RAJSHAHI UNIVERSITY JOURNAL
OF
ENVIRONMENTAL SCIENCE

ISSN 2227-1015

Vol. 7, December, 2018 (Published in June, 2019)

CONTENTS

Volume 7

December
2018

RAJSHAHI UNIVERSITY JOURNAL OF ENVIRONMENTAL SCIENCE

ISSN 2227-1015

Institute of Environmental Science (IES)
University of Rajshahi
Rajshahi-6205

RAJSHAHI UNIVERSITY JOURNAL OF ENVIRONMENTAL SCIENCE

ISSN 2227-1015

Volume No. 7, December, 2018

(Published in June, 2019)

Published by

Institute of Environmental Science
University of Rajshahi
Rajshahi-6205, Bangladesh
www.ru.ac.bd/ies

Subscriptions

Institutions:	Inside Bangladesh	Tk. 500 per copy
	Out side Bangladesh	US$ 50 per copy
Individual:	Inside Bangladesh	Tk. 300 per copy
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All correspondence should be addressed to the Chief Editor, Rajshahi University Journal of Environmental Science, Institute of Environmental Science, University of Rajshahi, Rajshahi-6205, Bangladesh.
Website: www. ru.ac.bd/ies, **E-mail**: akazad_ies@yahoo.com and rujes_ies@yahoo.com, **Tel**. 880-0721 750930

Cover Design: Prof. Dr. Md. Abul Kalam Azad

Printed at: Uttoran Offset Printing Press, Greater Road, Rajshahi

ISSN 2227-1015

RAJSHAHI UNIVERSITY JOURNAL OF ENVIRONMENTAL SCIENCE

An Annual Journal of the Institute of Environmental Science

Vol. No. 7, December, 2018

(Published in June, 2019)

Published by:
Institute of Environmental Science (IES), University of Rajshahi, Rajshahi-6205, Bangladesh
E-mail: akazad_ies@yahoo.com and rujes_ies@yahoo.com, website: www.ru.ac.bd/ies
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FOREWORD

Conservation of environment is essential to ensure the security of water, food and energy for human beings. The challenges of environmental pollution, climate change and disasters must be addressed carefully with integrated initiatives, enhanced awareness and research. For deltaic landmass with vast coastal areas, the peoples of Bangladesh are the main sufferers of climate change and natural disasters. Therefore, interdisciplinary researches are utmost important for the control, mitigation, adaptation and dissemination of experiences for sustainable environmental management.

The Rajshahi University Journal of Environmental Sciences (RUJES) is a multi-disciplinary journal to promote understanding of environmental issues includes environmental pollution, biodiversity loss, emission of carbon dioxide from fossil fuel, climate change and their impacts on air, water, soil and ecosystem. Thus, the journal offers a scientific platform for publishing the critical reviews and original research achievements through peer-review.

All the contributors and reviewers are highly acknowledged for their interest, efforts and co-operation. I would like to express my sincere appreciation to the members of editorial board and associates for their support in publishing the current volume of the journal. I also thanks to the employees of printing press for their necessary help. Any further suggestion for the improvement of the next issues will be highly appreciated. The Chief Editor and Members of the Editorial Board do not bear any responsibility of the views expressed in the papers. The online version of the journal is available at: http://dept.ru.ac.bd/ies

Chief Editor

INSTRUCTIONS TO AUTHORS

Manuscripts: The manuscript must be sent in MS Word Document file format containing title of the paper, author's name(s), affiliation(s), author's full postal address and corresponding author's e-mail. Abstract should be within 250 words along with maximum of 5 keywords indicating the objectives, results or conclusion of the study. The text of the full paper should preferably be within 5000 words (max. 10 pages) having the following sub-titles:

- **1. Introduction**: Introduction should be concise and precise relevant to objectives of study.
- **2. Materials and Methods**: Standard and published methods should not be described rather only be cited as references. Any modification or new set up should be stated.
- **3. Results and Discussion**: Results should be presented with appropriate figures, tables, graphs etc. with proper interpretation and justification by relevant previous studies.
- **4**. **Conclusion:** Concise form of results with concluding remarks.
- **Tables, Graphs and Figures**: The paper should contain maximum of 12 tables, graphs and figures all together. Figures, graphs and photographs should be given as attached file along with appropriate marking numbers in standard BMP format (uncompressed). Original illustrator, graphic or photo files must be supplied with finally accepted manuscript.
- **Acknowledgements (if any)**:
- **References.** Appropriate and relevant recent references must be cited following instruction given.

The following format needs to follow for preparation of manuscript:

1. Format Instructions

1.1. Instructions for Typists

Margins are to be set to a width of 15.2 cm, and each page must be typed in Times New Roman 11 points letter for the main text with a 13 points spacing between the lines. The footnotes to be typed in Times New Roman 10 points letter with an 11 points spacing between the lines. Each page must be typed in a page depth of 21.6 cm. On the first page, the title of the paper should start after three blank lines below the journal heading. New paragraphs should be started without any indentation. Title of paper should be typed in bold, 14 point all upper-case letters, with 6 and 12 points spaces above and below respectively. The headings used are:

2. First-Order Heading

These should be typed in bold, 12 point upper- and lower-case letters, with 6 points space above and below the heading. The text after the heading will begin at the left-hand margin (i.e., not indented as for new paragraph).

2.1. Second-Order Heading

This should be typed in 12 point bold with a capital initial for each word at the left-hand margin, 6 points space above and below the heading.

2.1.1. Third-Order Heading

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Special Attention

3.1. Tables

Put a table heading at the top of the table and skip one line above and below the tables. If table heading extends over one line, continue on the second and following lines immediately below the first letter of the heading. Do not use full stop at the end of each table caption. Use horizontal lines above tables, below column headings, and below tables. Use capitals for the first letter of column headings. As far as practicable, arrange the tables in the vertical direction just as in text. Tables and text may appear on the same page. Table 1 is an example of an acceptable table format.

Table 1. Annual rainfall and water table of the study area

Areas	Annual Rainfall (mm)		Water Table (m)	
	Wet Season	Dry Season	Wet Season	Dry Season
Rajshahi	20.4	27.4	90.0	20.4
Natore	30.6	38.6	34.6	31.6
Pabna	45.9	46.9	45.0	43.9

3.2. Figures

Skip 6 points space above and below the figures. Put a figure caption at bottom of the figure and leave 6 points space between figure and caption, and use a full stop at end of the caption. Start second and subsequent lines immediately below the first letter of caption. Skip 6 points space after caption. Figures and text may appear on the same page. Legends, scales, etc. must be large enough to be legible. Give the consecutive numbers for tables and figures, respectively. You can break a paragraph for placing the figure. Try to avoid blank spaces within the text.

3.3. Equations

Equations should be numbered sequentially as follows: Use 1 line spacing instead of a 13 points spacing for the lines from just above to just below the equation.

$$\nabla^2\phi = 0 \qquad (1)$$

3.4. References

In the text, author's last name should be followed by the year of publication; e.g. "(Islam, 2016; Mostofa *et al.*, 1997; Redwan and Shafiuzzaman, 2015) or "Azad (1998) showed that …". In the list of references, arrange authors' last names in alphabetical order with 0.5 cm indentation for the second and following lines of each reference. When two or more references by the same author are listed, the earlier work should appear first. All references must be cited in the text.

Style of References

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Mostafa MG, Chen YH, Jean JS, Liu CC and Lee YC. 2011. Kinetics and Mechanism of Arsenate Removal by Nanosized Iron Oxide-coated Perlite. *J. Hazardous Mat.*, **187**: 89-95.

Sen I, Parua DK, Bera S, Islam MS and Poole I. 2012. Contribution to the Neogene Fossil Wood Record and Palaeoecological Understanding of Bangladesh. *Palaeontographica, Abteilung B: Palaophytologie, Palaeobotany-Palaeophytology,* **288(1-4)**: 99-133.

For Book:

Blanford WT and Godwin-Austen HH. 1908. *The Fauna of British India, including Ceylon and Burma, Mollusca*: Testacellidae and Zonitidae: Taylor and Francis, London. 311p.

For Book Chapter:

Islam MB and Islam MS. 2006. Floods in Bangladesh: A Combined Interaction of Fluvio-anthropogenic Processes in the Sourse-sink Region, *In*: (Alphen JV, Beek EV and Taal M; eds): *Floods, From Defence To Management*. Taylor and Francis Group, London, England. P:589-595.

For Book Edited:

Kumar A and Bidhan D. 1989. *A Text Book of Environmental Science* (eds). (3rd edt) University Press, Dhaka, 525p.

For Dissertation/Thesis:

Mostafa MG. 2000. Thermodynamic Simulation of Cobalt-carbonate Aqueous System. *PhD Dissertation* (unpubl). Faculty of Engineering, Ehime University, Matsuyama, Japan, 200p.

For Report:

WDATCP (Wisconsin Department of Agriculture, Trade, and Consumer Protection). 1991. Report to the State Legislature: Agricultural Clean Sweep Demonstration Projects, *Madison, WI: Agricultural Resource Management Division*.

For Regulation:

USEPA (United States Environmental Protection Agency). 1995. Water Quality Standards-Revision of Metals Criteria, *Fed. Reg.*, **60**: 229-240.

For Proceedings:

Krewitt W, Trukenmueller A, Mayerhofer P and Freidrich R. 1995. An Integrated Tool for Environmental Impact Analysis. *In:* (Kremers H and Pillmann W) *Environmental Information Systems*, (eds), *pp* :90-97.

Online published articles with DOI (with /without page no):

Mutton D and Haque CE. 2004. Human Vulnerability, Dislocation and Resettlement: Adaptation Processes of River-bank Erosion-induced Displacees in Bangladesh. *Disasters*, **28(1)**: 4-62(22), March. http://www.ingentaconnect.com/content/bpl/disa/2004/028/001/art0,03;jsionid=2hcpbncdh3r.alice?format=pri. Cite the date of visit the web pages.

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Institute of Environmental Science
University of Rajshahi
Rajshahi-6205, Bangladesh
E-mail: akazad_ies@yahoo.com and rujes_ies@yahoo.com

ISSN 2227-1015

RAJSHAHI UNIVERSITY JOURNAL OF ENVIRONMENTAL SCIENCE

Vol. 7, December, 2018 (Published in June, 2019)

CONTENTS

Eco-friendly Management of Aphid with Botanical Pesticides in Country Bean Field at Rajshahi, Bangladesh

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Abstract

Country bean (*Lablab purpureus* L) is infested by a number of insects specially black bean aphid which damage the growing points, stems, leaves, inflorescences, fruits and whole bean plant. Chemical pesticides are commonly used to control aphid but it has residual effect which is very harmful to environment and human health. Therefore, this research was conducted to find out the less hazardous, environment friendly and locally available botanicals to control black bean aphid. Ten plant extracts: Neem leaves (*Azadirachta indica*), Go-ganda *(Lantana camera)*, Gol-murich (*Piper niagram*), Bandarlathi (*Cassia fistula*), Patabahar (*Acalypha welkesiana*), Chirata (*Swertia chirata*), Gada leaves (*Tagetes erecta*), Pudina (*Mentha arvensis*), Lemon outer shell (*Citrus aurantifolia*) and Holud leaves (*Curcuma longa*) were prepared for experimental country bean (variety Noldog) field. About 100 gm of grinding leaves, stems, outer shell of fruits and seeds were dissolved in one liter of water. These samples were kept in water for three days. Then solutions were filtered with plastic filter. In this study, a less number of aphid attack on bean plants was observed in the Lemon outer shell treatment (0.212±0.064), whereas a high number of aphids were found in the Go-ganda treatment (81.280±22.251).The Lemon outer shell treatment kept about 43.92 times better performance than that of control treatment. Plant extracts of Lemon outer shell and Holud leaves can be used as promising botanical pesticides in the control of bean aphid in Bangladesh.

Keywords: Plant extracts, Bean aphid, Effective, Lemon outer shell and Botanical pesticides

1. Introduction

The country bean (*Lablab purpureus* L) is a leguminous vegetable. The area of Bangladesh, where the soil is light in texture and comparatively low temperature prevails during the winter season with less rainfall has been found suitable for bean cultivation (Mozumdar *et al.*, 2003).

Legume crops grown for human consumption belong to the Fabacae (formerly Leguminosae) family. They are important foods in most tropical and subtropical countries of the world and are ranked to second after cereals as a food for human and animals (Graham and Vance, 2003).

The country bean *(Lablab purpureus* L) plays an important role in the world food and nutrition requirements. As a food, this common bean may be consumed as dried or in the fresh state as green beans. Beans are also used as a vegetable when harvested while the young tender pods are still immature. Beans are rich in protein and iron and contain essential nutrients such as ascorbic acid, vitamin A, vitamin B and calcium (Kelly and Scott, 1992; Ndegwa *et al.*, 2006).

The country bean (*Lablab purpureus* L) as a legume crops are also important for their nitrogen fixing capabilities (Piha and Munns, 1987; Keyser and Li, 1992; Amanuel *et al*., 2000), and can be used in crop rotation systems to improve soil conditions. Nitrogen fixation by legume crops offers an alternative to nitrogen fertilizers which may present a serious environmental problem (Nason and Myrold, 1992; Brentrup *et al*., 2001). It may tolerant of heat and drought conditions and produce well on marginal soils.

Leguminous plant species are susceptible to pests attack and diseases. Pest and disease problems are the major constraints to agricultural productivity of the common bean, particularly in the tropics (Graham and Vance, 2003). Worldwide, yield losses due to insect pests alone have been estimated to be from 35% to 100% annually (Singh and Schwartz, 2011). Pest problems prohibiting more extensive production of legume crops include such diseases as brown rust, powdery mildew and insect pests such as aphids, caterpillars, leafhoppers and whiteflies.

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Country bean (*Lablab purpureus* L) is infested by a number of insects specially bean aphid which damage the growing points, stems, leaves, inflorescences, fruits and whole bean plant. Beans suffer damage to flowers and pods due to improper development (BBA, 2013). Hence, in order to protect the beans from aphid infestation, growers in Bangladesh often apply synthetic chemical insecticides. Although, synthetic insecticides usually provide quick and adequate control for the time being but they are usually expensive and leave long-lasting residual impacts on soil and water (Hussain, 1989). Undesirable side effects, development of pest genotypes resistant to pesticides, resurgence and upset of pests and environmental pollution are caused by the continuous use of synthetic chemical pesticides (Nas, 2004). Therefore, there is an interest in the application of botanical pesticides for crop protection.

There have been a large number of plant products, which possess pesticidal properties and have been used successfully for controlling various pest in field and laboratory conditions (Bajpai and Sehgal, 2000). Bangladesh and many other Asian countries are rich in plant products and traditionally used by the rural inhabitants for medicinal purpose and in some instance as preparations for insect control (Talukder and Howse, 1993). Botanical pesticides tend to have broad spectrum activity, are relatively specific in their mode of action and easy to process and use in farm-level. They are also safe for higher animals and the environment (Anonymous, 1991). Plants are rich sources of natural substances that can be utilized in the development of environmentally safe methods for insect control (Sadek, 2003). Certain plant families, particularly Meliaceae, Rutaceae, Asteraceae, Labiaceae, Piperaceae and Annonaceaeare viewed as exceptionally promising sources of plant-based insecticides (Isman, 1995). Botanical products like tobacco extract, neem oil and extract, which can be easily and cheaply collected from the rural area of Bangladesh have been found promising and useful for pest control. Although they have been found promising for protection of stored products, botanicals have received little attention for field crops in Bangladesh.

Bangladesh is rich in plant biodiversity. This research in botanical pesticides has a good scope of study to find out different indigenous plants of Bangladesh to produce an eco-friendly plant-based pesticide for sustainable aphid management in bean field. This study was conducted at Rajshahi University to find out the suitable botanical pesticides for eco-friendly pest control in bean field.

Objectives of this Study

This study was conducted considering the following objectives:

- To investigate the plants, herbs and shrubs having the pesticidal properties in Bangladesh,
- To observe the efficacy of botanical pesticides for the control of aphid in experimental bean field and
- To identify the effectiveness of botanical pesticides on growth and yield of bean compared to control.

2. Materials and Methods

2.1. Collection of Botanicals

Ten plants were collected from the campus of University of Rajshahi, Bangladesh (Table 1). After collection, fresh plant parts were washed in running tap water and air dried in the shade for one week at room temperature.

Table 1. Plants used for the preparation of botanical pesticides

Sl. No.	Local Name	English Name	Scientific Name	Plant Parts Used
1	Neem leaves	Margosa	*Azadirachta indica*	Leaves
2	Go-ganda	Lantana	*Lantana camera*	Leaves
3	Gol-murich	Black piper	*Piper niagram*	Fruits
4	Bandarlathi	Golden raintree	*Cassia fistula*	Leaves
5	Patabahar	Patabahar	*Acalypha welkesiana*	Leaves
6	Chirata	Chirata	*Swertia chirata*	Leaves and stem
7	Gada	Merigold	*Tagetes erecta*	Leaves
8	Pudina	Mint	*Mentha arvensis*	Leaves and stem
9	Lemon outer shell	Lemon peel	*Citrus aurantifolia*	Fruits
10	Holud leaves	Turmeric	*Curcuma longa*	leaves

2.2. Preparation of Land for Bean Cultivation

The experimental land was first opened with a country plough. Ploughed soil is then brought into desirable final tilth condition by five operations of pouching followed by laddering. The stubbles of the crops and uprooted weeds were removed from the field and the land was properly leveled for planting of beans.

2.3. Experimental Plot Preparation

The field experiment was conducted at IES Botanical Pesticides Research Field of University of Rajshahi. To support the plant growth cow-dung, Triple Super Phosphate (TSP), Murate of Potash (MP) and Urea fertilizers were applied. The whole amount of fertilizers was used as the basal dose during pit preparation. Then, the seeds were planted in the experimental plot (Table 2). The plot was irrigated with tap-water when necessary.

Table 2. Information about Bean Cultivation

Information	Bean variety and Cultivation Period
Name of Crop	Country Bean
Bean Variety	Noldog
Scientific Name	*Lablab purpureus*
Date of Planting	7th November 2017
Spray Date	25th December 2017 to 25th March 2018
Practiced Intercultural Operations	-Earthing -Stalking -Weeding (3 times) and -Supply irrigation water (kept in furrow)
Harvesting Period	Starting on 25th February 2018 and continued up to 25th March 2018

2.4. Preparation of Botanical Pesticides for Spray

Plant parts were dried at room temperature for seven days before grinding or cutting into small pieces. About 100 gm of grinding or cutting leaves, stems, outer shell of fruits and seeds were dissolved in one liter of water. These samples were kept in water for three days. Then solutions were filtered with plastic filter. The filtrated water extract was kept in plastic bottles. The water extracts was kept in refrigerator until use.

2.5. Spraying Method

Botanicals pesticides were sprayed on experimental field twice a week with the help of sprayer. One control treatment of without botanical pesticide was maintained in this experiment where only water was sprayed.

2.6. Pest Attack Counting

The pest attack was monitored every day and the damages were counted every 3-day in a week. The number of plants attacked, leaves attacked and the number of leaves perforation was also recorded.

2.7. Data Collection from the Experimental Bean Field

The following data were collected from experimental bean field:

- Plants length (cm)
- Total leaves
- Number of leaves attacked by insects

- Number of perforation
- Aphid affected plant's length (cm)
- Total number of branches
- Number of total flowering branches
- Bean productions (number & weight)

2.8. Statistical Analysis of Data

The observed values were statistically analyzed by RCBD. Mean values were adjusted by one way ANOVA and the significant leaves were tested by Duncan's Multiple Range Test (Duncan, 1951) ($P < 0.05$) using standard software.

3. Result

3.1. Effect of Botanical Pesticides against Pest Attack on Country Bean Leaves

From this study, it is found that insect attacks on country bean leaves decreased significantly ($P < 0.05$) with the applications of botanical pesticides which protect country bean leaves from insect.

A less number of insect attacks was found on bean leaves in the treatment of Holud leaves (2.000±0c) and Patabahar (2.000±0c), whereas a high number of insect attacks were found in Bandorlathi treatment (3.667±0.101a) and Gada leaves treatment (3.667±0.1005a) and in control treatment (2.333±0.101bc). The extract of Lemon outer shell treatment (2.667±0.1005abc) showed moderate country bean leaves protection against pests (Figure1).

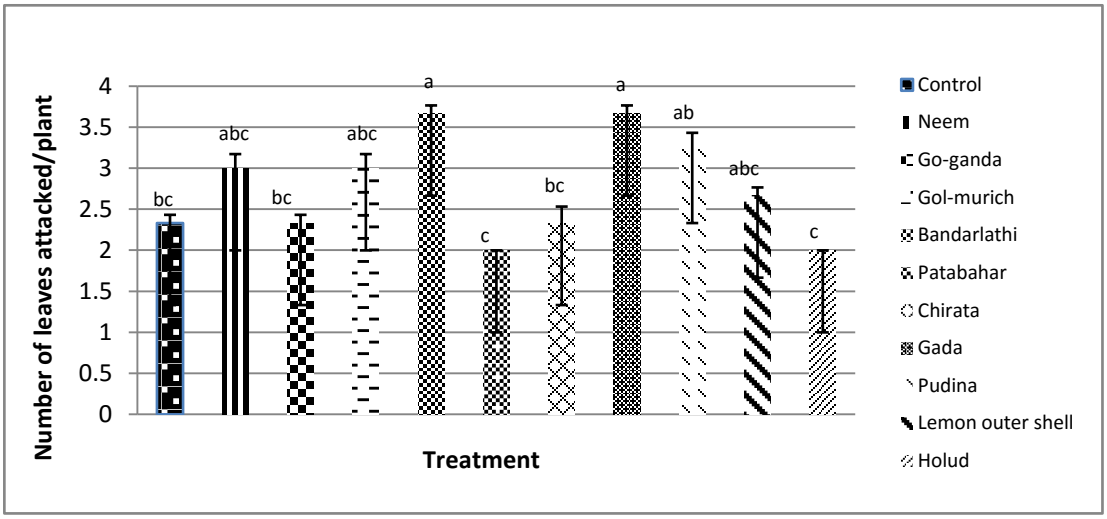

Figure 1. Effect of botanical pesticides against pest attack on country bean leaves

3.2. Effect of Botanical Pesticides against Country Bean Leaves Perforation

Leaves perforation was regularly monitored. This study found significant effect of botanicals on the reduction of leaves perforation of bean leaves. Holud leaves treatment (2.333±0.101d) showed best performance against country bean leaves perforation caused by pests. The extract of Go-ganda (4.333±0.266cd) and Chirata (4.333±0.201cd) showed moderate country bean leaves perforation. Whereas a high number of country bean leaves attacked by insect/pest were found in control treatment (16.333±1.159a).The Holud leaves treatment kept about 7 times better performance than that of control treatment. The study also found significant effect of other studied botanicals against leaves perforation of country bean leaves (Figure 2).

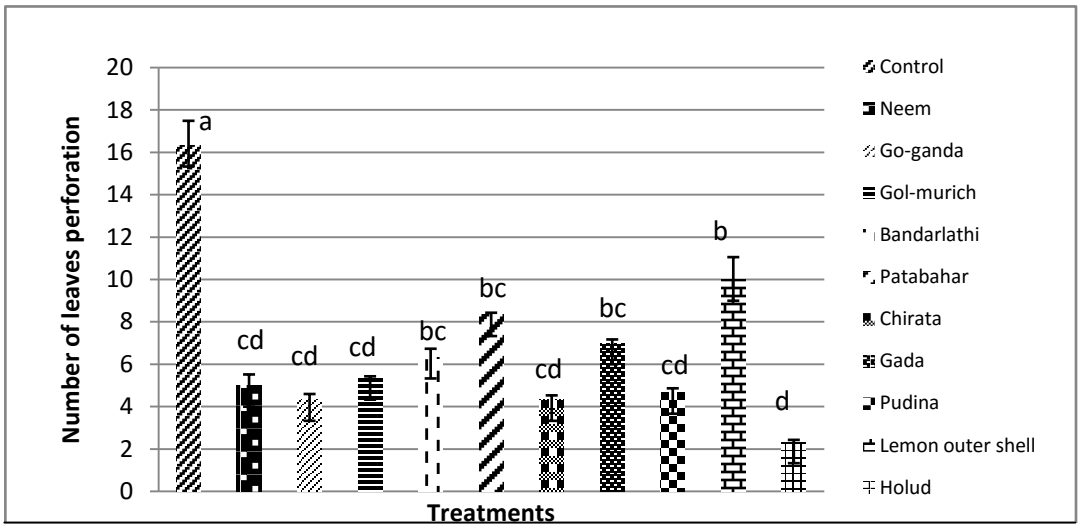

Figure 2. Effect of botanical pesticides against country bean leaves perforation

3.3. Effect of Botanical Pesticides on Country Bean Plant Growth

The study also minutely investigated the plant height of bean, which are significantly differed among the botanicals and control treatments. The mean number of plant height was significant ($P < 0.05$). The highest plant was observed in the Chirata treatment (333.587±5.125a), whereas lowest bean plant was observed in the Control treatment (223.520±0.442b) (Figure 3).

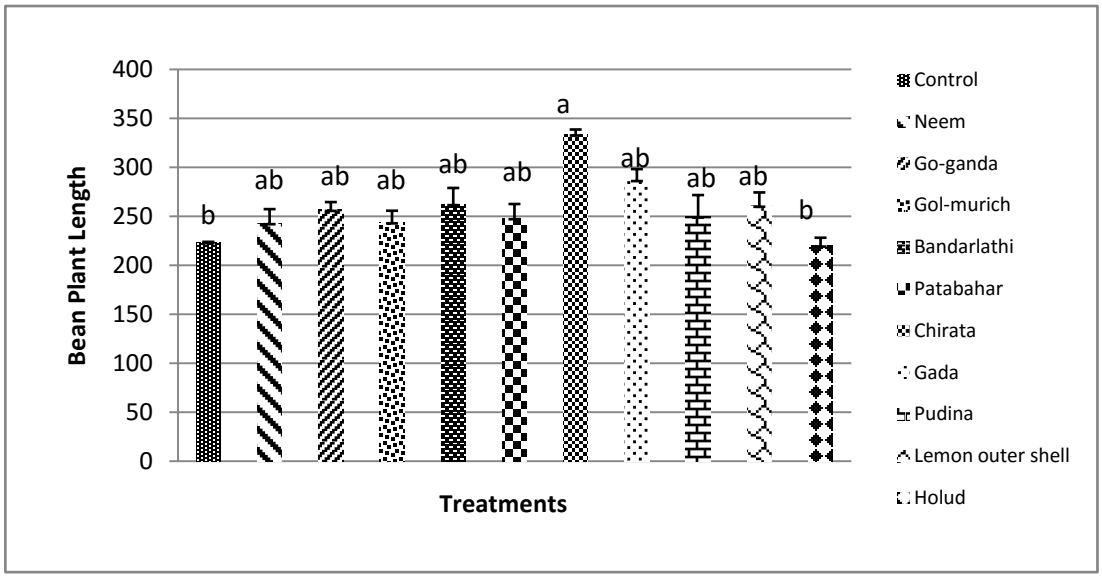

Figure 3. Botanical pesticides effect on country bean plant growth

3.4. Effect of Botanical Pesticides against Aphid Attack on Country Bean Plant

Aphid attacks on bean plant/stem decreased significantly ($P < 0.05$) with the application of botanical pesticides. In this study, a less number of aphid attacks on bean plants was found in the Lemon outer shell treatment (0.212±0.064b), whereas a high number of aphids were found in Go-ganda treatment (81.280±22.251a). The application of Patabahar extracts (0.423±0.064b) also showed good protection of bean plant from aphid (Figure 4).

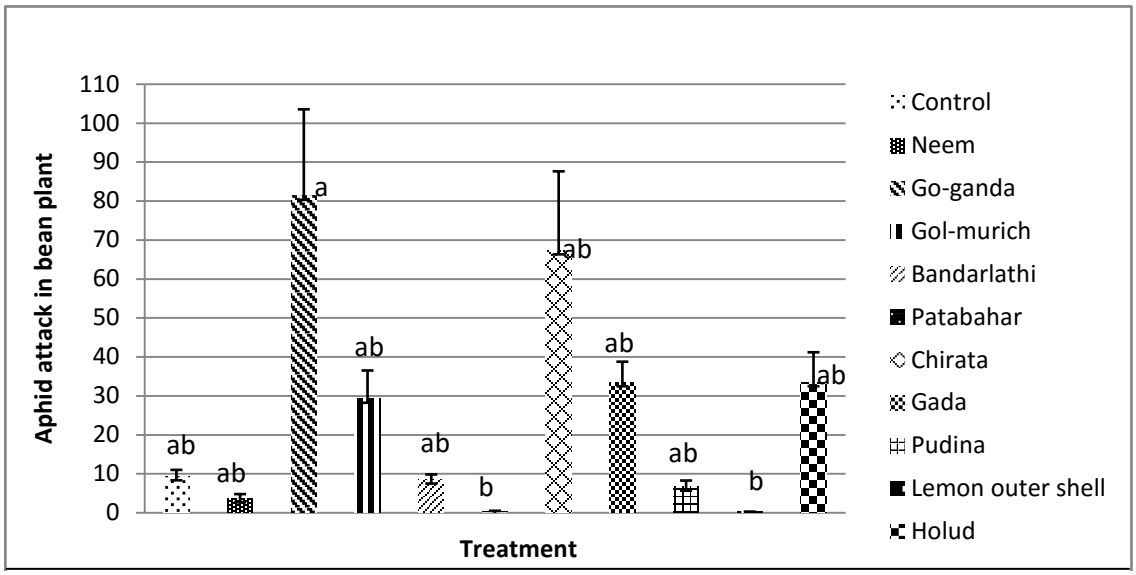

Figure 4. Effect of botanical pesticides against aphid attack on country bean plant

3.5. Effect of Botanical Pesticides on Country Bean Leaves Growth

The study investigated the total number of leaves per plant of bean, which was significantly differed among the botanicals and control treatment. The mean number of leaves per plant was significant ($P < 0.05$). The highest number of leaves per plant was observed in Chirata treatment (26.667±1.283a) while the least number of leaves was in Holud Leaves extract (4.333±0.704d) (Figure 5).

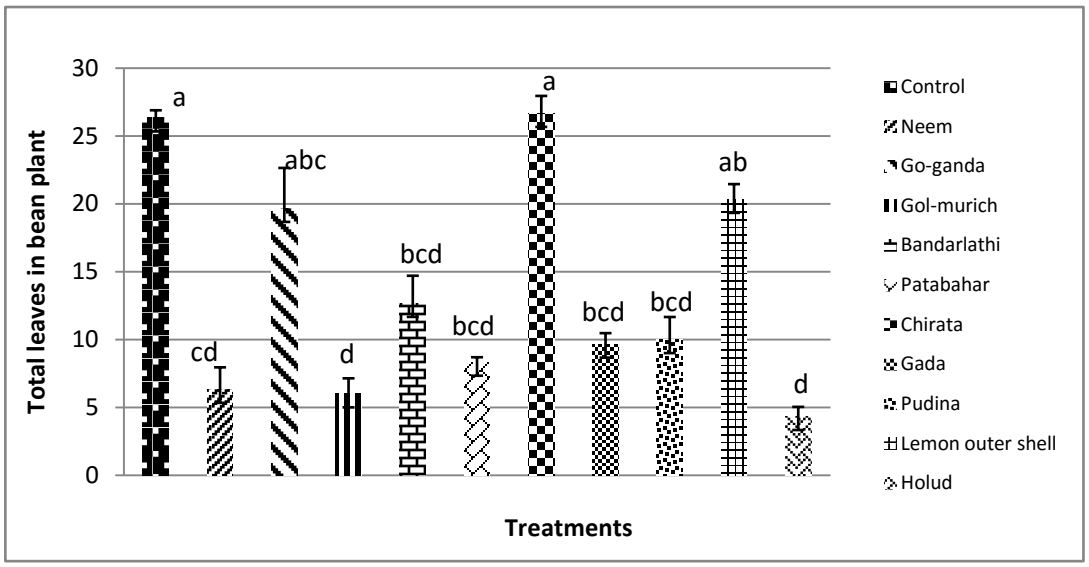

Figure 5. Effect of botanical pesticides on country bean leaves growth

3.6. Effect of Botanical Pesticides on Country Bean Production

The study investigated the bean production, which was significantly differed among the botanicals and control treatment. From the bean production result, it was very clear that among the tested botanicals, Chirata treatment (155.000±12.138a) produced a highest production of bean, whereas a lowest production of bean was observed in the treatment of Gol-murich (30.667±5.586c) (Figure 6).

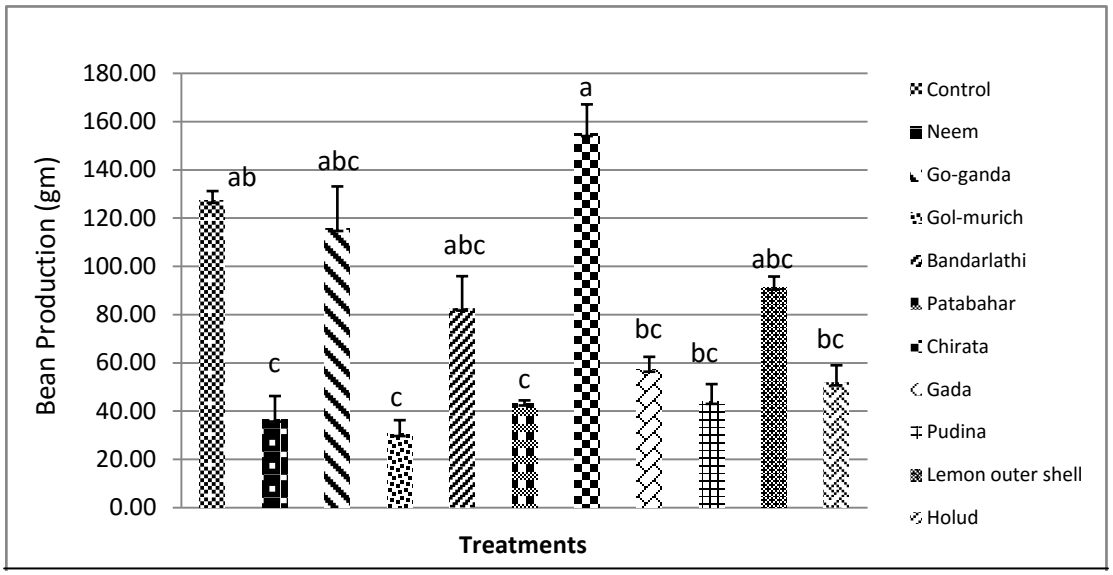

Figure 6. Effect of botanical pesticides on country bean production

4. Discussion

From the result, it is very clear that bean production was significantly differed among the botanicals compare with control treatment. Vegetable cultivation in Bangladesh provides an ample employment opportunity for men and women folk of the disadvantaged groups. But the yield is quite low since the insect pest cause 30- 40% losses in general and even 100% losses if no control measure is applied (Rahman, 2005). Botanical products can be easily and cheaply collected in rural area of Bangladesh, have been found promising and useful for pest control (Roy *et al*., 2005). Aqueous leaf extracts of Neem in combination (mixtures) with leaf extracts of other plant species exhibited various levels of reduction of pod borers and pod sucking bugs numbers and offered various degrees of protection to cowpea plants compared with *Eucalyptus* based extract formulations (Oparaeke *et al*., 2005). These observations are also similar with the findings of this study.

Results in the present study found that different botanical extracts showed significant effects on number of bean leaves attacked by insects, number of bean leaves perforation, total number of leaves per plant of bean, plant height, aphid attacked and number of insects as well as bean production (gm/plant). The most commonly used method in Bangladesh is the application of insecticides (Karim, 1994), but due to the unconscious use of synthetic insecticide development of insect resistance to insecticides, induction of resurgence to target pests, outbreak of secondary pests and undesirable effect on non target organisms as well as serious environment pollution is occurred.

Botanical Pesticides (BPs) are naturally occurring chemical compounds extracted or derived from plants to manage field and storage crop pests (Sola *et al*., 2014). Botanical extracts induce insecticidal activity, repellence to pests, antifeedant effects and insect growth regulation, toxicity to nematodes, mites and other pests, as well as antiviral and antibacterial properties against pathogens (Prakash and Rao, 1997). These results were in agreement with the current observation.

This study detected the significant effect of botanicals on leaves perforation of bean leaves. The Holud leaves (*Curcuma longa)* treatment showed best performance against bean leaves perforation caused by pests, whereas a high number of bean leaves attacked by insect were found in the control treatment. The Holud leaves treatment kept better performance than that of control treatment. The study also observed significant effect of other studied botanicals against leaves perforation of bean leaves. Mwanauta *et al.*, 2015 reported that the use of agronomic, biological and botanical practices to be a promising strategy in controlling legume pests in the field.

In this study, a less number of aphid attacks on bean plants was observed in the Lemon outer shell treatment (0.212±0.064b), whereas a high number of aphids were found in the Go-ganda treatment (81.280±22.251a).The Lemon outer shell (*Citrus aurantifolia*) treatment kept about 43.92 times better performance than that of control treatment. The application of Patabahar (*Acalypha welkesiana*) extracts (0.423±0.064b) also showed good protection of bean plant from aphid.The insecticidal property of botanical extract has long been known and well documents against various insect pests including aphids (Pedigo, 2002). Saikia *et al*., (2000) reported that leaf (10-50%) and seed kernel (5%) extracts of neem caused effect of bean aphid. This result was in agreement with the observation of Bahar *et al*., 2007. Bean aphid is devastating pest of faba bean (*Vicia faba*) causing great yield loss. Chemical pesticides were used to control, it have negative effect on others useful organisms as well as human health. Alternative of chemical pesticides, several plant leaves extract were used against bean aphids (Subedi *et al.,* 2018). To use non-chemical (botanical pesticide) means to remove insects; and when using pesticides, select the one which is least toxic, most effective, most pest specific and has the least potential impact on the environment (Sarwar, 2015). Jute seed is very effective to control black bean aphid. The 10% dose of jute seed caused 98.33% mortality of bean aphid within 48 hours (Sultana, 2015). These observations are also similar with the findings of this study.

This study found significant effect of botanicals in respect of total number of leaves per bean plant. A less number of insect attacks was found on bean leaves in the treatment of Holud leaves (2.000±0c) whereas a high number of insect attacks were found in Bandorlathi (*Cassia fistula)* treatment (3.667±0.101a) and Gada leaves (*Tagetes erecta)* treatment (3.667±0.10a05) and in control treatment (2.333±0.101bc). The extract of Lemon outer shell (*Citrus aurantifolia*) treatment (2.667±0.1005abc) showed moderate country bean leaves protection against pests. The Holud leaves (*Curcuma longa)* treatment kept about 1.16 times better performance than that of control treatment. The study examined the effectiveness of extract from three plant species namely *Azaradichta indica, Annona squamosa* and *Tephrosia vogellii* in the control of aphid and pod borer of cowpea. The study as reaffirmed the efficiency of these morphological part of the plant extracts used as substitutes of synthetic insecticides **(**Kolo and Adamu, 2016). Botanical Pesticides (BPs) have been used as alternative to synthetic pesticides in agricultural systems worldwide. The BPs are believed to be safe to the environment and are used in pest control to avoid pesticidal pollution, which is a universal problem (Karani *et al*., 2017).These observations are also similar with the findings of this study.

5. Conclusion

Out of ten botanical pesticides, Holud leaves (*Curcuma longa)* and Lemon outer shell (*Citrus aurantifolia*) extracts showed good results for aphid control in bean field. The extract of Lemon outer shell ensured the less number of bean leaves attacked by insects/pests, less number of leaves perforation, less number of aphid attack and the highest plant height of bean as well as best bean production. The present study found that plant extracts not created any bad effect in bean field.

These plant extracts can be used instead of synthetic pesticides to avoid excessive use of chemicals for the eco-friendly aphid management. Bangladeshi farmers should avoid toxic synthetic pesticides and use botanical pesticides as water extract of Lemon outer shell in bean field.

Acknowledgement

This study was conducted under the financial assistance of National Science and Technology (NST) fellowship awarded for the year 2017-18. [Grant number-39.00.0000.012.02.009.17-474]. Mphil 1st year, Serial no.17.

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Water Stress Regulates Nutrient Availability and Uptake by Rice Plant in Two Paddy Rice Soils

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Abstract

Nutrient availability varies in paddy rice soil for both aerobic and anaerobic management. A study was undertaken to quantify nutrient availability and uptake by rice plant under water stress condition. Available nutrients of the soils showed considerable variations as a result of water stress at different growth stages of rice compared with control treatment. The effect was, however, found irregular among the nutrients in each of the soil studied. Some nutrients resulted variable response to water stress and hence, no regular trend was obtained from the study. However, the response of N and K towards water stress showed a definite trend of increase and P showed a decreasing trend of change. The uptake of nutrients by the rice plants was severely decreased as a result of water stress because of the reduction in straw yield in both the soils under study.

Keywords: Water stress, Rice, Nutrient Concentration, Uptake and Growth stages

1. Introduction

Rice is the only major food crop capable of growing in flooded soils. Flooding brings about a series of physical, chemical and biological changes that provide a complete different set of soil-plant relationships from those observed in case of arable crops. Plants take up the major part of essential elements from soil solution. Nutrient supply to the roots is governed by nutrient concentrations in the soil solution, nature of the nutrients, soil moisture status and plant's absorption capacity. It is a dynamic series of processes in which nutrients must be continually replenished in soil solution from the soil solid phase and transported to roots as uptake proceeds. Freshwater will be less available and irrigated rice will suffer from some degree of water scarcity (Tuong *et al*., 2005). In many Asian countries, per capita water availability declined by 40-60% in between 1955 and 1990, and expected to decline further by 15-54% in the next 35 years (Gleick, 1993). Water demand for agricultural production is becoming increasingly scarce (Rijsberman, 2006). Decreasing water availability for agriculture threatens the productivity of the irrigated rice ecosystem, therefore, new strategy must be sought to save water and sustain rice production. Region like Bangladesh has plenty of rainfall but, due to its erratic distribution, crop failure is not uncommon specially in dry winter season. The aim of the investigation was to observe the change in available nutrient contents in soils and their subsequent effect on their uptake by the rice plant in relation to the alteration in soil water regimes. It was hypothesized that nutrient uptake by rice plant will be inhibited due to aerated soil condition.

