstrated bacterial meningitis was not analyzed precisely by cerebrospinal fluids protein or glucose (Alamarat *et al.* 2020; Johansson *et al.* 2015 and Panuganti 2017).

The CSF protein lower limits >0.5 g/L and total leukocyte count of >100 cells/mm^3 were additionally emphatically connected with acute bacterial meningitis patients were shown within a prospective investigation of 198 offspring of whom 98 had bacterial meningitis patients (Dubos *et al.* 2008). Another planned microbiological cultural investigation of CSF for meningococcal meningitis had a WBC count of not more than 1000 cells/mm^3 (19%) and an ordinary composition of CSF only 5 (1.7%) (Alamarat *et al*. 2020).

Biochemical Profiling of the CSF

Protein Concentration: In this study, 100% (52) of positive cases showed that protein was more than 100 mg/dL, while 75.2% (240/319) and 22% (70/319) of the negative cases had a protein level under 45 mg/dL and 100 mg/dL, respectively and 2.8% (09/319) of the negative case patients had a protein level higher than 100 mg/dL (Fig. 2). The mean CSF protein levels in the positive group were 315 mg/dL, more than the 117 mg/dL of the negative group.

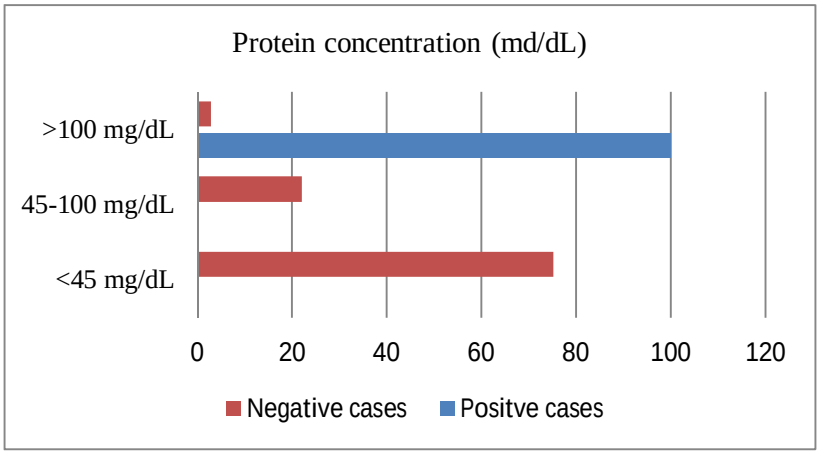


Fig. 2. Distribution of protein concentration between positive and negative cases suspected of acute bacterial meningitis in children.

Glucose Concentration: CSF glucose levels were also estimated in this study. CSF glucose levels at <40 mg/dL were found in about 94.2% (49/52) of 52 positive cases children, and only 5.8% (3/52) of positive cases had normal levels. Among the negative cases, CSF glucose levels at <40 mg/dL were found in only about 11.6% (37/319) of cases, while the glucose levels at 40 mg/dL were found in 88.4% (282/319) case samples (Fig. 3). In our study, 22.5 mg/dL and 53.3 mg/dl were the mean glucose level of bacterial meningitis positive cases and non-bacterial meningitis group, respectively.

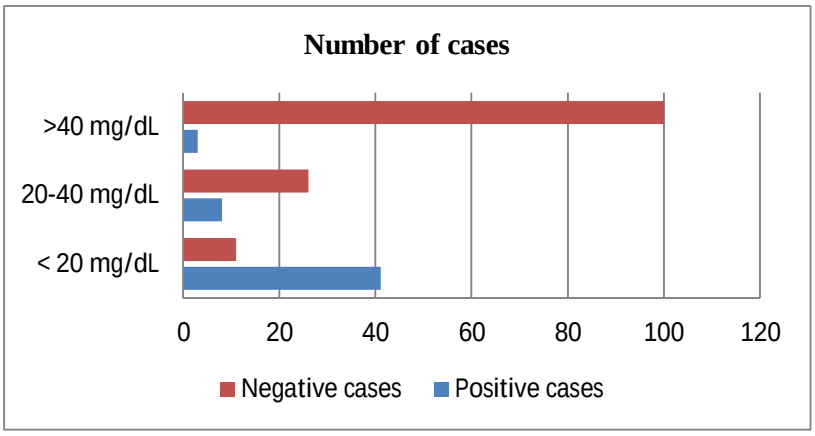


Fig. 3. Distribution of glucose concentration between positive and negative cases with suspected meningitis in children.

***C-Reactive Protein (CRP)*:** The amount of C-reactive protein (CRP) among culturally positive and negative suspected meningitis cases. CRP levels were high (>40 mg/dl) among 86.5% (45/52) of the positive bacterial meningitis children and only 24.8% (79/319) children with suspected non- bacterial meningitis had positive CRP tests. Only 13.4% (7/52) of the positive cases exhibited a negative CRP level, while 75.2% (240/319) of negative cases were also had negative CRP value.

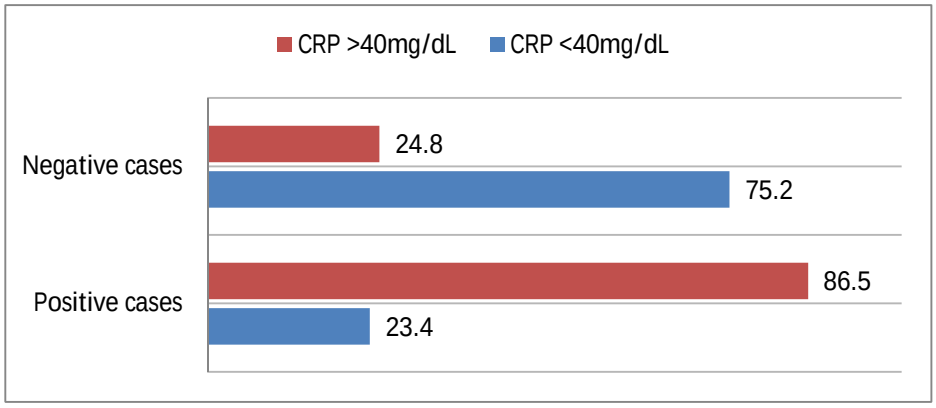


Fig. 4. C-Reactive Protein (CRP) levels are positive and negative in suspected meningitis cases.

In this study, the CSF protein value (>89.4 mg/dl) was higher than on average in bacterial meningitis cases whereas glucose estimation level (<28.8 mg/dl) was seen as diminished as normal range in meningitis patients (Table 4). The lab assumes a significant job in recognizing and affirming of meningitis cases. Assessment of the cerebrospinal liquid (CSF) is oftentimes used to give prompt affirmation of acute bacterial meningitis.

The amount of protein is expanded within the bacterial disease because the protein is discharged and microbial physiology within cerebrospinal fluids. Recognizing viral infection from bacterial meningitis can bring glucose and protein levels to normal value. The protein level is typically brought up in bacterial disease, and the glucose level is greatly low. If there is an occurrence of viral contamination, the protein value of remains practically typical. In this manner, this finding well with the built-up clinical information.

Conclusion

In this study, we have performed a cytological and biochemical analysis of CSF from acute bacterial meningitis of child patients in Bangladesh. The cytological characterization revealed 78.5% (41/371) positive meningitis patients when the TLC counts were more than 501cells/mm^3. Acute bacterial meningitis is depicted by increased total leucocytes cells (TLC) with amazing quality of neutrophils and reduced glucose and extended protein levels. The biochemical analysis of CSF showed >100 mg/dL of CSF protein. Most of the meningitis positive cases showed increased total cell counts as well as protein concentration, and decreased serum sugar concentrations. The most commonly observed pathogens in CSF latex agglutination test including *Streptococcus pneumoniae* (26, 50.0%), *H. influenzae* (14, 21.1%), *N. meningitides* (8, 15.4%), and *E.coli* K1 (7, 13.5%) as the causative bacterial pathogens.

Acknowledgments

Thanks to the staff of Microbiology and Biochemistry Laboratory of Popular Diagnostic Center Ltd, Dhanmondi, Dhaka, Bangladesh, for their assistance during the lab work. The contribution of the Asiatic Society of Bangladesh, which provided financial support, is acknowledged. We also thank Mr.Nurul Islam (Tutul) at Popular Diagnostic Center Ltd., Dhanmondi, Dhaka, Bangladeshfor his contribution to facilitating sample collection.

Funding: Asiatic Society of Bangladesh, Nimtoli, Ramna, Dhaka-1000, Bangladesh.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

Almeida, S.M.D., N.C. Barros, R. Petterle and K. Nogueira. 2019. Comparison of cerebrospinal fluid lactate with physical, cytological, and other biochemical characteristics as prognostic factors in acute bacterial meningitis. Arq. Neuropsiquiatr. **77**(12): 871-880. https://doi.org/ 10.1590/ 0004-282X20190185

Alamarat, Zain, and Rodrigo Hasbun. 2020. Management of Acute Bacterial Meningitis in Children. *Infection and Drug Resistance.* **13**: 4077-4089.

Collee, J.G., J.P. David, A.G. Fraser, B.P. Marnionand, S.A. Simmon 1996. Laboratory strategy in the diagnosis of infective Syndromes. *In Mackie and McCartney Practical Medical Microbiology.* 14th ed. New York: Churchill-Livingstone. pp. 77-80

Dubos, F., B. Korczowski, D.A. Aygun, *et al*. 2008. Serum procalcitonin level and other biological markers to distinguish between bacterial and aseptic meningitis in children: a European multicenter case cohort study. *Arch Pediatr. Adolesc. Med.* **162**: 1157-63.

Forgacs, P., C.A. Geyer and S.R. Freidberg 2001. Characterization of chemical meningitis after neurological surgery. *Clin. Infect Dis.* **32**(2): 179-85.

Greenlee, J.E. 2009. Approach to diagnosis of meningitis. Cerebrospinal fluid evaluation. *Infect Dis Clin. North Am.* **4**(4): 583-98.

Johansson, K.U.N.D., M. Borgströmand S.A. Silfverdal. 2015. The clinical presentation of acute bacterial meningitis varies with age, sex and duration of illness. *Acta Paediatr.* **104**(11): 1117-1124.

McGing, P. and R.O. Kelley. 2009. The biochemistry of body fluids. Ireland: The Scientific Committee of the Association of Clinical Biochemists in Ireland (ACBI).

Mace, S.E. 2008. Acute bacterial meningitis. *Emerg. Med.Clin. North Am.* **26**(2): 281-317.

Pandey, P., B. Jha and A. Shrestha. 2015. Cytological and Biochemical Profile of Cerebrospinal Fluid from Meningitis Patients. *Nepalese Association for Cl. Chem, ACCLM*. **1**(1): 2-5

Panuganti, S.K.N.S. 2017. Acute bacterial meningitis beyond the neonatal period. In: Long SSPC, Fischer M, editors. *Principles and Practice of Pediatric Infectious Diseases*. 5th ed. Elsevier. 278-287.

Shrestha, R.G., S. Tandukar, S. Ansari, *et al.* 2015.Bacterial meningitis in children under 15 years of age in Nepal. *BMC Pediatr.* 15, 94. https://doi.org/10.1186/s12887-015-0416-6]

Salih, M.A.M., O.H. Khaleefa, M Bushara, *et al.* 1991. Long term sequelae of childhood acute bacterial meningitis in a developing country. *Scand. J. Infect. Dis.* **23**: 175-82.

Venkatesh, B., P. Scott and M. Ziegenfuss. 2000. Cerebrospinal fluid in critical illness. *Crit. Care Resusc.* **2**: 42-54.

(Revised copy received on 03.11.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 149-160, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57278

VARIABILITY OF RAINFALL OVER THE COASTAL AREA IN BANGLADESH BY USING CLIMATE MODEL

SHAHANA ISLAM[1], MD. MONIRUZZAMAN[1]* AND M. A. MANNAN[2]
[1]*Department of Geography and Environment, Jagannath University, Dhaka-1100, Bangladesh*
[2]*Bangladesh Meteorological Department, Agargaon, Dhaka- 1207, Bangladesh*

Abstract

The study attempt to understand the variability of rainfall by looking into the previous and future climate of the coastal area in Bangladesh from 1850 to 2100 by using the climate model (CMCC-CM- the Centro Euro-Mediterraneo Sui Cambiamenti Climatici Climate Model) of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Rainfall data were collected from CMCC-CM by R programming for two GHGs emission scenarios (RCP 4.5 and RCP 8.5) referred to as 'Representative Concentration Pathways (RCPs)'. The analysis has been conducted based on four seasons and an annual basis by plotting model data in MS Excel and R programming. The model shows that the average annual rainfall will increase from 1055.6 mm (during 1850-1900) to 1368.1mm (during 2051-2100) for RCP 4.5 while it will reach 1569.7mm (during 2050-2100) for RCP 8.5. Rainfall is also increasing for all seasons except winter. In winter season, the average rainfall will increase from 35.37mm (during 1850-1900) to 41.75mm (during 2051-2100) for RCP 4.5, where it will decrease from 35.37mm (during 1850-1900) to 22.55mm (during 2051-2100) for RCP 8.5 in the study area. The increasing and decreasing trend are more in high GHGs emission scenarios than in the medium, which will be alarming. Accordingly, this projection will be helpful to understand the adverse impacts of climatic elements and take short and long-term planning of decision-makers in that area.

Key words: Climate model, Rainfall variability, RCP, Coastal area.

Introduction

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) allusions that the earth's temperature increased by 0.85°C from 1880 to 2012. As well, every successive decade has been warmer than the previous one for each of the recent three decades (Stocker *et al.* 2014). The long-term change in average weather conditions is climate change, whose main elements or variables are temperature and rainfall (Rahman *et al.* 2015). Continuing warming of the world is a result of climate change, by which the population can become more sufferer (Harmeling 2008). Developing countries have been experiencing intense outcomes by extreme weather

*Corresponding author: E-mail: mdmoniruzzaman_bd@yahoo.com

events which are expected from global warming. Projections by the IPCC and the World Meteorological Organization suggest increasing in the frequencies and intensities of climate extremes in the 21st century.