2. Materials and Methods

A pot experiment was conducted in a net house with Chhiata and Dhamrai series soils. The rice variety BR-11 was used as a testing plant. The major characteristics of the soils are shown in Table1. Soil samples collected from the field were air-dried, ground, passed through 2 mm sieve and uniformly mixed. A five kilogram of soil was placed in each of the 15 pots for both soils. Fertilizer was added in each pot @ 100 Kg N, 20 Kg P, 35 Kg K, 12 Kg S and 1 Kg Zn per hectare for both the soils according to BARC recommended guide (BARC, 2012). Nitrogen was added in three split doses (basal dose, 40 DAT and 75 DAT). Five treatments were included in the experiment with three replication and the treatments were i) control (continuous submergence), ii) water stress at seedling establishment, iii) water stress at tillering stage, iv) water stress at panicle initiation stage and v) alternate wetting and drying cycle from seedling establishment to flowering stage (repeated 5 times).

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Table 1. Important properties of Chhiata and Dhamrai series soils

Soils	Texture	Sand (%)	Silt (%)	Clay (%)	pH	CEC (me/100g soil)	Organic matter (%)	N (%)	P (%)	K (%)	S (%)
Chhiata	Silty clay	4.7	47.9	47.4	5.3	20	1.90	0.126	0.015	0.82	0.017
Dhamrai	Silty clay	5.9	48.0	46.1	6.2	13	3.61	0.173	0.150	0.20	0.098

After puddling, two healthy seedlings were transplanted in each hill and each pot contained 3 such hills in a triangular fashion. Water was maintained throughout the growing season according to the treatments except the grain maturing stage. In all the treatments, except control, plants were grown in submerged conditions all the time excepting when stress was imposed. In order to create moisture stress in a given pot, the soil was allowed to dry until the appearance of the first sign of wilting. Then water was again added and the plants were allowed to grow under submerged condition for rest of the period. Only in case of the alternate wetting and drying treatment the wetting-drying cycle was repeated 5 times after seedling establishment to flowering. The soils under this treatment were kept continuously submerged before and after the above-mentioned period.

Rice plant was cutted from the ground level and soil samples were collected at each of the growth stages after the period of water stress. No plant samples were taken at the time of seedling establishment. Plants were dried at 70^0 C for 72 hours and the dry weight of the samples was recorded. Samples were then processed and stored for chemical analysis. Soil samples were collected from the pots at the corresponding time of plant sampling. Available N was determined immediately after sampling. A portion of each sample was air-dried, ground and passed through 2 mm sieve and stored for chemical analysis.

Available soil nutrients were extracted by following the procedures mentioned in Table 2. Available soil N (KCl extractable) and total plant N were determined by Micro-Kjeldahl's method as described by Jackson (1973). Plants were digested with HNO_3-$HClO_4$ acid mixture (2:1 ratio) as outlined by Piper (1966) to determine total P, K, Ca, Mg and S. Elements both in soil and plant were quantified according to the following standard methods. Phosphorus was determined by ascorbic acid blue colour method (Murphy and Riley, 1962). Potassium was measured by Flame analyzer (Jencons). Sulfur was quantified turbidimetrically (Hunt, 1980). Calcium and Mg were determined by EDTA titrimetric method (Page *et al*., 1982).

Table 2. Procedure to extract soil available nutrients

Nutrients	Extractants	Soil to extractant ratio	Soil taken (g)	References
N	1 N KCl	1:10	10	Hesse, 1994.
P	0.5 M $NaHCO_3$	1:20	5	Olsen *et al*., 1954.
S	500 ppm P solution	1:5	10	Fox *et al*., 1964.
K, Ca, Mg	1 N NH_4OAc at pH 7	1:10	10	Schollenberger and Simon, 1945.

3. Result and Discussion

3.1. Available Nutrients of the Soils

Available nutrients of both Chhiata and Dhamrai series soils are presented in Table-3 and the results are briefly discussed as follows.

3.1.1. Nitrogen

Water stress increased the availability of soil N (Table 3). Water stress concentrates the ammonium form of soil N and hence, soils those were under stress produced higher values. When these dried soils were re-watered available soil N again became diluted and therefore, gave lower values. Under reduced soil condition NH_4^+ is the predominant form of available N and this ion is subjected to fixation by 2:1 clay minerals. Water stress affects this type of fixation by influencing their swelling and shrinkage (Tisdale *et al*., 1985).

3.1.2. Phosphorus

Availability of P was almost double in Dhamrai soil compare to Chhiata soil irrespective of growth stages. This could be due to the reason that Chhiata soil is more acidic than Dhamrai soil. Chhiata soil probably showed lower P availability because of P fixation in its colloidal fraction, which is dominated by the presence of oxides of Fe and Al. Moreover, stress treatments were found ineffective in this soil to increase P availability. Contrary to this, Dhamrai soil responded well in relation with P release as a result of stress treatments probably due to its different nature of colloidal fraction. Jahan *et al* (2013) stated P availability in flooded soil than in upland soil due to more

Table 3. Contents of available nutrients (µg/g) of Chhiata and Dhamrai series soils at different growth stages of rice

Treatments	Growth stages							
	Seedling		Tillering		Flowering		Harvest	
	Chhiata	Dhamrai	Chhiata	Dhamrai	Chhiata	Dhamrai	Chhiata	Dhamrai
	Nitrogen							
Control	87.29 b	35.51 b	25.73 c	20.83 b	53.02 b	32.24 b	34.10 a	33.64 b
Stress at seedling	113.05 a	84.93 a	18.06 c	26.12 b	56.84 b	20.30 b	32.31 a	26.80 b
Stress at tillering	--	--	71.53 b	70.23 a	68.07 b	59.54 a	29.64 a	53.29 a
Stress at flowering	--	--	--	--	36.12 b	22.84 b	28.42 a	28.83 b
Alternate wetting-drying	--	--	156.18 a	18.06 b	254.60 a	20.30 b	33.12 a	26.80 b
	Phosphorus							
Control	27.50 a	46.03 a	19.00 a	35.83 a	9.17 a	22.50 a	10.33 a	14.73 b
Stress at seedling	24.58 a	49.17 a	18.75 a	46.25 a	9.58 a	22.33 a	9.67 a	32.67 a
Stress at tillering	--	--	21.92 a	40.00 a	10.00 a	14.58 b	8.93 a	13.17 b
Stress at flowering	--	--	--	--	13.17 a	13.75 b	7.67 a	10.40 b
Alternate wetting-drying	--	--	17.50 a	32.67 a	10.83 a	16.25 b	9.32 a	12.37 b
	Potassium							
Control	202.50 a	61.24 b	156.33 b	44.17 c	96.50 c	38.50 b	74.33 a	31.33 b
Stress at seedling	201.17 a	85.00 a	190.17 a	74.50 b	143.33 b	45.33 b	72.00 a	30.33 b
Stress at tillering	--	--	196.50 a	54.50 c	149.67 b	44.33 b	66.50 a	31.00 b
Stress at flowering	--	--	--	--	145.67 b	46.33 b	76.67 a	37.00 a
Alternate wetting-drying	--	--	196.83 a	89.67 a	180.00 a	59.83 a	72.83 a	36.17 a
	Sulfur							
Control	6.18 a	14.20 a	15.42 a	39.38 a	6.67 b	6.29 b	21.02 a	24.76 a
Stress at seedling	2.93 b	5.57 b	16.98 a	23.50 b	5.09 b	4.83 b	12.98 b	17.33 b
Stress at tillering	--	--	14.17 a	15.90 c	10.63 a	24.17 a	5.38 c	23.71 a
Stress at flowering	--	--	--	--	6.67 b	4.63 b	6.31 c	6.75 d
Alternate wetting-drying	--	--	1.73 b	1.70 d	6.25 b	4.46 b	11.43 b	12.38 c
	Calcium							
Control	2632 a	2260 a	3472 a	3187 b	3543 a	3289 a	3415 a	3053 a
Stress at seedling	2643 a	2374 a	3360 a	3288 b	3397 a	3236 a	3036 a	3045 a
Stress at tillering	--	--	3415 a	3912 a	3480 a	2551 b	3601 a	2433 b
Stress at flowering	--	--	--	--	3584 a	2600 b	3643 a	2959 a
Alternate wetting-drying	--	--	3128 b	2531 c	3248 a	2501 b	3191 a	2307 b
	Magnesium							
Control	1042 a	619 a	866 a	473 a	1086 a	583 b	953 b	482 b
Stress at seedling	742 b	506 b	1007 a	538 a	1108 a	699 a	1120 a	538 b
Stress at tillering	--	--	989 a	381 a	740 b	470 c	707 c	431 b
Stress at flowering	--	--	--	--	1129 a	448 c	886 b	751 a
Alternate wetting-drying	--	--	918 a	381 a	740 b	381 c	853 b	425 b

Means having the same letter (s) are statistically similar by DMRT at 5% level of significance

available forms of P in flooded soils

3.1.3. Potassium

Available K content of a soil is directly related with the type and content of clay minerals. Chhiata soil contained 2.5 to 3 times more available K than that of Dhamrai soil irrespective of the growth stages (Table 3). Moreover, water stress increased the K availability in both the soils and these pots produced higher values as water shortage concentrates the K^+ ions in soil. These results were consistent with Jahan *et al*. (2013). Regardless of that native Dhamrai soil has 4 time less K content than Chhiata soil (Table 1).

3.1.4. Sulfur

Water stress was found as an important factor to regulate the availability of S in soil. Quite significant differences in available S contents were found among different treatments in both the soils under investigation (Table 3). These differences could be produced through the influence of water stress on the rate of mineralization, activity of sulfatases, forms of S released from organic matter and the movement of SO_4^{2-} in soil (Beiderbeck, 1978).

3.1.5. Calcium

Effects of water stress on the availability of Ca were found significant in both the soils. Except in Dhamrai soil at flowering, stress given at varying growth stages in these soils, concentrates the available Ca content. Continuous flooding a paddy soil provided the rice plants a constant adequate supply of Ca throughout the growing season. Exceptionally high values of available Ca were found in both the soils at all stages of measurement irrespective of treatment variations. It was beyond the expectation, however, BRRI (1989) reported a level of available Ca of 2010 µg/g soil in Savar Bazar series, which is situated in the same catena where Dhamrai series is located.

3.1.6. Magnesium

An examination of the data on soil Mg contents revealed that water stress had significant influence on the availability of Mg in soil. Magnesium availability to plants under water stress was declined in some cases, but was sufficiently above the requirements of the rice plants. Like the values of available Ca, Mg contents of both the soils were measured exceptionally high. There may be possibility that both soils are not able to make Ca-P and Mg-P complexes due to less P content in the initial soil.

3.2. Nutrient Uptake by the Rice Plants

The values of nutrient uptake by rice plants during the experiment are presented in Table 4.

3.2.1. Nitrogen

Nitrogen uptake by rice plant increased with the progress of its growth up to flowering stage and decreased thereafter in control pots. However, plants experienced water stress at any stages of growth showed significantly lower uptake of N due to the reduction in growth. Therefore, water stress was found very effective in influencing the N uptake by rice and delayed their maturity. Several authors (Hassan *et al*., 1996; Hossain *et al*., 1986 and Choudhury *et al*., 1991) earlier reported about the decrease in N uptake during the vegetative growth stages of rice. Mannan *et al*., (2012) found N-uptake was lower in the rice plant that affected by water stress especially at the vegetative or at reproductive stages.

3.2.2. Phosphorus

It was evident from the results that water stress retarded P uptake by the rice plants (Table 4). In dry soils, P transport up to rhizosphere is inadequate and hence, plant might not use P efficiently. Rice grown in Dhamrai soil showed higher P uptake over those grown in Chhiata soil. Hossain *et al*. (1986) and Chhillar *et al*. (1991) noticed that P uptake by rice increased markedly with the increase in soil water content. Nahar and Gretzmacher (2002) observed water stress decreased P uptake slightly in tomato plants.

Table 4. Uptake of nutrients (mg/hill) by rice straw in Chhiata and Dhamrai series soils at different growth stages.

Treatments	Growth stages					
	Tillering		Flowering		Harvest	
	Chhiata	Dhamrai	Chhiata	Dhamrai	Chhiata	Dhamrai
	Nitrogen					
Control	187.07 a	208.95 a	658.79 a	361.29 a	385.31 a	340.50 b
Stress at seedling	67.38 b	187.26 a	126.14 b	402.84 a	639.35 a	664.39 a
Stress at tillering	107.51 b	135.04 a	174.33 b	242.47 b	630.88 a	651.82 a
Stress at flowering	--	--	173.79 b	273.92 b	361.59 a	447.50 b
Alternate wetting-drying	83.07 b	35.13 (b	68.62 b	66.47 c	485.01 a	456.99 b
	Phosphorus					
Control	7.92 a	19.80 a	16.62 a	16.26 b	27.30 a	41.81 b
Stress at seedling	2.94 b	13.67 a	4.30 b	19.47 a	33.78 a	53.80 a
Stress at tillering	4.99 b	15.36 a	6.59 b	8.88 c	26.04 a	60.48 a
Stress at flowering	--	--	5.19 b	14.58 b	18.44 a	23.53 c
Alternate wetting-drying	3.11 b	1.12 b	0.97 b	2.74 d	20.94 a	30.27 c
	Potassium					
Control	212.04 a	185.15 a	355.23 a	180.68 b	384.01 b	306.11 a
Stress at seedling	55.45 b	118.81 b	118.74 b	236.39 a	635.09 a	481.50 a
Stress at tillering	101.88 b	110.75 b	134.31 b	113.03 c	448.12 b	337.47 a
Stress at flowering	--	--	133.12 b	186.22 b	425.52 b	354.91 a
Alternate wetting-drying	70.46 b	32.24 c	55.25 c	55.79 d	373.17 b	405.97 a
	Sulfur					
Control	13.88 a	16.82 a	34.93 a	21.56 a	95.04 a	88.77 a
Stress at seedling	3.69 b	8.52 b	9.35 b	24.78 a	64.90 b	84.12 a
Stress at tillering	6.42 b	8.74 b	10.01 b	12.35 c	52.15 b	58.15 b
Stress at flowering	--	--	10.97 b	16.38 b	34.21 c	46.59 b
Alternate wetting-drying	4.98 b	2.39 c	4.14 b	4.00 d	34.98 c	40.06 b
	Calcium					
Control	52.80 a	73.22 a	146.54 a	95.17 b	153.59 b	126.09 c
Stress at seedling	18.92 b	42.44 b	38.19 b	131.38 a	248.56 a	276.23 a
Stress at tillering	28.62 b	42.15 b	40.60 b	65.58 b	183.94 b	161.34 b
Stress at flowering	--	--	50.64 b	81.12 b	130.15 b	189.93 b
Alternate wetting-drying	21.42 b	10.60 c	16.94 c	20.40 c	91.02 c	93.04 d
	Magnesium					
Control	10.80 a	16.84 a	42.20 a	54.64 a	111.11 a	151.17 a
Stress at seedling	2.20 b	9.86 a	14.87 b	65.08 a	130.82 a	145.08 a
Stress at tillering	11.59 a	13.76 a	21.36 b	38.51 a	117.40 a	181.25 a
Stress at flowering	--	--	14.73 b	52.30 a	80.99 a	93.55 b
Alternate wetting-drying	4.82 b	1.44 b	10.05 b	6.04 b	76.19 a	91.53 b

Means having the same letter (s) are statistically similar by DMRT at 5% level of significance

3.2.3. Potassium

Data presented in Table 4 revealed that water stress reduced K uptake by rice plants compared with control treatment, but plants experienced stress at any stage of growth showed higher K uptake over control during harvest. It could be due to the reason that water stress inhibits K translocation by rice plant. The decrease in K uptake by rice plant under stress condition was observed (Hassan *et al.*,1996; Hossain *et al*., 1986).

3.2.4. Sulfur

Results of the experiment clearly showed that water stress imposed to rice plants decreased S uptake significantly. Stress at tillering and flowering treatments gave progressively lesser recovery in S uptake at the time of harvest. Hence, it can be concluded that stress applied at different growth stages of rice plants significantly reduced the S uptake and their recovery at the later stages of growth. This relationship was found in both Chhiata and Dhamrai soils.

3.2.5. Calcium

Uptake pattern of Ca by rice plants in Dhamrai soil was different from that of Chhiata soil. The effect of water stress on Ca uptake values did not show any consistent trend, but plants received stress at the early growth stages recovered in obtaining Ca from soil at the later stages of growth. However, Hassan *et al.* (1996) observed the highest uptake of Ca by rice during maturity stage under submerged condition.

3.2.6. Magnesium

Water stress given both at tillering and flowering stages decreased Mg uptake by the rice plants in most cases. At the time of harvest, however, plants suffered water stress at the early stages of growth showed enhanced Mg uptake and hence, a satisfactory recovery. Hassan *et al.* (1996) reported the highest uptake of Mg by rice at the time of maturity stage under flooded condition.

4. Conclusion

This study demonstrated that nutrient availability was more in Dhamrai soil than Chhiata soil. Findings of the present investigation conclude that variations in nutrient concentration was observed at different growth stages of rice due to water stress for both the soil studied. Nutrient uptake by the rice plant was severely affected due to water stress condition.

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Indigenous Practices for Coping with Flood: An Assessment of the Riparian People Living in the Teesta Floodplain

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Abstract

The present study examines the indigenous knowledge for coping with flood and identifies the role of local people to manage their lives and livelihoods from the severity of extreme flood incidents. Based on household questionnaire survey of 381 samples size, the study explores the traditional knowledge of how to cope with the socio-economic condition in a flooded environment. Hence, the existing study reveals the indigenous practices such as house platform raise, living in machan, dependency on dry food, fuel wood collection, indigenous cooking techniques and starvation has been adopted by the inhabitants of Teesta basin for coping with flood. The study investigated that the community of Teesta floodplain adopted indigenous flood defense techniques to reduce their vulnerability and survive in flood. The study advocates initiating bottom up approach in policy formulation to enhance flood resilience of Teesta riparian community. The study also recommends rather than implement more structural flood defense techniques on the river bank, it is very much crucial to encourage the community people, practice the indigenous knowledge more than before to survive in the flooding condition.

Keywords: Indigenous practice, Coping techniques, Riparian people and Teesta floodplain

1. Introduction

Bangladesh is recognized as a country of flood and natural disasters. Flood is the recurrent natural hazard in Bangladesh and increases vulnerability of people (Paul and Routray, 2010). The people of the country cope with flooding condition through their indigenous knowledge and practices. Indigenous knowledge is the foremost strength of disaster management in Bangladesh (Shafie and Rahman, 2009). Bangladesh is a low lying country with its almost flat topography. About 30% land of Bangladesh is affected by normal flood, 55% and above area is affected by severe floods. (Banglapedia, 2011). Living with flood is a perennial issue in the Teesta floodplain. Geographical locations, heavy monsoon rainfall and numerous rivers with their downstream locations are the main cause of flash flood in the Teesta valley. The intensity and frequency of flood has been increasing due to human intervention in the Teesta basin of northern Bangladesh. Deforestation, heavy rainfall, construction of dam and barrage in the upstream intensifies the flash flood and monsoon flood as well as rise of river bed with siltation process in the Teesta river (Shafie and Rahman, 2009). Flood causes massive damage to the socio-economic conditions of the victim riparian communities. The socio-economic impact of flood is widespread and distressing to the victim (Haque, 1993). The Teesta riparian community faces flood more than one time in a year. The study area is a multi-hazardous zone. Every year it experiences flood, river bank erosion, drought etc. Thus the community achieved local wisdom as well as developed indigenous practices to cope and reduce vulnerability.

Indigenous knowledge helps the riparian community to cope with the extreme flood event in the study area. Indigenous coping strategies reduce vulnerability towards flooding (Paul and Routray, 2011). People attempts to adapt with inundation by way of their previous understanding, believe and thinking regarding flood through their present socio-economic, cultural and environmental condition. Indigenous knowledge is traditional understanding which people gathers from their environment and implement the perceived knowledge in disaster resilience. Indigenous knowledge increases resilience (Hiwasaki *et al.*, 2014, McEwen *et al.*, 2016, Dutta *et al.*, 2017). Traditional knowledge gives assistance to people for reduction of risk in flooding conditions. Flood prediction through hydro climatic observation, makes local people to take necessary footsteps for their shelter, food and health management in pre, during and post flood occurrences. Indigenous knowledge and practices help community people to forecast weather and thus take necessary steps to improve food security (Ringo *et al.*, 2016).

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A number of studies have been conducted for review of literature regarding indigenous coping knowledge and practices. Haque (1993) evaluated the prevention and mitigation measures of flood in Bangladesh. Women's coping strategies for flood have been investigated by Sheheli and Khan (2015). Paul and Routray (2001), Islam (2007), Hakim (2012), Dutta *et al.* (2017) also explained flood impact minimization and disaster preparedness through indigenous knowledge. Chandra (2008), Fletcher *et al.* (2013), Hiwasaki *et al.* (2014), Danso and Addo (2017), Ngwese *et al.* (2018), Bwambale *et al.* (2018) investigated indigenous knowledge and survival techniques in different environmental settings and gave emphasis on combining the knowledge with scientific knowledge. Despite a lot of studies on coping with flood by indigenous knowledge there is a lacking of studies on indigenous practice of flood and community actions for flood defense. Therefore, the present study has taken an attempt to identify the indigenous practice for flood resistance in the Teesta riparian communities.

The present study tries to investigate the perceived knowledge and experiences of the Teesta floodplain community to survive in the hardship of flooding situations. The study area lies beneath the bank of Teesta river. Over bank spilling in the floodplain causes damage to life, property and destroys livelihood of community people. Therefore, it is highly significant to investigate the peoples coping capacity on behalf of flood fighting and identify their indigenous practices for resilience. The main objective of the study is to explore the traditional practices to cope with recurrent floods in the study area. The study also demonstrates the community resilience to flood with reference to community based flood management initiatives.

2. Materials and Methods

Different tools and techniques have been adopted to examine the indigenous knowledge about floods in the Teesta floodplain.

2.1. Selection of Study Area and Sample Size

The study has been conducted in the five districts (Nilphamari, Lalmonirhat, Rangpur, Kurigramand Gaibandha) of Teesta floodplain in the northern Bangladesh. Seven upazilas from the five districts (Dimla and Jaldhaka from Nilphamari, Lalmonirhat sadar and Hatibandha from Lalmonoirhat, Gangachara from Rangpur, Rajarhat from Kurigram and Sundarganj from Gaibandha have been selected randomly (Figure 1). Then the study unions from each upazila: Dimla (Purba chatnai union), Jaldhaka (Saulmari union), Hatibandha (Sindurna union), Lalmonirhat sadar (Khuniagachh union), Gangachara (Kolkonda union), Rajarhat (Bidyananda union) and Sundarganj (Belka union) have been selected randomly as study area to conduct household survey and gather preliminary information. Simple random sampling technique has been used to select household to collect information from respondents. Data of household population size of the unions were collected from Bangladesh Bureau of Statistics (BBS), 2011. The study followed multi-stage sampling technique to conduct the research.

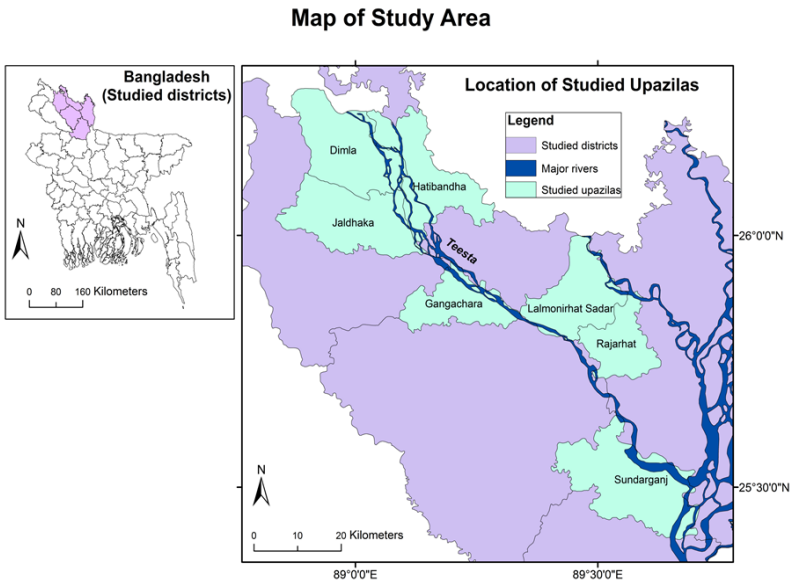

Figure 1. Map of study area.

2.2. Data Collection, Analysis and Interpretation

Both qualitative and quantitative data have been collected through field survey. A well-structured questionnaire has been used to collect data from the study area. Moreover observation, case studies and FGD's were conducted to perceive information about believes, thoughts, practices and knowledge of the riparian people. Primary and secondary data have been used in the present study. Books, journal articles, reports and thesis papers were investigated to collect data and information. The collected data have been processed, and analyzed through SPSS software. Data representation has been carried out through bar diagram and pie chart with SPSS and Microsoft Excel. The map of the study area has been prepared with Arc GIS software.

3. Results and Discussion

The community of Teesta river basin implements different indigenous practices for their survival due to recurrent flood occurrences. They use various precautionary techniques for coping with flood which includes early crop cutting, house platform raise, keep the livestock in high land, send family member in relative's house, etc. The people of the study area developed early warning system and implement their indigenous knowledge and practices in shelter, food, health and livelihood management to minimize their vulnerability against flood. The Teesta riparian community takes different coping steps according to the impact and severity of flood. Table 1 shows the FGD results regarding flood impacts and coping strategies.

Table 1. Flood impacts and coping strategies of Teesta riparian community

Flood impacts	Indigenous coping strategies
Death of poultry and livestock	Keep poultry and livestock in safe and high place.
Washing away of poultry	Eat and sell poultry.
Lack of fodder	Give animals to rice from own meal and starch of boiled rice.
Inundation of shelter	Shift in embankment, school, relative's house and flood shelter.
Land become sandy	Grow nut, pumpkin and pulses in sandy land.
Destruction of transport network	Make vela with bamboo and banana tree for transportation
Unemployment problem	Migration for occupation
Interruption in electricity supply	Use solar energy

Source: Based on FGD, 2017

3.1. Take Precautionary Techniques through Warning

Intensity of rainfall, color of cloud, wind direction and water flow analysis by the local elderly helps a community for early warning of flood which prompts the community for flood preparedness (Chandra, 2008). The study area is a remote rural region which has lack of easy access of communication. Moreover most of the people are illiterate. But they have achieved hydro-climatic knowledge through sky observation, anticipation of animal behavior and river water observation. When they predict that flood is coming then they disseminate the data among the community which make them to take necessary steps for flood adaptation. The local government also convey important role for flood awareness. Local mosques take part to deliver information of flood to the community people. During field survey it has been noticed that in the study union's, people heard flood warning from announcement from mosque which made them conscious to save their life and property.

3.2. Indigenous Practice for Shelter Management

The shelter of the respondents disrupts in flood. The adaptation strategies in main land adjacent to the river and in the bars (char) are different though the community of main land and the bars get same shock from river morphology change. During flood, when mid channel bar is submerged, the people of the study area tries to take

shelter in top of corrugated iron sheet but in the land in critical flooding condition people take shelter in high land. Poultry and livestock are also kept in top of corrugated iron sheet. If flood water height occurs 1-3 feet and inundation duration is 2-5 days then people tries to live in house but when height of flood water exceeds 3 feet and inundation stays weeks to months the people seek another shelter to survive.

3.2.1. Precaution Technique for Homestead Management

Every year homestead management is very essential issue for the people of the study area. The people of Teesta basin acquired indigenous precaution technique before flood for homestead adaptation. House platform raise (43.2%) is a well excepted precaution technique for homestead management in the study area. The respondents replied about increasing the height of their house platform with own attempt but some of them raised house platform with the help of NGOs. Another effective way of homestead management found in the study area is to make house with corrugated iron sheet (34.8%). The respondents replied about making house with corrugated iron sheet helps them to cope in the flooding condition. Moveable housing materials such as corrugated iron sheet, thatch are less susceptible to flood (Haque, 1991). Moreover it helps to save money for buy house building materials again. Among the respondents 21.9% replied about make house in relatively high land (Figure 2).

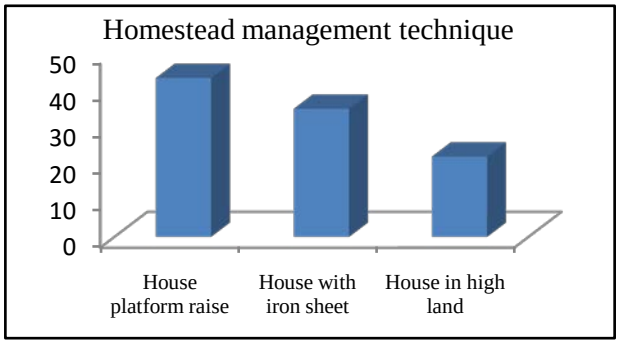

Figure 2. Indigenous precautionary techniques for homestead management

3.2.2. Coping with Own Shelter

During flooding period people of land (locally termed as kaim) took shelter in higher place such as embankment, road, flood shelter and schools. Sometimes the flood victims took shelter in relative's house. A good practice of the respondents regarding shelter is to live in machan (bamboo or wooden platform) during flood. The people who does not get any place in school, flood shelter and relatives house, lives under open sky in road side with their necessary goods. Table 2 designates that the community of Teesta floodplain highly depends on embankments during flood (31.8%). They take shelter on machan (24.4%) and live in school (17.1%) which characterizes the second and third highest percentage. The respondents also seek accommodation in road (12.6%), in relative's house (5.2%), in flood shelter (5%) and live in top of corrugated iron sheet (3.9%) for flood.

Table 2. Coping with own Shelter

Adaptation with own shelter	Frequency	Percent
Live in machan	93	24.4
Live in embankments	121	31.8
Live in school	65	17.1
Live in relatives house	20	5.2
Live in flood shelter	19	5.0
Live in top of corrugated iron sheet	15	3.9
Live in road	48	12.6
Total	381	100.0

Source: Household questionnaire survey, 2017

3.2.3. Coping with Shelter of Livestock

During flood the vulnerability of livestock increases for shelter destruction. Sometimes livestock washes away with flood water and dies in the tremendous whirl of river water. Most of the people keep livestock in a tiny room made with bamboo and straw which damages in flood. Therefore, the community people keep the livestock in relatively high and safe land to cope with inundation. Embankments are used as livestock shelter with polythene shed in the flooding condition. Natural highlands are also used as livestock shelter of the flood victims. In the char lands people along with their livestock and poultry take shelter in top of corrugated iron sheet. It is found from the study that 30.4% respondents keep livestock in embankment which is the highest adaptive measure for livestock shelter during flood. According to the study 20.7% respondents keep livestock in machan, 14.4% respondents keep in road to protect the livestock from flood water. School (11.3%), high land (10.5%) and flood shelters (5.2%) also play important role for cattle shelter in the study area to cope with flood.

3.3. Indigenous Practice for Food Management

Indigenous practice reduces vulnerability towards food management during flood. Precautionary technique adopted by the local community such as dry food preservation, fuel collection and preservation, making portable oven and indigenous food making before flood enforce the affected people fight against flood. Adoption of indigenous cooking technique, changing of eating habit and starvation help the people of the study area to combat with flood.

3.3.1 Fuel Collection and Preservation

Community resilience towards climate change adaptation regarding fuel preservation occupies use of machan, store dried cow dung, keep fuel under tin shed and stacking dried leaves for cooking (Dutta *et al*., 2017).Fuel collection and preservation is the best practice among the Teesta riparian community to cope with cooking during flood. The people of the study area collect fuel before monsoon season and preserve the collected fuel wood in machan (57.3%). When homestead inundates in flood water the respondents keep their fuel in machan which has been built in the high land and shed the fuel with polythene. Another remarkable coping technique of the community people regarding fuel in the flooding condition is to make fuel with cowdung (42.7%). Locally cowdung fuel is known as gushi. The women of the Teesta basin make gushi in two ways. Either they make gushi with cowdung cake dried in the sun or apply the cowdung on a stick and dry for preservation. The fuel collection and preservation technique also helps the people of the study area to reduce their expenditure.

3.3.2 Coping with Food during Flood

In flooding condition the people of the study area takes different initiatives for food consumption. To cope with flood hazard they either choose changing of eating habit or starvation. Respondents also argued that sometimes relatives provide food (8.9%) during flood occurrences. Among the respondents 51.1% replied that they change their eating habit. Changing of eating habit includes reduce number of meal, reduce food item, eat dry food item etc. A large portion of respondents (39.8%) took starvation as an adaptive measure during flood (Table 3). Among the studied unions changing of eating habit has been depicted highest (57.8%) at Belka union and starvation has been identified highest (48.6%) at Khuniagacch union. Figure 3 depicts the coping strategies of food during flood in the studied unions.

Table 3. Coping strategies for food during flood in the studied unions.

Union	Adaptation during flood (food)			Total
	Eating habit change	Relatives provide food	Starvation	
Purbachatnai	13 (38.2)	3 (8.8)	18(52.9)	34 (8.9)
Saulmari	35 (54.6)	6 (9.3)	23 (35.9)	64 (16.7)
Bidyananda	22 (53.6)	3 (7.3)	16 (39.0)	41 (10.7)
Khuniagacch	32(44.4)	5 (6.9)	35 (48.6)	72 (18.8)
Kolkonda	33 (51.5)	4(6.25)	27(42.1)	64 (16.7)
Sindurna	16 (53.3)	4(13.3)	10(33.3)	30 (7.8)
Belka	44(57.8)	9(11.8)	23(30.2)	76 (19.9)
Total	195 (51.1)	34 (8.9)	152(39.8)	381 (100)

Source: Household questionnaire survey, 2017. Note: value within bracket expresses percentage

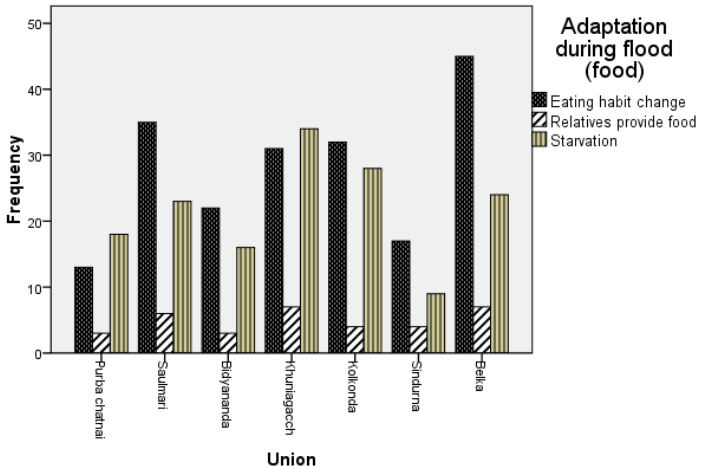

Figure 3. Coping strategies of food during flood in the studied unions.

3.3.3. Dry Food Preservation and Coping with Dry Food Items

Food preservation through drying and smoking increased food security during flood (Ringo *et al.*, 2016). Dry food item fulfills the basic requirement of food during flood in the study area. The people either stores or collects relief dry foods to survive in the disastrous situation of flood. During flood it is quiet impossible for the victim people to buy and cook food. Therefore, they try to alleviate hunger with dry food. People of floodplains of Bangladesh store puffed rice and flat rice for survival in the flooding condition (Dewan, 2015). Most of the people (70.6%) of the study area depends upon the traditional rural Bangladeshi dry foods such as chira (husked rice), muri (puffed rice). Among the respondents 16.3%, 8.4% and 4.7% respectively rely on sugar-chapatti, biscuit and bread. Thus the study unveils that the traditional dry food items play significant role for coping with flood in the Teesta floodplain.

3.3.4. Food Insufficiency and Number of Meal during Flood

The people of the study area replied about their food insufficiency during flood. Among the respondents 8.9% replied positive reflection regarding food sufficiency and 91.1% opined food insufficiency (once daily, twice daily food consumption and starvation) in flooding condition (Table 4). Among the respondents 44.8% take meal once daily and 6.2% receives cooked food twice daily. Insufficient food consumption makes the people weak. Observations from field investigation includes that the people of the study area looks more aged than their real age. The community of Teesta basin accused that the reason behind their more aged appearance is not only in flooding condition but most of the time of a year they take once or twice time meal and become starved due to impact minimization of flood and river bank erosion. Moreover, hard laborious job makes them aged. The respondents replied that they try to cope with flood through starvation, eating inexpensive food items and reducing the number of meal. Skipping a meal and eating inexpensive food during flood are well known adaptive technique of flood affected communities (Mavhura *et al.*, 2013). Among the respondents 39.8% took starvation as an adaptive technique during flood.

Table 4. Respondent's food sufficiency and number of meal during flood

Food sufficiency	Frequency	Percent	Number of meal	Frequency	Percent
Yes	34	8.9	Three times daily	34	8.9
No	347	91.1	Once daily	171	44.8
			Twice daily	24	6.2
			Starvation	152	39.8
Total	381		Total	381	100.0

Source: Household questionnaire survey, 2017

3.3.5. Condition of Cooking During Flood

The condition of cooking is vulnerable during flood. But the people of the study area adapted themselves with different techniques for cooking. Bangladeshi traditional oven made with mud (chula) is the only source of cooking in Teesta river basin community but it goes under water during flood. Therefore, every family of the study area prepares mud made portable oven for cooking during flood. The study identifies that 39.9% respondents stop cooking during flood due to problem of cooking place. The adaptation techniques about cooking in flood by the respondents are cook with portable oven arranged on machan (25.2%), cook in neighbor's house (8.1%), cook in road (5%), cook standing in flood water (4.7%), cook in embankment (4.7%) and cook in school/flood shelter (3.4%).

3.3.6. Indigenous Food Making Techniques Adoption and Item of Meal

The Teesta river basin community makes few dry food items to eat with rice like, sutki (dried fish) and sidol (made with dried fish, arum and turmeric) which they eat during flood. The indigenous food making technique helps the victim people to manage their meal during and after flood. Among 381 respondents, 229 respondents take meal either once, twice and three times daily. Mainly they cook rice and eat the rice with vorta (mashed food items), onion, salt, chili etc. These items are not enough for health and nutrition but they choose the items to adapt with flooding situation. The study result shows that 31.9% respondents depend upon rice and mashed food items (mainly eat sutki, sidol and potato vorta) during flood. Among the respondents 19.2%, 13.5% and 10.0% take rice-vegetables, rice-pulse and rice-fish as item of meal, respectively. The extreme poor who have no ability to collect pulse, vegetables and fish, take meal with rice-onion-chili (14.4%) and rice-salt (10.9%).

3.3.7. Correlation among condition of cooking, coping with food, number and item of meal

Significant positive correlation has been found between condition of cooking and coping with food (.221*), condition of cooking and number of meal during flood (.216*), coping with food and number of meal (.237*), number of meal and item of meal (.319*) at 0.01 level. But there is no correlation between condition of cooking during flood and item of meal because a large number of respondents stop cooking in inundation. On the other hand, coping with food during flood and item of meal also have no correlation due to starvation of most of the respondents.

Table 5. Correlations for condition of cooking, coping with food, number and item of meal.

	Condition of cooking during flood	Coping with food during flood	Number of meal during flood	Items of meal
Condition of cooking during flood	1.000	.221**	.216**	.003
Coping with food during flood		1.000	.237**	.035
Number of meal during flood			1.000	.319**
Items of meal				1.000

**Correlation is significant at the 0.01 level (2-tailed)

3.4. Coping with Drinking Water

During flood common problem in every family is safe drinking water in the study area. The respondents argued that they can't boil water because they face problem of cooking place due to inundation. The respondents also talked about use of water purifying tablet during flood which has been provided as relief materials. To cope with flood for safe drinking water the people of the study area used to place tube well in higher place (make mound with mud). Among the respondents 17.8% drink boil water, 5.2% purify water by water purifying tablet and 4.2% respondents replied about tube well has been placed in higher place. The respondents described their sufferings to collect drinking water in flood inundation. Moreover, quarrel also occurs to manage safe drinking water. The people who have no ability to place tube well in higher place and no scope to boil water, tries to collect safe drinking water from neighbor's house (72.7%). Therefore, the study finds out that neighbors play dominant role in flooding condition to manage safe drinking water.

3.5. Coping with Education

During flood schools become closed and used as flood shelters. Schools have been closed for 1-2 months due to prolonged flood inundation which hampers education. Moreover, cleaning problem arises to the school administration after flood. Figure 4 displays, 64.6% children of the study area stops school going to cope with flood. After flood, the back bone of the flood victim families break down. As a result drop out occurs to survive with economic condition. 24.4% respondents replied about drop out for flood. 11% respondents answered children go to school for relief collection during flood.

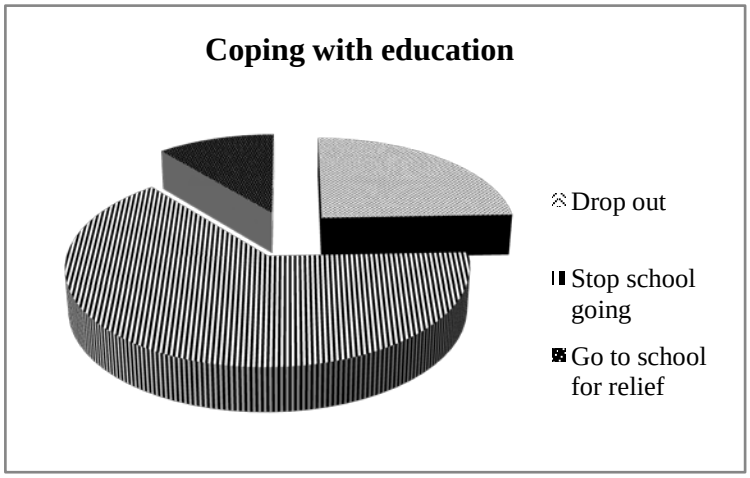

Figure 4. Respondent's coping with education.

3.6. Medicine Facilities during Flood

During flood different types of diseases (diarrhea, fever, cough, scabies, etc.) break out in the study area. People could not go to doctor for treatment. So they try to collect medicine to survive during flood. The study result indicates that 60.4% respondents buy medicine from pharmacy during flood. This type of coping strategy helps them reduce the cost of doctor's visit. Use of indigenous herbal medicine in the flooding condition reduces the vulnerability of waterborne disease (Paul and Routray, 2010). During flood 25.7% respondents of the study area depends on medicinal plants which is also a kind of adaptation technique of the river basin community. Medicinal plant includes tulsi (*Ocimum sanctum*), basak (*Adhatoda vasica*), turmeric (*Curcuma longa*), etc. The respondents mentioned kacha kola (*Musa balbisiana*) is very effective to get rid of diarrhea. They also apply mustard oil, coconut oil, kerosene on scabies affected skin during flood. Among the respondents, 10.8% replied about dependency on relief medicine and 3.1% answered that they keep extra medicine in house to cope with disease.

3.7. Coping with Livelihood

The study area is agro based and flood destroys the livelihood of the riparian community. Flood along with river bank erosion causes agricultural land loss which abolishes people's economic activities. As a result, the earning source of the household head disrupts and many of them become unemployed. Among the respondents, 10.8% lost their earning source due to the flood 2017. To cope with the adverse impacts of flood, the victim people migrate in the cities and towns for job seeking and income generation. In the monsoon, the flood victim male household head migrates in the cities for income generation (Sheheli and Khan, 2015). Moreover, the landless farmer tries to engage themselves in share cropping. People try to earn their living through wage laboring in both agricultural and nonagricultural sectors. Aquatic resource collection and wage labor in farm activities become livelihood survival strategy of flood victims (Nguyen and James, 2013).

3.7.1. Precaution Practice for Agricultural Production

Among the respondents, 75.9% replied that they cultivate crops suitable for char lands, because sand deposition hampers agricultural production after flood. The respondents answered about cultivation of nut, sugarcane, lentil,

maize, pumpkin, etc. in the char land. They used to cultivate these crops for loss reduction because the crop grows in the sandy soil. When silt deposition occurs in soil the farmer grows rice.

3.7.2 Precaution Practice for Crop and Seed

Flood causes enormous damage in ripen paddy. Therefore, the respondents have to take precautionary technique for crop harvest to cope with the vulnerable condition. Early crop cutting is adopted by the people of the study area to harvest the production before flood. The study result indicates that, 74.2% respondents follow early crop cutting technique as a precautionary practice for crop harvest regarding flood coping. Among the respondents, 25.8% replied about selling the crop in field without harvest for loss minimization. During field survey the respondents argued that early crop cutting and selling the crop in field are the best precaution practice adopted by the Teesta floodplain community to adapt with flood. But in the flash flood event they do not get enough time to implement these two techniques. Therefore they get enormous crop production loss due to flash flood.

Due to flood, every year huge amount of agricultural production do not come into the light of economic values. Harvested crop and seedlings washes away, crops become rotten and ripen crops goes into the river due to flood impacts. Transplanted Aman seedlings wiped out due to floods (Siddique, 1989). Sometimes the farmers keep huge amount of harvested paddy in the yard shaded with polythene. Precaution practice for harvested crop and seed includes keep crops in crop storage store in mud pot, stock in machan and store under polythene shed. Among the respondents, 8.6% replied regarding store crop and seed in crop storage, 3.9 % answered store seed and crop in mud pot, and 19.6% answered store crops under polythene shed. Most of the respondents opined (67.7%) about store crop and seed in machan which is regarded as a best precaution technique to save crops and seeds. Figure 5 illustrates the precaution practice for crop and seed storage.

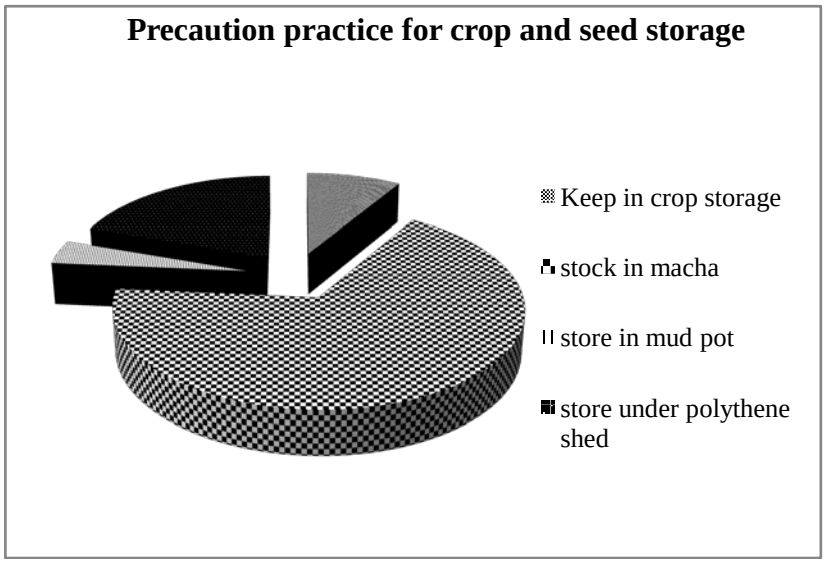

Figure 5. Precaution practice for crop and seed storage

3.8. Coping with Flood through Community Defense

Coping with flood needs strong community support. Community participation for flood protection in Ghana includes use of flood barrier 41.7%, channelization of water 12.9% and barrier through mud heaps 17.9% (Ngwese *et al*., 2018). To cope with flood, the community of Teesta floodplain adopted different techniques to defense against flood including release of flood water through road cutting, making earthen barrier and sand bag stacking in the passage of flood water to control inundation. Among the flood defense techniques, artificial levee construction shows highest percentage (37.3%). Another important technique adopted by the respondents is make barrier through sand bag stacking which represents 32%. Release of flood water through road cutting also has been adopted by 16.8% of respondents. Union wise highest percentages have been observed regarding making barrier through sand bag stacking (23.8%) at Belka union, artificial levee construction by mud (23.2%) at Saulmari union, release of flood water through road cutting (25%) at kolkonda union and community based

awareness (20%) at Purba chatnai and Saulmari union. Table 6 shows union wise percentage of flood defense by local community.

Table 6. Flood defense by local community.

Union	Flood defense by local community for adaptation					Total
	Make barrier through sand bag stacking	Artificial levee construction by mud	Make barrier through tree cutting	Release flood water through road cutting	Community based awareness	
Purbachatnai	19 (15.6)	-	-	7 (10.9)	8 (20.0)	34 (8.9)
Saulmari	11 (9.0)	33 (23.2)	-	12 (18.8)	8 (20.0)	64 (16.8)
Bidyananda	9 (7.4)	17 (12.0)	4 (30.8)	8 (12.5)	3 (7.5)	41 (10.8)
Khuniagachh	21 (17.2)	32 (22.5)	9 (69.2)	5 (7.8)	5 (12.5)	72 (18.9)
Kolkonda	24 (19.7)	19 (13.4)	-	16 (25.0)	5 (12.5)	64 (16.8)
Sindurna	9 (7.4)	13 (9.2)	-	4 (6.2)	4 (10.0)	30 (7.9)
Belka	29 (23.8)	28 (19.7)	-	12 (18.8)	7 (17.5)	76 (19.9)
Total	122(32.0)	142 (37.3)	13 (3.4)	64 (16.8)	40 (10.5)	381(100.0)

Note: Value within bracket expresses percentage. Source: Household questionnaire survey, 2017

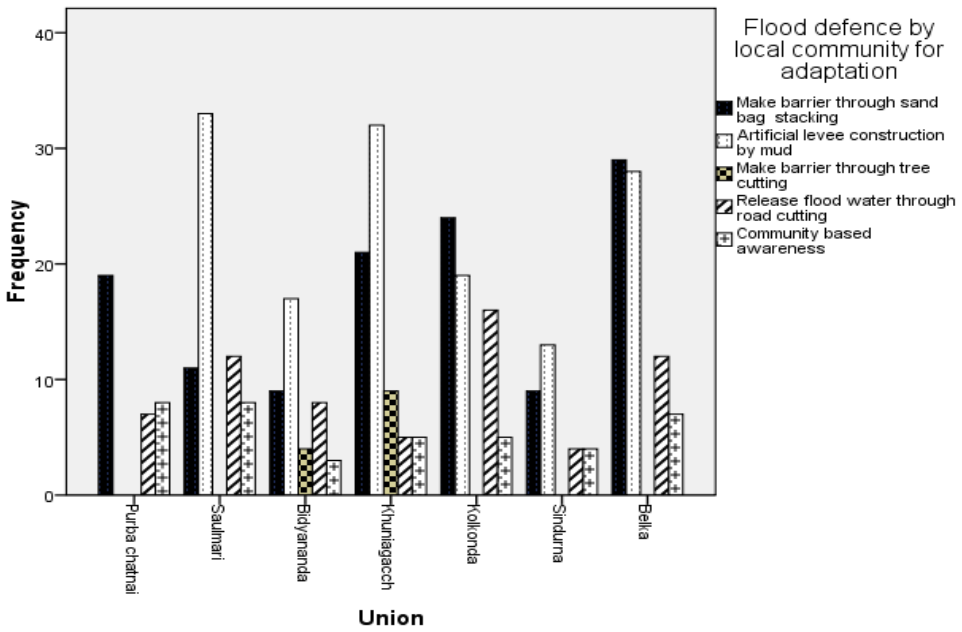

Figure 6. Flood defense by local community for coping

4. Conclusion and Policy Implications

The people of Teesta basin has both physical and mental strength to survive in the flooding condition but economic strength of the people fall down due to livelihood and property loss by flood. Respondents coping with flood depend upon the intensity, duration and height of water of flood. During flood, the Teesta river basin community tries to adapt with food, shelter, health and education but after flood the main challenge is to manage employment opportunities for livelihood. Moreover livelihood intensification and diversification also helps them

to adapt with flood. The study findings indicate that precautionary technique adoption through indigenous practice gives strength to the agrarian society of Teesta basin to manage livelihood. The present analysis also specifies the indigenous practice and community initiatives for flood defense enhances riparian people's resilience towards flood. Based on the study findings, the following policy has been formulated to cope with flood through indigenous practices:

- Local government, NGOs and civil society should take steps for awareness building program regarding implementation of indigenous practice for flood fighting.
- Government should take Policy regarding motivation of the community people to use more indigenous practices for flood management and also encourage the riparian community through print and electronic media.
- Give community people training of indigenous knowledge along with scientific knowledge for adaptation with flood.
- Motivate riparian people to work together and take collective measures for flood prevention.
- Initiate bottom up approach in policy formulation to mitigate flood problem.

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Assessment of Heavy Metals Toxicity and Ecological Impact on Surface Water from Padma River

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Abstract

The present study deals with the estimation of seven heavy metals in surface water collected from the Padma river near Rajshahi City, Bangladesh and assessment their impacts on human health and ecology by heavy metals contamination. Water sample from three locations were collected, acid digested and the concentrations of trace metals such as Pb, Mn, Cu, Ni, Cd, Cr, and As were determined using atomic absorption spectrophotometer (AAS). The average concentration of studied metals in water of Padma River followed the decreasing order of: Mn> Cr > Zn >Pb> Ni > Cd > Cu >As. The calculated water quality index (WQI) values of Padma River ranged between 30.07-35.19 and 35.86-41.84 for drinking water; 11.44 to 13.58 for irrigation and 48.85 to 56.47 for aquatic life according respectively. Most of the samples were found within the limit of standards of DoE, WHO and CCME for surface water. Human health risk assessment revealed that non-carcinogenic health risk posed by the ingestion or dermal contact of heavy-metal-contaminated water is low, having overall HI values of $2.31x10^{-4}$.

Keywords: Heavy metals, Surface water, Padma River, Ecological impact and Human health risk

1. Introduction

Bangladesh is a country of rivers having about 230 small and large rivers on which people depend for their daily living and for transportation. However, most of the rivers have been polluted due to increasing industrialization, urbanization or anthropological activities. In Bangladesh, everyday near about 1176 industries that discharge about 0.4 millions m^3 of untreated easily oxidized industrial and municipal organic waste to the rivers without any consideration of the environment (Alam, 2004) have negative implications for water quality (Rabbani and Sharif, 2005). Bangladesh has got diverse water bodies that have profound impact and high potential for fisheries production which, play an important role in the agro-based economics of Bangladesh by providing nutrition, increasing employment opportunities and earning foreign exchange (Mustafa and Brooks, 2009).

Surface water is undoubtedly not safe for drinking purposes compared to ground water and hence is not direct sources of drinking water for humans. However, they have indirect impact on the quality and availability of ground water. Sometimes polluted water may be considered suitable for some of the uses but may remain unsuitable for other purposes (Shivanna and Nagendrappa, 2015). Both natural processes and anthropogenic activities influence water quality, causing degradation in surface and groundwater and affecting their potential use for human and animal consumption, agriculture, recreation, industry, and others (Simeonov *et. al*., 2017). Therefore, to use these resources for agriculture or drinking consumptions continues monitoring of their quality to develop strategies to improve water resource and watershed management.

The water of the river Padma are highly productive ecosystems supporting a rich brackish water fishery, and serving as necessary ground for a variety of fish and shellfish species. They serve not only as food and natural resources on which human society depends, but are also the livelihood for a majority of population. To gain sustainable results overexploiting the organisms and abusing the ecosystems should be avoided as the environmental health of these waters reflected on the health of the organisms. Heavy metals are normal constituents of the aquatic environment and present in trace quantities but their increasing levels act as cumulative poisons to estuarine as well as marine organisms. Aquatic ecosystems and rivers, estuaries and coastal areas that is contaminated with heavy metals make water unsuitable for human drinking, irrigation, recreation,

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aquaculture, agriculture, livestock framing, and biodiversity. Indication of long term exposure as well as some historical data might be possible to gain by analyzing them. Moreover, river water quality is one of important factors directly concerning with health of human and living beings (Kazi *et al*., 2009) and hence for effective pollution control and water resource management it is very much crucial to have reliable information on water quality characteristics. Therefore it is a great need to evaluate and maintained the river water quality to achieve successful aquaculture (Rahman, 1992). So, efforts have been made to evaluate the heavy metals toxicity and their ecological impact on surface water from Padma River.

2. Materials and Methods

2.1 Collection of Water Sample

For the analysis of heavy metals, water samples (10 samples from each sites) from three sites namely I-dam, T-dam and Padma garden were collected in dry season (March to April, 2016) at a depth of about 0.3m below water surface into 500 ml plastic bottles previously cleaned with 10% nitric acid. Samples were then collected by direct immersion of the sampling bottle into the river. Immediately after collection, the sample was acidified with 2 ml nitric acid stored and at 4^{o}C until further analysis). Details of surface water sampling location along with their longitude and latitude are presented in Table 1 and Figure 1.

Table 1. Sampling station with GPS points

Sampling station	GPS points (Latitute, Longitute)
1. T-dam	N-24º21´42.41´´ E-88º34´31.18´´
2. Padma garden	N-24º21´42.30´´ E-88º35´52.44´´
3. I-dam	N-24º21´34.95´´ E-88º36´39.92´´

Figure 1. Location of the study area (Google Earth, 2017)

2.2. Digestion of Sample for Heavy metal Analysis

To prepare water sample for analysis heavy metal, concentrated HNO_3 acid was added to 50 ml of water and then heated on a bloc digester until its volume reduced to 20 ml. Another 5ml of concentrated HNO_3 was added and then heated for 10 minutes and allowed to cool. Then filtered using Whatman 0.42 µm filter paper and made 100 ml with distilled water.

2.3. Estimation of the Trace Metals

Estimation of heavy metals in water was carried out by AAS with Graphite Furness (AA-6800, Shimadzu, Japan) from the Central Science Lab of University of Rajshahi.

2.4. Risk assessment Due to Contamination of Heavy Metals

2.4.1. Water Quality Index (WQI)

To evaluate the suitability of water quality of Padma River WQI has been calculated using the weighted arithmetic water quality index method (Brown *et al*., 1972), which classifies the water quality according to the degree of purity by using the most commonly, measured water quality variables.

The water quality index parameter was calculated using the widely used mathematical formula (Tyagi1 *et al*., 2013; Chowdhury *et al*., 2012; Balan *et al*., 2012) developed by Brown *et al*. (1972).

$$\text{WQI} = \sum_{i=1}^{n} Q_i W_i / \sum_{i=1}^{n} W_i$$

Where, Q_i is the sub quality index of ith parameter (or Q_i is thequality rating scale of each parameter). Wi is weight unit of each parameter, n is number of parameters.

Q_i value is calculated as follows:

$$Q_i = [(V_i - V_0) / (S_i - S_0)]$$

V_i = measured value of ith parameter, S_i =standard permissible value of ith parameter, V_o = ideal value of ith parameterin pure water, V_o = zero for all parameters except for pH =7.0 and DO = 14.6 mg/l (Tripaty and Sahu, 2005). Calculation of unit weight (W_i) for various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$W_i = K/Si$$

Where, K is the proportionality constant of the ‘‘Weights’’ for various water quality characteristics:

$$K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}$$

WQI has been classified into 5 classes, the water quality is rated excellent, good, poor, very poor and unfit corresponding to the values of 0–25, 26–50, 51–75, 76–100 and>100, respectively (Table 3).

2.4.2. Risk Assessment on Human Health from Water

In this study, several procedures were used to assess human health risks due to heavy metal exposure from water. Three major pathways ingestion, dermal contact and respiration are generally considered in human health risk assessment. The following equations are applied in calculating the exposure through these two pathways ingestion and dermal contact (USEPA, 1989, 2004; Rovira *et al*. 2011; Iqbal *et al*. 2013).

$$\text{EXP}_{\text{ing}} = \frac{\text{Cm} \times \text{IR} \times \text{CF} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

$$\text{EXP}_{\text{derm}} = \frac{\text{Cm} \times \text{CF} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

Where, EXP_{ing} is the ingestion exposure from the metals in water; Cm represent the measured concentration of the metals in water (mg/L); IR is the ingestion rate, as there is no set value for consumption of river water in Bangladesh, 2.0 L/day for adults was regarded as the ingestion rate (Wang *et al*., 2017; Saha and Paul, 2018); CF represent the unit conversion factor (10^{-6} kg/mg); EF is the exposure frequency (350 days/years); ED represent the exposure duration (30 years); BW is the average body weight (70 kg for adult); AT represent the average day (10,950 days); EXP_{derm} is the dermal uptake; SA is the exposed skin surface area (5700 cm^2); AF represent the adherence factors from water/sediment to skin (0.07 mg/cm^2); and ABS is the dermal absorption from water (0.001).

2.4.3. Hazard Quotients (HQ)

To assess the non-carcinogenic health risks from the exposure to heavy metals in water/sediment according to USEPA (2004) health risk assessment guidelines Hazard quotients (HQ) were used and were calculated by adopting the following for the two exposure pathways:

$$HQ_{ing/derm} = \frac{EXP_{ing/derm}}{RfD_{ing/derm}}$$

$$HI = \sum_{i=n}^{n} HQ_{ing/derm}$$

Where, HQ is health HQs via ingestion or dermal contact under the respective exposure amount; RfD_0 is the reference dose for the resulting hazardous health effect caused by contaminants. The reference dose via dermal contact is typically hypothesized to be identical to the reference dose via ingestion for heavy metals in water/sediment (Iqbal *et al*., 2013).

3. Statistical Analysis

The data was analyzed by the use of Statistical Package for Social Science (SPSS software Version 20.0). Two way ANOVA was used to show the interactions between the sites while One way ANOVA was used to determine the significant differences at $P \leq 0.05$. For significance difference, Duncan Multiple Range Test (DMRT) was used to separate the means. Correlation coefficient test was used to determine whether there was a relationship between water and heavy metal parameters separately.

4. Results and Discussion

4.1. Heavy Metal Concentration in Water

The results of heavy metal concentrations in surface waters are shown in Table 2. The amount of total Cr at three sampling station (I-dam, T-dam and Padma Garden) found to be ranged between (0.228-0.313) ppm among which PG (Padma garden) had the highest amount of Cr compared to other locations. The average concentration of Cr in water of Padma River was 0.27±0.04 mg/l, which exceeded the recommended value of the DoE (0.05 mg/l) and WHO (0.10 mg/l) guidelines for drinking water, DoE standard for irrigable land (0.10 mg/l) and Canadian Council of Ministers of the Environment (CCME) guideline for aquatic life (0.001 mg/l). The present value was much higher than the recorded Cr level (0.0346 mg/l) of Meghna River (Hassan *et al*., 2015) and 0.114 mg/l of Buriganga River (Bhuiyan *et al.,* 2015)). Anthropogenic sources of emission of total Cr in the surface water are possibly attributed from municipal wastes, chemical industries; paints, leather, and road run off due to tire wear, corrosion of bushings, brake wires and radiators (Dixit and Tiwari, 2008). Therefore, the data findings of present study suggest that municipal waste might be the possible source of Cr in the water of Padma River as such chemical industries are absent at Rajshahi City. As the Cr concentration of the present investigation was higher than the recommended values, indicating Cr pollution of Padma River at Rajshahi.

Table 2. Heavy metal concentration of water (mg/l) at different locations of Padma River during the study period. (n=30)

Sampling Sites	Heavy metals concentration (ppm)						
	Cr	Pb	Ni	Cd	Mn	As	Cu
T-dam	0.228	0.012	0.005	0.035	0.581	0.002	0.012
PG	0.313	0.102	0.144	0.046	0.755	0.003	0.045
I-dam	0.283	0.043	0.026	0.039	0.641	0.006	0.051
Mean±SD	0.27 ± 0.04	0.05 ± 0.05	0.06 ± 0.08	0.035± 0.01	0.66 ± 0.09	0.004 ± 0.002	0.036 ± 0.02

The average concentration of Pb was 0.05±0.05 mg/l which did not exceed the recommended value of DoE (0.05 mg/L) and WHO (0.01 mg/L) for drinking water, FAO and CCME (0.1 mg/L) for irrigation and CCME for aquatic life (Table 3) and found to be maximum in PG (Padma Garden) and lowest in T-Dam (Table 2). While the present concentration was higher than the findings of Mokaddes *et al.* (2013) at Shitalakhya river (0.0011 mg/l) and Jolly *et al*. (2013) at Padma River (0.0015 mg/l). This may be due to presence of local pollution sources in the study area and / or river discharge and the rainfall.

The value for Ni was observed between 0.035 to 0.144 with an average concentration 0.06±0.08 mg/l which was lower than the recommended limits for drinking water of DoE (0.1 mg/L) and WHO (0.07 mg/L) and FAO (0.2 mg/L) guidelines of irrigation water, while it was slightly above the permissible value of aquatic life guidelines of CCME (0.065 mg/L, Table 3). However, Bhuiyan *et al.* (2015) reported a higher value of Ni (0.150 mg/l) in water of Buriganga River. However, previous report on the Padma River at Rooppur area of Pabna district (Joly *et al*., 2013) showed much lower value of Ni (0.0081 mg/l) than the present findings. Ni is quite abundant in the Earth's crust, enters surface waters from the dissolution of rocks and soils, from biological cycles, atmospheric fallout and especially from industrial process and waste disposal (Perona *et al*., 1999). Therefore, dumping of domestic waste from Rajshahi City into the river Padma might be the reason for elevated Ni in the river water.

The mean value of Cd (0.035±0.01 mg/l) was higher than the value recommended by DoE, WHO, FAO and CCME guidelines for drinking, irrigation and aquatic life (Table 3). It was also higher compared to the mean concentration of Dhaleshwari river (<0.001 mg/l) reported by Ahsan *et al.* (2018) and Jolly *et al*. (2013) for water of Padma River. Highest concentration was found at PG (0.046 mg/l) and lowest in T-Dam. Disposal of sewage sludge and industrial effluents that come across the septic tank and metal industries (Alloway and Ayres, 1993) might be the possible sources of Cd pollution of Padma river water.

The average concentration of Mn in Padam River water was 0.66±0.09 mg/l which exceeds the maximum permissible level of DoE, WHO, FAO and CCME recommended guidelines (Table 3). It was also exceeds the previous reported value (0.07 mg/l) of Mn in Padma River by Rasul and Jahan (2010). The highest value of Mn was found at PG and lowest in T-Dam. According to Alam, 2003, the variation of concentration of heavy metal from locations to locations may be correlated with the flow of the rivers and location of industries and their waste disposal system.

The average concentration of As was 0.004±0.002 mg/l, which was lower than the permissible limit of DoE (0.05 mg/L) and WHO (0.01 mg/L) drinking water guidelines (Table 3) and maximum in I-dam (0.006 mg/l). Jolly *et al*. (2013) reported lower amount (0.0015 mg/l) of As in Padma River in comparison with the present study.

Table 3. Selected water quality criteria for drinking, irrigational waters and aquatic life (µg/L)

Element	Drinking waters		Irrigational waters		Aquatic life
	WHO (2011)	DoE (2002)	FAO (1985)	CCME (2007)	CCME (2007)
As	10	50	100	100	5
Pb	10	50	100	100	2
Cd	3	5	10	10	0.18
Cr	50	50	100	100	1-8.9
Cu	2000	1000	200	200	2
Mn	400	100	200	200	-
Ni	70	100	200	200	65

The average value of Cu was 0.036±0.02 mg/l with highest in I-dam. The mean value was observed below the recommended value by DoE (1.0 mg/L), WHO (2.0 mg/L) for drinking water and FAO (0.2 mg/L) for irrigation water, while it crosses the limit for aquatic life standard according to CCME (0.002 mg/L, Table 3). It is also slightly higher than the reported value (0.002 mg/l) by Jolly *et al*. (2013) and Rasul and Jahan (2010) 0.01 mg/l. The average concentration of studied metals in water of Padma River followed the decreasing order of: Mn> Cr > Zn >Pb> Ni > Cd > Cu >As.

4.2. Water Quality Index

The water quality index (WQI) of Padma River during the study period is shown in Table 4. The WQI score for Drinking water was computed using guidelines of (Department of Environment, 2002; Bangladesh) and World Health Organization (WHO). Guidelines of DoE, (1997) were used to compute the WQI value for irrigation water. Protection of aquatic life was computed using guidelines of (CCME, 2007).

Table 4. Water quality index (WQI) and its categorization of Padma River water for drinking, irrigation and aquatic life utilizations at different sampling locations

Sampling Sites	Computed WQI value with rank						
	For drinking water according to the guideline of		Rank	According to the guideline of DoE (1997) for Irrigation water	Rank	According to the guideline of CCME (2007) for aquatic life	Rank
	DoE (2002)	WHO (2011)					
T-dam	30.75	36.67	Good	11.71	Excellent	49.41	Poor
PG	35.19	41.84	Good	13.58	Excellent	56.47	Marginal
I-dam	34.42	40.98	Good	13.41	Excellent	54.86	Marginal

The mean WQI of Padma River was 33.45 and 39.83, 12.90 and 53.58 with respect to drinking water, irrigation water and aquatic life protection according to DoE, WHO and CCME drinking water quality standards, irrigation guidelines and protection of aquatic life guidelines respectively. The results showed that calculated WQI value of Padma River ranged between 30.07-35.19 and 35.86-41.84 for drinking water according to drinking water quality standards guidelines of DoE (2002) and WHO (2011), while it was varied from 11.71 (T-dam) to 13.58 (PG) for irrigation according to DoE (1997) and 49.41 (T-dam) to 56.47 (PG) for aquatic life according to CCME (2007) respectively. According to the water quality rating as per weight arithmetic water quality index method (Table 5), it can be said that the water of Padma River was good for drinking, excellent for irrigation and slightly poor to marginal for aquatic life. Our study results indicate that the water quality fluctuation of Padma River could be classified as good for drinking and excellent for irrigation utilizations. While water quality was poor for aquatic life at T-dam but it becomes poor to marginal at PG and I-dam respectively. However, it is also essential need for regular monitoring of water quality in order to detect changes in physiochemical parameters through WQI for safe consumption.

Table 5. Water quality rating as per weight arithmetic water quality index method (Goher *et al*., 2014; Minakshi and Dulal, 2017)

WQI value	Rating of water quality	Grading	Possible Usage
0–25	Excellent	A	Dinking, Irrigation and Industrial
26–50	Good	B	Dinking, Irrigation and Industrial
51–75	Poor	C	Irrigation and Industrial
76–100	Very poor	D	Irrigation
>100	Unsuitable for drinking purpose	E	Proper treatment required before use

4.3. Pearson's Correlation (PC) Matrix

Pearson's correlation (PC) matrix for the analyzed heavy metals of water is presented in Table 6. The Pearson's correlation (PC) matrix showed some significant positive correlation among the estimated metals. Cr showed significant positive correlation with Pb (*r = 0.725*), Cd (*r = 0.920*), Mn (*r = 0.936*), As (*r = 0.832*) and Cu (*r = 0.830*) at *p < 0.01* level and with Ni (*r = 0.645*) at *p < 0.05* level. Pb showed significant positive correlation with Ni (*r = 0.962*), Cd (*r = 0.728*), Mn (*r = 0.754*) and As (*r = 0.714*) at *p < 0.01* level and with Cu (*r = 0.688*) at *p < 0.05* level. Ni showed significant positive correlation with Cd (*r = 0.702*), Mn (*r = 0.696*) and As (*r = 0.619*) at *p < 0.05* level. Cd showed significant positive correlation with Mn (*r = 0.933*) at *p < 0.01* level and with As (*r = 0.702*) and Cu (*r = 0.707*) at *p < 0.05* level. While Mn showed significant positive correlation with Cu (*r = 0.756*) at *p < 0.01* level and As showed significant positive correlation with Cu (*r = 0.759*) at *p < 0.01*.

Table 6. Correlation between the heavy metals of water of Padma River

Heavy Metals	Cr	Pb	Ni	Cd	Mn	As	Cu
Cr	1						
Pb	0.725**	1					
Ni	0.645*	0.962**	1				
Cd	0.920**	0.728**	0.702*	1			
Mn	0.936**	0.754**	0.696*	0.933**	1		
As	0.832**	0.714**	0.619*	0.702*	0.798**	1	
Cu	0.830**	0.688*	0.492	0.707*	0.756**	0.759**	1

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

4.4. Risk Assessment on Human Health

Health risk posed by heavy metal contaminated water were calculated and listed in Table 7. The results showed the estimated average exposure value, non-carcinogenic HQs and HI of the water of Padma River. The HQ value in order of Cr > Cd >Pb> As > Ni > Cu > for ingestion and *via* dermal contact in water. The HI for ingestion of water was 2.31×10^{-4}, while *via* dermal contact the HI value was 8.12×10^{-7} (Table 5). According to Lim *et al.* (2008) an HI > 1 means an unacceptable risk of non-carcinogenic effects on health, while HI < 1 means an acceptable level of risk. In all the sampling locations, the HQ of the non-carcinogenic heavy metal in water are less than 1, while the HI are also less than 1 in water. The non-carcinogenic health risk indicating that ingestion pathway significantly contributed to the health risk of the contaminated water of Padma River. Human health risk assessment revealed non-carcinogenic health risk posed by the ingestion or dermal contact of heavy-metal-contaminated water is low. Therefore, metal content of water of Padma River does not have non-carcinogenic effects on health.

Table 7. The health risk posed by the contaminated water of Padma River

Metals	RfD_{ing} (mg/kg/day)	RfD_{derm} (mg/kg/day)	The water of Padma River			
			Exposure assessment		Non-carcinogenic risk	
			EXP^{a}_{ing}	EXP^{b}_{derm}	HQ^{c}_{ing}	HQ^{d}_{derm}
Cr	3.00×10^{-3}	$7.5x10^{-5}$	4.04×10^{-7}	1.42×10^{-9}	1.34×10^{-4}	4.73×10^{-7}
Pb	3.50×10^{-3}	$4.2x10^{-4}$	6.56×10^{-8}	3.00×10^{-3}	4.04×10^{-7}	6.57×10^{-8}
Ni	1.10×10^{-2}	8.0×10^{-4}	7.03×10^{-8}	3.50×10^{-3}	6.56×10^{-8}	2.24×10^{-8}
Cd	1.00×10^{-3}	2.5×10^{-5}	5.47×10^{-8}	1.91×10^{-10}	5.47×10^{-5}	1.91×10^{-7}
As	3.00×10^{-4}	2.85×10^{-4}	4.64×10^{-9}	1.64×10^{-11}	1.55×10^{-5}	5.47×10^{-8}
Cu	4.00×10^{-2}	12.0×10^{-3}	4.50×10^{-8}	1.75×10^{-10}	1.13×10^{-6}	4.38×10^{-9}
$HI_{ing/derm}$					2.31×10^{-4}	8.12×10^{-7}

EXP^{a}_{ing} = Exposure through ingestion, EXP^{b}_{derm} = Exposure via dermal contact

HQ^c_{ing} = Hazard quoients through ingestion, HQ^d_{derm} = Hazard quotients *via* dermal contact,

$HI_{ing/derm}$ = Hazard index through ingestion and *via* dermal contact

5. Conclusion

The present study investigated the concentrations of heavy metals in water from the Padma River near Rajshahi City Corporation area. The results revealed that the heavy metals were present in the water of Padma River following the decreasing trend Mn> Cr > Zn >Pb> Ni > Cd > Cu >As and most of their concentrations did not exceed the recommended values provided by some standard authorities. As a results from water quality index rating in can be concluded that the water of Padma River was good for drinking, excellent for irrigation and slightly poor for aquatic life. Moreover, human health risk assessment revealed low non-carcinogenic health risk posed by the ingestion or dermal contact of heavy-metal-contaminated water. However, the continuous monitoring of these toxic trace elements in water is recommended to ensure the quality of surface water as well as aquatic foods harvested from Padma River.

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Comparative Study of the Antimicrobial Activity of Methanol Extract and Ultrasound Assisted Water Extract of the Leaves of *Azadirachta indica*

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Abstract

Neem (*Azadirachta indica*) is a popular medicinal plant and widely used for different purposes in the rural area of Bangladesh. In the present study, *A. indica* leaves were used to compare the efficacy of methanol extract of dried leaves and ultrasound assisted extraction (UAE) of fresh leaves using water as a solvent. After drying, the yields of UAE aqueous extract and methanol extract were 14.6% and 11.6%, respectively. From the phytochemical study, it was found that UAE aqueous extract contained alkaloids, flavonoids, glycosides, saponins, tannins, terpenoids and vitamin C, whereas methanol extract from dried leaves contained only alkaloids and glycosides. Antimicrobial activity of these two extracts was performed against 5 pathogenic bacteria and 3 pathogenic fungi through disc diffusion technique. Ultrasound assisted aqueous extract showed good activity with clear zone of inhibition against *Escherichia coli* (16 mm), *Shigella boydii* (11 mm), *Staphylococcus aureus* (15 mm), *Salmonella typhi* (14 mm) and *Fusarium chlamydosporum* (13 mm) whereas methanol extract of dried leaves showed activity against *Shigella dysenteriae* (12 mm), *Curvularia lunata* (12 mm) and *F. oxysporum* (12 mm). However both extracts showed better sensitivity compare to the standard antibiotic erythromycin. After overall observation, it is concluded that ultrasound assisted aqueous extraction (UAE) method for fresh plant materials is a good option for the extraction of bioactive compounds without using any chemical solvent. Therefore, UAE method is cost-effective and environment friendly for the study of bioactive compounds from fresh leaves of plants.

Keywords: Ultrasound assisted extraction, Methanol extract, Phytochemical and Antimicrobial activity

1. Introduction

Azadirachta indica is locally known as Neem belongs to the family of Meliaceae which is widely found in tropical and sub-tropical areas of the world including Bangladesh, India, Pakistan and Nepal (Alzohairy, 2016). Every part of the *A. indica* (leaves, bark, fruit, flowers, oil and gum) has been used for household treatment. Plants are rich in a wide variety of secondary metabolites such as tannins, terpenoids, alkaloids and flavonoids, which have been found a lot of pharmacologic effects such antimicrobial (Khan *et al*., 2008), antifungal (Viveros and Castaño, 2006), antiviral (Alche *et al*., 2002), antihelmintic (Avello *et al*., 2006), as well as pregnancy interceptive (Keshri *et al*., 2004), antioxidant (Ahmed *et al*., 2008; Nahak & Sahu, 2010), antihepatotoxic (Samudram *et al*., 2009) agent. Scientific evidences have confirmed their role as anti-inflammatory, antiarthritic, antipyretic, hypoglycemic, antigastriculcer and antitumour activities (Bandyopadhyay *et al*., 2004; Ebong *et al*., 2008; Paul *et al*., 2011). It is commercially used as a natural insecticide, pesticide and agrochemical in various countries (Boeke *et al*., 2004; Koul and Wahab, 2004).

Ultrasound assisted extraction (UAE) is one of the novel extraction techniques which has several potential advantages over traditional methods of extraction such as less extraction time, high percentage of extraction yield and easily controllable in terms of process parameter (Rathod and Rathod, 2014). The classical methods are fairly simple, standard and continue to have widespread use, but quality related problems viz. lack of consistency, safety and efficacy are also the issues (Gupta *et al*., 2012). The possible benefits of ultrasound extraction are mass transfer intensification, cell disruption, improved penetration and capillary effects (Vinatoru *et al*., 1999). During sonication, the cavitation process causes the swelling of cells or the breakdown of cell walls, which allow high diffusion rates across the cell contents in the second (Vinatoru, 2001). Besides the solvent, temperature and

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pressure, better recoveries of cell contents can be obtained by optimizing ultrasound applicaton factors including frequency, sonication power and time, as well as ultrasonic wave distribution (Wang and Weller, 2006). The generally accepted explanation for ultrasound enhancement is that the effect of ultrasonic waves on the vegetal material breaks the cells and releases the cells' contents into the extraction medium.

The objective of the present study was to implement UAE method to prepare aqueous extract from fresh leaves of *A. indica* and the efficacy of this extract compared with a conventional methanol extract from dried leaves.

2. Materials and Methods

2.1. Collection of Plant Material

Azadirachta indica (neem) leaves were collected from Botanical Pesticide Garden of the Institute of Environmental Science and identified by the professional taxonomist of the Department of Botany of University of Rajshahi and a voucher specimen was deposited at the herbarium of the department.

2.2. Extraction Procedure

Fresh and shade dried leaves of *A. indica* were used for the study (Cheenickal and Mendez, 2017). Neem leaves were washed properly by running tap water followed by distilled water and placed in a shade for drying out the surface water (Francine *et al*., 2015). After 6 hours, 100 gm fresh leaves were taken and divided into two parts, 50 gm in each. Part-A: fresh leaves were used immediately for UAE aqueous extraction and Part-B: fresh leaves were allowed for week long drying and grinding for methanol extraction. After drying and grinding 50 gm fresh leaves reduced to 18 gm dried powder.

2.2.1. Processing of Part-A

Fresh leaves (50 gm) of *A. indica* were blended in a conventional juice machine with 250 ml distilled water (material solvent ratio 1:5) for better extraction (Toma *et al.*, 2001). The juice was transferred to a 500 ml conical flask and placed in an ultrasonic bath for 30 minutes treatments at 40^{o}C bath temperature. Power Sonic 405 (Microprocess controlled Bench Top Ultrasonic Cleaner) was used for ultrasound treatment. The plant extract were then collected and filtered through three layers of polyester cloth and liquid extracts were dried at 60^{o}C in a conventional water bath. Dried crude UAE aqueous extracts stored in an air tight bottle and preserved in cold chamber for further use.

2.2.2. Processing of Part-B

Dried leaves powder (18 gm) of *A. indica* were dissolved in 54 ml of methanol (material solvent ratio 1:3) in a conical flask for 72 hours with intermittent shaking as per standard method (Latha *et al.,* 2015). The plant extract was then collected and filtered through filter paper (Whatman No.1) and the obtained liquid extracts were subjected to rotary evaporator and subsequently concentrated under reduced pressure (in vacuum at 40^{o}C). The dried leaves methanol extract was stored in an air tight bottle and preserved in cold chamber for further use.

2.3. Percentage of Yield Calculation

The percentage yield indicated the efficiency of the extraction procedure. It was calculated by using the following formula (Terblanche *et al*., 2017).

$$\%\, Yield = \frac{(W1\ x\ 100)}{W2})$$

Here, $W1$: weight of dried extract

$W2$: weight of the plant material for extraction

2.4. Phytochemical Screening Test

Phytochemical screening tests are the qualitative study of the extract to identify the presence of different types of pharmacologically active compounds in the extract. These studies were helpful to compare the efficiency of the existing extraction procedure with conventional extraction procedure. The extract was subjected to phytochemical tests for plant secondary metabolites, alkaloids, anthraquinones, flavonoids, glycosides, saponins, steroids,

tannins, terpenoids and vitamin C as per procedure of Allen (1973) and Harborne (1980) with slight modification (Table 1).

Table 1. Phytochemical screening test *A. indica* leaves extract

Phytochemical Tests	Method	Observation
Alkaloid Test: (i) Dragendroffs test	0.5ml of mother solution + 2ml of HCl + 1ml of dragendroffs reagent.	Orange precipitate
(ii) Mayer's test	1.2 ml mother solution + 0.2 ml dilute HCl + 0.1 ml of Mayer's reagent.	Yellowish puff coloured precipitate
Anthraquinones	5 mL of $CHCl_3$ + 2ml mother solution + few drops 10% ammonia solution.	A bright pink color in the aqueous layer
Flavinoid Test: (i) by H_2SO_4	Mother solution + Conc. H_2SO_4.	Yellow colouration observed which disappeared on standing
(ii) by aluminum solution	Mother solution + Few drops of 1% aluminum solution.	Yellow colouration was observed
Glycoside	5 ml mother solution was treated with 2 ml of glacial acetic acid containing one drop of ferric chloride solution. This was underlayed with 1 ml Conc. H_2SO_4.	Brown ring of the interface was observed
Saponin	Shaken vigorously	Develop stable persistent froth
Steroid	2 ml of acetic anhydride + 3ml of mother solution + 2ml concentrated H_2SO_4.	Color change from violet to blue
Tanin	2 ml mother solution + few drops 0.1% ferric chloride	Observed blue-black coloration
Terpinoid	5ml of mother solution + 2 ml $CHCl_3$ + 3 ml Conc. H_2SO_4	Develop a layer and observed a reddish brown coloration of the inter face
Vitamin C	Mother solution + 1 drop 5% w/v Sodium Nitroprusside + 1ml of diluted NaOH + 0.4 ml HCl.	The yellow colour turns blue

2.5. Antimicrobial Activity

Antimicrobial activity was done by disc diffusion method (Baker *et al*., 1993; Mukhtar and Tukur, 2000) on 5 pathogenic bacteria and 3 pathogenic fungi. Five human pathogenic bacteria (*Escherichia coli, Staphylococcus aureus, Shigella boydii*, *Shigella dysenteriae* and *Salmonella typhi*) and three pathogenic fungi (*Curvularia lunata*, *Fusarium chlamydosporum* and *Fusarium oxysporum*) were collected from the Microbiology Lab, Department of Biochemistry and Molecular Biology, University of Rajshahi, Bangladesh. Nutrient agar media was used for sub-culturing bacteria at 37^{o}C and potato dextrose agar (PDA) media was used for sub-culturing fungus at 25^{o}C.