IPCC has recognized South Asia as the most vulnerable region globally (Yousuf 2016). As a developing country, Bangladesh is one of the major climate-vulnerable countries of the world due to its geographical arrangement and its least capacity to address the devastating impacts that are occurred by climate change (Yousuf 2016; Bhuyan *et al.* 2018). Various climate change issues in Bangladesh, such as cyclones, riverbank erosion, floods, coastal flash floods, lower level of groundwater, drought, increasing salinity, land erosion, water logging which have increased the vulnerability for Bangladesh's people and the coastal communities (Moniruzzaman 2012; Titumir and Basak 2012) that is one-third of the country's total area (Ministry of Water Resources 2005). So, many populations of the coastal zone are relatively more vulnerable than any part of the country since more than half of them are poor and landless (Bhuyan *et al.* 2018). Besides, man-made global climate change and associated sea level rise can have a major adverse penalty for coastal ecosystems.

To overcome the uncertainties as well as to apprehend the magnitude and direction of future changes, it is necessary to evaluate the spatial and temporal changes of past climate and future prediction. The previous study noticed that high temperatures, heavy rainfall, and seasonal variation are the unique characteristics that distinguish the climate of Bangladesh from that of other tropical regions (Partal and Kahya 2006). The country's yearly average maximum temperature from 1953 to 2011 increased by 0.52°C at a rate of 0.01°C per year (Yousuf 2016). It has been observed that the annual rainfall and daily mean temperature of Bangladesh have increased by an amount of 5.2 mm/year and 0.9°C/decade respectively (Shahid 2011). As well, it is well established that the rainfall is changing on both the global (Hulme *et al*. 1998; Lambert *et al*. 2003; Dore 2005) and the regional scales (Rodriguez-Puebla *et al*. 1998; Gemmer *et al*. 2004; Kayano and Sansigolo 2009) due to global warming. The rainfall-dominated climate of Bangladesh receives the heaviest rainfall in the world. Heavy rainfall in the monsoon of 2007, together with the onset of flooding by Himalayan-fed Rivers, resulted in a severe flood in Bangladesh which affected more than 9 million people in more than half of the districts of the country (Shahid 2010). Shahid (2010) also identified a significant increase of annual and pre-monsoon rainfall in Bangladesh from 1958 to 2007, and substantial changes in most extreme rainfall indices are observed in Northwest Bangladesh.

On the other side, climate models are the foremost used comprehensive tools to develop future climate change projections. The new sets of climate model output become

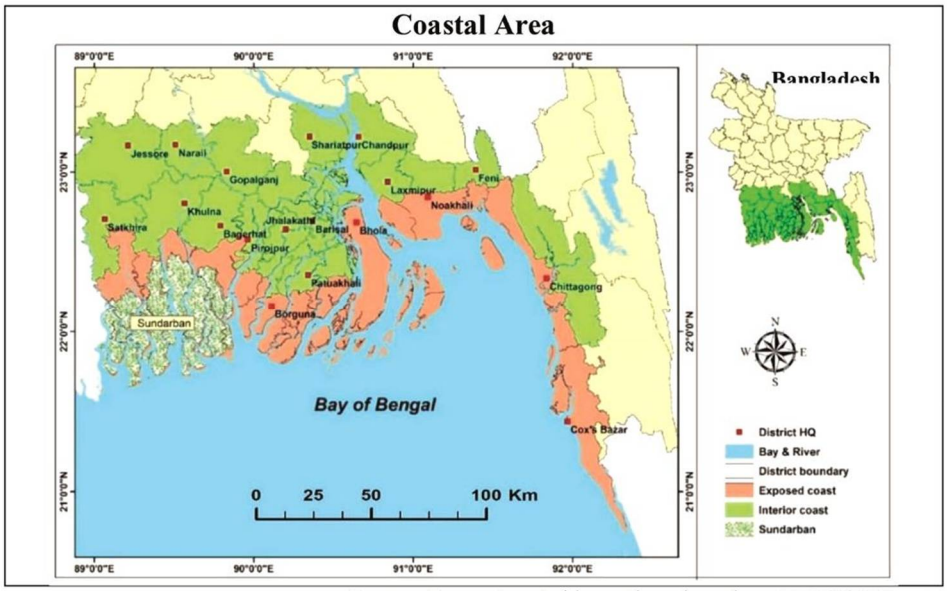
available for the IPCC fifth assessment report (AR5), which are also known as the CMIP5 (5th Phase Coupled Model Inter-comparison Project) multi-model dataset (Stocker *et al.* 2014). According to MPI-ESM-LR (CMIP5) model data, the future average temperature in north-western region will be increased at a rate of 1.62˚C during the period 2040-2100 (Bhuyan *et al.* 2018). Another model study by Haque *et al.* (1992) indicated that the average increase in temperature would be 1.3°C and 1.5°C for the projected years of 2030 and 2075, respectively. Projections are made for rainfall in Bangladesh by Regional Climate Model (RegCM) is about +35% for the monsoon season (JJAS), -67% for pre-monsoon (MAM), -12% for post-monsoon (ON), 107% for winter (DJF) for 2050 and an average rainfall may be less by more than 50% for all seasons for the year 2060. Moreover, the model simulates more rain than observation the over central and southeastern part of Bangladesh (Mannan *et al.* 2018). Similarly, mean surface air temperature in different months is projected at about (0.5-2.1)◦C and (0.9-3.5)◦C for the years 2050 and 2060, respectively (Rahman *et al.* 2012). However, there have some differences between the values of observation and model data (Islam *et al.* 2019).

But comparatively few studies have been done on future climate from model predictions in Bangladesh. These are based on atmospheric and coupled atmospheric oceanic general circulation models (GCM), and regional climate models. Therefore, the climate change studies of climatic variables using different models or tests to estimate future projections and uncertainties over the coastal regions of Bangladesh are urgently necessary. So, the study attempts to understand rainfall variability by looking into the previous and future climate from 1850 to 2100 using the climate model (CMCC-CM- The Centro Euro-Mediterraneo Sui Cambiamenti Climatici Climate Model) of the coastal areas in Bangladesh. Model data were cracked and collected by R programming. A basic statistical method was used to understand the variability of rainfall by annual and seasonal analysis over the coastal area in Bangladesh.

Materials and Methods

Study Area: According to PDO-ICZMP (Project Development Office-Integrated Coastal Zone Management Project), 2003, the coastal areas of Bangladesh (Fig. 1) are classified by 19 coastal districts (147 Upazilas), where a total of 48 Upazilas in 12 districts are exposed to the sea and or lower estuaries, are defined as the exposed coast, and the remaining 99 Upazilas of the coastal districts are termed interior coast (Uddin and Kaudstaal 2003; Parvin *et al.* 2010). This 711 km long coastline consists of a vast

network of river systems draining the vast flow of the Ganges-Brahmaputra-Meghna River system.



Source: Reconstructed by authors based on PDO-ICZMP map

Fig. 1. Location of Study Area.

Data Source and Analysis: Rainfall data of the coastal area of Bangladesh were collected from a general circulation model (CMCC-CM) of the 5th Phase Coupled Model Inter-comparison Project (CMIP5) within IPCC during the period of 1850 to 2100 where historical data have been divided into 1850 to 2005 and future data is divided into 2006 to 2100 within four different emission scenarios. CMIP5 has many different models, and every model has different surface variables data. Again, a study of Climatic Change (2011) has shown that Representative Concentration Pathways (RCPs), a set of four new emission scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) developed as an appropriate approach for investigations of future climatic conditions (Van Vuuren *et al.* 2011). As southern coastal Bangladesh is a small region, we have been trying to use RCP 4.5 (medium stabilization scenarios of greenhouse gas emission) and RCP 8.5 (very high baseline emission scenarios) based model for looking into the previous climate and for future climate. According to literature, data availability and data resolutions, the selected model (CMCC-CM) of CMIP5 was used (Table 1).

Table 1. Detail climate model was used to project climate change scenarios in the study basin.

Name of GCM		CMCC-CM (The Centro Euro-Mediterraneo sui Cambiamenti Climatici Climate Model)
Research Center		The Euro-Mediterranean Centre on Climate Change, Italy
Spatial Resolutions (°)		X axis: whole world in 480 0.75° steps Y axis: Gaussian grid with 240 0.75° steps
Forcing		Nat (natural forcing), Ant (anthropogenic forcing), GHG (well-mixed greenhouse gases), SA (anthropogenic sulfate aerosol), TO (tropospheric ozone), Sl (solar irradiance)
Emission Scenarios		RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5
Frequency		Month
Time Span	Historical	1850 - 2005
	RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5	2006 - 2100

Source: KNMI- Koninklijk Nederlands Meteorologisch Instituut 2020

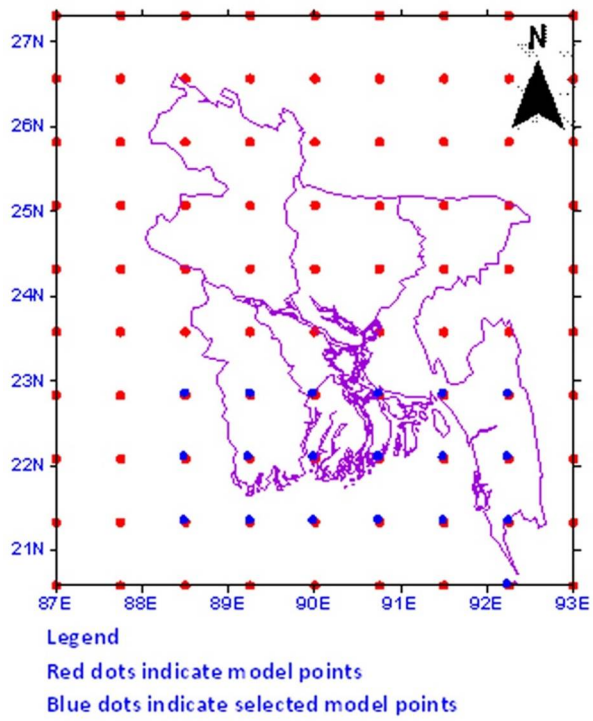


Fig. 2. Coordination maps of CMCC-CM over coastal areas in Bangladesh.

In this regard, NetCDF format data of selected variables were downloaded from the KNMI (Koninklijk Nederlands Meteorologisch Instituut) website and then cracked the NC file by using R programming. As these data are divided by grid points into the whole world, so picked the data of selected variables according to the appropriate 19 grid points (latitude-longitude) of coastal areas of Bangladesh for 1850 to 2100 (Fig. 2). Basic statistical method was used in this study and the analysis has been conducted based on four specific seasons: winter (December-February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-November); which was followed by different researchers (Islam and Uyeda 2007; Rahman *et al.* 2017; Shahid 2010) and on an annual basis for CMCC-CM model for both RCPs (4.5 and 8.5) by plotting data in MS Excel and R programming. The figures are represented by graphs, charts, and WinSurfer, and GIS software was utilized in this research to make a map.

Results and Discussion

The the study result presents the distribution of the CMCC climate model (for RCP 4.5 and RCP 8.5 scenarios) predicted the rainfall variation by annual and seasonal basis of the coastal areas Bangladesh for the period of 1850-2100.

Annual variation: The annual analysis is represented by Fig. 3a-b, which found that average, median, highest and lowest values of rainfall for both senarios decreased from 1951 to 2000, but it shows an increasing trend afterward up to 2100. Here for RCP 4.5, the average value of rainfall is 1055.62 mm, 1094.98 mm, 1084.07 mm, 1238.43 mm, and 1368.10 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100 respectively. For other scenario RCP 8.5, the average value of rainfall are 1055.62 mm, 1094.98 mm, 1084.07 mm, 1230.35 mm and 1569.71 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively.

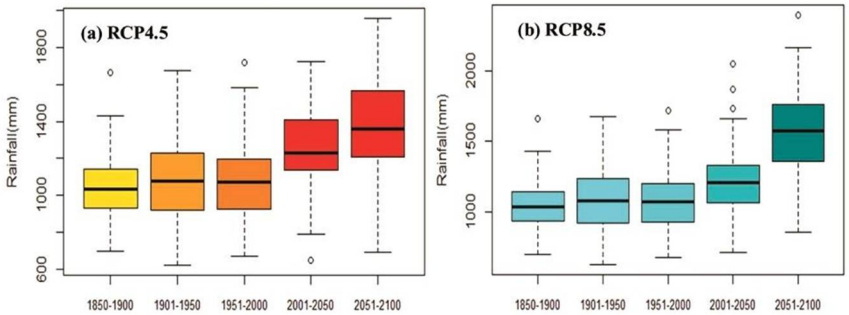


Fig. 3a-b. Variation of annual rainfall derived from CMCC-CM for RCP 4.5 and RCP 8.5 in the study area.

Seasonal variation

Summer Season: The total rainfall for the summer season (March to May) for the period of 1850-2100 for both Representative Concentration Pathways (RCPs) is depicted by Fig. 4a-b and found that the average values and lowest values of rainfall for RCP 4.5 decreased from 1951 to 2000 where these values of rainfall for RCP 8.5 decreased from1951 to 2050, but it shows an increasing trend afterward up to 2100. Similarly, the median values, lowest values and highest values of rainfall are increased in the future. The average rainfall for RCP 4.5 are 69.47 mm, 85.05 mm, 74.70 mm, 78.40 mm and 94.95 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively. For RCP 8.5, these are 69.47 mm, 85.05 mm, 74.70 mm, 70.90 mm and 80.67 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively. In addition, May was recorded as the highest rainfall month for both RCPs in the summer season (Fig. 5a-b).

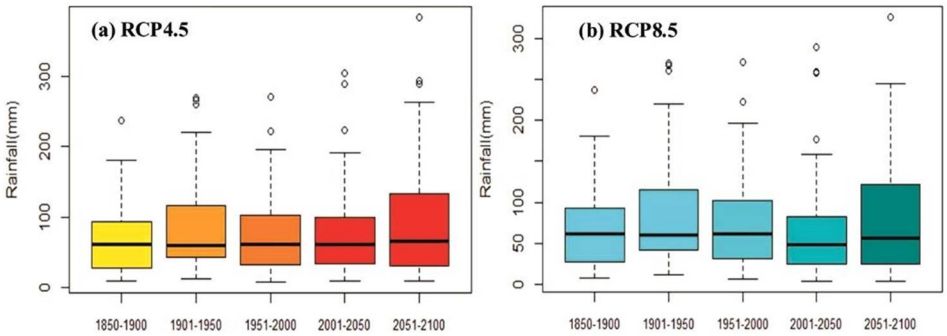


Fig.4 (a-b). Variation of rainfall in summer derived from CMCC-CM for RCP 4.5 and RCP 8.5.