The antibacterial and antifungal activity was evaluated as in traditional antibiotic susceptibility testing using the disc diffusion method (Bauer *et al*., 1966; Servan *et al*., 2011; Latha *et al*., 2015). The filter paper discs (sensitivity discs) impregnated with the 300 µg/disc of extracts was then placed on the surface of the inoculated nutrient agar and PDA plates with the aid of sterilized pair of forceps. Erythromycin 15 µg/disc was also placed as positive control. A pre-diffusion time of 30 minutes was allowed for the extracts to diffuse from the discs into

the agar medium before incubation. The degree of sensitivity of the organisms to the extracts was determined by measuring diameter of visible zones of inhibition to the nearest millimeter. The observed result of clear zone in petridish was compared to the standard zone of inhibition: <8 mm = no sensitivity; <10 mm= insignificant sensitivity; 10-15 mm = moderately sensitive; >16 mm = highly sensitive (Mukhtar and Okafor, 2002).

3. Results and Discussion

After drying, the weight of crude extract of *A. indica* fresh leaves obtained by UAE aqueous extraction method was 7.2 gm and methanol extract from dried leaves was 4.7 gm. The yield of UAE aqueous extraction method was found 14.4% whereas methanol extracts only 9.4% (Table 2). Yield percentage results indicated that the efficiency of UAE aqueous extraction from fresh leaves of *A. indica* was much better than the conventional methanol extraction procedure. From similar studies, Francine *et al.* (2015) found 2.2 gm crude extract from 25 gm fresh leaves (yield was 8.8%) and 1.7 gm crude extract from 20 gm dried leaves (yield was 8.5%) by using conventional aqueous extraction method. They also found 2.1 gm crude extract from 20 gm dried leaves (yield was 10.5%) of *A. indica* after conventional ethanol extraction procedure. Comparison with Francine *et al.* (2015) results, it was observed that UAE aqueous extraction procedure which introduced in the present study was provided much better extraction than the conventional water, methanol or even ethanol extraction procedure.

Table 2. Percentage of yield of *Azadirachta indica* leaves

Plant part	Extraction Method	Weight of Plant Part W2 (gm)	Weight of Empty Bottle (gm)	Weight of Bottle with Extract (gm)	Extract Weight W1(gm)	Percentage Yield (%)
Fresh leaves	UAE aqueous extraction	50	8.55	15.75	7.2	14.4%
Dried leaves	Methanol Extraction	50	8.67	13.37	4.7	9.4%

Phytochemical screen test showed that UAE aqueous extract from fresh leaves contained alkaloids, flavonoids, glycosides, saponins, tannins, terpenoids and vitamin C, whereas methanol extract from dried leaves contained only alkaloids and glycosides (Table 3). As per the study of Cheenickal and Mendez (2017), ethanol showed better extraction over aqueous and methanol both from fresh and dried leaves. Alkaloid, anthraquinones, flavinoid, glycoside, saponin, steroid, tanin and terpinoid were found in ethanol extract. In aqueous extract, only glycoside was found in fresh and dried leaves extract whereas in methanol extract alkaloid and glycoside were found in both fresh and dried leaves extract. Some controversy was observed in case of Ramadass and Subramanian (2018) study as they did not find terpinoids and steroids in their ethanol or even chloroform extract from dried leaves. However comparison with the above two results it was observed that UAE aqueous extract from fresh leaves of *A. indica* was satisfactory.

Table 3. Phytochemical screening test of *Azadirachta indica*

Phytochemical Identification Tests		UAE Aqueous Extract from Fresh Leaves	Methanol Extract from Dried Leaves
1. Alkaloid	(i) Dragendroffs' test	+	+
	(II) Mayer's test	+	+
2. Anthraquinones		-	-
3.Flavinoid	(i) by H_2SO_4	+	-
	(ii)by aluminum solution	+	-
4. Glycoside		+	+
5. Saponin		+	-
6. Steroid		-	-
7. Tanin		+	-
8. Terpinoid		+	-
9. Vitamin C		+	-

+: present; -: absent

Antimicrobial sensitivity tests were performed by disc diffusion method. Human pathogenic bacteria and fungi were included in this study. Total five bacteria and three fungi were treated by disc diffusion method using erythromycin as a standard. The results of antibacterial and antifungal are summarized in Table 4 and Table 5. Comparison of antibacterial and antifungal activity of crude extracts with erythromycin is presented in Figure 1 and Figure 2. From these figures it was observed that UAE aqueous extract from fresh leaves (dose 300 µg/disc) and methanol extract from dried leaves (dose 300 µg/disc) of *A. indica* had moderate sensitivity against most of the test organisms (ZI = 10-15 mm).

Table 4. Antibacterial sensitivity study of crude *A. indica* leaves extract

Name of Bacteria	Zone of Inhibition (mm)*		
	UAE Aqueous Extract from Fresh Leaves (300 µg/disc)	Methanolic Extract from Dried Leaves (300 µg/disc)	Erythromycin (15 µg/disc)
Escherichia coli	16	15	12
Shigella boydii	11	10	7
Shigella dysenteriae	11	12	10
Staphylococcus aureus	15	12	7
Salmonella typhi	14	13	7

*Zone of Inhibition: <8 mm = no sensitivity; <10 mm = insignificant sensitivity; 10-15 mm = moderate sensitivity; >16 mm = high sensitivity

Table 5. Antifungal sensitivity study of crude *A. indica* leaves extract

Name of Fungus	Zone of Inhibition (mm)*		
	UAE Aqueous Extract from Fresh Leaves (300 µg/disc)	Methanolic Extract from Dried Leaves (300 µg/disc)	Erythromycin (15 µg/disc)
Curvularia lunata	11	12	8
Fusarium chlamydosporum	13	12	11
Fusarium oxysporum	12	12	8

*Zone of Inhibition: <8 mm = no sensitivity; <10 mm = insignificant sensitivity; 10-15 mm = moderate sensitivity; >16 mm = high sensitivity

Most of the microorganisms showed resistance to erythromycin at the dose of 15 µg/disc. Both the extracts showed better sensitivity in comparison with the standard erythromycin against all the test organisms. UAE aqueous extract from fresh leaves showed better activity than methanol extract from dried leaves against *Escherichia coli* (16 mm), *Shigella boydii* (11 mm), *Staphylococcus aureus* (15 mm), *Salmonella typhi* (14 mm) and *Fusarium chlamydosporum* (13 mm). Similarly methanol extract from dried leaves showed better activity over UAE aqueous extract against *Shigella dysenteriae* (12 mm) and *Curvularia lunata* (12 mm). In case of *F. oxysporum*, both UAE aqueous and methanol extracts showed same activity (12 mm).

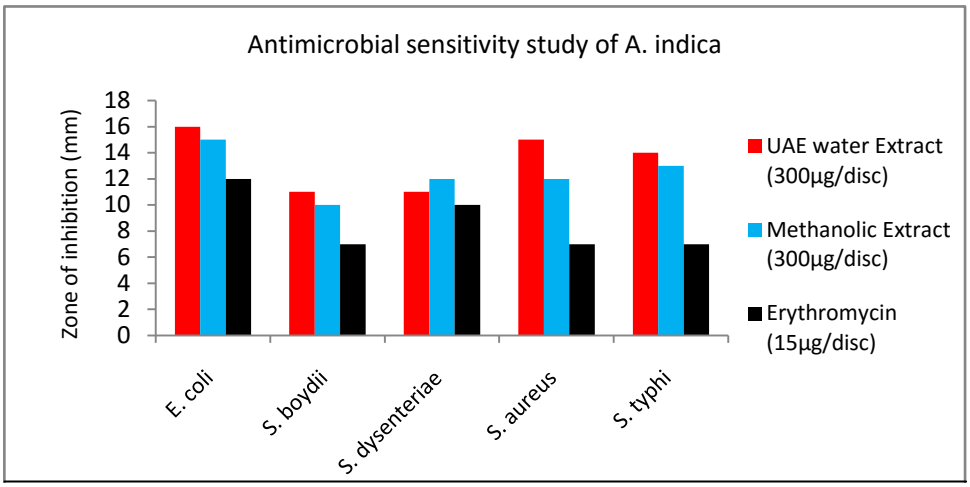

Figure 1. Comparison of antibacterial activity of crude extracts with erythromycin.

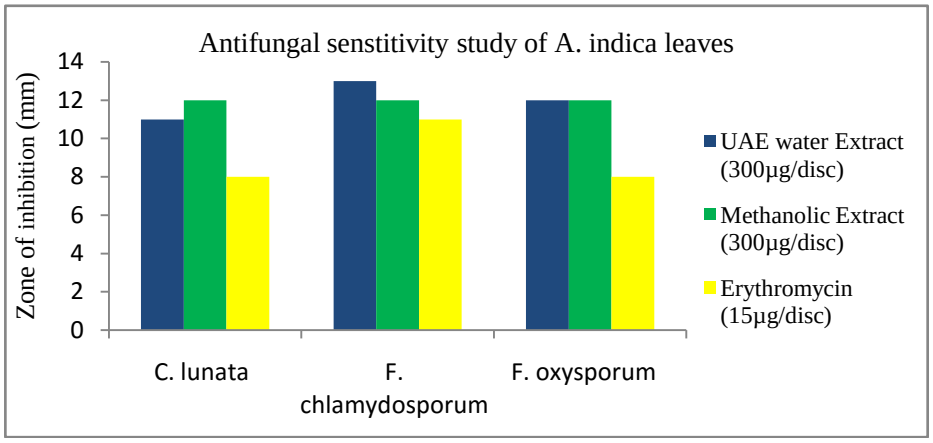

Figure 2. Comparison of antifungal activity of crude extracts with erythromycin.

Raut *et al.* (2014) performed conventional aqueous extract of *A. indica* leaves extract against some microorganism and found that the extract was sensitive against *S. typhi* (10 mm) and *E. coli* (11 mm). Comparing to their study, the present UAE aqueous extract showed better results against *S. typhi* (14 mm) and *E. coli* (16 mm). Similarly Dzulkarnain and Rahim (2014) conducted a methanolic extract of leaf of *A. indica* and observed 10 mm sensitivity against *S. aureus* using 200 mg/ml dose, which is almost similar to the present methanolic extract, 12 mm zone of inhibition at the dose 300 ug/disc. Maragathavalli *et al*., 2012 did not find any activity against *S. aureus* and *E. coli* using ethanol extract of dried leaves where as Latha *et al.*, 2015 found high sensitivity against *S. aureus* and *E. coli* by using methanol, hexane and ethyl acetate extract at the dose of 1000 µl/disc. Moslem and El-Kholie (2009) found significant sensitivity against some bacteria using ethanolic, hexane and methanolic extract from *A. indica* dried leaves. In the comparison to the past studied data, the performance of the present study of methanolic extract and UAE aqueous extract of *A. indica* was fairly good against bacteria and fungus.

4. Conclusion

The efficiency (quantity) and efficacy (potentiality) of aqueous ultrasound assistant extraction (UAE) method for fresh leaves of *A. indica* is quite satisfactory. This is a green technology as this method does not require any chemicals as well as it is less laborious and less time-consuming extraction procedure. For the minimization of

using hazardous organic solvent, cost management and reducing the extraction process, introducing of aqueous ultrasound assistant extraction (UAE) method in industry as well as in the research purpose is suggested.

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Removal of Color from Textile Dyeing Effluents Using Coagulation Process

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Abstract

The textile industry is one of the utmost imperative and swiftly emerging industrial hubs in Bangladesh. The characteristics of textile dyeing effluent are generally high because of the use of many chemical substances in textile processing. The study mainly focused on the coagulation efficiency of $FeSO_4$ and a combined coagulant (PAC and $FeSO_4$) for treating the textile dyeing effluents. The study optimized the parameters including pH, coagulant dose, agitation speed and contact time to assess the supreme coagulation efficiency for the treatment of textile dyeing effluents. The result showed that the optimum pH was found to be 7 for the combined (PAC and $FeSO_4$) and between 9 and 10 for the coagulant $FeSO_4$. The best coagulant efficiency was found to be 96% at a dose of 400 mg/L for the combined coagulant while it was about 80.64% for 800 mg/L of ferrous sulfate used individually. The study results clearly indicated that the combined coagulant (PAC and $FeSO_4$) showed a better coagulant efficiency compared to the individual coagulants.

Keywords: Coagulation**,** Decolorisation, Effluent, $FeSO_4$ and PAC

1. Introduction

Different types of dyes and pigments are used in many industries including leather, textile, rubber, paper, plastic, cosmetic, food etc. Among them, the textile industry is the first position in the usage of dyes and pigments (Saiful *et al.*, 2005). At present, it is noticed that about 10,000 of different dyes and pigments are obtainable (Eren and Acar, 2006; Ozer *et al*., 2006). It is also estimated that annually the production of dyes and pigments are more than 7×10^5 tons in the world (Crini, 2006; Saiful *et al*., 2005; Islam and Mostafa, 2018). Few researchers have stated that dyeing processes contribute 10 - 15% of these dyes in effluents (Gejdzicki, 1998). The color of these compounds is not only engagingly unpleasant but they also hinder light penetration, delay photosynthetic activity and prevent the growth of biota. Some dyes also carry carcinogenic and toxic properties (Eren and Acar, 2006). Many microorganisms in soil and water bodies reduced the azo dyes to their corresponding amines (Wang *et al*., 2013). Aquatic lives are greatly affected by these colorless amines (Siew *et. al*., 2006). Even a small amount of dyes presents in water (less than 1 ppm for some dyes) is vastly observable and objectionable (Crini, 2006). Therefore, it is essential to remove dyes from textile dyeing effluents before discharged since dye compounds are exactly designed to be unmanageable with less biodegradability due to strong stability. It is difficult to degrade by aerobic biological treatments, such as the activated sludge process. Thus, physicochemical processes are applicable to treat textile-dyeing effluents (Ozer *et al*., 2006; Shi *et al*., 2007). Adsorption, flocculation, coagulation, precipitation, ionization, irradiation, electrochemical coagulation, oxidation etc. are used as physical and chemical methods for the treatment of textile dyeing effluents (Shi *et al*., 2007; Wang *et al*., 2009a; b). Among them, coagulation is the utmost and inexpensive active method for color removal from textile dyeing effluents. Chemical coagulation in textile dyeing effluents treatment involves the adding of chemicals to change the physical state of dissolved and suspended solids and contribute their removal by sedimentation. In some cases, the difference is small, and removal is overstated by setup within a bulky coagulate covering mostly the coagulant itself. Another result of chemical adding is a net rise in the dissolved constituents in the effluents. Coagulation is applied for removal of the waste ingredients in a suspended or colloidal form that do not settle out on standing or may settle down by taking an elongated time. In textile dyeing effluent treatment, coagulation as the pretreatment is regarded as the utmost fruitful pretreatment (Huang *et al*., 2009; Leiknes, 2009). In this work, the color removal efficiency of dyeing effluents was investigated using $FeSO_4$, poly aluminium chloride (PAC) and their combination (1:1 w/w) (PAC and ferrous sulfate). $FeSO_4$ is a hydrolyzing metallic salt and PAC is a pre-hydrolyzing metallic salt (Verma *et al.*, 2012). The aim of this study was to evaluate the efficiency of the coagulants in terms of decolorization for the textile dyeing effluents.

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2. Materials and Methods

A batch type coagulation experiments were carried out to evaluate the color removal efficiency of different coagulants**.** In this study, commercial grades of PAC (30% w/w Al_2O_3) and $FeSO_4$ were used as coagulants. Themolecular structure of PAC is $[Al_2(OH)_nCl_6.nH_2O]_m$ ($m \leq 10$, n=3~5) and molecular weight: 174.45 g/mol. Coagulation and flocculation occur in successive steps intended to overcome the forces stabilizing the suspended particles, permitting particle crash and growing of flocs. It gives the results in particle destabilization and charge neutralization because of the addition of coagulants. The coagulation goals the colloid particles of size 10^{-7} to 10^{-14} cm in diameter. The fruitful collision that happens when destabilized particles are obsessed toward each other by the hydraulic cut force in the fast mix and flocculation basin. It agglomerates of a few colloids then quickly link together to form microflocs which is turned into observable flocsmasse (Gregory, 2006), which is shown in Figure 1.

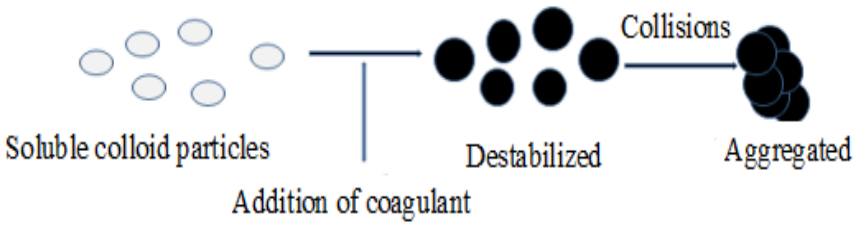

Figure 1: Mechanism of Coagulation

Textile dyeing effluents were collected from BSCIC industrial zone of Rajshahi district. The collected effluent was kept in a plastic container. The effects of various parameters including coagulant dose (200 mg/L to 1200 mg/L), pH (3 to 12), agitation speed (30 rpm to 180 rpm) and contact time (15 min to 360 min) were investigated. The effluent pH was adjusted with 0.1M HCl and 0.1M NaOH solutions. A definite dose of coagulant, i.e., $FeSO_4$ or a combination of $FeSO_4$ and PAC (define as a combined coagulant) was added to a desired volume of effluent containing beaker and immediately mixed rapidly with a magnetic stirrer for 1 to 2 min. Then mixed slowly and finally, the mixed solution was allowed to settle for 30 min. The color of the mixed solution was measured after filtration of supernatant through Whatman No. 42 filter paper. The absorbance was measured using UV- spectrophotometer (SHIMADZU UV-mini1240). Percentage of color removal was calculated using the following equation (1):

$$\% \text{ of color remove} = \frac{Ao - Af}{Ao} \times 100 \qquad (1)$$

Where, A_o and A_f are initial and final absorbance of the effluent respectively. All the experiments were performed at room temperature.

3. Results and Discussion

3.1. Effect of the Coagulants Dose

In the study, the effect of coagulant dose on color removal efficiency was measured by adding different doses of $FeSO_4$ and combined coagulants (PAC and $FeSO_4$) into the untreated effluent. The variations of color removal with coagulants dose are shown in Figure 2. The results showed that the color removal efficiency increased in the beginning and the slowly with doses for combined coagulants (PAC and $FeSO_4$) while the efficiency increased gradually with a dose for the coagulant $FeSO_4$. The color removal efficiency decreased for combined coagulants may be due to restabilize the colloids at higher doses (Metcalf and Eddy, 1991; Le and Nguyen, 2014). The maximum efficiency of combined coagulant was observed to be near about 96% at a dose 400 mg/L (1:1 PAC and $FeSO_4$) and about 84% was observed at 1200 mg/L of $FeSO_4$ coagulant. The color removal efficiency of $FeSO_4$ coagulant was increased gradually due to high positive-charged and very effective polymeric for dye removal (Georgiou *et al*., 2003; Joo *et al.*, 2007). The results indicated that the color removal of combined coagulant was higher than the $FeSO_4$ coagulant.

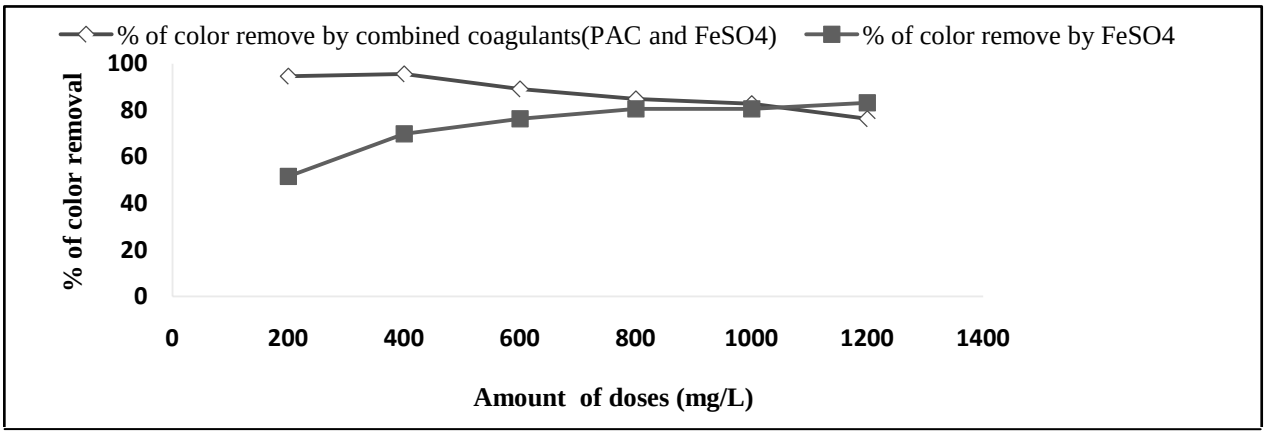

Figure 2. Effect of coagulant dose on the color removal efficiency of textile dyeing effluents (effluent pH 6.61; contact time 30 min and agitation speed 60 rpm)

3.2. Effect of pH

Perng and Bui (2014) reported that pH has a significant role in the solo coagulation process (Perng and Bui, 2014). pH variations influence the charge on hydrolysis products and precipitation of metal hydroxides. Therefore, it must require controlling the pH of the solution to get the optimum efficiency of the coagulant (Li and Gregory, 1991). Figure 3 shows the color removal efficiency of the coagulants as a function of pH. The optimum pH for $FeSO_4$ and combined coagulants were 9 and 7 respectively. The maximum color removal efficiency of combined coagulants was about 98% at pH 7. This result might be caused due to the coagulatory advantages of both Al and Fe salts and able to form flocs quickly with more large and rapid sedimentation (Gao *et al*., 2001). About 95 % color of dyeing effluent was removed by $FeSO_4$ coagulant at pH between 9 to 10. However, a combined coagulant (PAC and $FeSO_4$) showed better removal efficiency at neutral pH indicating its applicable suitability as a coagulant in textile dyeing effluents treatment.

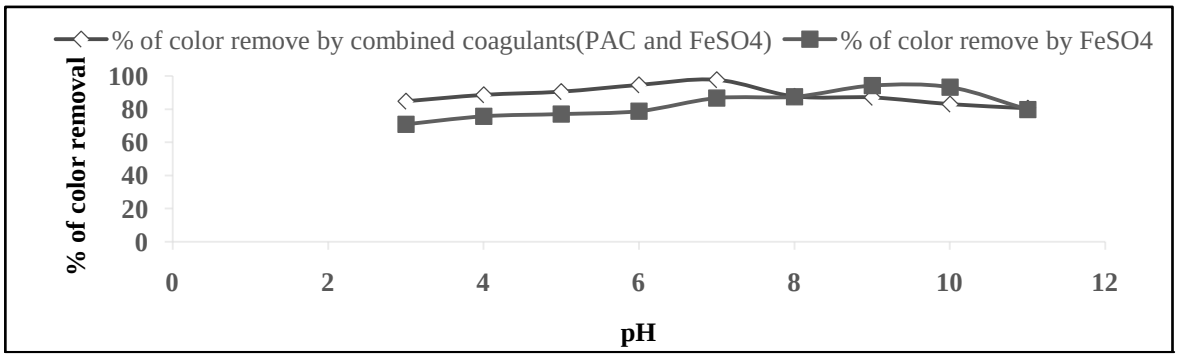

Figure 3. Effect of pH on the color removal efficiency of textile dyeing effluents [coagulant dose: $FeSO_4$ 800 mg/L and combined coagulants dose 400 mg/L(1:1 PAC and $FeSO_4$), contact time 30 min and agitation speed 60 rpm].

3.3. Effect of Agitation Speed

Agitation speed is one of the important factors in achieving higher color removal efficiency. In this study, the effects of agitation speed (30 rpm to 180 rpm) on decolorization were investigated while maintaining other factors constant.

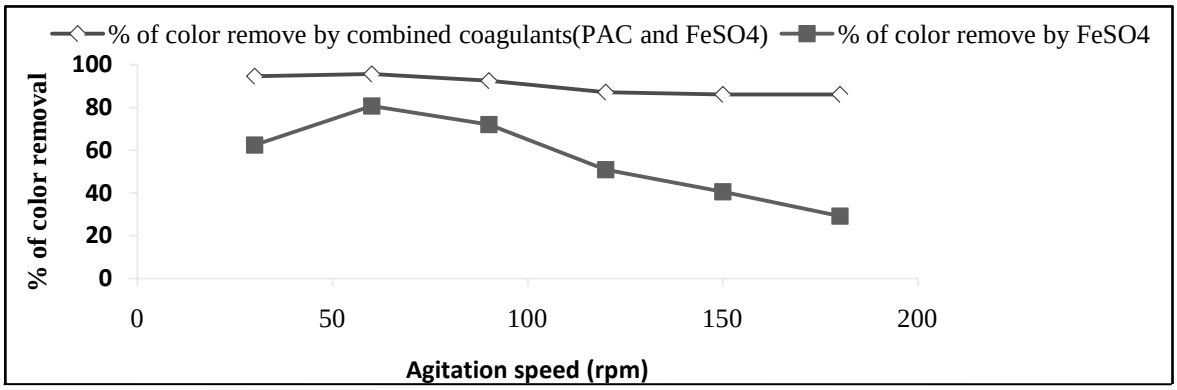

Figure 4. Effect of agitation on the color removal efficiency of textile dyeing effluents [effluent pH 6.61; coagulant dose: $FeSO_4$ (800 mg/L) and combined coagulants dose 400 mg/L (1:1 w/w PAC and $FeSO_4$), and contact time 30 min]

Figure 4 shows that the color removal percentage slowly decreased with agitation speed for combined coagulant. This result might be caused by the effect of fast soluble rate and fast sludge precipitation rate of the inorganic coagulant with dyes structure present in the textile dyeing effluent. This similar observation was reported by Tatsi *et. al*.(2003). However, the color removal efficiency increased initially (from 30 to 60) and then decreased with increasing the speed for the coagulant $FeSO_4$. This might be the cause of increasing the shear stress and breakage of flocs with agitation speed. A report showed that flocs formation and breakage were intensely affected by the mixing rate (Xu *et. al.*, 2010). The maximum color removal efficiency of $FeSO_4$ and combined coagulants was about 90% and 96% respectively at a speed of 60 rpm.

3.4. Effect of Contact Time

In general, the reaction contact time has an influence on the effluent treatment process. Along with agitation speed, reaction contact time between coagulant and dyeing effluents play a significant role. The effect of contact time on coagulation of textile dyeing effluents was studied using a time range from 15 min to 360 min and kept other parameters constant. Figure 5 shows that the color removal efficiency $FeSO_4$ and combined coagulants decreased with the increasing contact time. While the significant decrease could be recorded in case of $FeSO_4$, dropped from 94.7% (15 min) to 50.40% (360 min), the dye removal efficiency of combined coagulants became same constant or slightly decreases. This result may be due to the restabilization phenomenon (Klimiuk *et al.*, 1999). The color removal rate of $FeSO_4$ and combined coagulants was about 92% and 96% respectively at contact time 30 min.

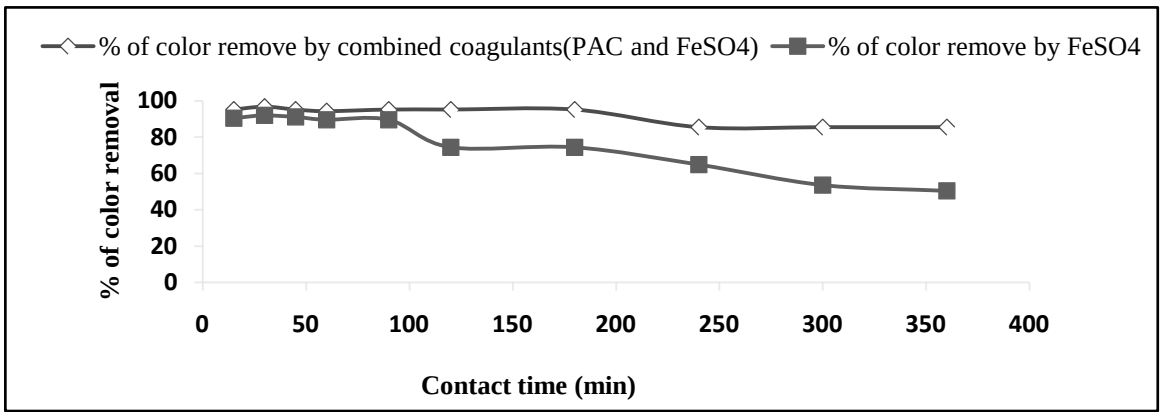

Figure 5. Effect of contact time on the color removal efficiency of textile dyeing effluents [effluent pH 6.61; $FeSO_4$ (800 mg/L) and combined coagulants dose 400 mg/L: (1:1 w/w PAC and $FeSO_4$), and agitation speed 60 rpm].

4. Conclusion

The color removal efficiency of coagulants for textile dyeing effluents was carried out in this study using $FeSO_4$ and combined coagulants (PAC and $FeSO_4$). Different parameters including pH, coagulant dose, agitation speed and contact time were taken into account to investigate the color removal efficiency. The results illustrated that the combined coagulant showed better performance in terms of color removal efficiency over the coagulant $FeSO_4$. The results showed that the optimum pH was found to be 7 for the combined (PAC and $FeSO_4$) and it was between 9 to 10 for the coagulant $FeSO_4$. Values of parameter include dose (400 mg/L and 200 mg/L), pH (7 and 9), agitation speed 60 rpm and contact time 30 min in coagulated textile dyeing effluent with $FeSO_4$ and combined coagulants (PAC and $FeSO_4$), respectively. The combined coagulant shows superiority over $FeSO_4$ coagulant. Firstly, the color removal efficiency of combined coagulant is higher than $FeSO_4$ at the same dose. Secondly, the optimum dose range of combined coagulants is lower than ferrous sulfate. The maximum color removal efficiency of combined coagulants obtained was about 96% at an agitation speed of 60 rpm with a contact 30 min for the combined coagulant (PAC and $FeSO_4$). It could be concluded that a combined coagulant (PAC and $FeSO_4$) was eminently capable of removing color from the textile dyeing effluents at a comparatively low dose. Hence, the combined coagulant has the potential to use as a coagulant in treating textile dyeing effluents treatment.

Acknowledgements

The authors are thankful to the Ministry of Science and Technology and University grants commission, Government of the People's Republic of Bangladesh for the financial support.

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Wheat Seed Treatment with Plant Extract and Its Effect on Germination, Yield and Fungal Disease Control in Experimental Field

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Abstract

Wheat is the main cereal crop in Bangladesh after rice. For eco-friendly control of fungal pathogens in experimental wheat field at University of Rajshahi, extracts of different plants were prepared. These plants were babla (*Acacia nilotica*), bael (*Aegle marmelos*), chirota (*Swertia chirota*), allspices (*Pimenta dioica*), turmeric (*Curcuma longa*), lemongrass (*Cymbopogon citratus*), khoksha (*Ficus glomerata* Roxb.) and henna (*Lawsonia inermis*). Wheat seeds were pre-treated by extracts before sowing to the field and evaluate their effect on germination, fungal disease control and yield of wheat cv. Pradip during November, 2017 to April, 2018. Treatments used in this experiment were control (without plant extracts), T_1 – turmeric powder extract, T_2 – babla leaves extract, T_3 – bael leaves extract, T_4 – chirota leaves extract, T_5 – allspices extract, T_6 – turmeric leaves extract, T_7 – lemongrass extract, T_8 – khoksha leaves extract, T_9 – dry henna leaves extract and T_{10} – fresh henna leaves extract. Treatment T_8 (khoksha leaves extract) gave the highest germination (98.67%**)** whereas lowest germination (52.67%) was found in T_{10} (fresh henna leaves extract). The highest branching was observed in T_7 and lowest in T_3. Leaf blight symptoms of wheat were observed highest in T_5 and lowest in T_{10}. The leaf blight infected plants were maximum in control and minimum in T_6 (turmeric leaves extract). The highest yield (312.00 g**)** was found in T_6 and lowest in T_{10}. Total numbers of seed were also highest (6638.67**)** in T_6 and lowest (5951.67) in T_{10}. Number of healthy seeds were found maximum (5478.67) in T_6 and minimum (4198.33) in T_{10}. Numbers of infected seed were highest (1756.67) in T_3 and lowest in T_6 (1160.00). Therefore, this study concludes that plant extracts of turmeric leaves (*Curcuma longa*) and khoksa leaves (*Ficus glomerata* Roxb.) can be used for eco-friendly management of fungal diseases in wheat field of Bangladesh.

Keywords: Wheat, Plant extracts, Seed pre-treatment, Germination, Yield and Fungal disease

1. Introduction

Wheat (*Triticum aestivum* L.) is grown under a wide range of climate and soil condition. It grows well in clay loam soils. In Bangladesh, wheat is a crop of Robi season. It requires dry weather, bright sunlight and well distributed rainfall between 40-110 cm for growth. Depending on the variety and weather condition, 100-120 days are required from sowing to harvest. Wheat is attacked by 20 different diseases at various stages of its growth in Bangladesh (Ahmed and Hossain, 2005). Pathogens associated with the black-point disease has become one of the most serious problems of wheat, causing great losses in both yield and quality of wheat grains (Bhandari *et al*., 2003; Fernandez and Conner, 2011; Draz *et al*., 2016). The significance of the pathogens causing the grain black-point disease of wheat is that they cause common root rot, seedling blight, leaf spot, head blight and black-point diseases of wheat (Kumar *et al*., 2002). Among them, five are considered to be economically important because of their damaging nature and wide occurrence throughout the wheat growing areas of the country. Black point caused mainly by *Bipolaris sorokiniana*, *Alternaria alternata*, *Cladosporium cladosporioides*, *Curvularia lunata* and *Fusarium sp.* (Fakir, 1998). The disease is characterized by brown to black discolouration usually restricted to the embryonic end of the grain, but in case of severe infection, the whole grain may be discoloured and shrivelled (Hanson and Christensen, 1953). The disease occurs almost all over the world wherever wheat is grown. In Bangladesh, the prevalence of the disease was found to vary from 5 to 55% depending on different varieties grown in the major wheat growing areas. Economical management, trade and market price of black-pointed wheat grains showed that the qualitative appearance of the grain, particularly the colour and luster, reduced the market price of wheat by 3.71 to 12.49% in infected seed lots compared with healthy seed lots (Solanki *et al*., 2006; Mishra and Srivastava, 2015). The foliar blights of wheat caused by *Bipolaris sorokiniana* and found that the pathogen is capable of causing damage from the primary leaf stage, though the plant tends to become more susceptible after flowering.

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Plant extracts, essential oils, gums and resins have been shown to exert biological activities against plant's fungal pathogens *in vitro* and *in vivo* and can be used as bio-fungicidal products (Fawzi *et al*., 2009). Bio-fungicides are generally assume to be more acceptable and less hazards for the ecosystems and could be used as alternative remedies for treatment of plant diseases (Chuang *et al.*, 2007). Many reports approve the efficacy of natural products of plants in controlling fungal growth and mycotoxin production, e.g. cinnamon clove, oregano, palmarosa and lemon grass oil (Marin *et al.*, 2004), tea tree oil, common thyne, cinnamon and any seed oil, sweet basil, neem, eucalyptus, dhutura, garlic and oleander extracts (Nashwa and Abo-elyousr, 2012). Thymol and carvacrol are definitely the most effective active constituents against most fungal species tested (Numpaque *et al.*, 2011; Gavaric *et al.*, 2015). Production of healthy wheat is the important priority for the food security of the people of Bangladesh. Therefore this research was conducted considering the following objectives,

i) To assess the effect of plant extracts on wheat seed germination

ii) To assess the effect of plant extracts on wheat plant growth and yield, and

iii) To evaluate the effect of plant extracts on healthy and infected wheat seeds production.

2. Materials and Methods

2.1. Plant Materials

Plants having the bioactivity against the fungal diseases were surveyed through survey of literature and published papers. Thereafter, a field survey was conducted to identify the origin, habitat and status of these plants in the campus of University of Rajshahi. Ten most bio-active plants were selected to verify the activity against fungal pathogens of wheat. The collected plants are Turmeric powder *(Curcuma longa),* Indian Gum Leaf *(Acacia nilotica),* Bael Leaves (*Aegle mormelas),* Chirota (*Swertia chirota),* Allspices (*Pimenta dioica*), Turmeric Leaves *(Curcuma longa),* Lemongrass (*Cymbopogon citratus*), Khoksha Leaves (*Ficus glomerata* Roxb.), Dry Henna Leaves (*Lawsonia inermis)* and Fresh Henna Leaves (*Lawsonia inermis).*

2.2. Plant Extract and Seed Pre-treatment

About 100 gram of plant material was dissolved in 1000 ml distilled water (w/v, 1:10) and kept in room temperature for 2-3 days, and then passed through two layers of cheese cloth (Hossain and Hossain, 2012). The extracts were centrifuged at 3000 rpm for 20 minutes and stored in a refrigerator at 4°C until used. Wheat seeds were treated with the prepared plant extracts separately by dipping method for 30 minutes. The treated seeds were soaked on blotting paper and sown in the experimental field to determine seed germination and other yield contributing character.

2.3. Experimental Plot and Treatments

This field experiment was conducted at Botanical Pesticides Research Field of the Institute of Environmental Science, University of Rajshahi, Bangladesh during Robi season of 2017-2018. Wheat variety Pradip was sown on 15th November, 2017 in the experimental field. Ten plant extracts were used against fungal pathogens of wheat.

The experiment was laid-out under three replications following eleven (11) treatments (T). These are control (without plant extracts), T_1 – turmeric powder extract, T_2 – babla leaves extract, T_3 –bael leaves extract, T_4 – chirota leaves extract, T_5 – allspices extract, T_6 – turmeric leaves extract, T_7 – lemongrass extract, T_8 – khoksha leaves extract, T_9 – dry henna leaves extract and T_{10} – fresh henna leaves extract.

3. Result and Discussion

For each treatment, 150 seeds were considered, therefore, 50 seeds were shown in each replication. Treatments T_6 (turmeric leaves) and T_8 (khoksha leaves) gave the highest germination rate (98.67±4.977%) and T_{10} (fresh henna leaves) treatment gave the lowest germination (52.67±2.265%) of wheat seeds (Table 1).

Table 1. Field experiment on germination, branching and infected plant with botanical extract treated wheat seeds

Treatments (T)	% Germination	Number of Branches	Leaf Blight Symptoms	Leaf Blight Infected Plant
Control	80.67±5.409abc	2.52±0.096b	0.47±0.067ab	**6.33±0.438a**
T_1	78.33±2.884abc	2.62±0.084b	0.41±0.028b	1.33±0.101cd
T_2	65.33±1.318bc	2.47±0.061b	0.66±0.047ab	2.33±0.101bcd
T_3	68.00±1.045abc	2.37±0.043b	0.65±0.054ab	1.33±0.101cd
T_4	78.00±1.741abc	2.89±0.195b	0.60±0.030ab	2.00±0.348bcd
T_5	64.67±1.718bc	2.68±0.121b	**1.07±0.113a**	1.67±0.438bcd
T_6	98.00±1.255a	4.45±0.032a	0.26±0.037b	**0.67±0.101d**
T_7	88.67±2.793ab	**4.46±0.183a**	0.23±0.015b	5.50±0.560ab
T_8	**98.67±4.977a**	4.33±0.091a	0.62±0.163ab	4.67±0.785abc
T_9	74.00±5.022abc	4.04±0.023a	0.19±0.030b	4.33±0.659abc
T_{10}	52.67±2.265c	4.15±0.102a	0.12±0.021b	2.00±0.348bcd

Control (without plant extracts), T_1 – Turmeric powder extract, T_2 – Babla leaves extract, T_3 – Bael leaves extract, T_4 – Chirota leaves extract, T_5 – Allspices extract, T_6 – Turmeric leaves extract, T_7 – Lemongrass extract, T_8 – Khoksha leaves extract, T_9 – Dry Henna leaves extract and T_{10} – Fresh Henna Leaves extract.

Hosain *et al.* (2017) reported that the seed germination varied from 88.14 to 97.77%, where significantly the lowest germination was recorded with extract of neem leaf followed by control and the highest was found in BAU-Biofungicide. Naznin *et al.* (2016) observed 50.80% higher germination over the control in cowpea by applying BAU-Biofungicide. *Trichoderma harzianum* treated seed of blackgram resulted up to 16.66% seed germination over control (Shamsuzzaman and Hossain, 2003). Ahmed *et al.* (2013) reported that Garlic extract (1:1) was best for successful reduction of seed-borne infection which increased seed germination up to 68.39% over control. This result is also supported by Bhuiyan *et al.* (2013) and Khaleduzzaman (1996). It was found that Tilt 250 EC reduced seed germination of wheat but produced healthy seedlings (Ashraf, 2015). Mahal (2014) reported that Neem extracts shows the highest seed germination on pulse crops. BAU-fungicides have great effect than Neem and Garlic extracts in seed germination and seedling vigor (Debnath *et al.*, 2012). Biofungicide improved the plant characters as percent germination, number of branches per plant, plant height and seed yield and decreased the damping off disease incidence of the bean. Alam *et al.* (2014) reported that seed treatment with *Trichoderma* based biofungicide decreased the prevalence of seed-borne fungi of chili. Considering the overall dimensions of treatments and conditions, it is clear that BAU-Biofungicide (3%) and garlic extract (1:1) showed better performance for reducing of the chili seed borne diseases, and increasing seed health and seedling vigor (Hossen *et al*., 2017).

In the present study, the branching numbers are higher in T_6 and T_7 (Turmeric leaves and Lemongrass) treatments and lowest in T_3 (Bael leaves) treatment (Table 1). Maximum number of branches per plant, plant height and seed yield compared to control was observed from BAU-Biofungicide treated seeds (Azad *et al.*, 2017).

The highest numbers of leaf blight symptoms were observed in T_5 (All spices) treatment and minimum in T_{10} (Fresh henna leaves) treatment (Table 1). The highest plant height was recorded from the treatment with DLEFS (Datura leaf foliar spray) which followed BBSFS (bio-fungicide seed treatment and foliar spray) and minimum plant height was recorded from untreated control (Hasan *et al*., 2016). The numbers of leaves at the different count and maximum number of leaves at 4th and 5th counts were found in DLEFS which followed by BBSFS and minimum in untreated control (Hasan *et al*., 2016).

The leaf blight infected plants are maximum in Control and minimum in T_6 (Turmeric leaves) treatment (Table 1). Hasan *et al*., 2016 observed maximum number of infected leaves under untreated control at all five counts and maximum number of pods and weight of pods were from BBSFS where the lowest was found under control. Sultana *et al*. (2001) reported that BAU-Biofungicide increased germination and seedling vigor of some vegetable seeds.

Number of seeds was maximum in T_6 (Turmeric leaves) treatment and lowest in T_{10} (Fresh Henna leaves) treatment. Number of healthy seeds were maximum in T_6 (Turmeric leaves) and minimum in T_{10} (Fresh Henna leaves) treatment. Total yield was highest in T_6 (Turmeric leaves) treatment and lowest in T_{10} (Fresh Henna leaves) treatment (Table 2).

Table 2. Number of seeds, healthy seeds, infected seeds and seed weight of wheat

Treatments	Total No. of Seeds	Total Yield (gm)	No. of Healthy Seeds	No. of Infected Seeds	1000 Seed Weight (gm)
Control	6384.33±36.56 abc	291.33±1.84bc	5114.33±22.99a	1270.00±51.33cd	45.00±0.17bcd
T_1	6031.67±56.87bc	275.67±1.16cd	4677.67±61.98b	1354.00±60.68bcd	45.67±0.10abc
T_2	5972.67±28.30c	253.67±1.05efg	4346.00±27.29bcd	1626.67±24.43abc	42.67±0.27cdef
T_3	6008.33±35.96c	249.00±0.92fg	4250.67±27.39cd	1756.67±8.58a	42.00±0.30def
T_4	6128.67±56.65bc	267.67±0.44de	4642.00±33.33bc	1486.67±23.35abcd	44.00±0.46bcde
T_5	6092.67±30.58bc	253.67±1.62efg	4462.67±11.39bcd	1630.00±20.87ab	41.67±0.10ef
T_6	**6638.67±16.37a**	**312.00±1.96a**	**5478.67±13.58a**	**1160.00±10.58d**	**47.00±0.35ab**
T_7	6483.33±26.62ab	295.67±1.05ab	5206.67±21.76a	1276.67±17.16bcd	45.67±0.27abc
T_8	6264.00±41.27abc	302.67±1.31ab	5086.67±35.69a	1177.33±7.38d	**48.33±0.20a**
T_9	6032.00±2.76bc	261.33±1.84def	4545.33±10.54bcd	1486.67±7.84abcd	43.67±0.27cde
T_{10}	5951.67±21.04c	239.67±1.58g	4198.33±22.47d	1753.33±12.34a	40.33±0.10f

Control (without plant extracts), T_1 – Turmeric powder extract, T_2 – Babla leaves extract, T_3 – Bael leaves extract, T_4 – Chirota leaves extract, T_5 – Allspices extract, T_6 – Turmeric leaves extract, T_7 – Lemongrass extract, T_8 – Khoksha leaves extract, T_9 – Dry Henna leaves extract and T_{10} – Fresh Henna Leaves extract.

Hasan *et al*. (2016) reported that maximum number of pods was recorded under untreated control at all the five counts and weight of pods were recorded from BBSFS where the lowest was found under Control. He observed that root length, shoot length and vigour index was significantly increased after application with alcoholic and water extracts of rhizome of ginger, bulb of garlic and leaf of neem on seeds of wheat, while the lowest result was recorded in control. The highest growth parameter was recorded in neem and Debdaru leaf extract followed by untreated control. Shoot length, vigour index, root weight and shoot weight like as different growth parameter were maximum in BAU-Biofungicide spray and also reported that the highest and the lowest pod yield were produced by BBSFS and untreated control, respectively (Hossen *et al.*, 2017).

In this experiment, number of infected seeds was higher in T_3 (Bael leaves) and T_{10} (Fresh Henna leaves) and lowest in T_6 (Turmeric leaves). Table 2 shows that 1000 seed weight was maximum in T_6 (Turmeric leaves) and minimum in T_{10} (Fresh Henna leaves) treatment. Najnine *et al*. (2016) reported that the 1000 grain weight under different treatments ranged from 39.073 to 41.590 g, where the highest 1000 grain weight was found in case of seed treatment + foliar spray with BAU-Biofungicide followed by seed treatment + foliar spray with Bavistin and lowest in untreated control. This result is supported by Hossain and Hossain (2012). They reported that seed treatment + foliar spray BAU-Biofungicide higher grade of seeds and 1000 grain weight over control. Neem seed, garlic clove, onion bulb, ginger rhizome and pawpaw leaf led 3-10% reduction in the disease incidence, 10-15% reduction in disease severity than the control. The extracts of *A. indica* and *D. metel* increased the pod yield by 15-40% under field conditions which was comparable with the commercial fungicide Bavistin by Ihejirika *et al*. (2006).

4. Conclusion

In this experiment, Turmeric leaves (*Curcuma longa*) and Khoksha leaves (*Ficus glomerata* Roxb.) treatments gave the highest germination and healthy seeds production of wheat in experimental field. These two plants extracts can be used for eco-friendly management of fungal diseases in wheat field of Bangladesh.

Acknowledgement

The authors sincerely acknowledge the financial support of the Ministry of Science and Technology, Government of Bangladesh during 2017-2018.

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Molluscan Biodiversity of the South Western Region of Bangladesh

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Abstract

The ecological and geological characters of South Western part of Bangladesh provides a good molluscan fauna. World famous Mangrove forest the Sundarbans has a habitat for the vast water area which in highly nutritive for their fauna. In order to explore the present status of molluscan fauna the work has been carried out in the South Western Region of Bangladesh, and Khulna, Satkhira and Bagerhat districts were study areas. From May 2012 to February 2017 was done during this tenure. In present investigation a total species 68 belonging to 40 genera, 26 families and 10 orders were collected. *Cerithidea decollate* was found for the first time in Bagerhat district. It is a new record in Indian sub-continent. *Pila scutata, P. theobaldi, Bellamya b. f. eburnea* and *B. b. f. gigantica* are also new records for Bangladesh territory. Freshwater Bivalve specie density found very low; only four species were found randomly. *Nerpteron cornucopia* was found in Dumoria; Khulna. Previously, this species was first recorded in Hugli, Kolkata. Mangrove associated mollusk *Melampus coffea* was first found in Shamnagar, Shatkhira. In Bangladesh, snail sector has an important contribution to the national shrimp and other artificial fish farming sectors. It provides a source of income for rural poor people of this region. By proper management and planning this sector would be sustainable and productive for our country.

Keywords: Mollusca, Biodiversity, South Western Region, Coastal Zone and Bangladesh

1. Introduction

Bangladesh is a transitional zone of flora and fauna, because of its geographical settings and climatic characteristics. Freshwater molluscs are common in ponds, paddy fields, irrigation canals, lakes, hill streams and rivers. Marine molluscs live in a wide range of habitats, from supra tidal mark of a coast to the extremely deep water (Encyclopedia of Flora and Fauna of Bangladesh, 2007).

From ancient time molluscs have been a source of food for humans. A wide variety of molluscs like snail mussels, cockles, oysters, clams, cuttlefish, squids and octopuses are considered as food all over the world, particularly in the Indo-Pacific region, Europe and the Americas. In Bangladesh more than 36 types of tribal people use mollusk as food.

Mostly large, colorful, Gastropod and some Bivalve shells are used as souvenirs and decoration. Bivalve is used as bio-indicators to monitor the health of aquatic environments in both freshwater and the marine environments. By analyzing the innards of *Corbicula* heavy metal contamination was noted. *Corbicula* was collected from different location of the Ganges- Padma River and metal properties were different (Mitra, 2005). Ahmed *et al.* (2010) also detected some heavy metal in macro-benthic fauna of the Sundarbans mangrove forest of Bangladesh. They collect some Gastropods and Clams from intertidal zone. This heavy metal contamination detects pollution.

Some land molluscs act as pest. *Achatina fulica, Macrochlamys indica, M. sequax* and *Opeas gracile* pests of agro-horticulture. *Pila globosa* trading has been developed in Bangladesh for shrimp farming especially southwest region. Last year per packet (20/25 kg) snail was sold by 600-650 taka. Molluscs are also used for construction industry, lime industry, pearl industry and poultry industry. Many small lime industries were found in South Western region of Bangladesh. Various kinds of molluscan shell are used for lime production. Molluscs are also known as carrier of parasites infecting domestic animals. Terrestrial mollusks *Achatina fulica* has been reported by Abbott (1989) as an intermediate host of human lung fluke. Freshwater mollusks as *Lymnaea acuminata, L. stagnalis, Pila globosa, Bellamya bengalensis* and *Thiara tuberculata* causes various fatal diseases of man and domestic animals (Rahman *et al.*, 1998, 2003; Rahman 2000, Rahman and Jahan 1999a, 2001, 2002, 2004, 2005 and 2006).

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Molluscs are a bio energetically significant group. The freshwater molluscs play an important role in ecosystem. Land snail also act as pest, friend of nature, link in food chain, soil fertilizers and calcium supplier. It feeding on the dead material and contributing to the recycling of the plant nutrients.

In Bangladesh; many researchers work on this ground. Ali, 1975 made a survey in St. Martin Island, and reported 32 molluscan species belonging to 24 genera and 20 families. Ali and Aziz (1976) have made another taxonomic work in same place.

Ahmed *et al.,* 1978, 1998 and 2010 and Ahmed (1990 and 2003) conducted detailed surveys. In this continuous study, he covered the coast, St. Martin, Heron point and Dublarchar below the Sundarbans. They recorded 301 Molluscen Species under 151 genera and 79 families of 16 orders. Jahan and Raut (1984), Jahan (1992, 1993), Jahan and Rahman (2000a,b) Jahan *et al.* (1990, 1996a,b,c, 1998a,b,c,d 1999a,b, 2001a,b,c, 2002, 2003, 2005, 2007a,b), Saha (1998), Saha *et al*. (2000, 2002a,b, 2003, 2004), Sarker and Jahan (1998), Sarker *et al*. (2000), Islam (2006), Bhuiyan (2010) research on different aspect such as habit and habitat, food feeding, behaviour, biology, morphology, morphomatrics parameter, reproduction, economic importance and their ecology in the different district of Bangladesh.

Quader (2010) worked about coastal and marine biodiversity of Bangladesh. According to his work, the coastal area of Bangladesh 336 species of mollusks, covering 152 genera. In near future Mollusc would be a beneficial fisheries like prawn and crab. After Aila and Sidr highly saline water washed this area. So, in this time many biotas like fish, mollusks *etc* had been destroyed of that area is essential for the conservation of biodiversity. People of Koyra Thana said huge amount of *Pila* sp. died after Aila and now *Pila* sp. found from this area and a list of existing snail fauna by exclusive survey. The aim of this article is to record the molluscan biodiversity of the south western region of Bangladesh.

2. Materials and Methods

2.1. Description of the Study Area

The ecological and geological situation of South Western part of Bangladesh is unique in many ways. Southwest coastal region of Bangladesh has a unique brackish water ecosystem and comprising the districts of Satkhira, Khulna, and Bagerhat (Figure 1). This region covers a land area of 12211.9sq.km. People of this region are very interested in Shrimp and Prawn farming, in last 30 years. These developed numerous artificial wetlands. The world famous Mangrove forest Sundarbans are included in this region. There is many big river, beels, canals and wetland.

2.2. Soil Structure of the Study Area

The coastal areas of Bangladesh have less cropping intercity due to dry season salinity of the soil and water logging. This area is a part of Bengal basin that covers mostly the alluvial deposits of the Ganges delta plain. Geologically this area is located on high thickness of sedimentary rock mainly composed of clay, sand and alluvial deposits.

2.3. Soil Structure of Khulna District

Soil structure of Khulna is alluvial floodplain. Main rivers of Khulna are Rupsa, Pasur, Bhairab, Shibsha, Dharla, Bhadra, Ball, Kapotakkha, Vadra, Sholmari and Kobadak. Beel Dakatia is one of the big wetland situated in Khulna. Paddy, Jute, Coconut, Banana, Oilseed *etc* is main crops of Khulna. Soil structure is alluvial floodplain. Main fisheries resource of Khulna is Shrimp, Prawn, Crab and Fish.

2.4. Soil Structure of Satkhira District

Soil structure is Alluvial floodplain. The annual average maximum temperature of this district is 35.5°C and minimum temperature is 12.5°C. The annual rainfall is 1710mm. Soil structure of Satkhira is mainly alluvial floodplain. Main rivers are Morichap, Kholpotua, Betna, Raimangal, Hariabhanga, Ichamati, Betrabati and Kalindi-Jamuna.

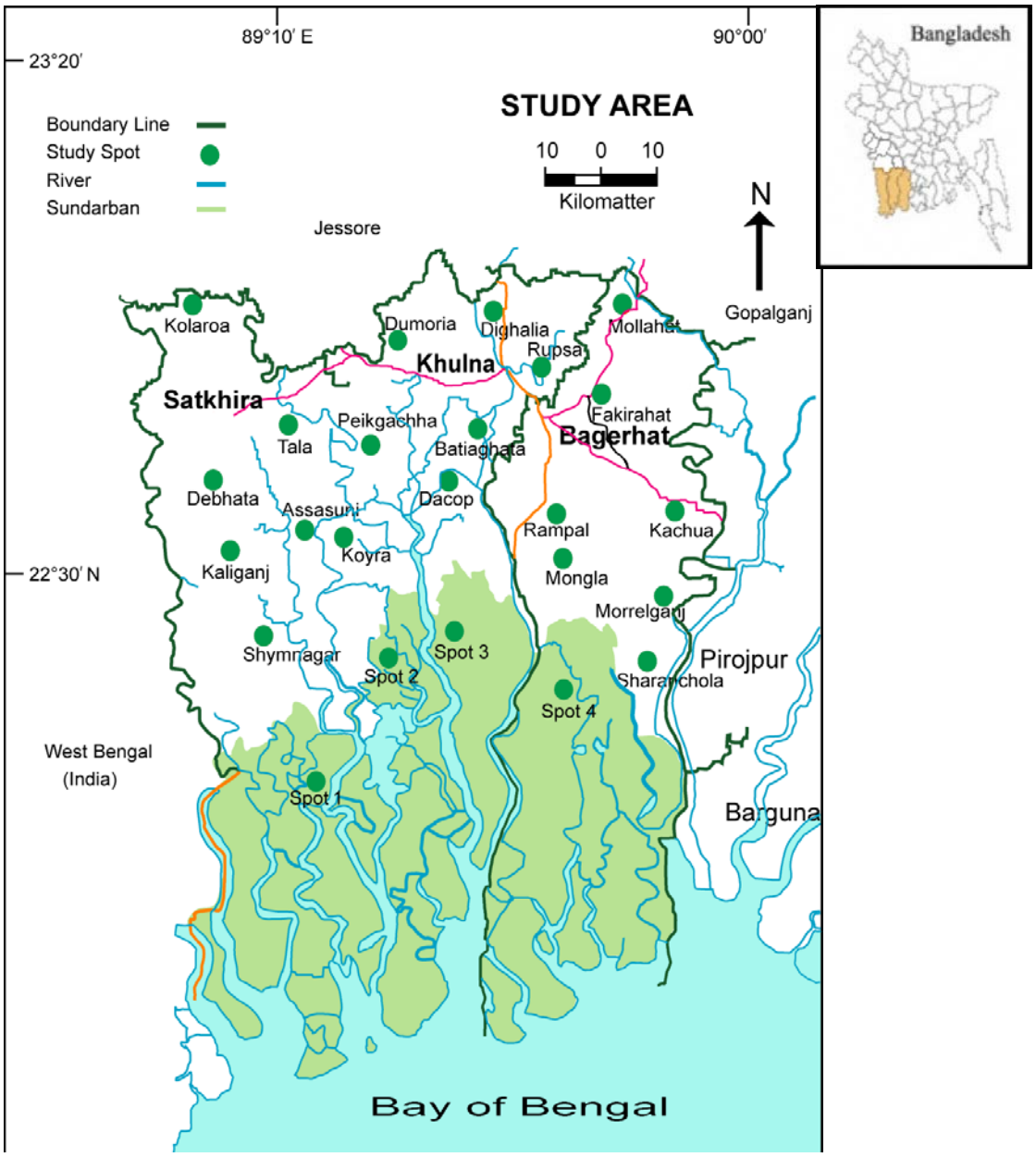


Figure 1. Map of Satkhira, Khulna and Bagerhat district in the South Western Region of Bangladesh

2.5. Soil Structure of Bagerhat district

Soil structure is Alluvial floodplain. Main crops are; paddy, coconut, jute, vegetable, *etc*. Fisheries are main source of income in this area

Main Rivers are Panguchi, Daratana, Madhumati, Pasur, Haringhata, Mongla, Baleswar, Bangra and Goshairkhali.

2.6. Methodology of the Sampling Spot Selection

Random selection method was followed for spot selection. 20 Thana and 4 spot of Sundarbans were selected for study. Sampling procedure plays an important role of a research. It provides good information about subject. Due to time and logistic support it is not possible to cover all the Thana of study area. There was 25 Thana and a large Mangrove forest. So, Yamane's mathematical formulae have been followed to determine the sample size.

Taro Yamane's (1970) formula: $n=\left(\frac{N}{1+N}\right)e^2$ Where N=Total Thanas = 25, n= Sample size, e= Level of confidence = 5%

2.7. Collection Technique Terrestrial Mollusc

Only the Sundarbans is included in this study, and for terrestrial fauna 4 study spots of Sundarbans and 20 spots of other area (Thana) were selected. Small garden; beside house and vegetable field is the habitat of terrestrial Mollusc. From each of the localities three spots of 10m² quadrate areas was taken and surveyed in summer, late monsoon and winter seasons. From all quadrates snails, slugs and empty shells were collected by hand. Empty shells and live species were put in to different plastic airtight pot. Primarily it washed with freshwater for remove mucous and then treated with ascending grade of ethyl alcohol.

2.8. Collection Technique Aquatic Mollusc

Twenty Thanas of 3 districts were selected for determination of population density. As the study area is rich of river, canals and wetland so 4 rivers 7 ponds and 11 wetlands were taken for the study. Each of selected spot three quadrates of 1m² area was taken in respect of summer, let-monsoon and winter season. Aquatic Mollusc was collected by hand, plastic baskets and small net. Primarily it washed with fresh water for remove mucous and then treated with ascending grade of ethyl alcohol. Through regular watch the habit and habitats of Molluscs species had been noted.

2.9. Washing and Preservation Method

For preservation good washing is necessary. Soil, algae, mucous and any kind of extra substance was washed by freshwater with NaCl. Bucket, brash and needles are used for washing. 70% ethanol is finest for hard shell preservation, but for soft or thin shell a solution of ethanol, glycerin and distil water were used.

2.10. Taxonomic Methods

Collected samples were carried to Ecology and Biodiversity Research Lab. in the Institute of Environmental Science, University of Rajshahi for identification. Molluscs were identified mainly on the basis of shell character. For taxonomic identification of freshwater and land molluscs, keys used were followed from Subba Rao (1989), Mitra *et al.,* (2005) and Ramakrishna and Day (2007). Some Mangrove Associate mollusc's identification keys were followed from Day (2006) and Zoological Survey of India (ZSI).

3. Result and Discussion

In present investigation a total species 68 were identified, of which terrestrial 11, freshwater 27 and brackish water 30 molluscs belonging to 40 genera, 26 families and 10 orders were recorded in the South Western region in Bangladesh (Table 1a, b, c, d and e).

The estimated number of living mollusc species presently varies from 80,000 to 135,000 (Boss, 1973). In Bangladesh 20 land, 22 freshwater and 437 marine and brackish water mollusc species belonging to 210 genera, 105 families and 23 orders under 4 classes have been recorded (Encyclopedia of Flora and Fauna 2007). India, with her vast land area and widely varied topographic and climatic conditions accommodate 5% of the total world fauna (Mitra *et al.*, 2005).

In Bangladesh, sporadic surveys and investigations were carried out by Ali, 1975; Ali and Aziz, 1976; Ali and Begum, 1976 and 1978; Ali *et al*., 1985; Ahmed, 1978, 1990 and 2003; Alam and Patra, 1986; Begum *et al.*, 1989; Islam, 2009; Jahan, 1992 and 1993; Jahan and Raut, 1994; Jahan and Rahman, 1996 and 2000), Jahan *et al*., (1990, 1996, 1998, 1999, 2001, 2001, 2001, 2002, 2003, 2007 and 2007 , Khanom (2007), Mannan and Khan (1990), Rahman (2000), Rahman and Jahan (1999a, 1999b and 2001), Rahman *et al.*, (1999 and 2000), Saha (1998), Saha *et al*., (2002, 2003 and 2004) and (Bhuiyan, 2010) studied the distribution, abundance, ecology and developmental biology of molluscs in Bangladesh.

Table 1a. Species Name and Localities of Recorded Mollusca in the Present Study in the South Western Region and Previous Recorded by others Authors in Bangladesh

No. of Species	Name of Species and Localities from where Recorded during the Study Period	Recorded from other Localities in Bangladesh by Different Authors	
1	Species: *Pterocyclus parvus* (Pearson, 1833) Distribution: In the study area, it was found in Rupsa and Dighalia Thana.	Sylhet, Chittagonj, Garo, Khasi His, Maulvibazar	Ahmed, 1990 and Bhuiyan, 2010
2	Species: *Rachis bengalensis* (Lamark, 1822) Distribution: In the study area, it was found Kochua and Bagerhat.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
3	Species: *Indosuccinea semiserica* (Gould, 1846) Distribution: In the study area, it was found in Rupsha, Mollarhat.	North Eastern Region of Bangladesh	Bhuiyan, 2010
4	Species: *Indosuccinea plicata* (Blanford 1924) Distribution: In the study area, it was found in Rupsha, Mollahat, Soronkhola, Tala and Kolaroa.	North Eastern Region of Bangladesh	Bhuiyan, 2010
5	Species: *Filicaulis (Eleutherocaulis) alte* (Ferrussac, 1821) Distribution: In the study area *F. alte* was found in only Rupsha thana.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010
6	Species: *Lamellaxis gracilis* (Hutton, 1834) Distribution: In the study it was found in Khulna, Mollarhat, Kochua and Fakirhat.	Rajshahi University Canpus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
7	Species*: Glessulan otigena* (Benson, 1853) Distribution: In this study, it was found in Rupsha Thana.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
8	Species: *Achatina fulica fulica* (Bowdich, 1822) Distribution: Bangladesh: Almost all districts of Bangladesh.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and and Bhuiyan, 2010
9	Species: *Macrochlamys opiparus* (Godwin-Austen 1883) Distribution: In the study area, it was found in Khulna, Bagerhat, Shatkhera.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
10	Species: *Macrochlamys sequax* (Benson, 1859) Distribution: In the study area it was found in Khulna, Bagerhat, Satkhira.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
11	Species: *Girasia crocea* (Godwin-Austen) Distribution: In this study area, it was found in Rupsha and Khulna.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010
12	Species: *Pila globosa* (Swainson, 1822). In this study area, it was found in maximum area.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003; Ahmed, 1990 and Bhuiyan, 2010
13	Species*: Pila virens* (Lamarck, 1822) Distribution: Almost all the districts of Bangladesh.	North Eastern Region of Bangladesh	Ahmed, 1990 Bhuiyan, 2010
14	Species: *Pila scutata* (Mousson, 1847) Distribution: In the study area, it was found in Rumpal and Sundarbans	No record	No record

Table 1b. Species Name and Localities of Recorded Mollusca in the Present Study in the South Western Region and Previous Recorded by others Authors in Bangladesh

No. of Species	Name of Species and Localities from where Recorded During the Study Period	Recorded from other Localities in Bangladesh by Different Authors	
15	Species: *Pila scutata compacta* (Reeve, 1856) Distribution: In the study area, it was found in Sundarbans.	No record	No record
16	Species: *Pila theobaldi* (Hanley, 1875) Distribution: In the study area, *P. theodaldi* was found in Bagerhat.	No record	No record
17	Species name: *Bellamya bengalensis* (Lamarck, 1822) Distribution: Almost all district of Bangladesh.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
18	Species: *Bellamya bengalensis* form *typica* (Lamarck, 1822) Distribution: Almost all districts of Bangladesh.	North Eastern Region of Bangladesh	Bhuiyan, 2010
19	Species: *Bellamya bengalensis* form *gigantea* (Reeve, 1862) Distribution: In the study area, it was found in Satkhira.	No record	No record
20	Species: *Bellamya bengalensis* form *eburnea* (Annandale, 1921) Distribution: In this study area, it was found in Satkhira district.	No record	No record
21	Species: *Bellamya crassa* (Benson, 1836) Distribution: Bangladesh: Almost all districts of Bangladesh	North Eastern Region of Bangladesh	Ahmed, 1990 and Bhuiyan, 2010
22	Species: *Bellamya dissimilis* (Mueller, 1774) Distribution: In the study area, it was found in Rupsha and Kolaroa.	North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
23	Species: *Melanoides tuberculata* (Muller, 1774) Distribution: In the study area, it was found in Dighalia, Dacop, Sundarbans and Mongla.	North Eastern Region of Bangladesh	Bhuiyan, 2010
24	Species: *Lymnaea stagnalis* (Linnaeus 1758) Distribution: In the study area, it was found in Satkhira, Dumoria and Mollarhat.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
25	Species: *Lymnaea luteola* (Lamarck, 1822) Distribution: In the study area, it was found in Satkhira, Rupsha, Mollarhat and Dighalia.	North Eastern Region of Bangladesh	Jahan *et al.*, 2003 and Bhuiyan, 2010
26	Species*: Tarebia granifera* (Lamarck, 1822) Distribution: Over all Bangladesh.	North Eastern Region of Bangladesh	Bhuiyan, 2010
27	Species*: Tarebia lineata* (Gray, 1828) Distribution: In the study area, it was found in Mongla, Shamnagar, Dacop and Dighalia.	North Eastern Region of Bangladesh	Bhuiyan, 2010
28	Species*: Brotia (Antimelania) costula* (Rafinesque, 1833), Distribution: In this study, it was found only Mollarhat and Bagerhat.	North Eastern Region of Bangladesh	Bhuiyan, 2010
29	Species: *Thiara scabra* (Mueller, 1774) Distribution: In this study, it was found in Rupsha, Digholia and Kolaroa thana.	North Eastern Region of Bangladesh	Bhuiyan, 2010

Table 1c. Species Name and Localities of Recorded Mollusca in the Present Study in the South western region and Previous Recorded by others Authors in Bangladesh

No. of Species	Name of Species and Localities from where Recorded during the Study Period	Recorded from other Localities in Bangladesh by Different Authors	
30	Species: *Indoplanorbis exustus* (Deshayes, 1834) Distribution: In the present study, it was found in Kochua.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 Bhuiyan, 2010
31	Species: *Gyraulus convexiusculus* (Hutton, 1849) Distribution: In present study this snail was found in Satkhira.	Rajshahi University Campus, North Eastern Region of Bangladesh	Jahan *et al.*, 2003 Bhuiyan, 2010
32	Species: *Cerithidea alate* (Philippi, 1847) Distribution: In this study, it was found in Koyra, Dacop and Shamnagar.	Sundarbans	Ahmed, 2003
33	Species: *Cerithidea cingulata* (Gmelin, 1791) Distribution: In this study area, it was found in Koyra, Dacop, Shamnagar, Mongla.	Dublar Char, Heron Point, Naf river, Nuniarchar	Ahmed, 2003 Jahan *et al.*, 1998
34	Species*: Cerithidea obtusa* (Lamarck, 1822) Distribution: In the present study, it was found Koyra, Dacop, Shamnagar and Mongla.	Dublar Char, Heron Point, Sundarbans	Jahan *et al.*, 1998, 1990 and Ahmed, 1990
35	Species: *Cerithidea quadrata* (Sowerby, 1866) Distribution: In the present study, it was found in Sundarbans and Shamnagar point.	Khulna, Satkhira, Bagerhat, Sundarbans	Ahmed, 2003
36	Species: *Cerithidea decollate* (Linnaeus, 1767) Distribution: Mainly found in Mozambique, South Africa and Australia. In this present study, it was found in Kochua and Bagerhat.	No record	No record
37	Species*: Telescopium telescopium* (Linnaeus, 1758) Distribution: In this study, it was found in Koyra, Shamnagar, Dacop and Mongla point.	Sundarbans, Heron Point, Cox's Bazar	Jahan *et al.*, 1990 and Ahmed, 1990
38	Species: *Nerita articulata* Gould, 1847 Distribution: In this study it was found in Dacop and Mongla point.	Sundarbans	Ahmed, 1990
39	Species: *Neritina smithi* (Wood, 1828) Distribution: In this study, it was found in Pikgasha, Mongla, Dumoria and Rumpal.	Paikgacha, Khulna, Sela Char	Ahmed, 1990 Jahan *et al.*, 1998
40	Species: *Nerpteron violacea* (Gmelin, 1791) Distribution: In the present study, it was found in Sundarbans and their adjacent area.	Dublar Char, Sela Char, Sundarbans, Heron Point	Jahan *et al.*, 1998, 1990 and Ahmed, 1990
41	Species: *Nerpteron cornucopia* (Benson, 1836). Distribution: In the present study it was found in only Dumoria and Khulna.	No record	No record
42	Species: *Littoraria melanostoma* (Gray, 1839) Distribution: In Bangladesh; Sundarbans; Koyra.	Sela Char, Koikhali, Sundarbans, St. Martin's Island	Jahan *et al.*, 1998, 1990 and Ahmed, 1990
43	Species: *Pugilina cochlidium* (Linnaeus. 1758) Distribution: In this present study it was found in Surdarban and Shamnagar.	Kobadak, Koikhali, St. Martin's Island, Cox's Bazar, Sundarbans	Ahmed, 1990 and Jahan *et al.*, 1998, 1990

Table 1d. Species Name and Localities of Recorded Mollusca in the Present Study in the South Western Region and Previous Recorded by others Authors in Bangladesh

No. of Species	Name of Species and Localities from where Recorded During the Study Period	Recorded from other Localities in Bangladesh by Different Authors	
44	Species*: Puglilina ternatena* (Gmelin. 1791) Distribution: In this present study, it was found in Sundarbans and Koyra zone.	Kobadak, Koikhali, St. Martin's Island, Cox's Bazar, Sundarbans	Ahmed, 1990 and Jahan *et al.*, 1998, 1990
45	Species*: Cassidula nucleus* (Gmelin, 1791) Distribution: In this present study, it was found in Sundarbans; Mongla, Dacop and Koyra zone.	Sundarbans	Ahmed, 1990
46	*Species:Melampus coffea* (Linnaeus, 1758) Distribution: In this present study area, it was found in only Shamnagar and Shatkhira.	No record	No record
47	Species*: Ellobium aurisjudae* (Linnaeus, 1758) Distribution: In this present study area, it was found in Shamnagar, Shatkhira and Mongla point of the adjacent area of the Sundarbans	Sundarban	Ahmed, 1990
48	Spesies: *Ellobium ganeticum* (Pfeiffer, 1855) Distribution: In this study area, it was found in Shamnagar; Shatkhira and Mongla point of the Sundarbans.	Sundarbans	Ahmed, 1990
49	Speciec: *Pythia plicate* (Gray, 1825) Distribution: In this study area, it was found in Botiaghata, Kochua and Mongla point of the Sundarban.	Sundarbans	Ahmed, 1990
50	Species: *Onchidium typhae* (Buchanan, 1800) Distribution: In this study area it was found in Botiaghata, Morrelganj and Mongla point of the Sundarbans.	Sundarbans	Ahmed, 1990
51	Species: *Onchidium tenerum* (Stoliezka, 1809) Distribution: In this study area, it was found in Morrelganj, Mongla and Kochua.	Sundarbans	Ahmed, 1990
52	Species: *Onchidium tigrinumtigrium* (Stoliczka, 1869) Distribution: In this study area, it was found in Morrelganj, Mongla, Kochua and Bitiaghata.	Sundarbans	Ahmed, 1990
53	Species: *Modiolus striatulus* (Hanley, 1844) Distribution: In this study, this species was found in Paikgachha.	Coastal region of Bangladesh	Ahmed, 1990
54	Species: *Modiolus undulatus* (Dunker, 1856), Distribution: In this study area it was found in only Morrelganj.	Coastal region of Bangladesh	Ahmed, 1990
55	Species*: Thais lacera* (Born, 1778) Distribution: In my study area: Koyra, Shymnagar.	Mangrove forest	Ahmed, 1990 and Day, 2006
56	Species: *Thais blaofordi* (Melvill, 1893) Distribution: In the present study, it was found in only in Koyra and Shymnagar.	St. Martin's Island	Ahmed, 1990
57	Species: *Lamelliden scorrianus* (Lea, 1834) Distribution: In the present study, it was found in Debhata, Kolaroa and Kaliganj.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010

Table 1e. Species Name and Localities of Recorded Mollusca in the Present Study in the South Western region and Previous Recorded by others Authors in Bangladesh

No. of Species	Name of Species and Localities from where Recorded During the study period	Recorded from other Localities in Bangladesh by Different Authors	
58	Species: *Lamellidens jenknsianus* (Benson, 1862) Distribution: In the present study it was found in most of the Thana of Satkhira.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010
59	Species: *Lamellidens jenkinsianus* sub sp. *daccaensis* (Preston, 1912) Distribution: In present study, it was found in only Satkhira.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010
60	*Lamellidens marginalis* (Lamarck, 1819) Distribution: In the present study, it was found in only Satkhira and Dacop.	Rajshahi University Campus, North Eastern Region of Bangladesh	Bhuiyan, 2010
61	Species name: *Novaculina gangetica* (Benson, 1830) Distribution: In the present study, it was found in Mongla and Peikgachha Thana of Khulna District.	Padma river of Bangladesh	Ahmed, 1990 and Subba Rao, 1989
62	Species: *Parreysia caerulia* Distribution: In present study it was found only Soni river of Satkhira.	Dhaka, Sylhet, Mymensingh	Ahmed, 1990 and Bhuiyan, 2010
63	Species: *Austromacoma birmanica* (Philippi, 1833) Distribution: In my study, it was found in Paikgachha and Mongla.	Mangrove forest	Day, 2006
64	Species*: Polymesoda bengalensis* (Lamarck. 1818) Distribution: In the present study, it was found in Koyra, Shymnagar and Mongla.	Sundarbans, Teknaf	Ahmed, 1990
65	Species: *Marcia pinguis* (Schroter, 1788) Distribution: In the present study, it was found in Koyra, Sundarban.	Cox's Bazar	Ahmed, 1990
66	Species: *Crassosttrea cuttackensis* (Newton and Smith, 1912) Distribution: In the present study, it was found in only Shymnagar.	Mangrove forest	Day, 2006
67	Species*: Crassostrea gryphoides* (Schlotheim, 1813) Distribution: In the present study, it was found in only Shymnagar.	Sundarbans	Ahmed, 1990
68	Species: *Saccostrea cucullata* (Born, 1778) Distribution: In the present study, it was found in only Shymnagar.	St. Martin's Island Sonadia, Cox's Bazar, Sundarbans	Ahmed, 1990

Ahmed (1990) recorded 301 Molluscs species under 151 genera and 79 families of 16 orders from the Coastal belt of Bangladesh. Jahan *et al.* (1990 and 1998) recorded 42 molluscs species from the intertidal zones of Sundarbans. In another study of the intertidal zones of Cox's Bazaar and its adjacent areas. Jahan *et al.* (1999a) reported 35 species of molluscs belonging to 27 genera under 18 families of 3 orders. Ali and Begum (1976) reported 19 molluscs species belonging to 12 genera and 9 families under the 4 orders from the Pond of Dhaka City of Bangladesh.

Ali *et al.* (1978) reported 10 species belonging to 8 genera and 7 families under the 3 orders from three Ponds of Dhaka City, Bangladesh. Ali *et al.* (1985) and Rahman *et al.* (2003) on abundance and depth wise distribution of benthic molluscan fauna from a pond in Bangladesh Agricultural University Campus in Mymensingh.

In 1993, Jahan reported 23 (13 terrestrial and 10 fresh water) gastropod species belonging to 19 genera, 14 families and 4 orders from different localities of Bangladesh. Later on Jahan *et al.* (2003) reported 16 molluscs species from Rajshahi University campus, Bangladesh of which 14 species were also reported previously by Jahan (1993). Thus Jahan (1993) and Jahan *et al.* (2003) recorded the presence of 14 species of land molluscs from the territory of Bangladesh for the first time after a long time of publication of the Fauna of British India. Ali (1975) recorded 32 Molluscs species belonging to 24 genera and 20 families from the St. Martins Islands of Bangladesh. Bhuiyan (2010) recorded 72 species from north western region of Bangladesh.

In the present investigation a total species 68 of this terrestrial 11, freshwater 27 and brackish water 30 molluscs belonging to 40 genera, 26 families and 10 orders were collected. Among these *Cerithedia decollate* was not reported in Fauna of British India and even not in any other work from the Bangladesh and India territory (Table 2a, b and c). This species may come in south western region after high tidal flow like Aila.

N. cornucopia was found in Dumoria; Khulna. This species was first time recorded in Bangladesh (Table 2a, 2b and 2c). In India it was recorded in Hugli; Kolkata. *Melampus coffea* was firstly found in Shamnagar; Shatkhira. Mangrove associated mollusk *Melampus pulchella* was recorded by Day (2006) in Sundarbans at Indian side (Table 2a, b and c).

The presence of *B. costula* confirmed the finding of Jahan (1993) though it was not reported in the Fauna of British India. The present investigation confirmed *B. costula* from Mollahat thana at Bagerhat district. *Pilascutata, P. scutata var. compacta, Pila theodaldi, Bellamya b.f. gigantea, Bellamya eburnea* were recorded for the first time in Bangladesh (Tables 2a, b and c).

Freshwater Bivalves *Austromacoma birmanica* and *Parreysia caerulia* were found in Paikghasa and Kaligonjthana during the present study.

In the present study *Pterocyclus parvus*, *Filicaulis alte* and *Glessula notigena* species is only found in Khulna district; *Crassostrea cuttackensis, Crassostrea gryphoides* and *Saccostrea cucullata* are found in Shamnagar, Munsiganj. Land slug *Onchidium tenerum, O. tigrinum,* and *O. typhae* were found in Mongla, Moralganj and Batiaghata.

Though snail related research is more in our country but this important sector could not able to attract our government. Applicable use of this resource and remarkable research is limited for lacking of necessary help. Uncontrolled and unscientifically breadth of shrimp sector of South Western region is influencing the ecosystem of this region which is really harmful for environment. Anthropogenic activities are more responsible than natural disaster for distracting the snail habitation in South Western Region. The present study recorded 68 species of Molluscs from this region, freshwater Bivalve specie density found very low, only four species were found.

Pila globosa was very rarely found but *Pila scutata* and *Pila theobaldi* was found in the Sundarbans, Rumpal, Morrelganj, Sharanchola and Mongla. It mentioned that *P. scutata* and *P. theobaldi* was adapted with high saline water but *P. globosa* cannot. Changes of land use pattern are the cause of it.

Rural people and ghare (shrimp farm) owner of our country are not conscious about biodiversity and it consequences on ecosystem services. So, for more profit they habitually import some awful culture which is damaging the environment.

Table 2a. A List of New Recorded Molluscs with Figure from South Western Region of Bangladesh (Identified by Molluscan Division, Zoological Survey of India)

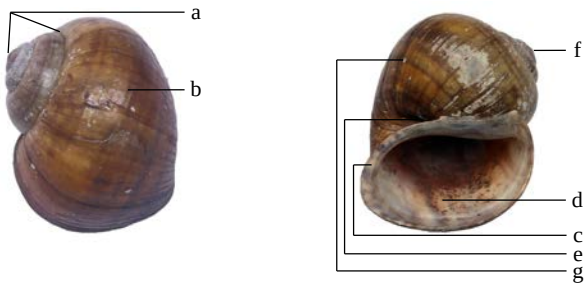
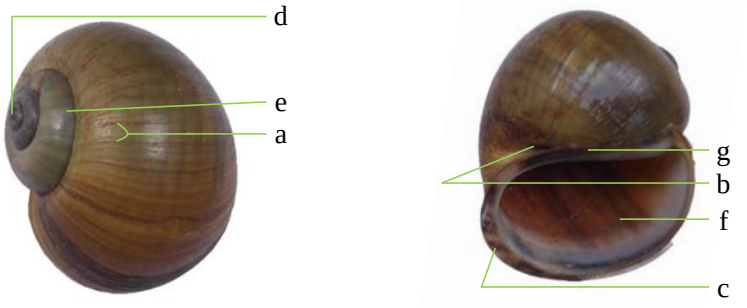
New recorded of Molluscan species with distributions of Different Localities	**Figures and Descriptions**
Pila scutata (Mousson, 1847) Rumpal upzilla and Sundarbans area	 **Figure**: Dorsal and ventral view of *P. scutata* a. Elongated spire, b. Large body whorl, c. Distinct colour bands, d. Aperture, e. Umbilicus narrow, f. Apex, g. Vartical growth line **Description**: Shell ovoid or semi-globose, with large body whorl; spire elongated; whorls descending step like; suture deeply impressed but without distinct carination; umbilicus narrow; olivaceous green with faint brownish spiral bands in young adults, deep brown clour with brownish spiral bands also distinct through the aperture. **Size:** Maximum shell length found 52 mm, shell width, aperture length and aperture width 47, 39, 31 mm respectively.
Pila scutata compacta (Reeve, 1856) Sundarbans, Rampal, Mongla	 **Figure**: Dorsal and ventral view of *P. scutata compacta* (Reeve, 1856). a. Transverse colour bands, b. Broad columellar callus, c. Distinct colour bands, d. Aperture, e. Narrow Umbilicus, f. Apex, g. Vertical growth line. **Description:** Shell larger, Thicker and stouter with strong vertical striations, sometimes making the shells quite malleated, columellar callus much broader; aperture more ovoid; darker in colour with faint transverses colour bands. **Size:** Maximum shell length found 48 mm, shell width, aperture length and aperture width 43, 46.5, 26 mm respectively.