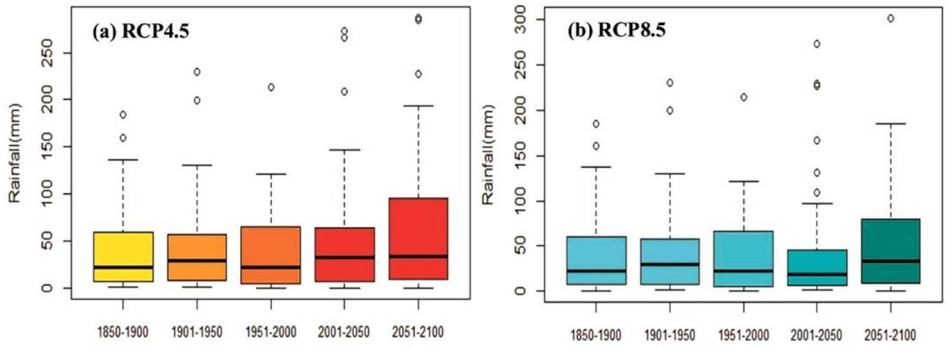


Fig.5 (a-b). Variation of rainfall in May derived from CMCC-CM for RCP 4.5 and RCP 8.5.

Monsoon Season: The rainfall for the monsoon season (June to September) for the 250 years is represented by Fig. 6a-b. It shows an increasing trend up to 2100 for the average rainfall values for both RCPs. The average rainfall for RCP 4.5 are 779.51, 786.85, 797.09, 948.63 and 1008.92 mm during the period of 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively. It is found that the median values, highest values, and the lowest values of rainfall for RCP 8.5 decreased from 1901 to1950, but it shows an increasing trend afterward up to 2100. The average rainfall for this scenario is 779.51, 786.85, 797.09, 960.33 and 1251.03 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively. July was the highest rainfall month in the monsoon season for both RCPs (Fig.7a-b).

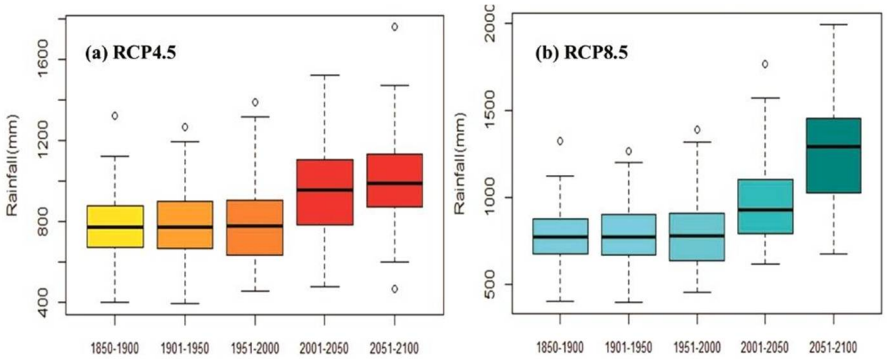


Fig. 6(a-b): Variation of rainfall in Monsoon derived from CMCC-CM for RCP 4.5 and RCP 8.5.

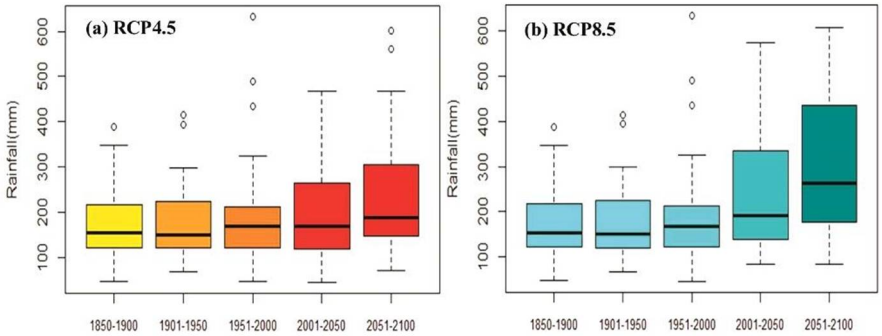


Fig. 7(a-b): Variation of CMCC-CM rainfall in July for RCP 4.5 and RCP 8.5.

Post-monsoon Season: Total rainfall for the post-monsoon season (October to November) of the coastal areas for the baseline period (1850-2100) is represented by Fig. 8a-b. It is found that the average and median values of rainfall for both RCPs decreased from 1951

to 2050, but it shows an increasing trend afterward up to 2100. Accordingly, the highest and lowest values of rainfall are found to be decreased in the future. Here, the average rainfall for RCP 4.5 are 171.81mm, 185.06 mm, 170.14 mm, 163.33 mm and 222.50 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100, respectively. Where, the average rainfall for RCP 8.5 are 171.81mm, 185.06 mm, 170.14 mm, 154.53 mm and 215.49 mm during 1850-1900, 1901-1950, 1951-2000, 2001-2050, 2051-2100 respectively.

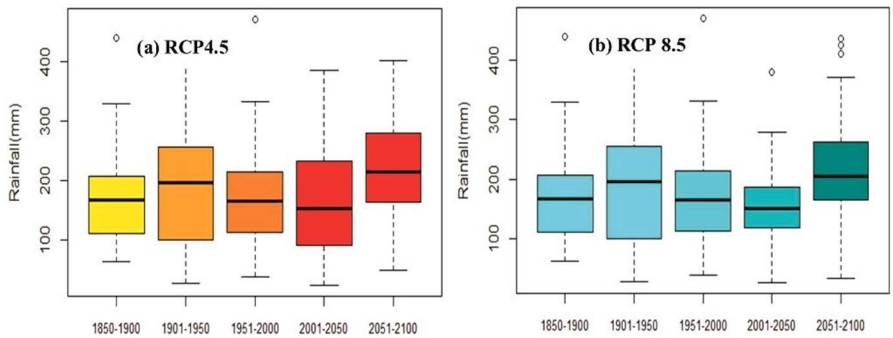


Fig. 8a-b: Variation of rainfall in post-monsoon derived from CMCC-CM for RCP 4.5 and RCP 8.5.

Winter Season: The total rainfall for thewinter season (December to January) for the period of 1850-2100 is represented by Fig. 9a-b and found that the average values of rainfall are increased from 1850 to 2050, but it shows a decreasing trend for both RCPs, afterward up to 2100. Similarly, the median values and highest values of rainfall are found to be decreased in the future for both cases. Furthermore, February was recorded as the highest rainfall month for both scenarios.

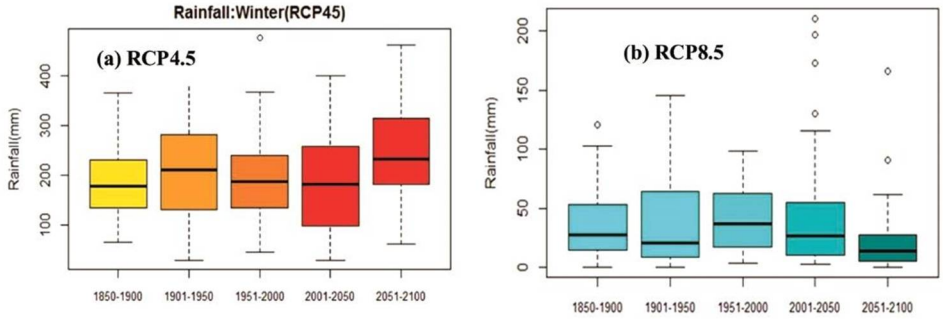


Fig. 9a-b: Variation of rainfall in winter derived from CMCC-CM for RCP 4.5 and RCP 8.5.

Conclusion

Bangladesh is considered as one of the most vulnerable countries to the impacts of climate changes (Moniruzzaman 2013). Still the coastal areas are exposed more to climate stresses and stay at a vulnerability front line. Every year Bangladesh faces an average of 1.8 tropical storms (Moniruzzaman and Rashid 2015). However, the casualties in terms of the number of death of people are conspicuously lower than previous experience (Paul *et al.* 2018). As one of the main elements of climate change is rainfall, these estimations possibly help understand the future climatic conditions and make short- and long-term planning in that area. CMCC-CM model showed an increasing trend of rainfall for both emission scenarios (RCP 4.5 and RCP 8.5) during the baseline period (1850-2100). The annual rainfall has been increased from 1055.62 mm to 1368.10 mm from 1850 to 2100 for RCP 4.5, while it has been increased from 1055.62 mm to 1569.71 mm for RCP 8.5. In the summer season, rainfall has increased from 69.47 mm to 94.95 mm for RCP 4.5, while it has increased to 80.67 mm for RCP 8.5. Similarly, in the monsoon season, the average rainfall has increased from 779.51mm to 1008.92 mm for RCP 4.5, while it has increased to 1251.03 mm for RCP 8.5. But in the winter season, the scenario is different. The average rainfall has increased from 35.37 mm to 41.75 for RCP 4.5, where it has decreased from 35.37 mm to 22.55 mm for RCP 8.5 from 1850 to 2100. It has also been seen that July and February have been recorded as the highest and lowest rainfall month for the monsoon and winter seasons respectively.

From this finding, considering new CMCC-CM (CMIP5) projections will be more helpful for decision-makers as they have a comparatively better representation of the Earth's physical processes. Generally, it shows an increasing trend of rainfall over coastal areas, which indicates more natural calamities in the future. Where the increase is more in high GHGs emission scenarios than the medium. But the rainfall also shows a decreasing trend for the only winter season in the high emission scenario (RCP 8.5), which indicates the barrier of crop productions and reducing groundwater level in the dry season. Consequently, if the GHGs emission can be minimized, the rise of temperature and disparity of rainfall could be controlled but if don't control, the agrarian economy of the coastal area will be more vulnerable.

Acknowledgement

This research was funded by the Ministry of Science and Technology, Government of Bangladesh, during the 2018-2019 fiscal year.

References

Bhuyan, M.D.I., M.M. Islam and M.E.K. Bhuiyan, 2018. A trend analysis of temperature and rainfall to predict climate change for northwestern region of Bangladesh. *Amer. J. Climate Change.* **7**(2): 115-134.

Dore, M. H. 2005. Climate change and changes in global precipitation patterns: what do we know? *Environ. Int.* **31**(8): 1167-1181.

Gemmer, M., S. Becker and T. Jiang. 2004. Observed monthly precipitation trends in China 1951–2002. *Theor. Appl. Climatol.* **77**(1-2): 39-45.

Harmeling, S. 2008. Global climate risk index 2009 weather-related loss events and their impacts on countries in 2007 and in a long-term comparison. pp. 9.

Haque, M.A., H.A. Quayyum, M.M. Hossain and M.S. Islam. 1992. Occurrence of grain sterility in different rice crops. In *International Botanical Conference on Plant Science and Man: Problems and Prospects, Dhaka (Bangladesh), 10-12 Jan 1991.* BBS.

Hulme, M., T.J. Osborn, and T.C. Johns. 1998. Precipitation sensitivity to global warming: Comparison of observations with HadCM2 simulations. *Geophysical Res. Lett.* **25** (17): 3379-3382.

Islam, M. N., and H. Uyeda. 2007. Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh. *Remote Sensing of Environ.* **108**(3): 264-276.

Islam, S., M. Moniruzzaman and M.A. Mannan. 2019. Estimation of Temperature and Rainfall over Coastal Areas of Bangladesh in a Predicted Climate Change Condition, *The J. NOAMI,* **36**(1-2): 145-156.

KNMI, 2020. Koninklijk Nederlands Meteorologisch Instituut.

Kayano, M. T., and C. Sansígolo. 2009. Inter-annual to decadal variations of precipitation and daily maximum and daily minimum temperatures in southern Brazil. *Theor. Appl. Climatol.* **97**(1-2): 81-90.

Lambert F, P. Stott and M. Allen. 2003. Detection and attribution of changes in global terrestrial precipitation. *Geophy. Res. Abst.* **5:** 06140.

Mannan, MA, F. Rahman, S. Ahmed, M.A.M. Chowdhury, S. Karmakar and M. Moniruzzaman. 2018. Study of Severe Thunderstorm and Associated Rainfall in Bangladesh during Pre-monsoon Season, *DEW-DROP, a Scientific Journal of Meteorology and Geo-Physics.* **5**(1): 62-71.

Ministry of Water Resources. 2005. *Coastal Zone Policy,* WARPO, Govt. of Bangladesh, Dhaka.

Moniruzzaman, M. 2012. Geospatial Analysis of Damage, Loss, Recovery and Reconstruction: A Case on Cyclone Sidr, Ph.D. Thesis, Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka, Bangladesh.

Moniruzzaman, M. 2013. People's Perception on Climate Change and Variability: A Study of Sabrang Union, Teknaf, Cox's Bazar, Bangladesh, *ASA Univ. Rev.* **7**(2): 1-10.

Parvin, G.A., S.R. Ahsan and R. Shaw. 2010. Community based coastal zone management in Bangladesh. *Communities and Coastal Zone Management, Research Publishing Services, Singapore,* 165-184.

Partal, T. and E. Kahya. 2006. Trend analysis in Turkish precipitation data. *Hydrol. Processes: An Int. J.* **20**(9): 2011-2026.

Moniruzzaman, M. and M.S. Rashid. 2015. Spatial Location and Management of Cyclone Shelter: A Case Study on Sarankhola Upazila. *Jahangirnagar Review Part II,* **35**:107-122.

Paul, P., N. Hawlader and M. Moniruzzaman. 2018. Impacts of Cyclone Mora in Cox's Bazar District, *Jagannath Univ. J. Life and Earth Sci.* **4**(2):124-134.

Rahman, A., M. J.H. Jiban and S. A. Munna. 2015. Regional variation of temperature and Rainfall in Bangladesh: Estimation of Trend. *Open J. Statis.* **5**: 652-657.

Rahman, M.A., S.M. Kamal and M.M. Billah. 2017. Prediction and trends of rainfall variability over Bangladesh. *Science J. Appl. Mathematics and Statistics.* **5**(1): 54-59.

Rahman, M. M., M. N. Islam, A. U. Ahmed and F. Georgi. 2012. Rainfall and temperature scenarios for Bangladesh for the middle of 21st century using RegCM. *J. Earth Syst. Sci.* **121**(2): 287-295.

Rodriguez-Puebla, C., A.H. Encinas, S. Nieto and J. Garmendia. 1998. Spatial and temporal patterns of annual precipitation variability over the Iberian Peninsula. *Int. J. Climatol*. **18**(3): 299-316.

Shahid, S. 2010. Rainfall variability and the trends of wet and dry periods in Bangladesh. *Int. J. Climatol*. **30** (15): 2299-2313.

Shahid, S. 2011. Trends in extreme rainfall events of Bangladesh. *Theor. Appl. Climatol.* **104**(3-4): 489-499.

Stocker, T.F., D. Qin, G.K. Plattner, M.M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley. 2014. Climate Change 2013: The Physical Science Basis. Contribution of working group I of the Fifth Assessment Report (AR5) of IPCC- the Intergovernmental Panel on Climate Change.

Titumir, R.A.M., and J.K. Basak. 2012. Effects of climate change on crop production and climate adaptive techniques for agriculture in Bangladesh. *Social Sci. Rev.* **29**(1): 215-232.

Uddin, A.M.K. and R. Kaudstaal. 2003. *Delineation of the Coastal Zone.* Program development office for the integrated coastal zone management plan *(PDO*-ICZMP, Working Paper-WP005), Ministry of Water Resources, GoB.

Van Vuuren, D. P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard and T. Masui. 2011. The representative concentration pathways: an overview. *Climatic Change,* **109**:5-31.

Yousuf, A.H.M. 2016. Characteristics of Temperature and Rainfall in Bangladesh: A Historical Perspective 1948-2011. *https://ssrn.com/abstract=3474166*

(Revised copy received on 14.11.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 161-171, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57279

PRODUCTION OF MICROALGAL BIOMASS AT DIFFERENT GROWTH PHASES TO USE AS BIOFUEL FEEDSTOCK

N.J. TARIN[1], N.M. ALI[2], A.S. CHAMON[3], M.N. MONDOL[3], M.M. RAHMAN[3] AND A. AZIZ[4]

[1]*Institute of Water and Flood Management, BUET, Dhaka-1000, Bangladesh.*
[2]*Bangladesh Tea Research Institute, Srimangal-3210, Moulvibazar, Bangladesh.*
[3]*Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh.*
[4]*Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh*

Abstract

The growth of microalgae under optimized conditions was determined for assessing their growth rate and biomass production. In this study, the growth of both green algae (*Chlamydomonas noctigama* and *Chlorella vulgaris*) and cyanobacteria (*Anabaena variabilis* and *Nostoc spongiaeforme*) was measured as optical density. *Chlamydomonas noctigama* and *Chlorella vulgaris* showed the doubling time of 9.5 and 8.0 hours, respectively, whereas *Anabaena variabilis* and *Nostoc spongiaeforme* showed the doubling time of 14.8 and 16.6 hours, respectively. All the species exhibited the highest growth in terms of biomass at the phase in between stationary and death phases.

Keywords: Green algae, Cyanobacteria, Biofuel feedstock, Growth phase

Introduction

Concerns about the shortage of fossil fuels, increasing crude oil price, energy security, environment deterioration, and accelerated global warming have led to growing worldwide interests in renewable energy sources such as biofuels (Griffiths and Harrison 2009, Hanjalic *et al.* 2008). Bioethanol is a non-conventional fuel produced by the process of saccharification and fermentation from the bio-renewable sources, including sugars, starches, and ligno-cellulosic materials from solid wastes and plant biomass, including algal biomass, whereas biodiesel (monoalkyl esters) is one of such alternative fuel, obtained by the transesterification of triglyceride oil with monohydric alcohols (Pothiraj *et al*. 2015, Jasim and Maysam 2014, Blinova *et al*. 2015, Dvoretsky *et al*. 2015, Al-lwayzy *et al*. 2014, Christi 2007). Algal biomass, considered one of the most promising third generation biofuel feedstocks, was reported earlier by many investigators (Kumar *et al.* 2013, Agwa *et al.* 2012, Nigam and Singh 2011, Li *et al.* 2008).

*Corresponding author: E-mail: <chamonafrose@du.ac.bd>

Microalgae, having massive, diversified characteristics, are emerging to be one of the most promising long-term, sustainable sources of biomass and fuel, food, feed, and other co-products (Strop 2014, Agwa *et al*. 2012, Milledge 2011). However, the potential for these natural resources as biofuel feedstock and other probable uses are assessed to some extent in relation to the techno-economic aspect (Quinn and Davis 2015). A few thousand algal species are reported to occur in Bangladesh's fresh water and marine environment in (Ahmed *et al*. 2008). Jones and Mayfield (2012) and Spolaore *et al*. (2006) reported a minimal commercial-scale cellulosic ethanol production because of the higher cost of production (almost twice than that ethanol production from corn). In view of the aforementioned issues, microalgae are gaining wide attention as an alternative renewable source of biomass for the production of bioethanol and biodiesel, which is grouped under 'third-generation biofuel' (Safi *et al*. 2014, Nigam and Singh 2011).

Algae can efficiently use CO_2 and are responsible for more than 40% of the global carbon fixation, with the majority of this productivity coming from marine microalgae. They are easy to grow and cultivate anywhere with fewer energy requirements and use very few nutrients following the appropriate culture designs and systems (Nwankwo and Agwa 2019, Sharma *et al*. 2011, Ugwu and Aoyagi 2012). Algal strains can produce biomass very rapidly, with some species doubling in as few as 6 hours and many exhibiting two doublings per day (Hannon *et al.* 2010). However, the ideal growth conditions for microalgal cultures are strain-specific and requires specific natural and supplement conditions where microalgae respond with physiological alterations to the environmental growth conditions, e.g., pH, light, temperature, aeration, nutrients, and accessible supplements (Nwankwo and Agwa 2019, Schenk *et al.* 2008). Higher productivity is usually considered an attribute to focus on the biochemical composition and growth characteristics of algal strains. High level of demand for clean, safe, and low-cost biomass production from selected strains requires to analysis on algal physiological response, i.e., growth under their optimum growth conditions with the possible potentials and challenges (Quinn and Davis 2015, Kim *et al*. 2014, Chia *et al*. 2013, González-Fernández *et al*. 2012, Pienkos and Darzins 2009).

Materials and Methods

Growth curves for *Chlamydomonas noctigama*, *Chlorella vulgaris*, *Anabaena variabilis* and *Nostoc spongiaeforme* were made using growth as µg chlorophyll per mL (chl *a* and chl *b* for green algae, and chl *a* for cyanobacteria) at respective optimum conditions to define the different phases of growth as described by Vonshak and Maske (1982).

Various optimum conditions considered as baseline for growth at different phases are given in Table 1 (Ali *et al.* 2016, Tarin *et al.* 2016).

Table 1. Optimum growth conditions for green algae and cyanobacteria.

Microalgae		Optimum growth conditions					
		pH	Light intensity ($\mu E\ m^{-2}\ s^{-1}$)	Temp. (^{o} C)	Aeration (hrs)	Nutrient element conc.	Vitamin supplement
Green algae	*Chlamydomonas noctigama*	6.5	110	25	72	2.0 × Chu 10D	B1+B6
	Chlorella vulgaris	6.5	110	25	72	1.5 × Chu 10D	B6
Cyano-bacteria	*Anabaena variabilis*	7.0	90	25	72	1.0 × Chu 10D	Not required
	Nostoc spongiaeforme	7.5	70	25	72	1.0 × Chu 10D	Not required

Growth rate and doubling time determination: Growth rate has been expressed in terms of the relative growth constant or specific growth constant (μ) (Fogg 1975):

$$\mu = \log_{10} N_t - \log_{10} N_0 / t$$

where, t = Time in the hour

N_t = Biomass after t hour

N_0 = Biomass at "0" time

The maximum growth rate is defined as the maximum growth rate under light saturation at a specified temperature. The mean generation time or doubling time (g) has been calculated from a specific growth constant, μ:

Doubling time, $g = 0.0301 / \mu$ (Fogg 1975)

Estimating O.D. (Optical Density): Growth was also estimated by measuring the optical density at 750 nm using a Shimadzu digital spectrophotometer (model UV-120-01) as described by Rodolfi *et al.* (2009).

Production of green algae and cyanobacteria biomass at the 3 phases of growth under optimum conditions: All the respective optimum conditions (i.e., pH, light intensity, temperature, aeration, nutrient element concentration in medium and vitamin supplement) were provided to produce both green algae (*Chlamydomonas noctigama* and *Chlorella vulgaris*) and cyanobacteria (*Anabaena variabilis* and *Nostoc spongiaeforme*) biomass at

their 3 phases of growth (i.e., logarithmic phase, stationary phase, and in between of stationary and death phases) where unialgal cultures were used.

Harvesting and processing of microalgal biomass: The microalgae were harvested by centrifugation at 5000 rpm for 10 minutes using a Kokusan refrigerated centrifuge (model H-103N).

The wet algal biomass (harvested on petri dish) was dried in an oven at 60°C for at least 24 hours. Then the dried biomass was scrapped and stored in a plastic jar.

Result and Discussion

Estimation of growth: From the respective growth curves (Fig. 1) of microalgae used in the experiment, acceleration phase, logarithmic phase, deceleration phase, stationary phase and death phase was observed and the duration of different phases are presented in the following Table 2.

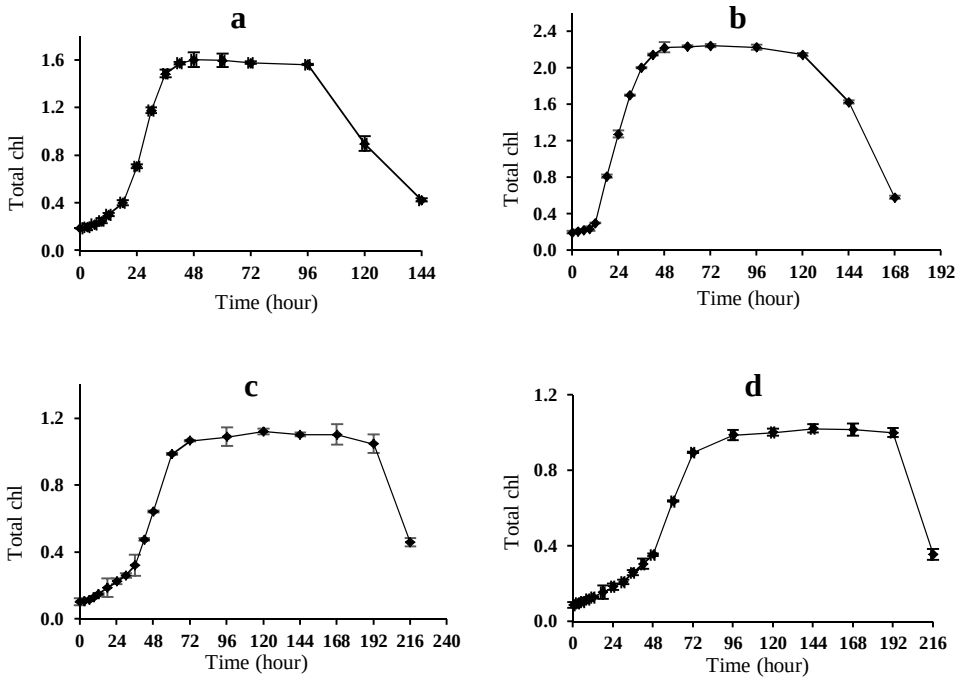


Fig. 1. Growth curve of *Chlamydomonas noctigama* (a), *Chlorella vulgaris* (b), *Anabaena variabilis* (c) and *Nostoc spongiaeforme* (d).

There was no lag phase or initial phase in the growth curve, which may be for the reason that fresh algal strain was taken for the experiment. Cyanobacteria took more time to show the respective phase than green alga (Table 2).

Table 2. Growth phases of microalgae.

Microalgae	Growth phase with Duration (hrs)				
	Acceleration phase	Logarithmic phase	Deceleration phase	Stationary phase	Death phase
Chlamydomonas noctigama	0-18	18-36	36-42	42-96	96-
Chlorella vulgaris	0-12	12-36	36-48	48-120	120-
Anabaena variabilis	0-36	36-60	60-72	72-192	192-
Nostoc spongiaeforme	0-48	48-72	72-96	96-192	192-

Before the log-growth phase, all the microalga started to be divided towards growth by 18, 12, 36, and 48 hrs, respectively. Moreover, both the green alga had the logarithmic growth within 36 hrs, whereas *A. variabilis* increased by 60 hrs and *N. spongiaeforme* showed growth exponentially by 72 hrs. Following the maximum growth phase, *Chlamydomonas noctigama* appeared at the deceleration phase within 42 hrs and *Chlorella vulgaris* showed that within 48 hrs where the cyanobacteria (*A. variabilis* and *N. spongiaeforme*) took the slowing down phase in 72 and 96 hrs, correspondingly. The periods in between stationary and death phase were found as 42-96, 48-120, 72-192 and 96-192 hrs for *Chlamydomonas noctigama*, *Chlorella vulgaris*, *A. variabilis* and *N. spongiaeforme*, separately after which the isolates started to be dead.

Growth rate and doubling time determination: The growth rate and doubling time of *Chlamydomonas noctigama*, *Chlorella vulgaris*, *Anabaena variabilis* and *Nostoc spongiaeforme* are given below in Table 3.

Table 3. Growth rate and doubling time of *Chlamydomonas noctigama, Chlorella vulgaris, Anabaena variabilis* and *Nostoc spongiaeforme*.

Microalgae	Growth rate (μ), (hr^{-1})	Doubling Time (g), (hrs)
Chlamydomonas noctigama	0.0316	9.5
Chlorella vulgaris	0.0037	8.0
Anabaena variabilis	0.0020	14.8
Nostoc spongiaeforme	0.0181	16.6

The doubling time (g) of *Chlamydomonas noctigama* was 9.5 hrs which was similar to the finding of Hemaiswarya *et al*. (2013). Again, *Chlorella vulgaris* exhibited a doubling time of 8 hrs. In contrast, Maxwell *et al*. (1994) showed that during the exponential phase of growth *Chlorella vulgaris* had a doubling time of 8.6 hrs at a temperature of 27°C. The reason behind the less time for doubling shown by *Chlorella vulgaris* may be the trend of fast-growing with the optimum environmental conditions. *Anabaena variabilis* exhibited a doubling time of 14.8 hrs while different strains of *Anabaena* showed a doubling time of 18-24 hrs observed by Prasanna *et al*. (2006). Meeks *et al*. (1983) observed that the doubling time of *Anabaena* 7120 and *A. cylindrical* in nitrogen free BG11 medium was 21.5 and 18.2 hrs, respectively. Besides, *Nostoc spongiaeforme* had a doubling time of 16.6 hrs which was less than that reported by Rodriguez *et al*. (1986) for *Nostoc* sp.