Table 2b. A List of New Recorded Molluscs with Figure from South Western Region of Bangladesh (Identified by Molluscan Division, Zoological Survey of India)

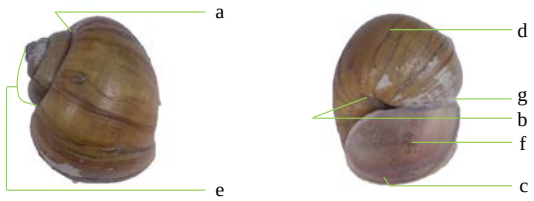
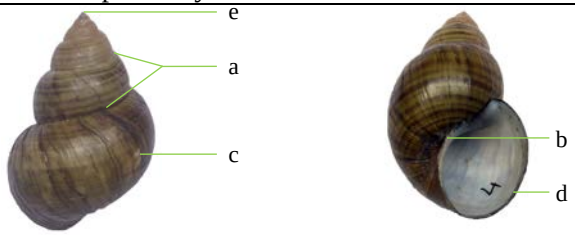
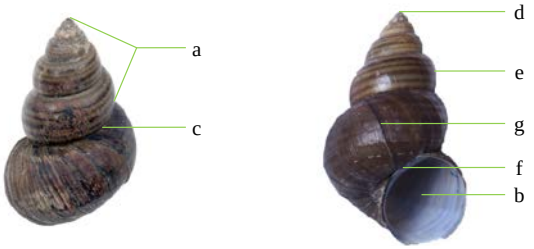
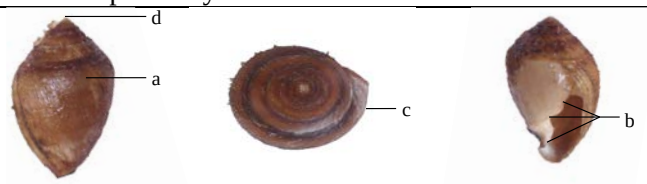
New Recorded of Molluscan Species with Distributions of Different Localities	**Figures and Descriptions**
Pila theobaldi (Hanley, 1875) Bagerhat District Sundarbans, Rampal, Mongla	 **Figure**: Dorsal and ventral view of *P. theobaldi*, a. Impressed suture, b. Widely open umbilicus, c. Irregularly streaked outer, d. Colour bands, e. Spire, g. Columellar margin **Desecration:** Shell large, whorls globose; suture more impressed; umbilicus widely open; aperture without colour bands (Ramakrishna and Day, 2007). The outer lip is rather irregularly streaked or biotched with the same colour and the aperture is obliquely ovate. **Size:** Maximum shell length found 60 mm, shell width, aperture length and aperture width 57, 42.5, 28 mm respectively.
Bellamya bengalensis form *gigantea* (Reeve, 1862) Satkhira Districts	 Dorsal and ventral view of *B. bengalensis* form *gigantea* a. Suture deep, b. Wide umbilicus, c. Body whorl, d. Onter lip, e. Apex **Description:** Shell medium, whorls larger than spire, sub circular aperture, wide umbilicus, suture deep and prominent spiral bands. **Size:** Maximum shell length found 49 mm, shell width, aperture length and aperture width 33, 24.5, 20 mm respectively.
Bellamya bengalensis form *eburnea* (Annandale, 1921) Satkhira Districts	 Dorsal and ventral view of *B. bengalensis* form *eburnea* (Annandale, 1921) , a. Spire high, b. Aparture small, c. Suture deep, d. Apex, e. Colour bands, f. Collumelar margin **Description: S**hell narrow with smaller aperture, whorls much less inflated with distinct flattening below the sutures; body whorl showing a tendency to become biangulate. **Size:** Maximum shell length found 42.5 mm, shell width, aperture length and aperture width 24, 18.5, 14 mm respectively.

Table 2c. A List of New Recorded Molluscs with figure from South Western Region of Bangladesh (Identified by Molluscan Division, Zoological Survey of India)

New Recorded of Molluscan species with Distributions of Different Localities	**Figures and Descriptions**
Cerithidea decollate (Linnaeus, 1767) Kochua Up zilla and Bagerhat District	 Dorsal and ventral view of *C. decollate* a. Axial rib, b. Blunt apex, c. Expended outer lip, d. Aperture, e. Inner lip **Description:** Shell thick, conical, approximately 3 cm long, axial rib present. The apex of shell is blunt or broken-off. Oral cavity round, outer lip thick, round and expended. Colour: light brown. **Size:** Maximum shell length found 27 mm, shell width, aperture length and aperture width 13, 10, 9.5 mm respectively.
Nerpteron cornucopia (Benson, 1836). Dumoria Upzilla and Khulna District	 Dorsal view of *N. cornucopia* a. Black line, b. Inner lip, c. Shaped calcareous operculum, d. Outer lip **Description:** Shell small thick low spired with a swollen last whorl and D-shaped calcareous operculum. In the perfect parallelism of the inner lip with the axis of the shell, its denticulation nearly throughout its whole length, instead of merely in the centre; in the compression of the whorl at the back of the callus, and its subcentrical position, thereby occasioning the approach of the shell to a symmetrical configuration, and finally in its suit at colours. The colour of the shell is brown with black outline. **Size:** Maximum shell length found 20 mm, shell width, aperture length and aperture width 13, 16, 13 mm respectively.
Melampus coffea (Linnaeus, 1758) Shamnagar upzilla and Shatkhira District	 Dorsal and ventral view of *M. coffea* a. Body whorl, b. Dentaculated inner lip, c. Pointed spire, d. Apex **Description:** Shell small, thin and ovate. Spire more then 7 and pointed. Aperture narrow, outer lip sharp, inner lip detacnlated. The maximum recorded shell length is 23 mm. **Size:** Maximum shell length found 20 mm, shell width, aperture length and aperture width 10.19, 10.49, 5 mm respectively.

4. Conclusion

The present investigation a total species 68 of this terrestrial 11, freshwater 27 and brackish water 30 molluscs belonging to 40 genera, 26 families and 10 orders were collected in the south western region of Bangladesh. Among them eight (8) species were recorded for the first time in Bangladesh. Now it is required to take step to ensure the ecological balance of South Western Region of our country. In Bangladesh till today nobody has become interested in snail farming, though the snail sector has an important contribution to the national shrimp and other artificial fish farming sectors. It provides a source of income for rural poor people of this region. Government should take proper policy to save this sector from smash up. By proper management and planning this sector would be sustainable and productive for our country. We hope that the snail will be commercially cultured in our country because, the production of aquaculture can be increased manifolds from only fish culturing to shrimps, crabs, molluscs, oyster *etc*. We should take proper management plan to protect the destructive collection of snail.

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Comparative Study of ARIMA and Artificial Neural Network Methods for Temperature Forecasting in Rajshahi

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Abstract

Temperature forecasting is a complex process and challenging task for researchers and has drawn a lot of research interest in the recent years. There is much dispute over the performance of ARIMA and Artificial Neural Networks (ANNs) in the forecasting of temperature. This paper examines the forecasting performance of ARIMA and ANN model with maximum temperature data in Rajshahi. The results from the comparative study show that ANN model is better to ARIMA model for maximum temperature forecast. The findings thus suggest that the use of ANN procedure in forecasting maximum temperature time series may improve the performance of forecasting model than that done by the traditional ARIMA model, which might be helpful for the weather-forecasting.

Keywords: Artificial Neural Network, ARIMA, Forecasting, Temperature and Rajshahi

1. Introduction

Temperature forecasting is one of the most important factors considered in climate impact studies in the sector of agriculture, water resources, vegetation and tourism. Bangladesh has an agro-based economy and most of the agricultural goods largely depend on the climatic variables and temperature is one of the precedences. Therefore, there is pressing need to forecast temperature accurately in order to minimize the impact (financial and human losses) of unexpected climatic hazards caused by temperature variation. Accurate prediction of temperature is a difficult task due to the dynamic nature of atmosphere. Several techniques have been developed to predict the time series data. The traditional approach based on Box and Jenkins (1976) Autoregressive Integrated Moving Average (ARIMA) models is commonly used because the resulting models in this approach are easy to understand and interpret. If the time series shows seasonal component, ARIMA model should be extended to include this component and then called seasonal ARIMA, SARIMA. ARIMA has widely been exercised over the years to predict temperature (Basak *et al.,* 2013; Nury *et al.,* 2013; Hossain *et al*., 2017; Nyatuame and Agodzo, 2018; Doulah, 2018).

Recently, Artificial Neural Network (ANN) has been used more frequently in the analysis of time series forecasting, pattern recognition and pattern classification capabilities (Chenard and Caissie, 2008; Lee *et al*., 2018; Mishra, *et al*., 2018). The ANN technique has been successfully employed in the atmospheric sciences. In particular, temperature forecasting has already been analyzed in some papers (Ustaoglu *et al*., 2008; Pankaj *et al*., 2013; Attoue, *et al*., 2018).Several studies have been conducted on the comparison between ARIMA model and ANN in forecasting time series data (Safi, 2016; Nury *et al.,* 2017; Bello and Mamun, 2018).Rajshahi is one of the vital agricultural and tourist attracting location in Bangladesh. Rajshahi and some other regions including Padma river basin are facing rapid ground water depletion. So the accurate forecasting of climatic variables in Rajshahi is an important issue in disaster management policy-making due to the effects of recently happened climate change. Therefore, the present study was aimed at comparing the performance of ANN and ARIMA model for a maximum temperature prediction, which is one of the better time series forecasting techniques.

2. Materials and Methods

2.1. Study Area and Data Source

The study area of Rajshahi is situated at Barind Tract and 75 ft above sea level. It is located in Northwestern Bangladesh between 24°07' and 24°43' north latitudes and in between 88°17' and 88°58' east longitudes. The climate of Rajshahi is generally marked with monsoons, high temperature, considerable humidity and moderate

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rainfall (Banglapedia, 2003). The maximum mean temperature observed is about 32 to 36 °C (90 to 97 °F) during the months of April, May, June and July (Wikipedia, 2008). For analysis, we used monthly maximum temperature data covering the period May, 1982 to September, 2018 from Bangladesh Meteorological Department (BMD).

2.2. Methods

2.2.1. Autoregressive Integrated Moving Average (ARIMA)

In time series analysis, the Box-Jenkins methodology applies Autoregressive Integrated Moving Average (ARIMA), or Seasonal Autoregressive Moving Average (SARIMA) models to find the best fit of a time series to make forecasts. The general form of the ARIMA (p,d,q) model using lag polynomial is given by

$$\varphi_p(L)(1-L)^d x_t = \theta_q(L)\varepsilon_t \qquad (1)$$

Where $x_t$is the series; ε_t is the error term; L is the lag operator; $\varphi_p = 1 - \varphi_1 \mathrm{L} - \varphi_2 \mathrm{L}^2 - \cdots \ldots \ldots \ldots - \varphi_\mathrm{p}\mathrm{Lp}$ is the autoregressive (AR) polynomial of order p; $\theta_q = 1 - \theta_1 \mathrm{L} - \theta_2 \mathrm{L}^2 - \cdots \ldots \ldots \ldots \ldots - \theta_\mathrm{q}\mathrm{L}^\mathrm{q}$ is the moving average (MA) polynomial of order q; d is the differencing order.

The ARIMA model (1) is for non-seasonal non-stationary data. Box and Jenkins (1976) have generalized this model with seasonality. This model is known as Seasonal ARIMA (SARIMA).The general form of the seasonal ARIMA (p,d,q) $(P, D, Q)_s$ model in terms of lag polynomial is given by

$$\varphi_p(L)\Phi_P(L^s)(1-L)^d(1-L^s)^D x_t = \theta_q(L)\Theta_Q(L^s)\epsilon_t \qquad (2)$$

Where φ_p = non-seasonal AR polynomial of order p; θ_q= non-seasonal MA polynomial of order p;Φ_P = seasonal AR polynomial of order p; Θ_Q= seasonal MA polynomial of order q; D = seasonal differencing order; s= number of periods in a season.

The Box-Jenkins methodology consists of four steps: (i) Model identification, (ii) Estimation of the model parameters (iii) Diagnostic checking of the model adequacy and (iv) Forecasting. The first step involves testing whether the time series is stationary and if there is significant seasonality that needs to be modeled. The second step is the model parameter estimation in which least square or maximum likelihood techniques can be used. The third step is the diagnostic checking where the residuals from the fitted model are examined, usually by correlation analysis through the residual autocorrelation function (ACF) and partial autocorrelation function (PACF). If the residuals are correlated and the parameters of the model are insignificant then the model should be needed to go back to the identification stage. Otherwise, if the model parameters are significant and the correlations are white noise then the model is competent to present the time series. The best model would be used for forecasting purposes. The best model has to be chosen by comparing the forecasting abilities of the competent models. For comparing the forecasting ability of the competing models, the data set is divided into two sub-data sets: (i) training set to estimate the model parameters and (ii) test set to evaluate these models by calculating error functions.

2.2.2. Artificial Neural Networks (ANNs)

Artificial Neural Network(ANN) is a computer technique that simulates the learning process of human brain. The greatest advantage of a neural network is its ability to model complex nonlinear relationship without a priori assumptions of nature of the relationship. The most widely used ANNs in forecasting problem are multi-layer perceptions (MLPs) which use single hidden layer feed forward network. The model usually consists of three layers: input layer, hidden layer and output layer. The output of the model is computed as follows:

$$x_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j\, g\Big(\beta_{0j} + \sum_{i=1}^{p} \beta_{ij}\, x_{t-i}\Big) + \varepsilon_t; \quad \forall\, t \qquad (3)$$

Where $x_{t-i}(i = 0, 1, 2, \ldots \ldots, p)$ are inputs and $x_t$is the output. The integers p, q are the number of input and hidden nodes respectively. α_j $(j = 0, 1, 2, \ldots \ldots, q)$and $\beta_{ij}\,(i = 0,1,2, \ldots \ldots p; j = 0,1,2, \ldots \ldots q)$ are the connection weights and ε_t is the random error; α_0 and β_{0j} are the bias terms. Usually the logistic sigmoid

function $g(y) = \frac{1}{1+e^{-y}}$ is applied as the nonlinear activation function. Linear and hyperbolic tangent activation functions can also be used.

To estimate the connection weights, non-linear least square procedures are used, which are based on the minimization of the error function (Kihoro *et al.,* 2006):

$$F(\psi) = \sum_t {\varepsilon_t}^2 = \sum_t (x_t - \widehat{x_t})^2 \quad (4)$$

Where ψ is the space of all connections weight, x_t and $\widehat{x_t}$ are the true and predicted vector respectively. The optimization techniques used for minimizing the error function (4) are referred to as learning rules. The best-known learning rule is the error back propagation, or generalized delta rule (Kamruzzaman *et al.,* 2006; Kihoro *et al.,* 2006).

For a univariate time series forecasting problem, the inputs of the network are past lagged observations $(x_{t-1}, x_{t-2}, \ldots\ldots\ldots x_{t-p})$ and the output is the predicted value (x_t) (Zhang *et al.*, 2001). Hence The ANN equation (3) can be written as:

$$x_t = g(x_{t-1}, x_{t-2}, \ldots\ldots\ldots x_{t-p}, \omega) + \varepsilon_t \quad (5)$$

Where ω is a vector of all parameters and $g(.)$ is a function determined by the network structure and connection weights.

2.3. Implementation and Evaluation of Models

R is an environment for statistical computing and graphics including time series analysis, modeling, classification and statistical tests. Statistical package R-version 3.4.4 was used to implement all models. We trained the ARIMA models in the forecast package. For ANN models, we used neural net package.

To evaluate forecast accuracy as well as to compare among different models fitted to a time series, we used three performance measures. They are Mean Absolute Error (MAE), Root Mean Squared Error (RMSE),and Mean Absolute Percentage Error (MAPE), which are defined by

$$MAE = \frac{1}{T}\sum_{t=1}^{T}\left|y_t^a - y_t^f\right| \quad (6)$$

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(y_t^a - y_t^f\right)^2} \quad (7)$$

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t^a - y_t^f}{y_t^a}\right| \times 100 \quad (8)$$

Where y_t^a *and* y_t^f are the real and forecast data point at time $t$respectively, T is the number of observation.Smaller values of the criteria indicate the better forecast of the model.

3. Results and Discussion

Result and discussion were done in three steps. First we examined the fitting of the ARIMA and ANN to the maximum temperature data. Then we compared the performance function of these two models in the prediction maximum temperature.

3.1. Fitting ARIMA to the Data

We used the famous Box-Jenkins (1976) modeling philosophy for choosing an appropriate ARIMA model for the monthly maximum temperature data. Out of the total 437 observations in this time series, we used the first 425 (i.e. May, 1982 to September, 2017) for training and the remaining 12 (i.e. October, 2017 to September, 2018) for testing. The time series plot of the monthly maximum temperature (°C) is presented in Figure 1, which shows that there is a seasonal cycle of the series and moving through a constant values. The data seem to be stationary; however, there is clear seasonality with periodicity of one year (12 months) in the data set.

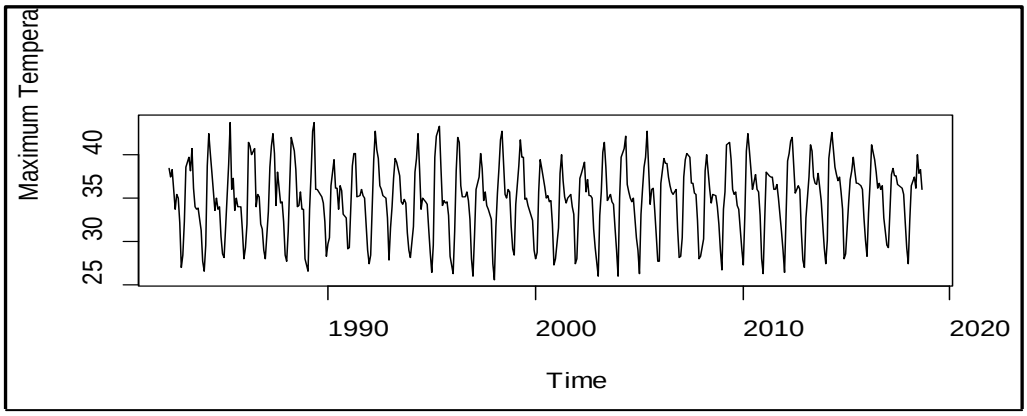

Figure 1. Time series plot of maximum temperature (°C) in Rajshahi.

Therefore, the original data series need to be seasonal differencing to remove the seasonal variation. The seasonal difference of the maximum temperature (°C) values is displayed in Figure 2. After seasonal differencing, ACF and PACF plots are shown in Figure 3. This figure shows that the series is stationary without seasonality, since ACF and PACF values at all the lags are within the 5% confidence limits.

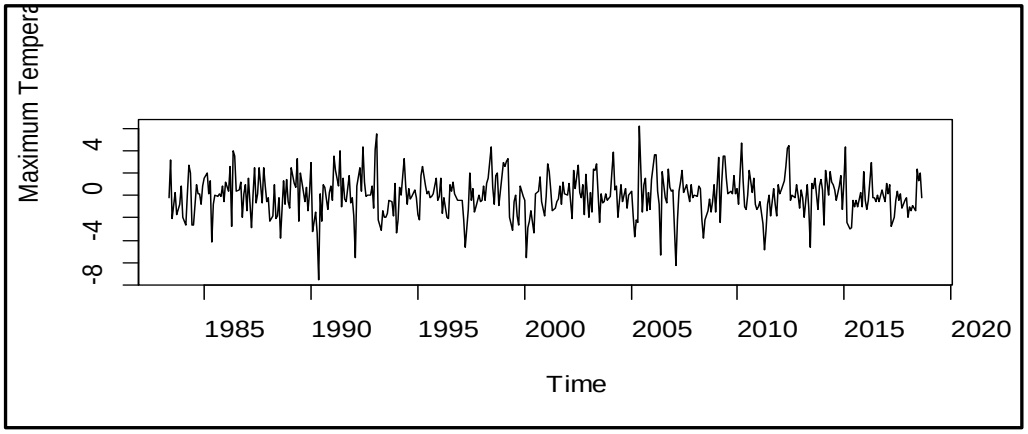

Figure 2. De-seasonalised series of maximum temperature of Rajshahi.

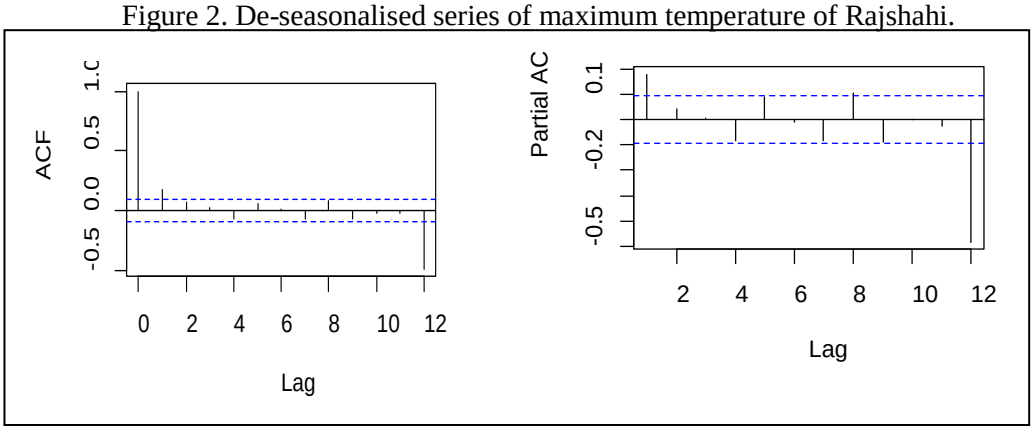

Figure 3. The correlogram of seasonal differenced of maximum temperature (°C) series.

Moreover, we applied some formal unit root tests for checking the stationary of the de-seasonalised series. Three unit root tests are performed: (i) most widely used Augmented Dicky-Fuller (ADF) test of Dicky and Fuller, (1979, 1981) (ii) Phillips-Perron (PP) test of Phillips and Perron (1988) and (iii) Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test of Kwiatkowski *et al*., (1992). After seasonal differencing the Augmented Dicky-Fuller (ADF) test with $\Pr(|\tau| \geq -6.495) < 0.01$ and Phillips-Perron (PP) test with $\Pr(|\tau| \geq -17.119) < 0.01$ and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with $\Pr(|\tau| \geq 0.016) > 0.1$ adequately declared that the data

series is stationary at 5% level of significance and suggest that there is no unit root in seasonal differenced series. Therefore the general ARIMA (p, 0, q) (P, 1, Q)$_{12}$ was proposed for maximum temperature(°C) data. After model identification, the p, q, P and Q parameters were estimated. The seasonal ARIMA is identified with the help of well-known model selection criteria like AIC and BIC. The lowest value of AIC= 1465.806 and BIC=1486.067 select the ARIMA (0, 0, 1) (0,1,1)$_{12}$ model for forecasting the maximum temperature(°C) of Rajshahi. The ARIMA (0,0, 1) (0,1,1)$_{12}$ model shows the more robust coefficients, white noise error and the smallest forecasting errors among the competitive models. The estimated model is

$$\nabla_{12} x_t = (1 - 0.1699L)(1 + 0.8894L^{12})\varepsilon_t \qquad (9)$$

$$(0.0474) \qquad (0.0296)$$

The parentheses under the model contain the value of standard error of each coefficient. Using the model (9), the forecasting values and the original values over the test period October, 2017 to September, 2018 are shown in Table 1.

3.2 Fitting the Artificial Neural Network Model to the Data

The number of observations in the training set is the same as the number of observations used in fitting the ARIMA model. That is, 425 observations of the series were considered a training set and 12 observations were used as test set. In this study, Multi-Layer Perceptron (MLP) neural network was constructed for time series forecasting. The time series contained a natural cycle of 12-months period and hence the data of present month had maximum correlation with data of 12 months lag. So the optimum number of neurons in the input layers was chosen as 12. Therefore feed-forward MLP neural networks with an inputs layer of number of neurons from 1 to 12 (with time lag from t-1 to t-12), one hidden layer and an output neuron (of time t) were used. That means the network predicted maximum temperature for next time step from a series of previous 12 time steps. The training and testing data were normalized in the range zero to one by using min-max normalization method. From the input layer to the hidden layer, the logistic sigmoid transfer function, commonly used in time series,was applied. From the hidden layer to the output layer, a linear activation function was applied as the transfer function because the linear function is known to be robust for a continuous output variable. The optimal number of neurons in the hidden layer depends on the problem domain and is a trial and error procedure but, generally, it can be related to the number of neurons in the input layer. Therefore networks with hidden neurons from 3 to 10 had been tried to find out optimal design of the MLP neural network. The optimum number of neurons in the hidden layer was chosen based on MAE, RMSE and MAPE value of forecasting accuracy criteria of the MLP network. Hence the best ANN model was chosen with the number of neurons in the hidden layer giving smaller values of the forecasting accuracy criteria to indicate the better forecast of the model. According to the forecasting accuracy criteria, (12:5:1) was the best MLP model. Therefore (12:5:1) MLP model could be considered the best selected model for forecasting maximum temperature of Rajshahi. Using this model, the forecasting values are shown in Table 1.

Table 1. Original and forecasting values for the test period Oct, 2017- Sep, 2018

Time	Original Values (Max. Temp.)	Forecasting Values (Max. Temp.)	
		ARIMA	ANN
Oct-17	35.4	35.240	35.078
Nov-17	32.3	32.304	33.116
Dec-17	29.4	28.786	29.699
Jan-18	27.5	27.723	28.183
Feb-18	32.5	32.761	32.031
Mar-18	36.4	37.901	37.097
Apr-18	37.5	39.985	38.471
May-18	36.2	39.894	38.902
Jun-18	40	38.319	37.049
Jul-18	37.9	36.056	36.951
Aug-18	38.3	36.189	37.363
Sep-18	36	36.072	36.457

3.3. Comparison between ARIMA and ANN Results

Now we got the results to compare the performances of the forecasting ARIMA and ANN model. The forecasting values for the test period of the models with the original series are shown in Table 1. The forecasting ability of these models was compared by using three forecasting accuracy criteria- MAE, RMSE, and MAPE. Table 2 contains the values of these criteria for the models. Table 2 shows that all three measurements of forecasting accuracy criteria are smaller when ANN was used in the models

Table 2. Forecasting accuracy criteria for the model ARIMA and ANN

Model	MAE	RMSE	MAPE
ARIMA	1.221	1.665	3.325
ANN	0.886	1.127	2.491

than that when ARIMA model was used. From Figure4, it is obvious that the forecasting values from ANN model is very close to the original series compared to ARIMA model. Thus, ANN model forecasts temperature data of Rajshahi more accurately and more efficiently than ARIMA model.

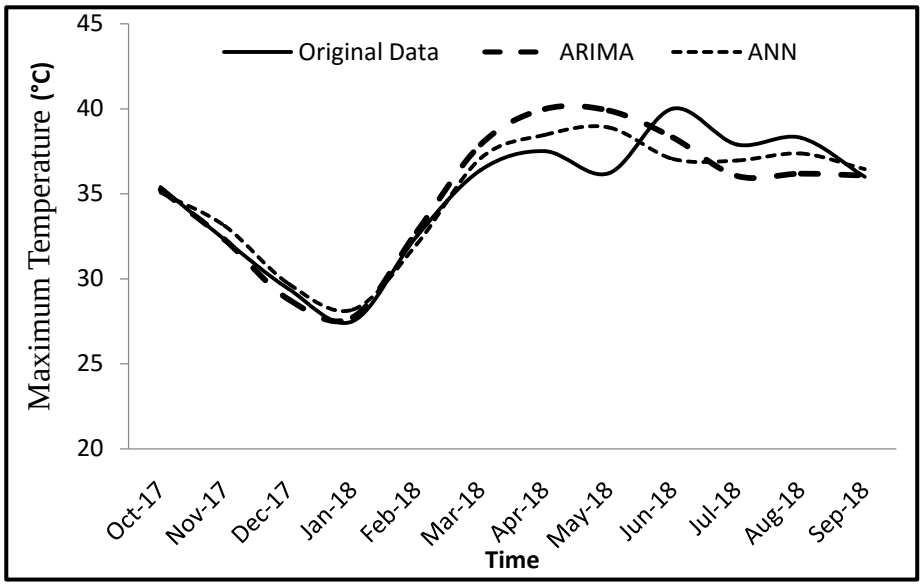

Figure 4. Original series along with the forecasting series of ARIMA and ANN model.

4. Conclusion

From the comparative evaluation of ANN and ARIMA over the forecast of maximum temperature in Rajshahi, it appears that ANN model is better to ARIMA model for maximum temperature forecast and it has lower MAE, RMSE and MAPE indicating that former model is better than the latter model. The findings thus suggest that the use of ANN procedure in forecasting maximum temperature time series may improve the performance of forecasting model.

Acknowledgement

The authors gratefully acknowledge Bangladesh Meteorological Department (BMD) for the provision of the data used in this paper.

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Serum Testosterone Level of Hormone Fed Tilapia (*Oreochromis niloticus*) in Northwest Bangladesh

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Abstract

Tilapia (*Oreochromis niloticus*) is one of the most cultured species in Bangladesh. For many practical reasons, almost all tilapia fry used in commercial tilapia culture are sex inversed male obtained by feeding of 17-alpha methyltestosterone. Sometimes methyltestosterone is also fed as growth promoter during growth stage of tilapia. The study was conducted to compare the serum testosterone level of sex inversed tilapia (marketable size) with the normal tilapia population and observe the effect of methyltestosterone feeding as growth promoter on serum testosterone level of adult tilapia. For the first objective, blood samples from both sex-inversed and normal tilapia were collected and serum testosterone level were determined using ELISA test kit. For the second objective, normal adult male and female tilapia were fed with feed (at the rate of 3% of body weight daily) containing 10 mg/kg methyltestosterone over the period of one month and blood serum testosterone level were determined at various point during feeding and up to another month after stopped feeding of the hormone. In this study, no significant difference in serum testosterone level was found in between adult sex inversed and normal tilapia (for both male and female). However, serum testosterone level was found to be several times higher than the normal population when methyltestosterone was fed as growth promoter and high serum testosterone level continued up to the end of the experiment (after one month of stopped feeding). Feeding methyltestosterone as growth promoter also triggered higher rate of reproduction of tilapia in cages.

Keywords: Tilapia, Serum testosterone, Methyl testosterone and Sex inversed

1. Introduction

Tilapia (*O. niloticus*) is the second most cultured species in the world after Carp and is often dubbed as 'aquatic chicken' (World Fish Center, 2015). Like many other parts of the world, tilapia is one of the single most cultured species in Bangladesh. Total production of tilapia has increased to 384,737 metric ton, 10.62 percent of total inland fish production in 2017-18 (Do F, 2018) from just 136,000 metric ton in 2012 (Hussain *et al*., 2014). Like the other parts of the country it is also commercially cultured in Barind tract as well. The production of tilapia in Bangladesh is good with high profitability along with less input cost and reduced risk (Rahman *et al.*, 2012). Helpful qualities like ability to take natural food from the pond, good interest in supplementary feed, surviving capacity in adverse weather condition and high disease resistance capacity made it favorable as one of the most cultured species throughout the world (Roysfarm, 2018). It is fast growing, hardy, environment friendly and easy to grow by all sort of fish farmers (World Fish Center, 2015). Availability of sex inversed male tilapia fingerling has played a significant role in expansion of commercial culture of tilapia by incorporating the advantage of faster growth rate of the male tilapia over the female ones and by eliminating the unconditioned propagation ability that makes the population uncontrolled, incurring management difficulty and hindering desired production (Mair and Little, 1991). Almost all the sex inversed male tilapia fingerlings are achieved through extensive feeding of steroid androgen, 17 alfa-methyltestosterone @ 50 to 70 mg/kg feed, in juvenile stage of tilapia fry for about 20 to 30 days (Rouf *et al*., 2008).

There is other use of methyl testosterone at the growth stage of the tilapia, where it is fed at relatively lower dose (at 10 mg/kg feed) compared to the sex reversal dose, with feed on regular basis to enhance the growth of *O. niloticus.* Ahmad *et al.* (2002) found that 5 mg/kg doses of 17 alfa-methyl testosterone when used as growth promoter resulted in higher growth of *O. niloticus*. Hybrid tilapia fed with low doses of 17 α-ethynyltestosterone

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have led in 11% additional weight gain over control in commercial polyculture pond conditions (Rothbard *et al*., 1988). A total of 825 private hatcheries produced a total of 2694.9 million juvenile tilapia seedlings in 2018 in Bangladesh (DoF, 2018). On the other hand, Din and Subasinghe (2017) reported that hormonal sex reversal is intensively practiced by the private hatcheries in Bangladesh to produce mono-sex male tilapia seedling. Therefore, it is safe to conclude that large percentage of all tilapia (*O. niloticus)* sold in the market in Bangladesh have either been exposed to the feeding of testosterone at juvenile stage or in both at juvenile stage and growth stage at lower rate. The experiment was conducted to determine whether sex inversed male tilapia has higher rate of blood testosterone level than normal resulting from feeding of testosterone at juvenile stage. At the same time part of the experiment was done to monitor the change of blood testosterone level in tilapia while feeding of methyl testosterone was done at lower dose (10 mg/kg feed) in growth stage and observed the duration to get normalized the serum testosterone level.

2. Materials and Methods

For the first objective testosterone levels of regular adult female, adult male and sex inversed tilapia (*O. niloticus*) were determined. For getting regular male and female tilapia, a stock was identified in a homestead earthen pond in Hatgodagari area of Pobaupazilla of Rajshahi district where natural stock of tilapia was maintained at least for last 5 years and no tilapia fingerling was released during that period. Therefore, it was considered as free from any kinds of hormonal feeding. Fish were caught with cast net; the blood sample were taken from the caudal vain of live fish, and then by dissecting the fish, sex was determined by observing (often under microscope for confirmation) the primary sexual organs (testis/ovary) to label the blood sample as regular male or female tilapia. At the same time the condition of the sex organs was documented. Similarly, live adult sex inversed (confirmed by the fish farmer) tilapia (treated group) were bought from the wholesale market located in Naodapara of Rajshahi city in several batches in between May to August-2018 and blood samples were taken. After taking the blood sample, the fishes were dissected for confirmation of their sex (often by observing under microscope) and condition of the sex organ was documented. For normal population, 53 blood samples were collected from 53 different fish. For sex inversed population 50 blood samples were collected from 50 different fish as well. The size of the fish ranged from 200 g to 500 g each. For each fish 2 to 3 ml blood sample was taken from caudal blood vessel using 5 ml disposable syringe.

After taking the blood sample the needle was removed from the syringe. Then the blood from the syringe was transferred to the sterile red top blood tube (glass tube) without anticoagulant. Then the blood tubes with blood sample were left for half an hour without shaking in room temperature. The serum was separated following the standard serum separation protocol (Texas Department of State health services, 2018). After half an hour the blood tubes were put in a centrifuge machine to centrifuge for segregating the blood serum from the blood cells. The blood samples were centrifuge for 10 minutes @ 2000 rmp (Thermo Fisher Scientific, 2018).

After completion of the centrifuge, the blood serum from the top were taken using vacuum dropper and put it in sterile Eppendorf tubes and put in freezer immediately. Because the collection of blood samples took several months, the frozen blood serum samples were stored in freezer at -80^0C in Biochemistry Department of Rajshahi Medical College until used for testing the testosterone level. Due to the distance of the collection site from Rajshahi University, to avoid the transfer of live fish frequently during the experimental period, a mobile laboratory (consisting of a compound microscope, a small centrifuge machine, blood tubes, syringe, Eppendorf tubes, dissecting box, ice box etc.) for fish blood collection was set near the sample collection site.

To determine the level of blood testosterone at adult stage of tilapia when fed with MT @ of 10 mg/kg feed, regular male and female tilapia were put in 3 *hapa*s (net cages) set in the pond. Each *hapa* was 3 meters by 1 meter in size with 1-meter depth. 10 tilapia fish ranging from 200 to 300 g in size consisting of both male and female were put in each of the *hapa*s. The experimental fish were collected from a pond that maintained a natural

stock in Hatgodagari area of Pobaupazila of Rajshahi district and the *hapa*s were set in the same pond to put the fish inside.

2.1. Feed Preparation

For feeding 'AIT' pellet carp feed was used (proximate composition was: 27.26% protein, 7.20% lipid, 11.54% ash, 13.70% moisture, 5.90% fiber and 34.40% carbohydrate). To prepare the 15 kg feed with hormone, first 150 mg (at the rate of 10 mg/kg feed) Methyl testosterone (marketed by 'Argenta' in Bangladesh) were diluted in 15 ml of lab grade ethanol. Then it was made 250 ml by adding tap water. Then the 250 ml solution was sprayed over the 15 kg feed and mixed up well so that the feed soaked up all the liquid containing 150 mg methyl testosterone. Then the moist feed was air dried in the shed. Despite being air dried the feed contained extra moisture, therefore, to avoid the fungal growth, the feed was preserved in the refrigerator, in a plastic bag.

2.2. Feeding of the Fish

The prepared feed was fed to the fish in the *hapa* at the rate of 3% of fish body weight once on daily basis for 30 days in the month of June. Feeding was maintained at the rate of 3% of body weight per day to ensure that all the feed is consumed by fish. The stock was maintained for another month with normal diet (without testosterone).

2.3. Collection of Blood Samples

Blood samples were collected from 2 to 3 male and female on every 5 days following the process mentioned above to monitor the serum testosterone level. After collection of the blood sample, the fishes were released in the *hapa* again. Because there were limited number of fish, in this case fish were not dissected after the collection of blood sample, rather sex was identified by observing their genital opening. Fish from different *hapa*s were collected on rotational basis for sampling to allow the fish recover from the physical injury that incurred in the process of blood collection. Thus, over the period of one month the fish were fed with methyl testosterone with feed and blood samples were collected to monitor the change in serum testosterone level in*O. niloticus*. Blood samples were kept collecting till another month after feeding of testosterone was stopped.

2.4. Determination of Testosterone Level

Serum testosterone level were determined by 'Das Plate Reader'- manufactured in Italy (http://www. dasitaly. com/ en/prodotti/Plate% 20 Reader), marketed by Bio-Trade International in Bangladesh, using 'Accu Bind ELISA Microwells' for Testosterone from 'Monobind Inc.', USA, following the prescribed systems/procedure of the ELISA kit using the reagents supplied with the kit (Monobind Inc., 2018) in the laboratory of Royal Hospital (pvt.) Ltd located in Laxmipur area of Rajshahi city. Since the ELISA kit is customized for human use it can determine the maximum concentration of 12 ng/ml of testosterone. After testing the blood serum, for those samples where values were over 12 ng/ml, were diluted with the diluent and tested again for determining the actual testosterone concentration.

2.5. Statistical Analysis

Comparison of means test (t test for independent samples) was used to determine whether there is any difference between the testosterone level of regular tilapia and sex inversed tilapia of marketable size.

3. Results and Discussion

Average testosterone level in male adult *O. niloticus* in normal population found to be 7.3 ng/ml of blood serum. While in female the value was 1.95 ng/ml. But the distinct feature of the testosterone level of both male and female is high internal variability. The highest value of testosterone in normal male population was 26.4 ng/ml, while the lowest was 0.6 ng/ml. For female in normal population the range was 0.01 to 10.3 ng/ml (Table 1).

Table 1. Testosterone level (ng/ml) of adult male and female in normal and sex inversed population of *O. niloticus*

Population Category	Sex	Number of Individuals	Testosterone Level (ng/ml)	Range of Value	Score for Appearance of Sex Organ
Normal Population	Male	7 (13.2% of total)	16.7±7.3	8.2-26.4	6
	Male	14 (26.4% of total)	3.9± 3.7	0.9-10.1	5
	Male	3 (5.66% of total)	0.8±0.4	0.6-1.2	3
	Combined	**24 (45.3% of total)**	**7.3±7.8**	**0.6-26.4**	
	Female	22 (41.5% of total	2.5± 2.9	0.04-10.3	5
	Female	7 (13% of total)	0.16±0.36	0.01-1.04	3
	Combined	**29 (54.7% of total)**	**1.95±2.8**	**0.01-10.3**	
Sex Inversed Population	Male	6 (12% of total)	19.4±11.6	4.35-36.8	6
	Male	14 (28% of total)	2.4±1.16	0.66-4.13	5
	Male	4 (8% of total)	2.85±1.04	2.22-4.42	4
	Male	10 (20% of total)	0.37±0.22	0.09-0.75	2
	Combined	**34 (68% of total)**	**4.87±8.29**	**0.09-36.8**	
	Female	5 (10% of total)	2.34±1.18	1.42-3.87	5
	Female	6 (12% of total)	1.38±0.83	0.25-2.69	3
	Female	5 (10% of total)	0.26±0.39	0.01-0.95	1
	Combined	**16 (32% of total)**	**1.33±1.17**	**0.01-3.87**	

Note: 6 means very well developed, 5 means well developed, 4 means one testis/ovary well developed, 3 means less developed, 2 means poorly developed, 1 means very poorly developed and functionally not ready to breed.