Production of Chlamydomonas noctigama, Chlorella vulgaris, Anabaena variabilis, and Nostoc spongiaeforme biomass at the 3 phases of growth under optimum conditions: The biomass of microalgae (*Chlamydomonas noctigama*, *Chlorella vulgaris*, *Anabaena variabilis* and *Nostoc spongiaeforme*) (as mg/L) at 3 different phases of their growth under respective optimum conditions were presented in Fig. 2. The test of significance of different treatment means was computed by Duncan's New Multiple Range Test (DMRT) at a 5% level. The result was statistically significant at the 5% level.

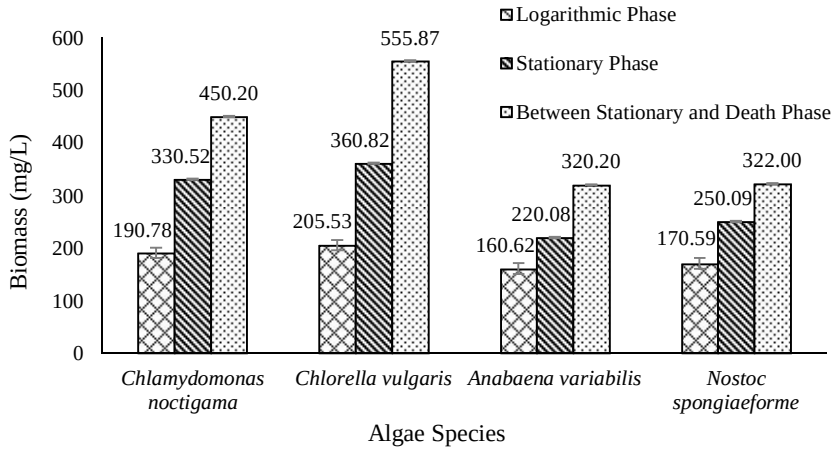


Fig. 2. Microalgal biomass (as mg/L) at 3 different growth phases under respective optimum conditions.

The result showed significant differences in the amount of biomass (as mg/L) obtained from the algal species (*Chlamydomonas noctigama, Chlorella vulgaris, Anabaena*

variabilis and *Nostoc spongiaeforme*) at 3 different phases of growth under the respective optimum conditions.

About *Chlamydomonas noctigama*, the highest biomass (450.20 mg/L) at the phase between stationary and death phase and the lowest biomass (190.78 mg/L) at the logarithmic phase under the optimum conditions were found statistically different and also from the biomass at the stationary phase (330.52 mg/L) under the optimum conditions.

In the case of *Chlorella vulgaris*, the highest biomass (555.87 mg/L) at the phase between stationary and death phase and the lowest biomass (205.53 mg/L) at the logarithmic phase under the optimum conditions were found statistically different from each other and also from the biomass obtained at the stationary phase (360.82 mg/L) under the optimum conditions.

Regarding *Anabaena variabilis*, the highest biomass (320.20 mg/L) at the phase between stationary and death phase and the lowest biomass (160.62 mg/L) at the logarithmic phase under the optimum conditions were found statistically different from each other and also from the biomass obtained at the stationary phase (220.08 mg/L) under the optimum conditions.

In the case of *Nostoc spongiaeforme*, the highest biomass (322.00 mg/L) at the phase between stationary and death phase and the lowest biomass (170.59 mg/L) at the logarithmic phase under the optimum conditions were found statistically different and also from the biomass at the stationary phase (250.09 mg/L) under the optimum conditions.

Both the green alga (*Chlamydomonas noctigama* and *Chlorella vulgaris*) and cyanobacteria (*Anabaena variabilis* and *Nostoc spongiaeforme*) showed the highest growth in terms of biomass at the phase between stationary and death phase. This phase of growth may provide the final concentration of biomass. It might be because the biomass parameter remains constant during this phase, according to Vonshak and Maske (1982). The depletion of some essential nutrients in the medium becomes limited inhibiting the growth and results into the death, in this regard.

Among all the microalgae (both green algae and cyanobacteria) in this experiment, green alga *Chlorella vulgaris* had the highest growth in terms of biomass (555.87 mg/L) at the phase between stationary and death phase under the optimum growth conditions considered. This result showed the similarity to the study by Yatirajula *et al.* (2019), where the growth phase was observed after the stationary phase though the duration was

varied due to the respective optimum conditions. It can be recommended to use biofuel feedstock for the biofuel, e.g. bioethanol and biodiesel, instead of conventional energy source (fossil fuel, coal, petroleum, natural gas, etc.) that are usually known as non-renewable sources of energy. The acceptability of the green alga, *Chlorella vulgaris*, as a potential biofuel feedstock is found worldwide, as mentioned by Ru *et al*. (2020), Varaprasad *et al*. (2020), Purkan *et al.* (2019), Ramírez-López *et al.* (2019), Sakarika and Kornaros (2019), Papapolymerou *et al*. (2018), Suthar and Verma (2018), Daliry *et al*., (2017), Lam *et al*. (2017), Rajanren and Ismail (2016), Villagracia *et al.* (2016), El-Sayed *et al*. (2015), Safi *et al*. (2014), Jasim and Maysam (2014), Mallick *et al*. (2011), Phukan *et al.* (2011), though the amount of biomass produced can vary due to the production scale, operational design, and optimum growth conditions taken under consideration.

Conclusion

All the randomly isolated and selected freshwater microalgae produced variable amounts of biomass with variable growth rates at different phases of their life cycles. The algal strains can be used as a source of biomass for biofuel and other valuable products if growing at the phase between stationary and death phase under the set of optimum conditions. Further research for analysis and large-scale biomass production by considering the highest amount with the growth phase is required.

Acknowledgments

The authors gratefully acknowledge the financial support from the Centre for Advanced Studies and Research in Biological Sciences, University of Dhaka for carrying out the research and the Department of Botany, University of Dhaka for providing laboratory facilities, particularly for giving access in the growth room.

References

Agwa, O.K., S.N. Ibe and G.O. Abu. 2012. Biomass and lipid production of freshwater algae *Chlorella* sp. using locally formulated media. *Int. Res. J. Microbiol.* **3**: 285-288.

Ahmed, Z.U., Z.N.T. Begum, M.A. Hassan, M. Khondker, S.M.H. Kabir, M. Ahmed, A.T.A. Ahmed, A.K.A. Rahman and E.U. Haque (eds.). 2008. Encyclopedia of Flora and Fauna of Bangladesh. Vol.3. *Algae, Chlorophyta. Asiat. Soc. Bangladesh*, Dhaka. pp. 591-592.

Ali, N.M., N.J. Tarin, M.N. Mondol, A.S. Chamon, A. Aziz and M.M. Rahman. 2016. Optimization of growth of two microalgal isolates for biofuel feedstock. *Bangladesh J. Sci. Ind. Res.* **51**(3): 183-192.

Al-lwayzy, S.H., T. Yusaf and R.A. Al-Juboori. 2014. Biofuels from the fresh water microalgae *Chlorella vulgaris* (FWM-CV) for diesel engines. *Energies.* **7**(3): 1829-1851.

Blinova, A., A. Bartosova and K. Gerulova. 2015. Cultivation of microalgea (*Chlorella vulgaris*) for biodiesel production. Research papers, Faculty of Materials Science and Technology in Irnava Slovak University of Technology in Bratislava. **23**(36): 87-95.

Chia, M.A., A.T. Lombardi and M.G.G. Melão. 2013. Growth and biochemical composition of *Chlorella vulgaris* in different growth media. *An. Acad. Bras. Ciênc.* (Annals of the Brazilian Academy of Sciences). **85**(4): 1427-1438.

Christi, Y. 2007. Biodiesel from microalgae. *Biotechnol. Advan.* **25**: 294-306.

Daliry, S., A. Hallajisani, J. Mohammadi Roshandeh, H. Nouri and A. Golzary. 2017. Investigation of optimal condition for Chlorella vulgaris microalgae growth. *Global J. Environ. Sci. Manage.* **3**(2): 217-230.

Dvoretsky, D., S. Dvoretsky, E. Peshkova and M. Temnov. 2015. Optimization of the process of cultivation of microalgae *Chlorella vulgaris* biomass with high lipid content for biofuel production. *Chem. Eng. Trans.* **43**: 361-366

El-Sayed, A.B., M.G. Mahamoud and S.R. Hamed. 2015. Complementary production of biofuels by the green alga *Chlorella vulgaris. Int. J. Renew, Energ. Res.* **5**(3, 2): 943-963.

Fogg, G.E. 1975. Algal Cultures and Phytoplankton Ecology. 2nd Ed., University of Wisconsin Press, Madison. pp. 175.

González-Fernández, C., B. Sialve, N. Bernet and J.P. Steyer. 2012. Impact of microalgae characteristics on their conversion to biofuel. Part II: Focus on biomethane production. *Biofuels Bioprod. Biorefin.* **6**(2): 205-218.

Griffiths, M.J. and S.T.L. Harrison. 2009. Lipid productivity as a key characteristic for choosing algal species for biodiesel production. *J. Appl. Phycol.* **21**: 493-507.

Hemaiswarya, S., R. Raja, R. Ravikumar, A.Y. Kumar and I.S. Carvalho. 2013. Microalgal Omics and Their Applications. *In:* Barh, D., V. Zambare and V. Azevedo (eds.). OMICS: Applications in Biomedical, Agricultural and Environmental Sciences. CRC Press. pp. 439-450.

Hanjalic, K., Van de Krol and R. Lekic. 2008. Sustainable Energy Technologies: Options and Prospects. Springer, New York. pp. 227-249.

Hannon, M., J. Gimpell, M. Tran, B. Rasala1 and S. Mayfield. 2010. Biofuels from algae: challenges and potential. *Biofuels* **1**(5): 763-784.

Jasim, M.S. and A.M. Maysam. 2014. Bioethanol production from green algae *Chlorella vulgaris* under different concentration of nitrogen. *Asian J. Natur. Appl. Sci.* **3**: 27-36.

Jones, C.S. and S.P. Mayfield. 2012. Algae Biofuels: Versatility for the Future of Bioenergy. *Curr. Opin. Biotechnol.* **23**(3): 346-351.

Kim, D.G., C. Lee, S.M. Park and Y.E. Choi. 2014. Manipulation of light wavelength at appropriate growth stage to enhance biomass productivity and fatty acid methyl ester yield using *Chlorella vulgaris. Bioresour. Technol.* **159**: 240-248.

Kumar, S., R. Gupta, G. Kumar, D. Sahoo and R.C. Kuhad. 2013. Bioethanol Production from *Gracilaria verrucose*, A Red Alga in A Biorefinary Aproach. *Bioresour. Technol.* **135**: 150-156.

Lam, M.K., M.L. Yusoff, Y. Uemura, J.W. Lim, C.G. Khoo, K.T. Lee and H.C. Ong. 2017. Cultivation of *Chlorella vulgaris* using nutrients source from domestic wastewater for biodiesel production: Growth condition and kinetic studies. *Renew. Energy* **103**: 197-207.

Li, Y., M. Horsman, N. Wu, C.Q. Lan and N. Dubois-Calero. 2008. Biofuels from microalgae. *Biotechnol. Progr.* **24**: 815-820.

Mallick, N., S. Mandal, A.K. Singh, M. Bishai and A. Dash. 2011. Green microalga *Chlorella vulgaris* as a potential feedstock for biodiesel. *J. Chem. Technol. Biotechnol.* **87**(1): 137-145.

Maxwell, D.P., S. Falk, C.G. Trick and N.P.A. Huner. 1994. Growth at Low Temperature Mimics High-Light Acclimation in *Chlorella vulgaris. Plant Physiol.* **105**: 535-543.

Meeks, J.C., K.L. Wycoff, J.S. Chapman and C.S. Enderlin. 1983. Regulation of Expression of Nitrate and Dinitrogen Assimilation by *Anabaena* species. *Appl. Environ. Microbiol.* **54**: 1351-1359.

Milledge, J.J. 2011. Commercial application of microalgae other than as biofuels: a brief review. *Rev. Environ. Sci. Biotechnol.* **10**: 31-41.

Nigam, P.S. and A. Singh. 2011. Production of Liquid Biofuels from Renewable Resources. *Prog. Ener. Combust. Sci.* **37**(1): 52-68.

Nwankwo, U.N. and O.K. Agwa. 2019. Growth Response of *Chlorella vulgaris* to Cultivation on Different Cassava Waste Mixtures. *Electronic J. Biol.* **15**(3): 68-78.

Papapolymerou, G., V. Karayannis and N. Gougoulias. 2018. Growing *Chlorella vulgaris* into bioreactors set in solar greenhouse, towards biofuel: Nutrient composition. *J. Appl. Biotechnol. Bioeng.* **5**(2): 106-110.

Phukan, M.M., R.S. Chutia, B.K. Konwar and R. Kataki. 2011. Microalgae *Chlorella* as a potential bio-energy feedstock. *Appl. Energy* **88**: 3307-3312.

Pienkos, P.T. and A. Darzins. 2009. The promise and challenges of microalgal-derived biofuels. *Biofuels Bioprod. Biorefin.* **3**: 431-440.

Pothiraj, C., A. Arun and M. Eyini. 2015. Simultaneous saccharification and fermentation of cassava waste for ethanol production. *Biofuel. Res. J.* **2**: 196-202.

Prasanna, R., R. Kumar, A. Sood, B.M. Prasanna and P.K. Singh. 2006. Morphological, Physiological and Molecular Characterization of *Anabaena* Strains. *Microbiologic. Res.* **161**: 187-202.

Purkan, P., E. Nidianti, A. Abdulloh, A. Safa, W. Retnowati, W. Soemarjati, H. Nurlaila and S.W. Kim. 2019. Biodiesel Production by Lipids from Indonesian strain of Microalgae *Chlorella vulgaris. Open Chem.* **17**: 919-926.

Quinn, J.C. and R. Davis. 2015. The potentials and challenges of algae based biofuels: a review of the techno-economic, life cycle, and resource assessment modeling. *Bioresour. Technol.* **184**: 444-452.

Rajanren, J.R. and H.M. Ismail. 2016. Investigation of *Chlorella vulgaris* microalgae as a source for renewable fuel. *Biofuels*. **8**(1): 37–47.

Ramirez-Lopez, C., H.V. Perales-Vela and L. Fernandez-Linares. 2019. Biomass and lipid production from *Chlorella vulgaris* UTEX 26 cultivated in 2 m^3 raceway ponds under semicontinuous mode during the spring season. *Bioresour. Technol*. **274**: 252-260.

Rodolfi, L., G.C. Zittelli, N. Bassi, G. Padovani, N. Biondi, G. Bonini and M.R. Tredici. 2009. Microalgae for Oil: Strain Selection, Induction of Lipid Synthesis and Outdoor Mass Cultivation in a Low-Cost Photobioreactor. **102**(1): 100-112.

Rodriguez, H., J. Rivas, M.G. Guerrero and G. Losada. 1986. Selection of nitrogen-fixing blue-green algae for biomass photoproduction. *In:* Proceedings of the 1986 International Congress on Renewable Energy. Vol.1. Consejo Superior De Investigaciones Cientificas, Madrid, Spain. pp. 183-186.

Ru, I.T.K., Y.Y. Sung, M. Jusoh, M.E.A. Wahid and T. Nagappan. 2020. *Chlorella vulgaris*: a perspective on its potential for combining high biomass with high value bioproducts. *Appl. Phycol.* **1**(1): 2-11.

Safi, C., B. Zebib, O. Merah, P. Pontalier and C. Vaca-Garcia. 2014. Morphology, composition, production, processing and applications of *Chlorella vulgaris*: A review. *Renew. Sustain. Ener. Rev. Elsevier.* **35**: 265-278.

Sakarika, M. and M. Kornaros. 2019. *Chlorella vulgaris* as a green biofuel factory: comparison between biodiesel, biogas and combustible biomass production. *Bioresour. Technol.* **273**: 237-243.

Schenk, P., S. Thomas-Hall, E. Stephens, U. Marx, J. Mussgnug, C. Posten, O. Kruse and B. Hankamer. 2008. Second Generation Biofuels: High-Effiency Microalgae for Biodiesel Production. *Bioenergy Res.* **1**: 20-43.

Sharma, R., G.P. Singh and V.K. Sharma. 2011. Comparison of different media formulations on growth, morphology and chlorophyll content of green algae *Chlorella vulgaris*. *Int. J. Pharm. Biologic. Sci.* **2**(2): 509-516.

Spolaore, P., C. Joannis-Cassan, E. Duran and A. Isambert. 2006. Commercial applications of microalgae. *J. Biosci. Bioeng.* **101**(2): 87-96.

Strop, P. 2014. Versatility of microbial transglutaminase. Rinat-Pfizer Inc., 230 East Grand Avenue, South Francisco, California 94080, United States. *Bioconjugate Chem.* **25**(5): 855-862.

Suthar, S. and R. Verma. 2018. Production of *Chlorella vulgaris* under varying nutrient and abiotic conditions: a potential microalga for bioenergy feedstock. *Process. Saf. Environ. Prot.* **113**: 141-148.

Tarin, N.J., N.M. Ali, A.S. Chamon, M.N. Mondol, M.M. Rahman and A. Aziz. 2016. Optimizing *Chlorella vulgaris* and *Anabaena variabilis* Growth Conditions for Use as Biofuel Feedstock. *J. Asiat. Soc. Bangladesh, Sci.* **42**(2): 191-200.

Ugwu, C.U. and H. Aoyagi. 2012. Microalgal culture systems: an insight into their designs, operation and applications. *Biotech.* **11**(3): 127-132.

Varaprasad D., N. Ragasudha, K. Paramesh, P. Chandramati Shankar, S. Nazaneen Parveen and T. Chandrasekhar. 2020. Production of Bioethanol from Green Alga *Chlorella Vulgaris*: An Important Approach to Utilize Algal Feedstock or Waste. *In*: Ghosh S., R. Sen, H. Chanakya and A. Pariatamby (eds.). Bioresource Utilization and Bioprocess. Springer, Singapore. pp. 57-65.

Villagracia, A.R.C., A.P. Mayol, A.T. Ubando, J.B.M.M. Biona, N.B. Arboleda, M.Y. David, R.B. Tumlos, H. Lee, O.H. Lin and R.A. Espiritu. 2016. Microwave drying characteristics of microalgae (*Chlorella vulgaris*) for biofuel production. *Clean. Technol. Environ. Policy.* **18**: 2441-2451.

Vonshak, A. and H. Maske. 1982. Algae: Growth Techniques and Biomass Production. *In*: Coombs, J. and D.O. Hall (eds.). Techniques in Bioproductivity and Photosynthesis. Pergamon Press, Oxford, New York. pp. 66-77.

Yatirajula, S.K., A. Shrivastava, V.K. Saxena and J. Kodavaty. 2019. Flow behavior analysis of *Chlorella vulgaris* microalgal biomass. *Heliyon. Elsevier.* **5**: 1-7.

(Revised copy received on 15.11.2021)

J. Asiat. Soc. Bangladesh, Sci. **47**(2): 173-190, December 2021 DOI: https://doi.org/10.3329/jasbs.v47i2.57280

FACTORS LEADING TO SECONDARY SCHOOL DROPOUT IN BANGLADESH: THE CHALLENGES TO MEET THE SDG'S TARGETS

MD. ATAUR RAHMAN*
Secondary Education Sector Investment Program (SESIP), Directorate of Secondary and Higher Education, Ministry of Education, Dhaka, Bangladesh.

Abstract

Bangladesh is regarded as a success story for rapid economic development and changes in social indicators that have taken place in the last couple of decades. Enrolment in education, especially women's education, has reached a desirable level. However, the dropout rate in secondary education is still a concern, which has not been reduced to the desired level. This research aims to understand better the undisclosed causes of dropout at secondary level schools. The primary data were collected from 790 former secondary school level students and 1580 parents/guardians, enabling in-depth and systematic analysis of the issue.. The method used in this study is quantitative with logit analysis. The study results showed that students' perceptions on education, working experience, low socio-demographic status (SDS), family size, total number of siblings, food deficit, distance of the school, bullied by peers/teachers have a significant effect on increasing the probability of dropping out of school. Contrariwise, parents' academic support, NGO membership of family members, mobility to the local power structure, and government's social safety net programmes support are significant variables to reduce the probability of dropping out. The research reveals that financial problems are severely engaged to increase the dropout rate, and non-financial factors together aggressively play a catastrophic role and lead the academic life of the dropout student towards the end. The study suggests authorities for rapid response to reduce dropout, which leads Bangladesh to achieve SDGs targets and eventually become an upper middle-income country by 2041.

Keywords: Dropout, SDGs, SDS, Human capital, Social capital

Introduction

Bangladesh has emerged as the fastest-growing economy globally, with an average pace of 7% GDP per year during the last decade. According to Zafar *et al*. (2020), Bangladesh shifted out from the World Bank-defined list of low-income countries (LIC) to Lower Middle-Income Country (LMIC) in 2015, much earlier than the targeted date of 2021. In 2018, it met all the UN criteria to graduate from Least Developed Countries (LDCs) to a

*Corresponding author: E-mail: <ataurdshe@gmail.com>

developing country. However, the latest estimated poverty rate reported by the Ministry of Finance (MoF) (2020) stood at 20.5 percent in 2019. Still, about one-fifth portion of the country's total population lives below the poverty line. Poverty has a cruel impact on education, especially on school dropouts. In Bangladesh, 10.3 million students attend secondary education in over 20,000 institutions and 246,845 teachers work at schools (BANBEIS 2020). Among 10.5 million enrollment, 5.6 million (54.41%) were girl students indicating that gender parity has got a momentum. At the beginning of the millennium, the secondary enrolment rate for girls was less than 40%. Although there is some progress, compared to growing countries, the completion rate is still low, and the dropout rate is high, which are the major challenges for quality secondary education. According to a government survey reports (BANBEIS 2011), the principal reason behind the high dropout rate is financial, which comes from poverty due to low-income financial problems. However, the reports and their findings have some deficiencies. The information is based on routine quarries and an aggregate report for all school levels. The survey also included out-of-school students who did not attend school. Therefore, the reports and present data do not have conceived the concept of whether students left secondary school mainly for financial problems or not.

Many previous studies have identified a strong relationship between financial problems and dropout. Still, little research has been carried out that investigated whether the factors affecting students to dropout vary by socio-demographic issues and how they compared.

Ahmed *et al.* (2010) conducted a study on ten high schools in rural areas of Brahmanbaria, Chandpur, Cumilla, Feni, Jessor, Munshiganj, Mymensingh, Naogaon, and Narshingdi districts with the assistance of Volunteers Association for Bangladesh (VAB), a US-based NGO (non-government organization). The study collected data over a period of six years and found that the dropout started slowly from class six and rose at up to 70% at class ten. The study also tried to explore the reasons for dropout. They argued that the students could not cope with the demands of their study and take the test exam at class ten. It also realized that the nationwide Secondary School Certificate (SSC) exam and in some cases, the parent's inability to afford the exam fees might explain the reasons for a sudden rise in dropout at class ten. The study finally confirms the prevailing views of the main reasons for dropout is poverty and its relevant factors.

Some studies usage respondents and learners who are still enrolled in school and compare with those who dropped out from school (South *et al.* 2007). It is observed that the usage of currently enrolled respondents and learners is inappropriate because there is no assurance that they will surely complete or graduate with SSC programme. If enrolled

students leave school before passing SSC, the results will be biased. Therefore, it is better to use graduated respondents instead of still enrolled respondents, compared to dropout students eventually.

Rumberger and Lim (2008) made reassessment in California, USA of the past 25 years of research on dropouts. They came up with two factors that anticipate whether students' dropout or graduate from secondary school. They categorized the factors associated with (i) individual characteristics which illustrates students' attitudes, behaviour, school performance, and (ii) factors associated with institutional characteristics, which denotes the respondents' families, schools, and communities.

For Bangladesh, people's awareness of the importance and significance of education needs to be enhanced in society to reduce the dropout and to capture better the benefit of demographic dividend and the fourth industrial revolution. Ingrum (2006) argued that if the dropout trend is not downsized or at least reduced to the desired level, the future of high school dropouts is anticipated to be grave. Ingrum (2006) also stressed the importance of more and more research on secondary school dropouts.

Investigation of the factors leading to secondary school dropout in Bangladesh regarding the challenges of meeting the Sustainable Development Goal's (SDG's) targets is vital because it can encourage government agencies, researchers of universities, school practitioners, community organizers, and other interested parties to construct effective policies with responsive strategies targeted at preventing dropout. Moreover, the efficient strategies and policies will, in the long run, support reducing poverty, ensuring people's welfare, and enhancing the nation's economic and sustainable development.

Methodology

The Primary data used in this research was collected in 3 phases. The survey created 16 primary sample units (PSUs) covering all administrative, demographic, and topological areas. The sample areas covered 8 administrative divisions, and 4 particular areas (*Char, haor, hill* districts, and *city corporation* areas) are 21,757.95 km^2 or approximately about 14.74% of the total area of Bangladesh and 5,130.00 km^2 or approximately about 3.47% in terms of upazillas. Following the objectives and the purpose of the presents study, 01 (one) district has been chosen from each division in which the literacy rate is low and from the selected districts 01 (one) upazilla taken from each in which the literacy rate is also very low. The study covered 2 schools from urban/municipal areas and 2 schools from rural areas and 1 madrasah randomly selected from each upazilla. A baseline survey was conducted in the selected 79 schools' catchment areas to identify the potential

respondents. The baseline data identified 1,50,188 ex-students as the population for this study who enrolled in Grade 6 (in the selected secondary schools) during the 2009-2020 academic year. In Bangladesh, every student at secondary level school must complete five years of schooling (from Grade 6 to Grade 10). At Grade 10 (final year of secondary school), there is a public examination to determine whether the student is competent to finish their education or not. The study uses two types of questionnaires, one for ex-students (who had either SSC passed or dropped out) and another for their parents/guardians. The study finally included the valid questionnaires of 790 ex-students (474 females and 316 males) and their 1580 parents/guardians (i.e., both mothers and fathers) who voluntarily responded. The data was computed mainly using Stata and SPSS software.

In the research, secondary school dropout is considered to be an individual who was enrolled as a regular student in secondary level school in Grade 6 (first year of junior secondary school) within the age[1] limit under a BISE (Board of Intermediate and Secondary Education) but left school permanently before completing secondary school (up to grade-10 or SSC) for reasons other than death. In addition, the learner who leave one school and is not enrolled in other formal education again or does not hold a certificate as a private examinee under any BISE or Bangladesh Open University (BOU)[2], or does not have a temporary absence from school due to expelling or illness.

The above definition was used as the selection criterion to identify the potential respondents. During the period of data collection at the field level, it was found that some students who were previously classified as 'dropout' students by their schools had passed SSC by either enrolling in another school or through participation in the programme of BOU or BISE as a private examinee.

Model specification

The research aims to analyze the impacts of individual, family, and school domain of factors, as well as Bangladesh government policy and social safety net programmes (i.e. Stipend, VGD/VGF) variables, on the probability of an individual to complete or dropout from secondary school education in Bangladesh.

---

[1] Age of regular students for appearing in the SSC Examination is at least 14 (Fourteen) years on 1st March of the year of examination. However, students above 18 (Eighteen) years old cannot study in class IX, and students above 19 (Nineteen) years old cannot study in class X as regular students.

[2] Currently, Bangladesh Open University (BOU) offers six programmes, including Secondary School Certificate (SSC).

First, the model specification of dropout in general form is adapted from Roebuck *et al.* (2004), as follows:

$$D_i = f\,(I, F, S, GPS)$$

Where *D* is a dichotomous measure of whether an individual *i* has completed secondary school or has permanently dropped out from secondary school education, *I* is a vector of individual domain factors variables, *F* denotes a vector of family domain factors variables, *S* represents a vector of school domain factors variables and *GPS* is a vector of government policy and social supports variables.

The next step is to turn the general model into an empirical model:

$$D_i = \beta_0 + \beta_i I_i + \beta_2 F_i + \beta_3 S_i + \beta_4 GPS_i + e_i$$

Where:

Di = 1 if individual *i* is a dropout, and 0 otherwise (the dependent variable).