Average testosterone level (4.87 ng/ml) of male individuals of sex inversed population was lower (though non-significant, P=0.2648 at t test) than the normal population with high internal variability like the normal population (Table 1). A total of 68% male individuals in sex inversed population (compared to only 45% in normal population) was inclusive of many of the sex inversed phenotypic male (but genetically female) have resulted in with higher number of males with poorly or less developed testis and lower level of testosterone production. The range of testosterone level varied from 0.09 to 36.8 ng/ml. Average testosterone level (1.33 ng/ml) of female individuals of sex inversed population was also lower (also non-significant, P=0.4041 at t test) than that of normal population with high internal variability. The testosterone value form female individuals in sex inversed population ranged from 0.01 to 3.87 ng/ml. Wahbi and Shalaby (2010) reported significantly decreased plasma testosterone level in six month's old sex inversed males of *O. niloticus* compared to the control. While Khalil *et al.* (2011) found significantly different level of serum testosterone in methyltestosterone treated male and untreated control group of *O. niloticus*, testosterone levels were higher in treated male in most months during observation but for couple of months testosterone level was several times higher in untreated control group.

In this study the sampling was done over the course of four months form May to the August, and the range of timing may have an impact on the testosterone level and could be the reason of high level of variability of testosterone level in group. Month to month variation of plasma testosterone level in *O. mossambicus* has also been reported by Cornish (1998). Varying testosterone level in *O. niloticus* in different months has also been

reported by Khalil *et al.* (2011). The high variability of serum testosterone level in this study may also be attributed to the size of fish. Cornish (1993) found the inverse relationship in-between size and plasma testosterone level in *O. mossambicus*, means larger specimen has relatively lower plasma testosterone level.

Ideally sex inversed population is expected to have all male individual, however, since the samples of this study were collected from market, there was no control of the researcher on the sex inversion process. Poor male percentage (68%) indicates that when sex inversion was done commercially to produce sex inversed population, it wasn't done properly. Contrary to the normal population, the sex inversed population consisted of 68% male and 32% female, though 10% fish (categorized within female) had very poorly developed ovary that was not ready or suitable for breeding, and functionally were serving as sterile individuals. Also, only 10% fish (female) of sex inversed population had well developed ovary. Unlike the normal population a total of 30% fish (combined male and female) in sex inversed population had poorly developed testis and ovary, it could be result of interaction between poor masculinization and expression of inherent genetic characters. Macintosh *et al.* (1988) reported testicular degeneration in tilapia when fed with 17-alpha methyltestosterone at the rate of 60 mg/kg feed at early developmental stage for sex reversal. Similar phenomenon was evident in decreased Gonado Somatic Index (GSI) for both male and female treated with high (5 to 40 mg/kg feed) methyl testosterone doses (Ahmed *et al.*, 2002).

The positive correlation between serum testosterone level and appearance of sex organ in normalmale (r value 0.72) was stronger than male (r value 0.55) of sex inversed population. However, the correlation between serum testosterone level and appearance of sex organ in female of normal population was weaker (r value 0.36) than the female (r value 0.64) of in sex inversed population of *O. niloticus*.

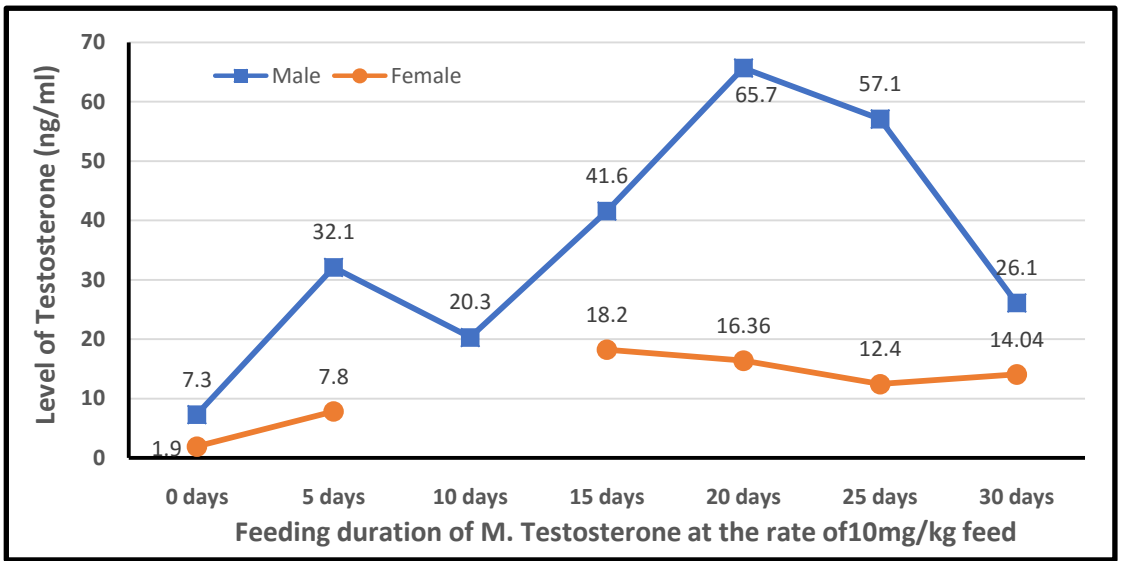

Figure 1. Testosterone level (ng/ml) in Adult *O. niloticus* serum when fed with methyltestosterone at the rate of10 mg/kg feed as growth promoter.

Serum testosterone level of both male and female tilapia increased with the feeding of methyl testosterone as growth promoter (Figure 1) at lower dose (10 mg/kg) compared to what is used (60 mg/kg) in sex reversal process. Since at each sampling in different days different individuals were collected from the treatment pool, the average level value of subsequent samplings is of different individuals. Therefore, it was not possible to determine the change pattern in testosterone in one individual fish. However, this graph gives a general idea of increase of testosterone level in the treated population. During the feeding stage highest level of blood serum testosterone in male tilapia was 70.8 ng/ml on the 20th days of feeding, compared to the highest value of 26.4 ng/ml found in male of normal population.

Since the fishes were not dissected for confirmation of sex after collection of blood sample, (sex was confirmed by observing the difference in genital opening), it is possible to have error in identification of sexes, which practically means male and female may have been labeled as opposite and may have impacted the value

presented in the graphs, based on its grouping as male or female. Therefore, the overall trend of higher testosterone level is more important rather than specific value (testosterone level) at any certain point of Figures 1 and 2.

While it is expected to increase the level of serum testosterone when methyltestoster one is fed to the treated group, some unexpected behavior was observed. Generally, it is hard to get free ranging male and female tilapia to breed naturally when put in captivity or confinement. However, in this experiment though the adult male and female tilapia (previously free ranging) were put in confinement (in *hapa*) due to the low dose (10 mg/kg) feeding of testosterone, fish bred frequently. As a result, during each sampling many of the hatchlings had to be taken out of the treatment pool and mouths of the female. This phenomenon continued even after the end of feeding of hormone. This unusual and increased mating activity might have positively influenced the serum testosterone level of the treated male and female. Significant increase of testosterone level in normal male *O. niloticus* has been attributed to the male paring with female during mating season by Khalil *et al.* (2011).On the other hand, Smith and Haley (1988) recorded high plasma testosterone in female mouth brooders (*O. mossambicus*) in the latter half of brooding period while testosterone level dropped at the end of brooding.

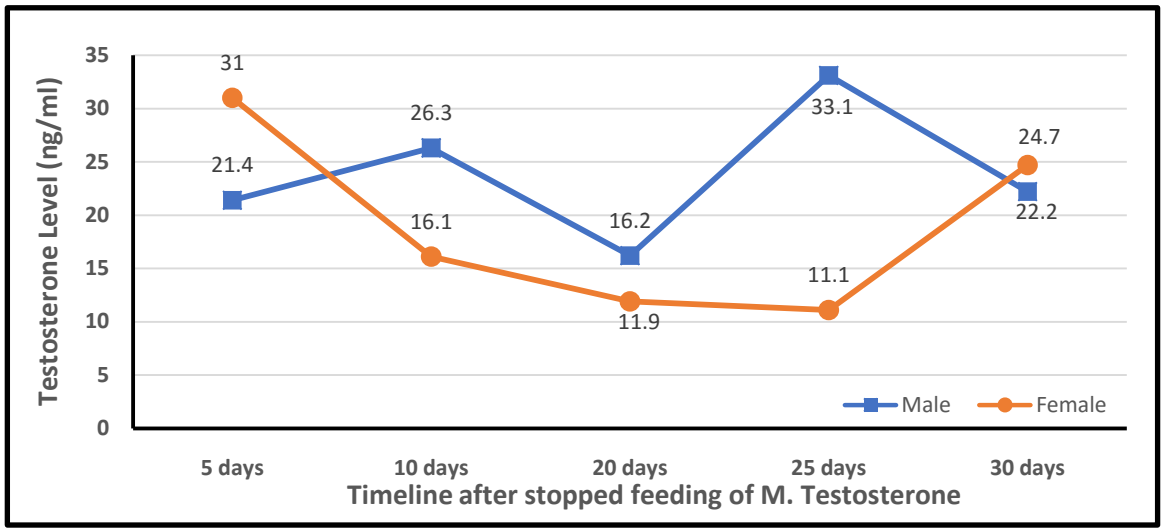

Figure 2. Serum testosterone level in adult *O. niloticus* after stopped feeding of methyltestosterone.

Serum testosterone level in adult *O. niloticus* found to be higher till the end of observation period after one month of stopped feeding of methyltestosterone (Figure 2). There was no indication of reducing the serum testosterone level even at the end of observation period (one month after stopping of methyl testosterone feeding). The highest value of serum testosterone level in female was found to be 40.3 ng/ml at the 5 days point after stopped feeding of methyltestosterone; compared to the highest testosterone value of 10.3 ng/ml in female of normal population. Since it takes several months to get to plasma testosterone level to normal in sex inversed male tilapia (Wahbi and Shalaby, 2010; Rizkalla *et al.*, 2004; and Khalil *et al.*, 2011), it seems in adult population where methyltestosterone is used as growth promoter, resulted in high serum testosterone will also take several months to get the level of serum testosterone normal. However, this increase in testosterone level can not only be attributed to the feeding of methyl testosterone as growth promoter, because external factors like seasonality (Khalil *et al*., 2011) and breeding cycle (Smith and Haley, 1988) has its effect on tilapia's testosterone level

4. Conclusion

About 6 to 8-month-old sex inversed tilapia found to have serum testosterone level similar to the normal population, therefore it should be equally safe for human consumption like the normal tilapia in regards to serum testosterone level. On the other hand, when methyltestosterone was fed as growth promoter in growing stage of tilapia, serum testosterone level was found to be higher even after one month of withdrawal period. Despite the rise of testosterone level, based on the available data it cannot be said that using methyltestosterone as growth promoter makes tilapia unsafe for human consumption even in short term.

Acknowledgement

Md. Mahbubur Rahaman, Assistant Professor, Biochemistry Department, Rajshahi Medical College, Rajshahi; for his assistance and cooperation regarding the assessment of serum testosterone level in the laboratory of Royal Hospital (pvt) Ltd. in Laxmipur, Rajshahi city.

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Temperature and Rainfall Variability in Teknaf Upazila of Bangladesh

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Abstract

This study determines the trends and the significant changes in the time series of temperature and rainfall data. Variations in temperature and rainfall in Teknaf Upazila are studied on the daily data from 1977 to 2017. It has been observed that the annual maximum temperature increased significantly at the rate of 0.037 ˚ C/Year. During summer period the temperature is increased at the rate of 0.041 ℃/Year. The annual minimum temperature increased significantly at the rate of 0.044 ℃ /Year. During winter period the temperature is increased at the rate of 0.054 ℃/Year. In time series analysis, mean annual maximum temperature shows the increasing trend with a coefficient of 0.46, while mean annual minimum temperature shows the increasing trend with a coefficient 0.26. The frequency distribution of annual maximum temperature above 30˚ C has been increasing continuously. The frequency distribution of summer period temperature is increased about 50% and 71% for the range of 30-33˚ C and 33-36˚ C respectively in two cycle operation. It has identified that the mean annual minimum temperature of 28-30˚ C has been recorded more than 70% of the annual days. In addition, this work has also shown that the seasonal rainfall trend is increasing with the coefficient 0.121. The results have shown significant increasing trend in maximum and minimum temperature, and rainfall. The increasing trend is further higher over last 21 years (1997-2017) than that of last 41 years (1977-2017).

Keywords: Temperature, Rainfall, Trend Analysis, Frequency Distribution and Cyclic Operation.

1. Introduction

Climatic change is one of the most important issues in global warming and the issues are directing numerous break events in trend analysis studies for meaningful realization about climate (Buhairi, 2010).

The Fourth National Climate Assessment (USGCRP, 2018) predicted that earth's climate is now changing faster than at any point in the history of modern civilization, primarily as a result of human activities. Global climate change has already resulted in a wide range of impacts across every region of the country and many sectors of the economy that are expected to grow in the coming decades. There are vital needs for sharing of strategies and technique to assist humans adapt to new conditions, while reducing their impact on earth and to predict and prepare for climate change related crises (Johnson *et al*., 1997).During this century, earth's average surface temperature rises are likely to surpass the safe threshold of 2°C above preindustrial average temperature (Singh *et al*., 2011).

Bangladesh is one of the largest deltas in the world which is highly vulnerable to climate change because of its geographical location, disaster prone morphology, flat and low-lying landscape, population density, poverty, illiteracy, lack of institutional setup etc. (Denissen, 2012). In other words, the physical, social as well as economic conditions of Bangladesh are very typical to any of the most vulnerable countries to natural disasters in the world.

Bangladesh is already evidencing the adverse impacts of global warming and climate change. IPCC (2007) also recognizes Bangladesh as one of the most vulnerable countries in the world. Different climate change effects like extreme hot in summer, extreme cold in winter, shifting of the seasons, recurring floods, river bank erosion, lowering ground water level etc. have been contributing to augment the vulnerability of many regions of the country (Chowdhury *et al*., 2011). Climate change impacts are already adding significant stress to our physical and environmental resources, our human ability, and economic activities (Akon, 2012).

Rainfall and temperature are the two most important driving factors for year-to-year variability in crop production and the available water resources. Stream flow is primarily driven by change in precipitation (Milliman *et al*.,2008), which is intimately related to water availability. Furthermore, rain fed agriculture directly

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depends on the magnitude and temporal distribution of the rainfall. The global average precipitation is likely to increase, although at regional and continental scales, this may either increase or decrease (Dore, 2005).This work aims to investigate annual and seasonal trends of temperature and rainfall records to understand the recent climate of the study area.

2. Study Area

The location of the study area is Teknaf, an Upazila of Cox's Bazar District in the Division of Chittagong, Bangladesh. The Teknaf Upazila, the southeastern edge of Bangladesh, stands in the trans-boundary of Bangladesh and Myanmar occupying an area of about 389 sq. km between latitude 21°10" N and 20°40" N and longitude 92°05" E and 92°25" E (Figure 1). It belongs to exposed coast bounded by hilly area and Ukhia Upazila on the north, the Bay of Bengal on the south and west and on the east the Naaf River and Myanmar coast. The area is blessed with a warm tropical climate and sufficient rainfall which enable to support a wide biological diversity.

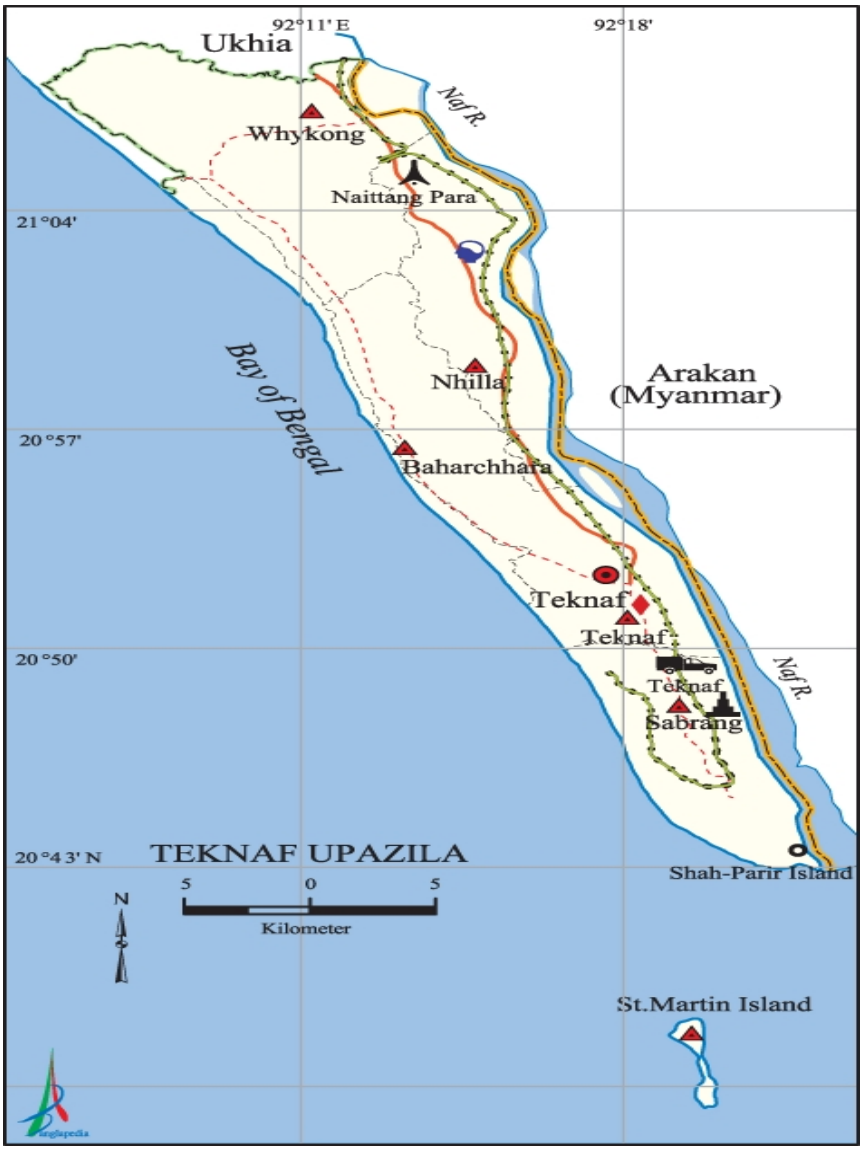


Figure 1. Map of study area (Source: Banglapedia, 2014).

3. Data and Methods

In the present study, the temperature and rainfall data of Teknaf Upazila have been considered to analyze the climate change of this area. The daily maximum and minimum temperature and rainfall for 41 years over the period 1977-2017 are collected from Bangladesh Meteorological Department (BMD).

The descriptive statistical methods are used in data analysis with summarize data using indexes such as mean, standard deviation and inferential form.

The detection, estimation and prediction of trends and associated statistical and physical significance are important aspects of climate research. Simple linear regression is most commonly used to estimate the linear trend (slope) and statistical significance. Trend of a time series data can be found by using the following formula.

$$b = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} \quad (1)$$

Where, x_i is the independent variable, $\bar{x}$ is the average of the independent variable, y_i is the dependable variable and $\bar{y}$ is the average of dependable variable. One way of testing significance of trends of temperature is calculating the coefficient of determination, R^2 of the trend. Values of R^2 vary between 0 and 1. It can be found by using the following formula.

$$R^2 = \frac{\left[\sum (x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2} \quad (2)$$

4. Results

The analysis of daily maximum and minimum temperature and their frequency of occurrence is an important parameter to estimate the climate change. The inter annual variation and linear trend of the annual and seasonal maximum and minimum temperature and rainfall of the study area have been determined using the time series analysis (Nahar, 2018). In this analysis the month of April, May, June and July are considered as summer season. Time series analysis of mean annual and seasonal maximum temperature of 41 years from 1977 to 2017 is shown in Figure 2.

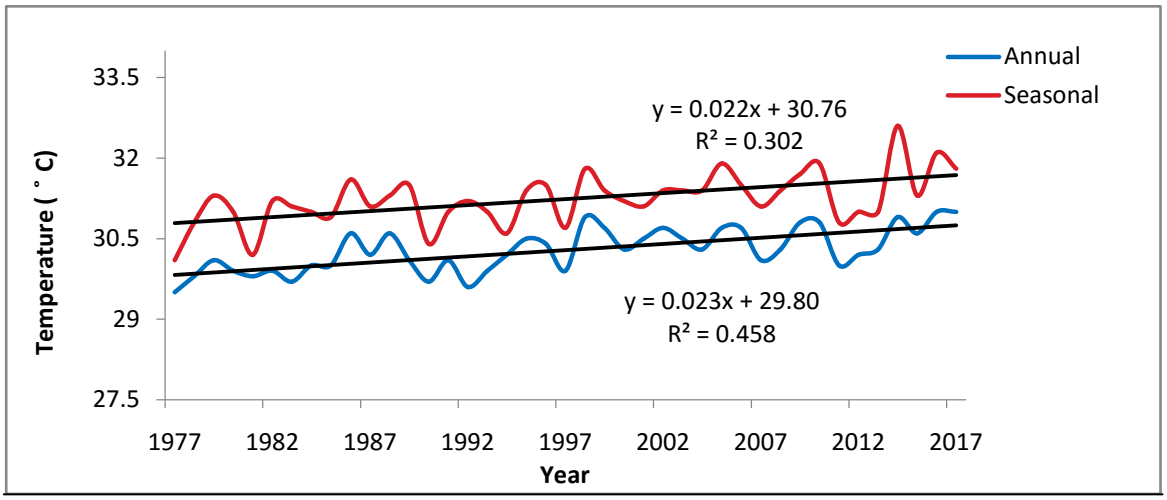


Figure 2. Trend of mean annual and seasonal maximum temperature of 41 years (1977-2017).

The duration of total study period has been classified into two cycle and three cycle operation. In the analysis the total period is divided into two series (said as cycle in the following sections) of 20 years from 1977 to 1996 and 21 years from 1997 to 2017, and later three as 13 years from 1977 to 1989, 14 years from 1990 to 2003 and 14 years 2004 to 2017 respectively. Frequency distribution and trend analysis are performed in maximum and

minimum temperature, and rainfall according to the time span as mentioned. Analysis show the changes of pattern of temperature and rainfall.

Figures 3 and 4 depict the frequency distribution of two cycle and three cycle operation in annual maximum temperature values.

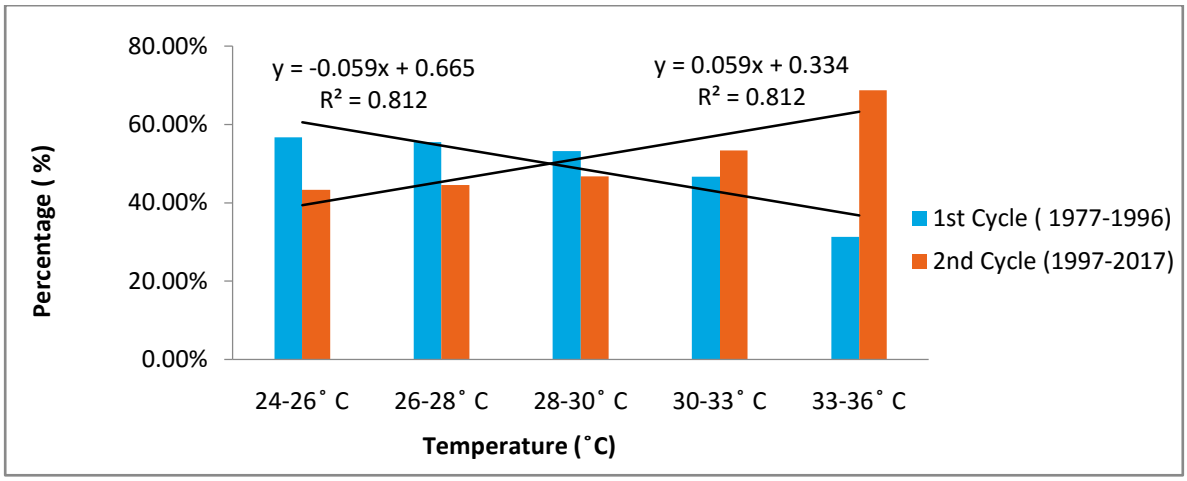


Figure 3. Frequency distribution of two cycle annual maximum temperature.

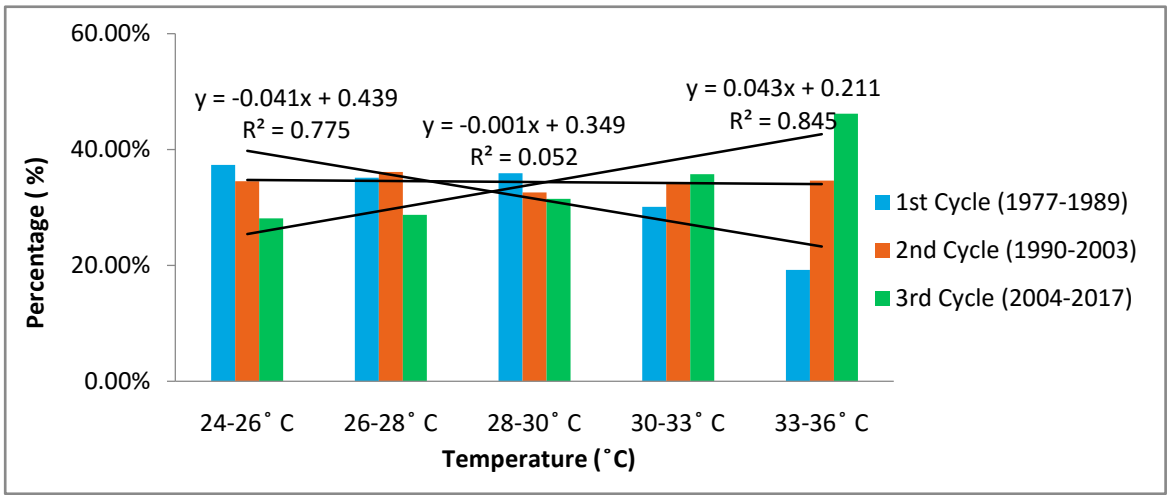


Figure 4. Frequency distribution of three cycle annual maximum temperature.

Similarly, the frequency distribution of two cycle and three cycle operation are performed in seasonal period of maximum temperature. Figure 5 shows two cycle operation and Figure 6 indicates three cycle operation in seasonal maximum temperature values.

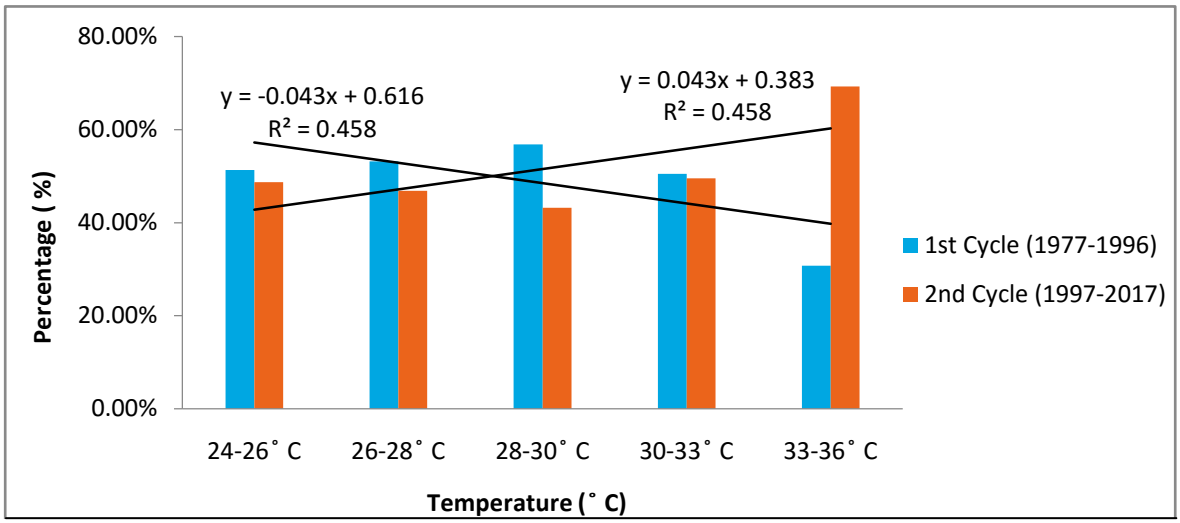


Figure 5. Frequency distribution of two cycle seasonal maximum temperature.

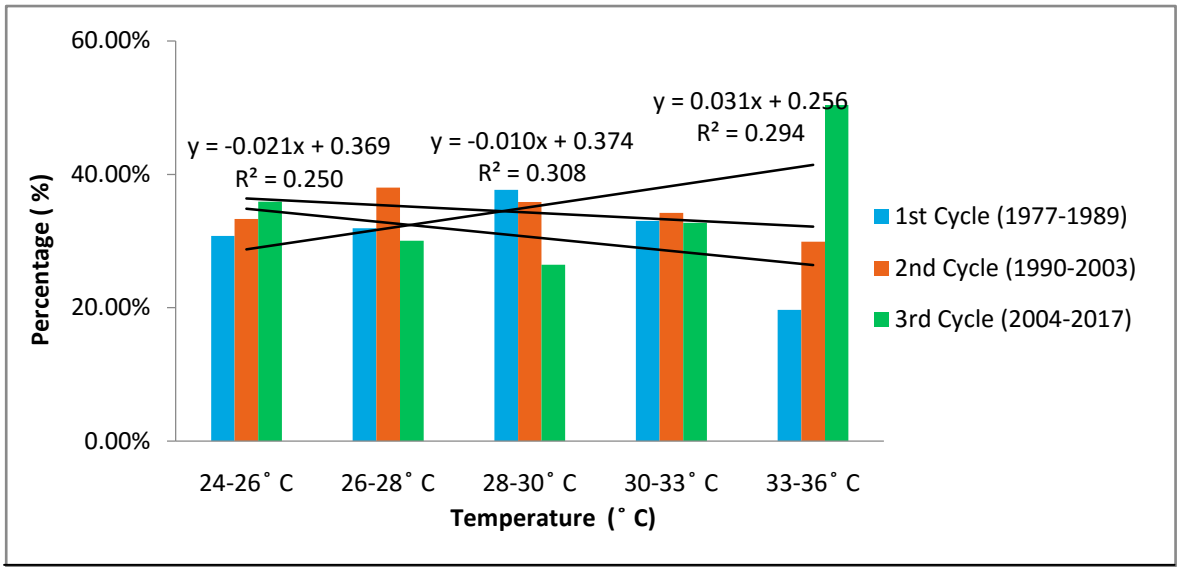


Figure 6. Frequency distribution of three cycle seasonal maximum temperature.

In minimum temperature analysis the month of November, December and January are considered as winter season. Figure 7 shows the trend of mean annual and seasonal minimum temperature of the study period.

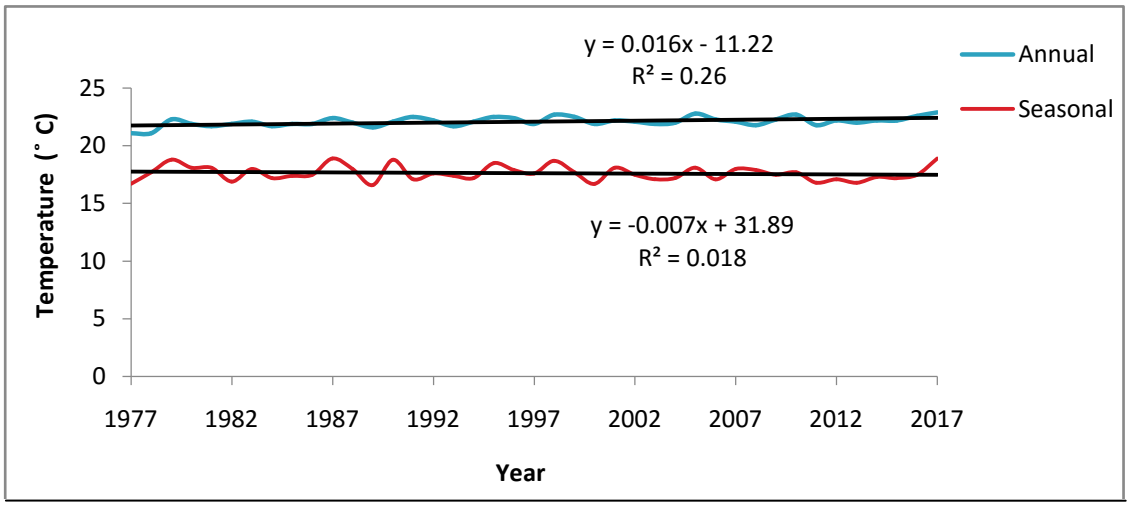


Figure 7. Trend of mean annual and seasonal minimum temperature of 41 years.

Similarly, the frequency distribution of two cycle and three cycle operations of minimum temperature are shown in Figure 8 and Figure 9 respectively.

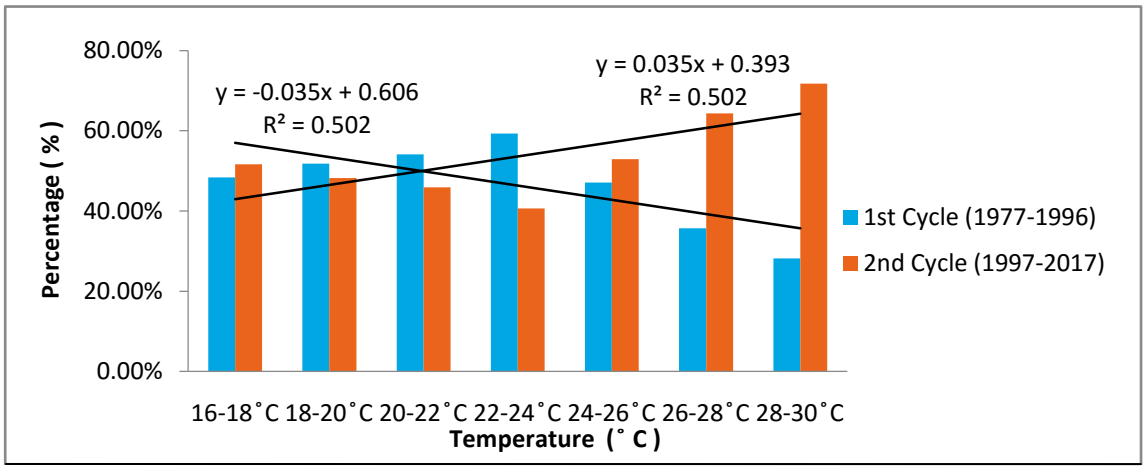


Figure 8. Frequency distribution of two cycle annual minimum temperature.

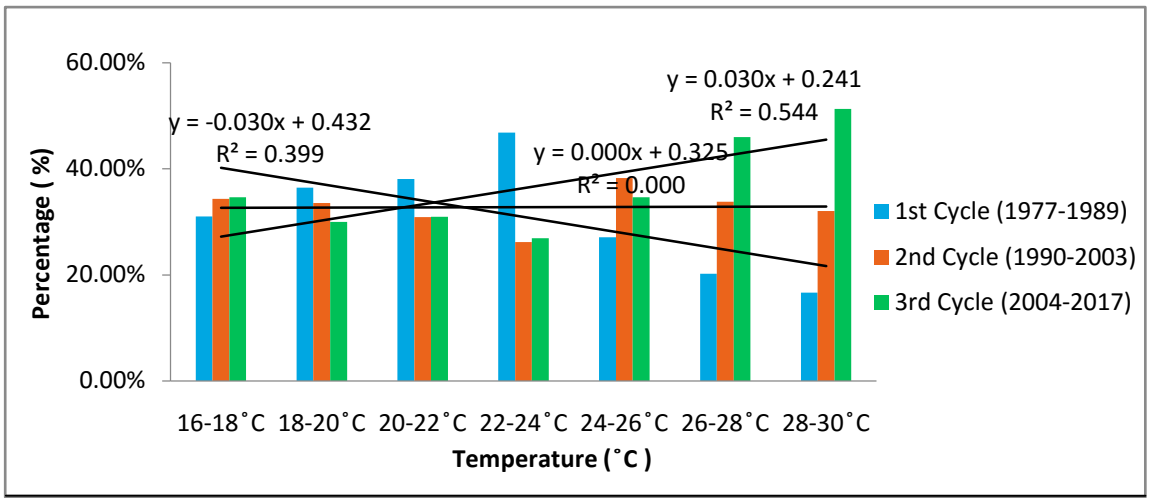


Figure 9. Frequency distribution of three cycle annual minimum temperature.

Frequency distribution of the cyclic operation in seasonal minimum temperature is shown in Figure 10.

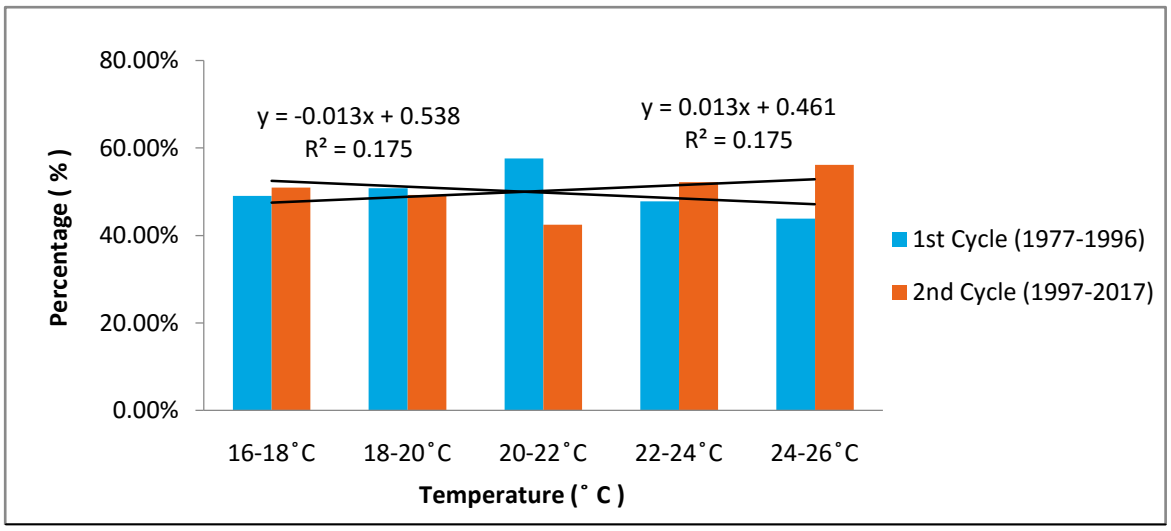


Figure 10. Frequency distribution of two cycle seasonal minimum temperature.

Rainfall is one of the most important and at the same time one of the most difficult hydrological parameter. There has been increasing operational demand for daily-monthly-annual rainfall analysis for a wide range of applications extending from the real time monitoring and prediction of climate change.

In the study area it is observed that the month of June, July and August are considered as rainy period. The annual and seasonal trend of rainfall is shown in Figure 11.

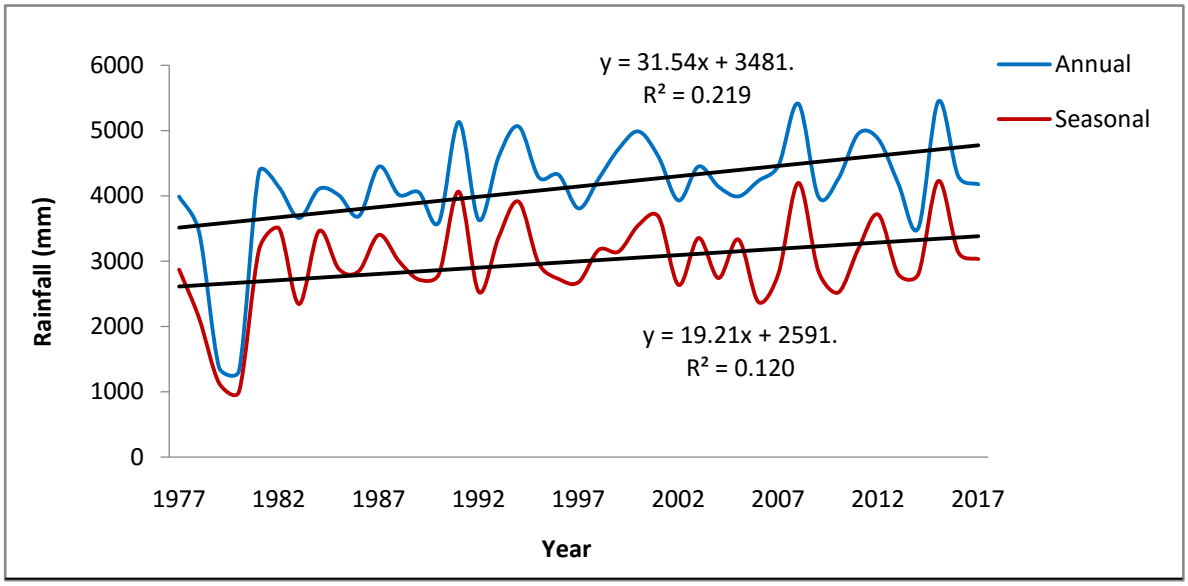
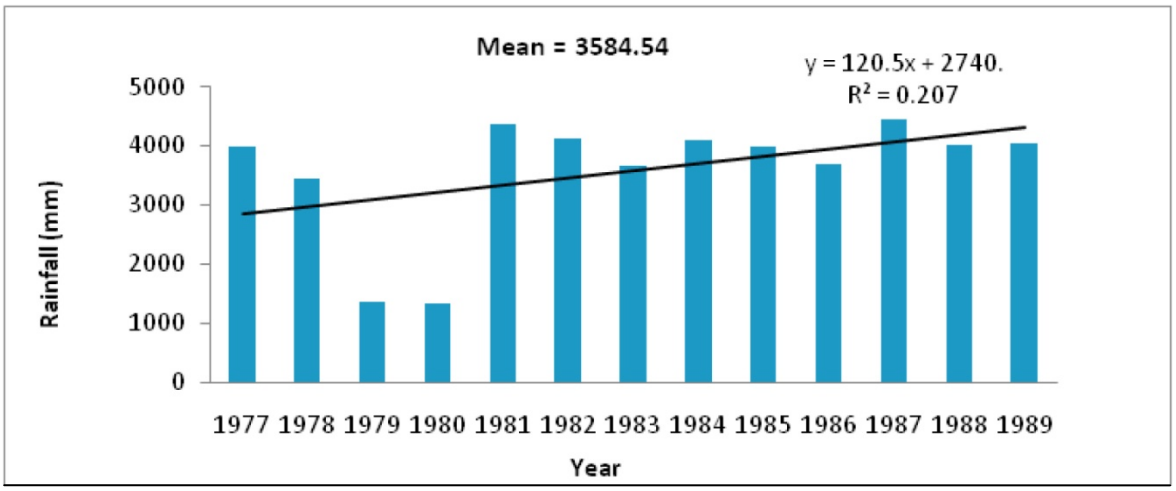
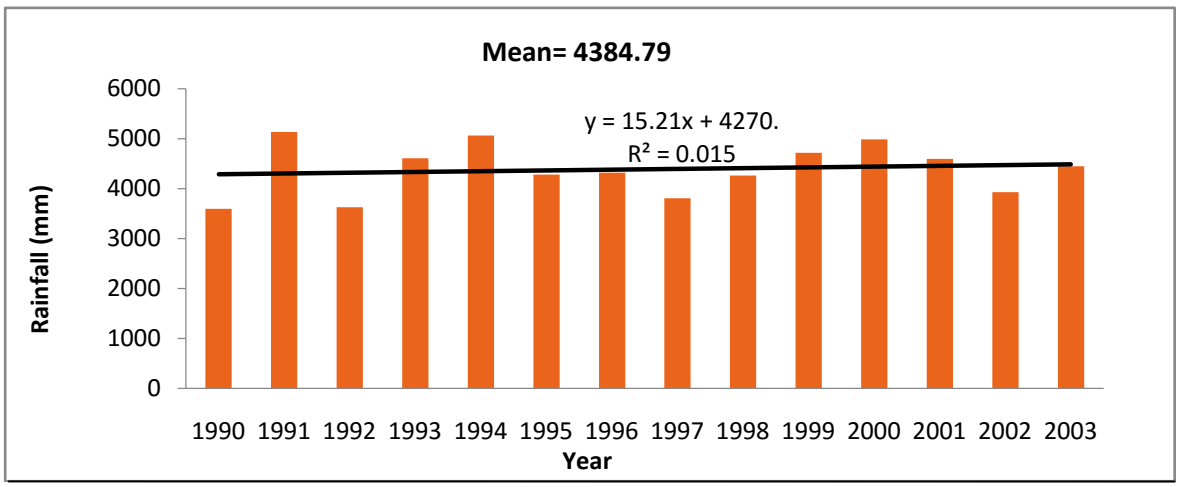


Figure 11. Annual and seasonal trend of rainfall.