$\beta_1; \beta_2; \beta_3; and \beta_4$ = Vectors of parameters to be estimated

Ii = Vector of individual domain factors

Fi = Vectors of family domain factors

S_i = Vectors of school domain factors

GPS_i = Vectors of government policies and social support

e_i = Error term.

$i = 1, 2, \ldots, n.$

The empirical model is estimated separately in three domains of factors, i.e., individual, family, and school, along with government policy and social support areas.

The vector of individual domain factors (I) consists of 11 explanatory variables: Gender, age at first entry, working experience, perception of education, student's home location, grade repetition, previous academic performance (two variables), changing school experience, deviant behaviour, and health.

The vector of family domain factors (F) contains 19 explanatory variables: Family's Socio-Demographic Status (SDS) and Socio-Economic Status (SES), household head's education level, family size, parent's academic support, total sibling, sibling rank, sibling's dropout experience, parents are divorced, time helping family with household

chores, time helping family with daily business/work for income generating, ICT and internet facilities in family, washroom facilities in family, NGO membership, Mobility to the local power structure, Food deficit, Children not living with their parents and parent's participation in household decision-making.

The vector school domain factors (S) consist 10 explanatory variables: School location, relation with the teacher (two variables), bullied by peers and/or teachers, school curriculum (general secondary school versus vocational secondary school versus Madrasah), school type (public versus private secondary school), distance to school, transport, student's schooling expenditure, and teacher quality. The vector GPS consists of five explanatory variables: Government's Social Safety Net Programmes (SSNPs) support, School initiatives to help the economically backward student, real minimum wages, unemployment rate, and spatial dummy (two variables).

The present study uses the term 'log odds' to discuss the positive or negative signs of the coefficients of logit regressions. The term 'log odds' is formally used by Gujarati and Porter (2009) to interpret logit models. The present study uses average marginal effects and the odds ratios for a more meaningful interpretation of the logit models. This study conducts Likelihood Ratio (LR) tests. In LR tests, the null hypothesis (H_0) is that all the coefficients are equal to zero ($\beta_1 = \beta_2 = ... = \beta_K = 0$), and the alternative hypothesis (H_A) is that at least one or more coefficients are different from zero. $H_{0\ is}$ rejected if the p-value is smaller than 0.10. In other words, it is concluded that at least one or more independent variables are different from zero (Hosmer *et al*. 2013). The study also performs Wald tests. Wald χ^2 is obtained from a vector-matrix calculation. If the p-value of the Wald test is smaller than 0.10 (p-value < 0.10), there is not enough evidence to accept H_0, which implies that the study cannot accept the hypothesis that the model is not significant (Hosmer *et al.* 2013).

Results and Discussion

Before discussing the main results, it is required to check the overall significance of the results. As shown in Table 1, LR tests indicate that the model is statistically significant at the 1% level, which means that at least one or more coefficients of independent variables are different from zero. The Wald tests also show that the model is statistically significant at the 1% level, supporting the LR tests.

Table 1. Analysis of logit regressions using the main data sample.

Variable	Coefficient	Marginal effects	Odds ratios
Individual Domain Factors			
Gender (Female = 1, Male = 0)	0.06 (0.20)	0.87* (0.86)	1.07 (0.21)
Age at first entry	0.87* (0.47)	-0.21** (0.11)	2.40* (0.48)
Working experiences (Yes = 1, No = 0)	0.50** (0.24)	-0.08** (0.04)	1.65** (0.25)
Perception on education (Good = 1, Bad = 0)	0.44** (0.20)	-0.15*** (0.03)	1.54** (0.21)
Home location (Rural = 1, Urban = 0)	0.17 (0.23)	-0.02 (0.04)	0.89 (0.23)
Repeat grade (Ever repeated a grade =1, No=0)	-0.60 (1.85)	0.26 (0.30)	0.55 (1.86)
Frequency of repetition at grade	-0.64 (1.87)	0.56 (1.18)	0.56 (1.18)
Junior Secondary School Certificate Examination (JSC) Final Result:			
Low	0.22 (0.16)	0.01 (0.23)	1.25 (0.18)
Average	Reference	Reference	Reference
High	0.14 (0.20)	-0.04 (0.07)	0.95 (0.24)
Changing of school experience since primary	0.45** (0.20)	-0.08** (0.03)	1.57** (0.20)
Deviant behaviour (No deviant behaviour=0, up to six deviant behaviour=1)	-0.18 (1.18)	-0.01 (0.23)	4.64 (1.47)
Health condition (poor health=0, up to excellent health=6)	0.92 (1.19)	-0.001 (0.02)	0.57 (0.65)
Family Domain Factors			
Lowest socio-demographic status (SDS) (Yes = 1, No = 0)	0.63** (0.30)	-0.16** (0.07)	0.53** (0.30)
Lowest socio-economic status (SES) (Yes = 1, No = 0)	0.02 (0.18)	-0.03 (0.05)	1.02 (0.19)
Household head with at least SSC level education (Yes=1, No=0)	0.44 (0.42)	-0.17 (0.10)	1.56 (0.42)
Family size	0.20* (0.10)	-0.03 (0.02)	1.22* (0.10)
Parent's academic support (no support=0, Max support=4)	-1.38*** (0.39)	0.31*** (0.06)	0.39*** (0.36)

Variable	Coefficient	Marginal effects	Odds ratios
Total number of siblings in family	-0.19*** (0.07)	0.61*** (0.12)	3.11** (0.52)
Sibling rank in family (1=1st born, 2=2nd born, … 6= 6th or above born	1.13** (0.51)	-0.14 (0.08)	0.83*** (0.71)
Number of siblings dropout	0.57** (0.28)	0.11** (0.05)	1.78** (0.29)
Parents are divorced (Yes=1, No=0)	0.23 (0.33)	-0.001 (0.06)	1.26 (0.34)
Helping family with household works (Yes=1, No=0)	-0.39 (0.30)	0.06 (0.05)	0.68 (0.31)
Helping family with daily business works for income generating (Yes=1, No=0)	-0.09 (0.20)	0.03 (0.03)	0.91 (0.20)
ICT and internet facilities in family (Yes=1, No=0)	0.67 (0.41)	0.02 (0.05)	1.95 (0.41)
Comfortable washroom in family	0.02 (0.20)	0.005 (0.03)	0.98 (0.20)
NGO membership in family members (Yes=1, No=0)	0.60*** (0.22)	-0.08** (0.03)	2.50*** (0.56)
Mobility to local power structure (Yes=1, No=0)	0.86*** (0.30)	0.05 (0.05)	0.42*** (0.30)
Food deficit in family (Yes=1, No=0)	-0.18** (0.09)	0.23** (0.09)	0.83** (0.09)
Children not living with their parents (Yes=1, No=0)	-0.20 (0.51)	0.02 (0.09)	0.82 (0.52)
Differently able person in family (Yes=1, No=0)	-0.42 (0.33)	0.003 (0.02)	1.11 (0.22)
Parent's participation in household decisions making (No=0, Max participation=15)	1.76 (1.40)	-0.27 (0.17)	5.87 (1.40)
School Domain Factors			
School location (Rural = 1, Urban = 0)	0.14 (0.17)	0.03 (0.06)	1.16 (0.18)
Relation with teacher:			
Not good	0.01 (0.32)	-0.06 (0.05)	1.01 (0.31)
Neutral	Reference	Reference	Reference
Good	-0.15 (0.17)	-0.09* (0.03)	0.98 (0.19)
Bullied by peers and/ or teachers (Yes=1, No=0)	0.23 (1.20)	-0.04 (0.23)	1.23 (1.20)
Major Stream of education (General, Vocational and Madrasah)	0.66** (0.30)	-0.07*** (0.02)	1.94** (0.31)

Variable	Coefficient	Marginal effects	Odds ratios
School's type (Public=0, Private=1)	0.68** (0.30)	0.12*** (0.05)**	0.50** (0.31)
Distance of school form home	0.53*** (0.20)	-0.09*** (0.03)	1.70*** (0.20)
Vulnerability of the school going transportation	-0.12 (0.13)	-0.01 (0.01)	0.89 (0.14)
Log of school's expenditures	-0.55 (0.33)	-0.02 (0.04)	0.58 (0.33)
Teachers' quality (Good=1, not good=0)	-0.20 (0.21)	0.03 (0.03)	0.81 (0.21)
Government policy support and poverty improvement			
Government's Social Safety Net Programmes (SSNPs) support (i.e. Stipend, VGD/VGF)	-0.33 (0.30)	-0.09* (0.04)	0.71 (0.30)
School initiatives to help the economically backward student	-0.16 (0.19)	0.004 (0.04)	1.00 (0.22)
Topological analysis of sample area			
Mainland (8 Divisions)	1.85*** (0.65)	0.93*** (0.12)	2.82*** (1.08)
Char area (Raumari)	2.95** (5.21)	0.30 (2.94)	0.70* (0.49)
Haor area (Austogram, Itna, Nikli)	4.91*** (1.64)	0.63*** (0.11)	4.94*** (5.90)
Beel and low land area (Chalanbil)	0.57* (1.48)	0.27* (0.25)	9.61* (11.18)
Hill area (Lama)	2.99 (2.23)	0.32* (0.18)	2.57 (6.15)
Urban area (4 City Corp., both of Dhaka, Rajshahi and Khulna)	-2.05* (1.73)	-0.53** (0.66)	0.41* (0.74)
Unemployment rate	0.24 (0.25)	-0.02 (0.05)	1.28 (0.26)
Nature of temporary employment	0.03 (0.10)	-0.22 (0.13)	0.97 (0.11)
Log of real minimum expected wages	0.15 (0.08)	-0.11 (0.08)	1.16 (0.08)
Number of observation	790		
Likelihood Ratio (LR)	78.22***		
Wald χ^2	96.30**		

Notes: Dependent Variable = School dropout (Dropout = 1, Graduated = 0); ***p ≤ 0.01; ** p ≤ 0.05; * p ≤ 0.10. A constant is also included but its coefficient is not reported here. Standard errors reported in parentheses. Reference = base category; Baseline explanatory variables are underlined.

Logit coefficients presented in the above table are obtained from the following equation:

$$Li = In\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 X_1 + \cdots + \beta_i X_i + \mu_i$$

Table 1 presents the estimated coefficients from logit regression. This study does not attempt to interpret logit coefficients because their interpretation is not as straightforward as in the case of Ordinary Least Squares (OLS) regressions coefficients. The interpretation of the coefficients is discussed in the next section by computing the average marginal effects and the odds ratios. It is important to understand that average marginal effects and odds ratios summarize the results differently. This part only discusses the positive or negative signs of the coefficients of logit regressions.

The discussion starts with individual domain factors. Not surprisingly, with the variable being statistically significant, it can be inferred that being a female student, results in higher log odds of dropping out than being a male student. Early marriage and pregnant students contribute to the high number of dropouts. In the questionnaire results, pregnancy is the main reason for female students' dropout. If students are the victim of early marriage and become pregnant, they only have one choice to leave voluntarily from school.

Students' perceptions about education are also statistically significant and positively impact dropping out. Moreover, students who repeat a grade while in secondary school have a higher likelihood of dropping out. Similarly, getting low grades at the previous level of schooling also contributes to higher log odds of dropping out, than students who get average grades. Students with more deviant behaviour significantly increased the log odds of dropping out. Only one explanatory variable in individual domain factors significantly impacts reducing dropout. As expected, valuing school more is associated with lower log odds of students dropping out.

One of the important family domain factors variables is the lowest socio-demographic status (SDS). It is a proxy for social contribution and describes factors of the family status. This study finds that students dropped out of school due to their families having many children. The variable lowest socio-demographic status (SDS), indicating the number of members in a family, was constructed to test whether the student's claim is supported by quantitative analysis. The estimates indicate that having a higher number of family members significantly increases the log odds of a student dropping out, and they are statistically significant. The finding shows that larger family size matters and contributes to dropout. For example, the survey shows that only 5% of the respondents had no sibling, 9% had only one sibling, and 86% had two siblings or more. As the

estimates indicate, having many family members can contribute to dropout; therefore, the long-run strategy is to start the family planning campaign again, especially targeting poor SDS families.

Also, having more siblings who dropped out of school is likely to increase the log odds of dropping out, and the presence of siblings who dropped out is likely to provide a role model that encourages other siblings to leave school. This study does not find any evidence that helping families with household works for variable and helping families with daily business work for the income-generating variable is associated with the log odds of dropping out. Further, there is no evidence to support the correlation between parents' participation in household decision-making variables with dropout.

Another important family domain factor variable is the lowest socioeconomic status (SES), and it is a proxy for poverty and describes factors of the family status. The survey observes that about 37% of dropout respondents expressed that they left school because of financial problems. In addition, more than half of respondents in the qualitative analysis also stated that financial problems are the main reason for them to leave school. The quantitative analysis shows that students from families with the lowest socioeconomic status are more likely to dropout (Table 1). There is strong quantitative evidence that poverty affects student dropout.

A variable named Household head with at least SSC level education was created. It is found that household heads with at least SSC level education are correlated with lower log odds of students dropping out. The results also indicate that parents' higher support of students' academic activities significantly reduces the log odds of students dropping out. With the concept of social capital, it has been discussed previously that parents' academic support is one form of social capital. As proposed by social capital theory (Stone 2001), the positive attention given by parents to their children is important for transmitting available human, social and financial capital to children (Teachman *et al.* 1996).

The estimates for school domain factors indicate that students from urban schools have significantly higher log odds of dropping out than those who studied in rural schools. Students who have a bad relationship with a teacher are more likely to dropout of school. At the same time, it is shown that students who have good relationships with teachers are more likely to stay in school (in comparison with those who only have a neutral relationship with teachers). This result supports social capital theory (Stone 2001) that the density of positive interaction between teachers and students improves students' human capital accumulation.

Being bullied by peers and/or teachers significantly increases the likelihood of dropping out. The government's social safety net programmes (SSNPs) support for poor students significantly reduces the log odds of dropping out. The Schools' financial and other initiatives to help the economically backward students also reduces the log odds of dropping out. The result supported a previous study by Khandker *et al.* (2021) in Bangladesh. Khandker *et al*. (2021) conclude that stipend has a significant effect on student dropout at the secondary school level. They reiterate that the subsidies to female secondary education through stipends and other forms of assistance are considered a direct and observable way to incentivize parents to educate girls at that level where gender disparity is high and persistent. The perceived wisdom is that since educating girls at the secondary level is costly for parents in developing countries for different reasons (both social and economic), providing subsidies for girls through stipends would be a way to promote secondary education, thus reducing dropout and persistent gender gaps.

Analysis of Average Marginal Effects for Logit Regressions

Most of the average marginal effect values are similar to the coefficients from OLS regressions, except for the perception of education variable. The average marginal effect values are slightly lower than the OLS coefficients. The estimates can be interpreted to imply that female students have an 87% higher probability of dropping out than male students on average. The difference between female and male students indicates that student dropout is not less likely because of gender bias in Bangladeshi culture. Instead, it could be due to the discrimination against female students in school. According to Roy and Basher (2021), the government recently enacted law '*The Child Marriage Resistant Act 2017*' and corresponding rules 2018 replacing the old Act of 1929, negatively influencing female dropouts. The marriageable age for females and males is 18 and 21 respectively, which is also discriminatory. Its' '*special provision*' allows child marriage with the court's permission, and the consequences are reflected in the education of the girls' students (Yasmin 2021; Roy and Basher 2021).

Students who believe that education is important for them, have a higher probability of finishing their study. It can be concluded that a good perception of education is one of the important explanatory variables as there is a 15% point difference between students who have a good perception of education and those that have a bad perception of education on average. Therefore, it is important to add strategies for raising students' awareness about the benefits of education for their future. The students from very low SDS families have a 16 % point higher probability of dropping out than students from high

SDS families on average. It is also shown that students from impoverished families have a 3 % point higher probability of dropping out than students from wealthier families on average. The 16 % point difference between low and high SDS families indicates that dropout is not solely a poor students' problem. Similarly, the 3 % difference in SES between poor and wealthier families indicates that dropout is not excessively a poor students' problem. This is also consistent with the survey that only 37% of dropout respondents withdraw from secondary school because of financial issues. In comparison, the other 63% of dropout respondents withdraw because of other reasons.

Having household heads that hold an SSC degree reduces the probability of dropping out by about 17% points compared to those who do not hold such qualifications on average. It is important to note that students who are raised in educated families have a better perception of education. It shows a significant effect of having educated parents compared to having non-educated parents.

The average marginal effect also shows that students who have a good relationship with teachers have a 9 % point lower probability of dropping out of school than those who only have a neutral relationship with teachers. It is recommended that teachers have a responsibility to create good relationships with their students.

Interpretations of Odds Ratios

Table 1 shows the odds ratios for logit regressions. The discussion begins from the individual domain factors. It can be seen from the Table 1 that odds of dropping out for female students are 1.07 times greater than the odds for male students, or the odds of dropping out for females are about 107% higher than the odds of dropping out for males. The odds of dropping out reduce by 1.54 times when students have a good perception of education compared to students who do not. In other words, the odds of dropping out for students who have a good perception of education are about 54% lower than the odds of dropping out for students who do not have a good perception of education.

The odds of dropping out for students who stay in rural areas are nearly two times higher than those who drop out for students who remain in urban areas. The odds of dropping out increase 1.25 times for students who have a low grade of Junior Secondary School's (JSC) final examination compared to students who have an average grade of Junior Secondary School's national final examination. When holding other independent variables at a fixed value, the odds of dropping out of a school, for a one-unit increase in

the number of changing schools since primary school increase by a factor of 1.57, or there is a 57% increase in the odds of dropping out for a one-unit increase in the number of changing schools since primary school. Also, the odds ratio for the Deviant behaviour variable indicates that keeping other independent variables at a fixed value, there is a4.64 times, or 364%, increase in the odds of dropping out for a one-unit increase in deviant behaviour.

For Family domain factors, the odds of dropping out for students who are from the lower socio-demographic status are 1.89 times higher than the odds of dropping out for students who are not from the lower socio-demographic status, which implies that the odds of dropping out for poor SDS students are about 89% higher than the odds of dropping out for students from higher SDS families. Similarly, the odds of dropping out for students who are from the lowest socio-economic status are 1.02 times higher than the odds of dropping out for students who are not from the lowest socio-economic status, which implies that the odds of dropping out for poor students are about 2% higher than the odds of dropping out for students from wealthier families. Students who have a household head with at least SSC level education have lower odds of dropping out by 1.56 times than their counterparts who have household heads with no SSC level education, or the estimate indicates that the odds of dropping out for students from more educated families are about 56% lower than the odds of dropping out for students from less-educated families.

When other independent variables are constant, for a one-unit increase in parent's academic support, there is 0.39 times, or a 61%, decrease in the odds of dropping out. Furthermore, the odds ratio indicates that having more siblings who dropped out of school increases the students' odds of dropping out by 1.78 times, , which implies that dropping out for students is 78% higher for additional siblings who dropped out of school.

For School domain factors, the odds of dropping out for students who study in urban areas are 1.16 times as large as for students who study in rural areas, which implies that the odds of dropping out for students who study in urban areas are 16% greater than the odds of dropping out for students who study in rural areas. Moreover, having a good relationship with teachers decreases the odds of dropping out by 0.98 times. Students who have a good relationship with teachers are 2% less likely to dropout than students who have a neutral relationship with teachers. Students who their peers and/or teachers bully have 1.23 times, or 23%, higher odds of dropping out than when compared to students whose peers and/or teachers do not bully.

The government's social safety net programmes (SSNPs) support (i.e., Stipend, VGD/VGF) for poor students successfully reduces the odds of dropping out by 0.71 times or it also indicates that the odds of dropping out for students who receive financial assistance from the government are 29% lower than the odds of dropping out for students who do not receive the assistance. Finally, the odds of dropping out are 9.61 times as high as for students who live in *Beel* and the low land area of Bangladesh. Similarly, the odds of dropping out for students residing in *Haor* areas are 4.94 times, 2.82 times in mainland, 2.57 times in Hill area, 0.70 times in *Char* areas, and 0.32 times city corporation areas of Bangladesh reported (see Table 1).

The high dropout rate is a key concern of meeting the SDG's targets. Bangladesh has employed full of its concentration to implement the United Nations Sustainable Development Goals (SDGs), which were adopted in September 2015, consists of 17 specific Goals and 169 Targets, and it's closely linked 232 unique indicators to assess the progress to be achieved by 2030 (Jeffrey *et al.* 2021). Sustainable Development Goal 4 (SDG 4) represents education, "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", consisting of 10 targets and 11 indicators. The high dropout rate of secondary level education will impede on most of the targets of SDG 4 and create partial challenges on other goals and targets.

Progress on SDG4 of Bangladesh by indicators is not come out in a good position. The high rate of school dropouts is one of the major concerns. The competency of children and young people achieving at least a minimum proficiency level in reading and doing mathematics by sex, Bangladesh is trailing back in achieving the SDG milestone for this indicator. According to a study, the minimum proficiency in reading Bangla is 54% (55% boys and 54% girls) of the students at the end of junior secondary level. Similarly, English reading proficiency is only 19% (22% boys and 18% girls). The students' minimum proficiency in mathematics is 57% (62% boys and 52% girls) (DSHE, 2016). The dropout and out-of-school children are not included here. The deficiency of competent teachers has treated a major reason for this poor performance.

The improvement in the proportion of schools with access to basic services and facilities has a wide opportunity for establishing equity. As per Global Education Monitoring Report (GEMR 2016), around 76.86% of the schools have access to electricity, 8.36% have access to the internet for pedagogical purposes, and 17.9% of the schools have computers for pedagogical purposes. Bangladesh needs to cover a long distance to achieve SDGs milestones for this indicator.

A paradigm shift is expected in the education sector by achieving the targets of SDG4 through the implementation of 8th Five Year Plan (8FYP) (GED, 2020). One of the major constraints that education and training face is the scarcity of resources (public and private investments). The government targeted to increase allocations through the 8FYP. However, the Perspective Plan 2041 (PP2041) set ambitious targets of increasing government spending in education to 4% of GDP by FY2031 and 5% of GDP by FY2041. Following those targets, government spending is targeted to raise 3.5% of GDP by FY2025. Currently, government's education spending is low, introduced a maximum of 2.47% in 2017, but downsized again in the following years to around 2% of GDP. The private sector investments need to be encouraged for quality education.

The lack of adequate student learning outcomes remains one of the major concerns and they are depriving of mastery skills and competencies. Additional teaching can be provided to those students willing to stay after school to improve their learning. Studies have shown that remedial assistance keeps students in school longer and lowers the dropout rate. Qualified, efficient teachers can enhance the education outcomes. The study reveals that the need for skilled teacher's development strategy meets the 21st centuries learning gap of the students.

The opportunity of demographic dividend is knocking at the door. In this respect, the high rate of school dropout and low schooling of the working age people need a positive change. The present study reveals that 37% of students show only financial and 63% non-financial factors for their school dropout. It suggests addressing the dropout problem in light of the demographic features of Bangladesh. Now Bangladesh is in the process of the demographic dividend. At present, working population (age group 15-64) is about 106.1 million (65%) (The Financial Express 2020). It is predicted that after 2040, the depended population ratio trend will increase, and economic growth will continue to shrink if other things remain the same. However, in the right way, reducing the high dropout, Bangladesh is supposed to capture the demographic dividend opportunity.

It is recognized that school dropout is not mere by a problem for quality education. It compresses the individual income enhancement and sends the country into the vicious cycle of poverty. The present study identified the root causes and their severity. Further research also desired to eventually make the stakeholders and the policy planners aware of specific interventions. However, the research also suggests that the students need alternative parenting support as most parents have low schooling and are unable to guide their children properly.

Conclusion

The research reveals that financial problems are severely engaged to increase the dropout rate and non-financial factors together aggressively play a calamitous role and lead the academic life of the dropout student towards the end. The study realizes the economic effect of school dropout and its consequences for the future economic development of Bangladesh. The study also explores that poverty is not the only reason for school dropout, and other reasons also contribute to increasing the likelihood of school dropout. To achieve the targets and goals of SDGs, and Upper Middle-Income Country (UMIC) status, there is no alternative but to reduce dropout to ensure quality education for all. The study suggests authorities for rapid response to reduce dropout, which will lead Bangladesh to achieve the targets of SDGs and come out an upper middle-income country by 2041.

References

Ahmed, S.G., M.M. Rahman and M. Pal. 2010. Dropout Rate in Secondary Level Education in Bangladesh. *University Press Limited*, Dhaka.

BANBEIS (Bangladesh Bureau of Educational Information and Statistics). 2020. *Bangladesh Education Statistics*. Dhaka.

BANBEIS (Bangladesh Bureau of Educational Information and Statistics). 2011. *Secondary School Dropout Survey*. Dhaka.

DSHE (Directorate of Secondary and Higher Education, Bangladesh). 2016. *Learning Assessment of Secondary Institutions 2015, Australia: ACER.*

GED (General Economics Division). 2020a. Sustainable Development Goals Bangladesh Progress Report, *Bangladesh Planning Commission, Ministry of Planning*, Government of the People's Republic of Bangladesh.

GED (General Economics Division). 2020b. Eighth Five Year Plan (July 2020-June 2025), *Bangladesh Planning Commission, Ministry of Planning*, Government of the People's Republic of Bangladesh.

GEMR (Global Education Monitoring Report). 2016. Education for people and planet: Creating Sustainable future for all, *Paris: UNESCO*.

Gujarati, D.N. and D.C. Porter. 2009. Basic econometrics (5th ed.). New York, *NY: McGraw-Hill/Irwin.*

Hosmer, D.W., S. Lemeshow and R.X. Sturdivant. 2013. Applied logistic regression (3rd ed.). Hoboken, *NJ: John Wiley & Sons, Inc.*

Ingrum, A. 2006. High school dropout determinants: The effect of poverty and learning disabilities. *The Park Place Economist*, **14:** 73-79.

Jeffrey, D.S., C. Kroll, G. Lafortune, G. Fuller and F. Woelm. 2021. Sustainable Development Report: The Decade of Action for the Sustainable Development Goals, *Cambridge University Press*.

Khandker, S. R., H.A. Samad, N. Fuwa and R. Hayashi. 2021. The Female Secondary Stipend and Assistance Program in Bangladesh: What did it Accomplish?, *ADB: South Asia Working Paper Series*, Vol. **81**, pp. 40-41.

MoF (Ministry of Finance). 2020. *Bangladesh Economic Review 2020*, Dhaka, pp. 219.

Raihan, S. 2020.Turning South Asia's youth into demographic dividend. Dhaka: The Daily Financial Express. (Retrieved from www.thefinancialexpress.com.bd/views/turning-south-asias-youth-into-demographic-dividend-1504964086)

Roebuck, M.C., M.T. French and M.L. Dennis. 2004. Adolescent Marijuana Use and School Attendance. *Economics of Education Review*. **23**: 133-141.

Roy, P. and N. Basher. 2021. Child marriage in pandemic: A scourge returns on tiptoe. Dhaka: The Daily Star. (Retrieved from www.thedailystar.net/news/bangladesh/news/child-marriage-pandemic-scourge- returns-tiptoe-2195446)

Rumberger, R.W. and S.A. Lim. 2008. Why students drop out of school: A review of 25 years of research, *University of California: Research Project Report* #15, pp. 1-130. (Retrieved from http://cdrp.ucsb.edu/dropouts/pubs_reports.html)

South, S. J., D.L. Haynie and S. Bose. 2007. Student mobility and school dropout. *Social Science Research*, **36(1)**: 68-94.

Stone, W. 2001. Measuring social capital: towards a theoretically informed measurement framework for researching social capital in family and community life. Research Paper. Melbourne: AIFS.

Teachman, J.D., K. Paasch and K. Carver. 1996. Social capital and dropping out of school early. *Journal of Marriage and the Family*. **58**:773-783. (https://doi.org/10.2307/353735)

Yasmin, T. 2021. Penalising victims of child marriage isn't the right way to go. Dhaka: The Daily Star. (www.thedailystar.net/views/opinion/news/penalising-victims-child-marriage-isnt-the-right-way-go-2152996)

Zafar, A., M. Reaz and F. Tasin, 2020. Bangladesh's Journey to Middle-Income Status: The Role of The Private Sector, *Washington: WB*. pp. 39-46.

(Revised copy received on 23.11.2021)