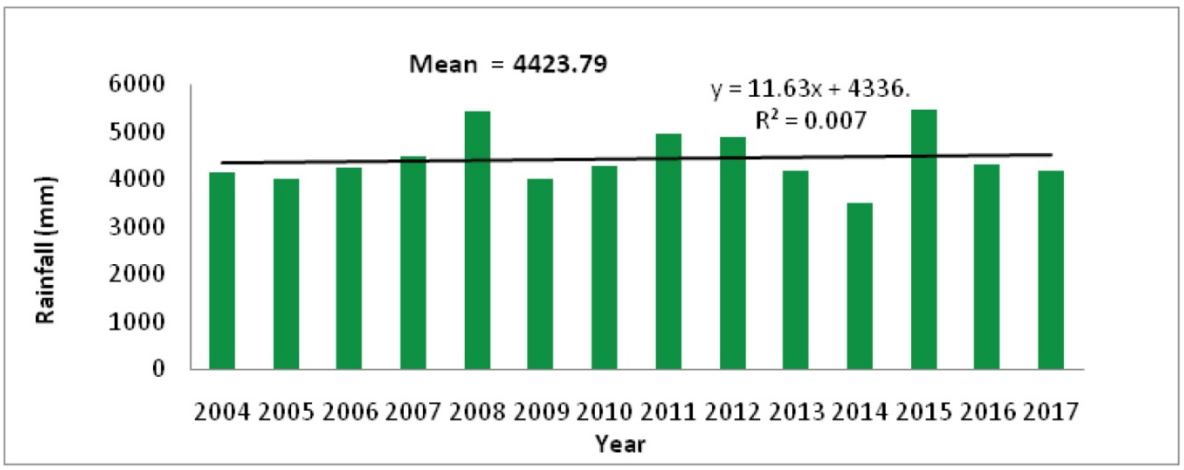
The three cycle operations of 14 years interval of the annual rainfall data are estimated and plotted in Figure 12.



(a) First cycle operation



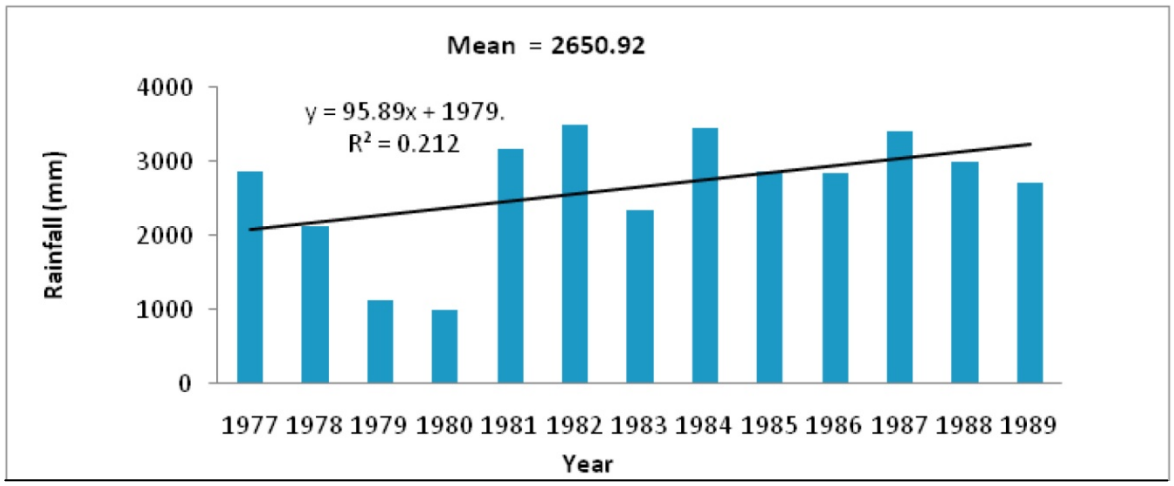
(b) Second cycle operation



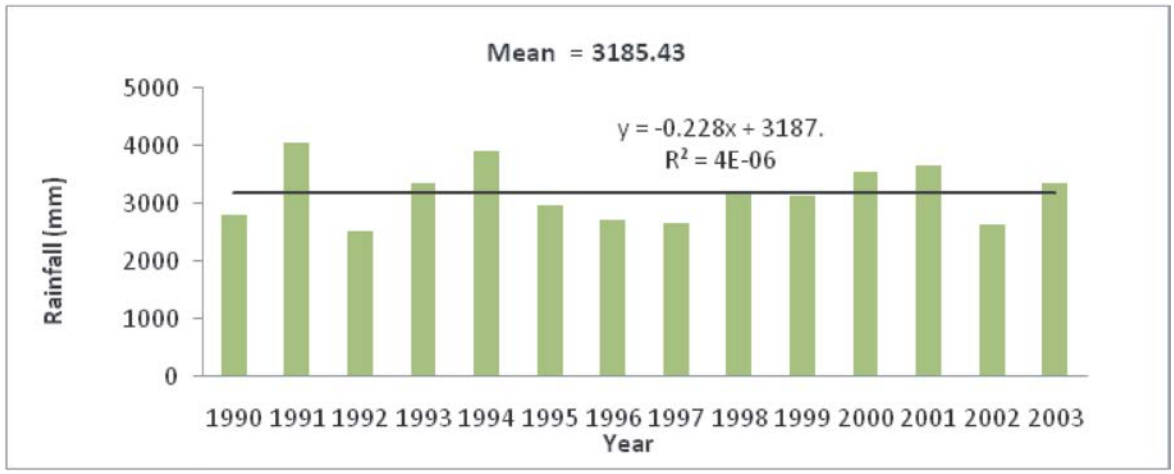
(c) Third cycle operation

Figure 12. Three cycle operation of annual rainfall.

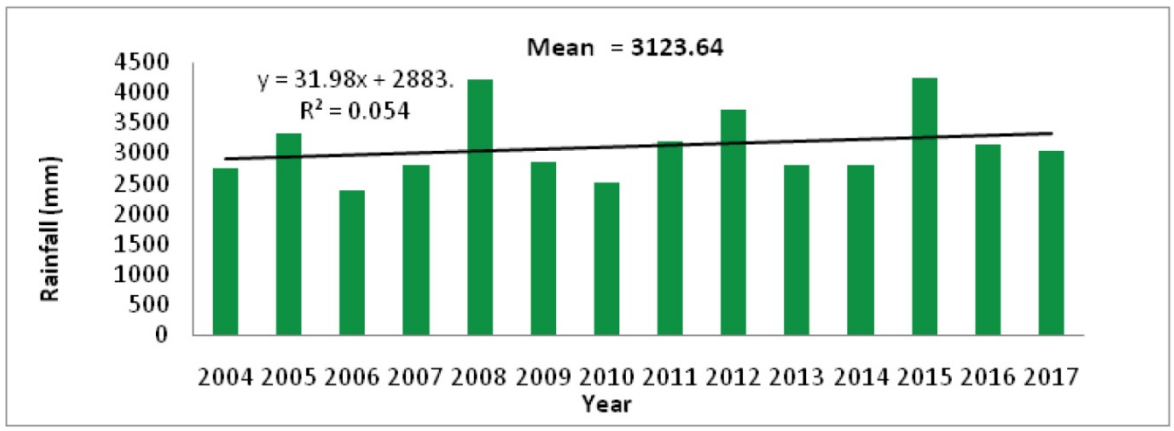
Analysis of seasonal trends of rainfall has also been done. The cyclic operation of seasonal rainfall analysis is shown in Figure 13.



(a) First cycle operation



(b) Second cycle operation



(c) Third cycle operation

Figure 13. Three cycle operation of seasonal rainfall.

5. Discussion

The time series analysis of mean annual and seasonal maximum temperature (Figure 2) shows a continuous increasing of temperature with a coefficient 0.46 and 0.3 respectively. From Figure 3 and Figure 4 it is observed that in cyclic operation the frequency of occurrence of annual maximum temperature value above 30˚C have been increased. In two cycle operation of seasonal maximum temperature it is observed from the Figure 5 that the occurrence of 30-33˚ C and 33-36˚ C temperature is about 50% and 71% respectively in second cycle operation. It is the indication of higher frequency distribution of higher temperature range. From the Figure 6 it is observed that the frequency occurrence of 33-36 ℃ temperature in the first cycle is 20% and the second cycle is 30% and 50% in the third cycle. This observation indicates the occurrence of higher temperature values above 33˚C is 50% of the annual day in the third cycle since the year 2004.

It is found from the Figure 7 that the mean of minimum temperature is also increasing in annual and seasonal analysis with a coefficient of 0. 26 and 0.02, respectively. The occurrence of frequency of different minimum temperature in two cycle operation is shown in Figure 8. It is clear from the Figure that the number of occurrences of higher temperature values gradually increased in the second cycle operation . It is also identified that the mean minimum temperature of 28-30˚ C has been recorded more than 70% of the annual days. It is noticed from the Figure 9 that the frequency of occurrence of temperatures 26-28˚ C and 28-30˚ C have been increased in the third cycle which indicates the rising trend of mean minimum temperature since the year 2004. It is observed from the Figure 10 that the frequency of occurrence of temperatures of 22-24˚ C and 24-26˚ C have been increased in the second cycle which indicates the rising trend of seasonal minimum temperature in second cycle.

Figure 11 represents the positive trend of annual and seasonal rainfall in the study area. From Figure 12 it is depicted that the annual mean rainfall during the last two cycles are remain constant. But the observation of seasonal effect (Figure 13) identified an increasing nature of the rainfall in the third cycle.

From the investigation it has been observed that annual maximum temperature increased significantly at the rate of 0.037 ˚ C/Year. During summer period the temperature is increased at the rate of 0.041 ℃ /Year. The annual minimum temperature increased significantly at the rate of 0.044 ˚ C /Year. During winter period the temperature is increased at the rate of 0.054 ℃ /Year. Khan *et al.* (2019) found that all the temperature extremes in most of the regions show a warming trend, while the daily average temperature in Bangladesh has significantly increased by 0.27˚C/ decade in the last 30 years (1988-2017).On other hand, Asfaw *et al.* (2018) have revealed the rate of change of temperature, 0.067 ℃ and 0.026˚C per decade for minimum and maximum respectively; Zaman (2013) has shown the temperature increased significantly at the rate of 0.00569˚C /Year for average maximum temperature and 0.014498˚C /Year for average minimum temperature. All the results found in this work are almost agreed with the mentioned contributions.

6. Conclusion

This study has investigated annual and seasonal climatic variability in Teknaf Upazila of Bangladesh based on maximum and minimum temperature, and rainfall. Deviation from the natural climatic pattern, a different tendency of temperature and rainfall was one of the focusing of this research. Findings have shown that the annual maximum and minimum temperature increasing rates are respectively 0.037 ℃/Year and 0.044 ℃ /Year. While, seasonal increasing rates are 0.041 ℃ /Year and 0.054 ℃ /Year respectively. Moreover the maximum temperature has been increased dramatically over the last 21 years (1997-2017) with a rate of 0.052 ℃ /Year. Rainfall is obtained for the same region is slightly increasing trend for both the annual and seasonal period.

Acknowledgements

Authors acknowledge Bangladesh Meteorological Department for providing data, which are used in this research work.

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Floods in Bangladesh and Their Impacts: A Review

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Abstract

The study attempts to identify the causes and effects of flooding in Bangladesh and helps to minimize future damages. It found the causes of flooding including heavy monsoon downpour, synchronization of flood-peaks of the major rivers, river bed aggradations, riverbank erosion, and river base-level changes. Some anthropogenic factors including environmental degradation, population growth, rapid urbanization, and climate change have further aggravated the flood situation of the country. It caused serious threats to life and property as well as the environment. The floods play important roles in the ecosystem including flora and fauna in wetland areas. The floods create lots of negative impacts on water resources, human health and life, livestock and the natural ecosystem. Effective flood management including flood monitoring, understanding of flood risk, mitigation measures and communication system has to be considered to reduce the loss of life and property in the future.

Keywords: Flood, Causes, Impact, Environmental degradation and Bangladesh

1. Introduction

Bangladesh is characterized by an extremely high population density, a low resource base, and a high incidence of natural disasters. Bangladesh is therefore recognized worldwide as one of the country's most vulnerable to the impacts of climate change and climate variability (Gunter *et al*., 2010). Besides, the geographic setting of Bangladesh makes the country vulnerable to natural disasters (Pramanik *et al.*, 1992). The effects of a natural disaster or a combination of more than one natural disaster may be the direct loss of life, and certainly damage to physical properties. This requires huge resources for disaster management including mitigation, recovery and preparedness. Bangladesh is known as the 'land of rivers' and major rivers that flow through Bangladesh are the Ganges, Brahmaputra and Meghna with a complex network of 230 rivers including 57 international trans-boundary (cross-boundary) rivers. The Ganges (Padma), Brahmaputra (Jamuna) and Meghna are largest fluvial systems in the world (Paramanik *et al.,* 1992). The topography of the country is mainly flat except for some northeastern and southeastern parts, which are hilly. About 60 to 65 percent land areas of the country is considered a flood prone area and 20 to 22% of the land is inundated for normal rainfall (Alauddin, 2010).The land elevation changes from 3 to 90 m above MSL (Mean Sea Level) and more than 50% of the floodplains in Bangladesh are within the 5 m above MSL (BUET'88, CLUB, 2010). The geographical location and the meteorological and the topographical characteristics make the country vulnerable to floods. Besides, Bangladesh is a land of monsoon rains and mighty rivers. The greater part of the landscape of the country is dominated by alluvial plains with numerous and unstable stream channels. Geologically, Bangladesh is a part of Bengal basin flanked by the Rajmahal Hills (in west Bengal, India) to the West and the Shillong Plateau (in Meghalaya, India) to the North (Mosharaf *et al.,* 1967).

There are some shorts of different between inundation and flood. When inundation causes damage to property and crops, disrupts communication and brings harmful effects to human beings as well as to flora and fauna, is called flood (Nishat, 1998).

Thus, Flood = Inundation + damage

Flooding may result from the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its normal boundaries. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, it is not a significant flood unless such escapes of water endanger land areas used by man like a village, city or other inhabited areas

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(O'Connor and John, 1995). Floods can also occur in rivers, when the strength of the river is so low it flows out of the river channel, particularly at bends or meanders and causes damage to homes and businesses along such rivers (Thompson, 1964). About 30 to 35 percent of the total land surface of the country is flooded in every year during wet monsoon (Milliman *et al.* 1989). The normal floods are considered a blessing for Bangladesh providing vital moisture fertility to the soil through the alluvial silt deposition (UNEP, 2001).

There is a close correlation between the trends of increased demographic pressure especially in developing countries like Bangladesh, escalated environmental degradation, increased human vulnerability and the intensity of flood. Environmental degradation increases the intensity of natural disasters, and is often the factor that transforms a natural hazard, or a climatic extreme such as heavy downpour, into a disaster. Thus, flood is intimately related to the environment. Therefore, the systematic review of the flood in Bangladesh is essential for implementing mitigation to reduce the environmental impact of the flood. The aim of the present study is to understand the environmental effects of flooding in Bangladesh and to recommend the environmental management for sustainable development of the country.

Figure 1 shows the flood free area, flash flood area, river/monsoon flood area and tidal surge flood area of Bangladesh. A large part of the country covers with river/monsoon flood. In every year flood is occurred in the country and damage the agriculture, social life as well as the economy.

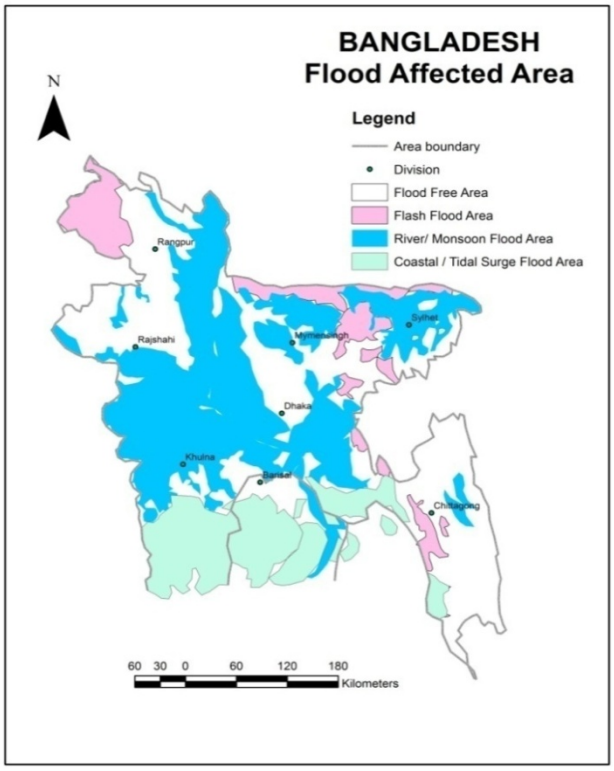

Figure 1. Map of flood prone areas of Bangladesh.
(Source: Base map-Banglapedia)

2. Background of Floods in Bangladesh

Bangladesh is a deltaic country that occupies an area of 1,47,570 sq. km. between latitudes 20˚-30 N and 26˚- 45 N and longitudes 88˚- 0 E and 92˚- 45 E. The geographical boundary is shared with India in north, east and west; Myanmar in the East; and the Bay of Bengal in the south (Chowdhury, 2000). The country has sub-tropical monsoon climate with three prominent seasons: winter (November to February), summer (March to June) and

monsoon (July to October). Flood is a frequent natural hazard in Bangladesh. Monsoon rains are the major causes of flooding but there are various other factors such as rapid runoff, the effect of the confluence of the major rivers, the flat topography of the delta and surges in the Bay of Bengal (Paramanik *et al.,* 1992). Khalequzzaman (1994) identified riverbed aggradations, deforestation in the upstream region, damming of rivers, and soil erosion due to tilling, excessive anthropogenic growth, seismic and non-tectonic activities and greenhouse effects as some of the additional causes behind flood occurrence in Bangladesh. The history of flooding in Bangladesh showed that the major floods occurred were in 1787, 1871, 1885, 1892, 1918, 1922, 1954, 1955, 1963, 1968, 1969, 1971, 1974, 1987, 1988, 1992, 1996, 1998, 2004 and 2006 (Pramanik *et al.,* 1992).

The country has experienced 17 large floods in the last 60 years since 1954. The damages caused by the annual floods and particularly by the devastating abnormal ones are enormous. The 1987 flood completely or partially damaged 2.06 million houses (or 16.67% of the national housing stock). The 1988 flood has displaced and affected an estimated 45 million people and destroyed or partially damaged 12.8 million houses of which 5.4 million were completely destroyed and 7.4 million were partially damaged (BBS, 2008). The losses of standing crops and livestock and damage to rural and urban infrastructures have also been colossal. The 1998 flood affected 30.92 million people in 52 out of the 64 districts (BDM, GOB handout, 1998). An estimated 916,660 houses were totally damaged with other 1,300,000 houses damaged partially, (Alauddin, 2010).

Table-1 shows the impact of the flood in different sectors in Bangladesh. It describes the major flood occurrences accordance with the percentage of total area, cost of damage in million-taka, population affected in million persons and death in the number of persons. It can be found that the flood of 1998 was the most vulnerable to the country since 1954 in consideration with flooding areas and cost of damages.

3. Types of Flood in Bangladesh

Floods are categorized based on spatiality, timing, intensity and duration into four groups in Bangladesh: viz. Monsoon floods, Flash floods, Rainfall-induced floods and Tidal floods.

Table 1. Coverage of inundation and damage caused by major floods in Bangladesh

Year	Source: BWDB, 2007			Source: BDM, GOB, 1998		Source
	Flooded area (sq. km.)	% of total area	Cost of damage (approx. million taka)	Population affected (approx. million persons)	Death (no. of persons)	
1954	36,920	25	1200	-	112	
1955	50,700	34	1290	-	129	
1956	35,620	24	900	-		
1962	37,440	25	560	-	117	
1963	43,180	29	580	-	87	
1968	37,300	25	1160	-	120	
1970	42,640	28	1100	-	1987	
1971	36,475	24	-	-	553	
1974	52,720	35	28490	30	1657	
1984	28,314	19	4500	20	2379	
1987	57,491	38	35000	30	1000	
1988	77,700	52	100000	47	2379	
1998	84,000	68	300000	100	918	
2004	55,000	38	-	3.8	700	MoEF, 2009
2007	32,000	22	-	-	649	Ibid
2010	26,530	18	-	-	-	FFWC, 2014
2014	36,895	25	-	-	-	Ibid

3.1. Monsoon Floods

Floods in Bangladesh are usually within tolerable limits. However, sometimes it appears as devastating. In Bangladesh, about 26,000 sq km (18%) of the country is flooded in every year. During severe floods, the affected areas may exceed 55% of the total area of the country (May to October) by the three main rivers the Ganges the Brahmaputra, Jamuna and the Meghna (Banglapedia).

3.2. Flash Floods

A flood, which is caused by heavy or excessive rainfall in a short period of time over a relatively small area, is referred to as a flash flood. In a flash flood, the water level rises and falls quite rapidly with little or no advance warning. Typically, flash floods occur in areas where the upstream basin topography is relatively steep and the concentration-time of the basin is relatively short. In Bangladesh flash floods generally occurs in the north-east, south-east and Chittagong region. But the devastating and extended flash flood is a recurrent phenomenon for the north-east region of Bangladesh. The extreme flashy character of the rivers and sudden excessive rainfall in the region causes frequent flash floods in the northeastern Haor areas. In the Haor area, the flash flood comes from the very steep uplands adjacent to the region in Asam and Meghalaya hills range in India causing immense damage to the standing Boro crops, lives, and properties every year (Edward, 2003).

3.3. Rainfall-induced Floods

The word flood is generally synonymous with the river flood. Cross-boundary inflow, the coincidence of the flood peaks of Ganges, Brahmaputra and Meghna and huge rainfall are the cause of this type of flood. In the middle of the country, a broad strip of land is flooded by bank overflow from the main rivers Jamuna, Ganges, Padma, and Meghna, and their tributaries and distributaries. Heavy rains also cause flooding, as drainage is impeded by high stages in the main rivers (BWDB, 2007).

3.4. Tidal Floods

In Bangladesh, the coastal line of the northern part of the Bay of Bengal is about 800 km and this type of flood occurs alongside the coastal area. The entire coastal belt is flooded when a cyclone hits strongly and the approximate height of the surges is about 10 m to 15 m, which sometimes cause great loss of lives. From June to September coastal areas are also subjected to tidal flooding (WMO/GWP, 2007).

4. Causes of Flood

The causes of flooding can be divided into two categories as Short-term causes and Long-term causes.

4.1. Short-term Causes

There are two major causes of the short-term flood stated below.

4.1.1. Monsoon Downpour

An increased amount of precipitation can cause flooding. An above normal monsoon downpour in the Ganges-Brahmaputra-Meghna drainage system is thought to be the primary cause of the 1988 flood in Bangladesh (GOB and UNDP, 1989; Brammer, 1990).

4.1.2. Synchronization of Flood Peaks

For the major three rivers the synchronization of flood peaks took place within a two week time period, causing a sudden increase in water level in virtually all areas of the country that reduce the water carrying capacity of the drainage system and decrease land elevation with respect to the base level of the rivers in Bangladesh (GOB and UNDP, 1989; Brammer, 1990).

4.2. Long-term Causes

There are several causes of long-term floods and short descriptions about them are below.

4.2.1. Compaction and Subsidence of Sediments

Most deltas subside due to the weight of the thick sediment layer. Subsidence along with compaction reduces land elevation with respect to the rising sea level. Even though the rate of subsidence and compaction are not yet well documented, based upon our knowledge about processes active in other deltas it can be assumed that Bangladesh's delta is also undergoing subsidence and compaction (Khalequzzaman, 1989).

4.2.3. River Bed Aggradations

River bed aggradations are most pronounced for the Ganges and its distributaries. The riverbed has aggraded as much as 5-7 meters in recent years from the border with India to the point where the Ganges meets the Brahmaputra. River bed aggradations reduce the water carrying capacity of rivers, causing them to overflow their banks and it is so pronounced in Bangladesh that changes in river bed level can be observed during one's lifetime (Khalequzzaman, 1989).

4.2.4. Accumulation of Inadequate Sediment

The earlier described data showed that the average sediment accumulation rate for the last few hundred years in the coastal areas of Bangladesh is 5-6 mm/year, which is not enough to keep pace with the rising sea level. As a result, net land elevations must have been decreasing over time, resulting in more flood inundations. For the land, the counter effects of a rising sea level are accumulating sediment at a rate that is sufficient to keep pace (Edward, 2003; Gupta and Asher, 2005).

4.2.5. Deforestation in the Upstream Region

An extreme amount of deforestation increased in the hills of Nepal due to the rapid increase in population in the Indian Subcontinent over the course of the present century to meet the increasing demand for food and fuelwood. Deforestation of steep slopes is assumed to lead to accelerated soil erosion and landslides during monsoon precipitations. It, in turn, is the result of devastating floods in the downstream regions in Bangladesh (Khalequzzaman, 1989).

4.2.6. Rivers Damming

River damming reduces the velocity of water flow downstream from the dam. As a result of reduced velocity, the sediments carried by the river start to settle down faster on the riverbed, causing riverbed aggradations and in turn reducing the water carrying capacity of the river. The Farakka Barrage (river barrier between Bangladesh and India) on the Ganges has already caused tremendous damage to the agriculture, navigation, environment, and hydrodynamic equilibrium in Bangladesh (Khalequzzaman, 1989).

4.2.7. Soil Erosion due to Tilling

The surface run-off can easily wash away the topsoil from cultivated land. This surface erosion reduces land elevation, which in turn increases flood intensity in an area. The land elevations in Bangladesh must have been reduced over time due to cultivation. Aside from this, the rapid river bed aggradations in Bangladesh eventually increased due to the tilling on the mountain slopes of the Himalayas which is thought to be responsible for massive soil erosion in Nepal (Khalequzzaman, 1989).

4.2.8. Excessive Development

In overcrowded Bangladesh, the enormous amount of increasing population produced an extra pressure on the land and as a result, agricultural lands are given way for roads and to the real state for housing developments. Thus, the construction of unplanned roads, railways, barrages, embankments and etc., may also create obstacles to the flow of water and may aggravate the flood (Kangas, 2005).

4.2.9. Seismic (Earthquake) and Geotectonic Activities

Geotectonic activities (recent movements in the Earth's crust) are affecting river courses in the area. Most of the recent floods have been approximately simultaneous with earthquake activities. The floods of 1988 and 1991 also are coincident with earthquake activities in northern parts of Bangladesh. Similarly, an earthquake can change the surface drainage pattern and consequently the course of a river, causing sudden flooding in an area. The historical records show the relationship between floods and earthquakes even though the cause and effect relationship between them is not very clear (Andy and Stanley 2001; Edward, 2003).

4.2.10. Climate Change

Recently the extreme flooding events increase around the world. Scientists assumed that the flood increased as the world gets warmer, which is absolutely true as the world is about to enter a period of rapid warming. Rising sea level of even greater magnitude will cause a flood on the low land and slow the speed at which rivers can remove water from the land. Bangladesh will be severely impacted by such an increase in sea level. Besides many other adverse environmental, economic, and climatic consequences, the base level of all rivers will change following any change in the sea level. The greenhouse effect will cause frequent cyclone as a result of high temperature will lead to flood problem and the rainfall could increase by 10% to 15% by the year 2030 (O'Riordan, 2008).

5. Impacts of Flood

Flood is always a damaging and devastating disaster for Bangladesh. As it is a very low-lying country with 70% of its land less than 1m above sea level and 80% of its floodplains. The country receives large amounts of water passing through it by two major rivers (the Ganges and Brahmaputra) converging with tributaries on the huge delta formed from silt deposited by the same rivers as they entered the sea. Both rivers have large volumes of water flowing through them to the sea as they have large drainage basins which increase the flood risk, especially on the environment in the long run. There are two types of impacts on the natural environment due to flooding are usually occurred.

5.1. Positive Impact of Flood

Seasonal flooding is needed to maintain the ecological and hydrological balance, and rural people perceive this to be essential to their livelihoods. Floodplain people have developed wide-ranging and ingenious strategies to live with (normal) floods. But extreme flooding can devastate crops, infrastructure, and livelihoods and bring misery for prolonged periods of time, creating disasters that challenge the resilience of the population.

The annual floods are essential and desirable for the overall growth of the Bangladesh delta and the economy (Chowdhury, 1988 and Brammer, 1990). The annual flooding of the plains of these rivers is a blessing because it makes the land fertile (Elahi, 1991). Small scale flooding in Bangladesh is required to sustain the agricultural industry, as sediment deposited by floodwaters fertilizes fields. The water is required to grow rice, so natural flooding replaces the requirement of artificial irrigation, which is time-consuming and costly to build. Salt deposited on fields from high rates of evaporation is removed during floods, preventing the land from becoming infertile. The benefits of flooding are clear in El Niño years when the monsoon is interrupted. As El Niño becomes increasingly frequent, and flood events appear to become more extreme, the previously reliable monsoon may be succeeded by years of drought or devastating floods (Wikipedia).

5.2. Negative Impact of Flood

The impacts of flood hazard on agricultural food production are global concerns, and they are very important for Bangladesh. Agriculture is the single most and the largest sector of Bangladesh's economy, accounting for about 35% of the GDP and about 63% of the labor force. Agriculture in Bangladesh is already under pressure both from huge and increasing demands for food and from problems of agriculture land and human lifestyle. The prospect

of flood hazard makes the issues particularly urgent (Hutton and Haque, 2003). Floods make an enormous impact on the environment and society.

Table 2. District wise flood impact in 2014 and 2017 flood

District	No. of affected Upazilla		Affected people			Affected family (partially)	Affected crops land (hec.)	Affected road (km.)	No. of death
	*2014	**2017	*2014	**2017	*2014	*2014	**2017	**2017	**2017
Bogura	3	5	432620	136217	1230	105130	10520	114.67	0
Bhola	7	-	460000	-	0	92000	-	-	-
Brahmanbaria	-	4	-	360	-	-	1180	0	1
Comilla	-	13	-	146534	-	-	3176	881	0
Dinajpur	-	13	-	702554	-	-	121170	0	30
Dhaka	1	3	4100	37510	1013	0	61.1	0	0
Faridpur	3	3	4190	54250	272	803	581	0	0
Gaibandha	3	7	132047	532126	11508	16708	24937	426	13
Jamalpur	4	7	513740	1044642	20525	87253	48787	701	12
Jessore	-	3	-	118334	-	-	7666	61	3
Joypurhat	-	5	-	36910	-	-	11330	106	0
Kurigram	9	9	279669	511032	3823	61171	50031	142.5	22
Lalmonirhat	5	5	46327	41959	839	10198	31400	222.71	6
Madaripur	2	1	4161	29260	1067	0	21	0	0
Manikgonj	3	6	18127	181580	4648	0	13657	280	0
Moulvibazar	-	5	-	8682	-	-	585	0	2
Munshigonj	3	-	12263	-	79	2886	-	-	-
Mymensingh	-	5	-	675593	-	-	11101	543	0
Nilphamari	1	6	20310	116140	260	3802	38050	0	8
Netrakona	5	5	32624	123980	0	8156	11567	21.5	2
Naogaon	-	11	-	452325	-	-	72485	0	5
Natore	-	2	-	265472	-	-	1200	70	0
Panchaghar	-	5	-	181220	-	-	1252	0	0
Rangamati	-	3	-	32000	-	-	2370	0	0
Rajbari	5	5	53695	142943	0	10739	3424	0	0
Rangpur	3	8	12148	0	665	2372	38815	165	3
Sirajganj	5	6	250624	413491	8496	60942	17935	102	6
Sunamgonj	4	10	445000	93750	4120	32678	10475	0	2
Sylhet	3	7	128630	133740	0	29845	7664	0	0
Sherpur	-	5	-	4850	-	-	3590	0	3
Shariatpur	3	3	21490	0	4298	0	0	0	0
Tangail	8	8	110565	442698	3679	34804	18433	978.5	2
Thakurgaon	-	5	-	115200	-	-	14660	0	1
Total	80	183	2983330	6775352	66522	559487	578123	4814.88	121

Source: *DMIC, Situation Report, 2014, **DDM, 2017

It is estimated that at least 1 million people are displaced due to flood and riverbank erosion in the country every year (Elahi, 1992). This adversity is further worsened when the devastating flood throughout the country makes the millions of people homeless every year and causing an alarming socio-economic impact on our society and economy. An estimate indicates that about 85 percent of the people live below the poverty level (Khondkar, 1996). Bangladesh has always been an agrarian country where over 50 percent of the population is still dependent on crop agriculture (BBS, 2008). It has been estimated that because of the damages to Aman crop due to the 1998 flood, the harvest has been reduced by about 2 million tons (Saleh *et al.,* 1998). For instance, in 2010, floods affected 49 districts of Bangladesh and tens of millions of people (Gunter *et al.,* 2010). The Third World Water Forum: Poverty and Floods held in March 2003 indicated that in recent years, floods had become more frequent and of increasing severity resulting into loss of life, injury, homelessness, damage to infrastructure and environment as well as impacting on other critical sectors such as education and agriculture. Some anthropogenic factors including environmental degradation, population growth, rapid urbanization, and climate change have further aggravated the flood situation of the country.

District wise flood-affected people, family, cropland and road in 2014 and 2017 floods in Bangladesh are shown in Table 2. Among 20 districts all Upazillas of Kurigram, Lalmonirhat and Bhola districts were affected by 2014 flood. A total of 80 Upazillas were affected by these floods and the total affected people were 2983330 and 6775352 in 80 Upazillas, respectively in 2014 and 2017 floods.

6. Flood Management

The structural measures and non-structural measures are considered for flood management.

6.1. Structural Measures

Over the second part of the last century, flood management strategies adopted in the country have continuously evolved in three distinct phases of their development, and with mixed experiences. In the beginning, the emphasis was on structural measures through the implementation of some large-scale Flood Control, Drainage and Irrigation (FCDI) projects. After some time later it has been realized that a huge amount of investment is required to implement the idea as well as it is going to take more time to complete. It is then opted for the construction of small and medium scale Flood and Coastal Defense (FCD) projects so as to provide early benefits. After this, it is observed that other sectors related to water resources development and utilization should also be taking care of like the way they do for agriculture. Environmental protection has been given first priority. As a result, since the 1960's about 628 large, medium and small-scale FCDI projects have been implemented; they comprise levees and embankments, drainage channel improvements, drainage structures, dams and barrages, pumping systems, etc. They have provided flood protection to about 35% of the total area; the meaning is about 5.37 million ha of land (WMO/GWP, 2007; Khalequzzaman, 1994).

6.2. Non-structural Measures

It has been proven that structural measures alone are not the only solution to improved flood conditions. Non-structural measures like Flood Forecasting and Warning System (FFWS) have been introduced to share the flood problems. In the early '70s, the FFWS has been established in Bangladesh and was modernized in 1996 and then again in the year 2000. It is now covering all the flood-prone areas of the country with 85 flood-monitoring stations and provides real-time flood information and early warning with lead-times of 24 hours and 48 hours. The FFWS is currently assisting Government, disaster managers and the communities living in the flood-prone areas in matters of flood preparedness, preparation of emergency mitigation plans, rehabilitation and agricultural planning (Brammer, 1990; WMO/GWP, 2007). Furthermore, for the flood mitigation, more emphasis is now put on other non-structural means in particular by adopting a policy of involving communities in flood management, the stopping of encroachments on the flood plains through legislation controlling the developments in the flood plains and wetlands. However, a new concept is being introduced of controlling the flood as per desire of the stakeholders, instead of protecting some areas to make them completely flood-free (Brammer, 1990; WMO/GWP, 2007). Integration of structural and non-structural measures is essential for effective flood management.

7. Conclusions and Recommendations

Bangladesh is a flood-prone area due to being situated on the Ganges delta and the many distributaries flowing into the Bay of Bengal. Bangladesh has an extensive sea coastline with about 80% of the land area of Bangladesh is a floodplain, rendered the nation at risk of widespread damage. The floods usually occur during the monsoon season of the country started in June and ended in September. The causes of natural disasters in Bangladesh have an international dimension. About 57 main trans-boundary rivers are flowing through Bangladesh. Of them, 54 have the origins in India and the remaining 3 in Myanmar. The upstream deforestation, heavy rainfall, melting of glaciers, and soil erosion plays a vital role in causing siltation in riverbeds. The study observed that the Farakka Barrage on the Ganges has already caused tremendous damage to the agriculture, navigation, environment, and hydrodynamic equilibrium in Bangladesh. The study found that the flood of 1998 was the most vulnerable to the country since 1954 in consideration with flooding areas and cost of damages. The study also illustrated that the floods have some devastating impacts on agriculture, environment, life, property, etc. Some anthropogenic factors including environmental degradation, population growth, rapid urbanization, and climate change have further aggravated the flood situation of the country. But it has some positive impacts on the environment too. But still, now the flood is the vulnerable natural disaster of the country. In every year more area and huge people are affected by flood and riverbank erosion. For sustainable flood management in Bangladesh the study would consider the following recommendations:

Public perception and awareness regarding flood risk assessment should be considered. Tree plantation program has to be implemented properly on the bank of the river. Protective embankments or walls have to be built. An intensive hydrological survey and investigations have to be considered. The government should take long-term flood control and river bank erosion program and incorporate different organizational programs to get the maximum benefits in achieving the desired goals of flood protection and river erosion plan.

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Communication and Transport Facilities of Periodic Rural Markets in Chapai Nawabganj District

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Abstract

Periodic rural market is known as *haat* and the regular market as bazar in Bangladesh. Both periodic and regular rural markets are important media of the marketing system in Bangladesh. The present study deals with the communication and transport facilities of periodic rural markets in Chapai Nawabganj district of Bangladesh. There are 40 rural periodic markets (RPMs) in the study area, 16 RPMs under revenue collection and 18 are non-governments RPMs. It is found that 07 *haat*s are connected by water ways and 18 *haat*s are connected by pucca road. Most of the *haat*s are situated in flood-free area but some *haat*s are affected by flood. Bus, truck and pickup van are common transport used in carrying goods and people to the RPMs in the Northern side of the Chapai Nawabganj Sadar upazila. On the other hand, in Southern part, all goods are transported using cart, head loaded, bi-cycle and motorcycle to the nearby RPMs. However, these transport facilities are totally out dated and time consuming, as a result many perishable goods are damaged on the way. People of southern part have to spend huge amount of money for transporting their goods particularly perishable items like fish, meat, fruit and vegetables.

Keywords: Periodic Rural Market, Distance Decay, Perishable and Goods

1. Introduction

Bangladesh is heavily dependent on agriculture and more than 80 percent of the populations are living in the village. Rural Periodic Markets (RPMs) therefore plays a vital role in the economic life of the people, particularly in the marginal economy. In Bangladesh, rural economy is highly dependent on the RPMs. In fact, RPM acts as an out-let of local rural surplus. The Rural Periodic Markets (RPMs) are not only act as an important media of the marketing system in both the underdeveloped and developed countries of the world. The present study deals with the Environmental Perspectives and Distance Decay Function of the commodities attended in the exchange center.

Distance decay and perishability of the study area are not equal of the whole study area. In the study area, Northern part is well communicated but the Southern part is poorly communicated.

However, in this paper, the distance decay and perishability of the rural periodic markets in Nawabganj sadar upazila have been explained with an special emphasis of consumer travel distance, transport and environmental impediments, transport condition of RPMs, distance and cost price formation and process of price formation. Perishable food is the main source of energy, portion and vitamins required by human body (Khatun, 1988). Development of transport and communication system and trade has been evolving as complements to each other since long ago (Sultana, 1988). Development programs of the developed and underdeveloped countries of the world is greatly dependent on the relationship between efficient transport and communication system and rural marketing (Weber (1911). Christaller (1933) have found a promulgated influence of transport system on various economic activities. Distance decay is a term, which describes the effect of distance on cultural or spatial interactions. The distance decay effect states that the interaction between two localities declines as the distance between them increases.

Haque (1986) found that Nawabganj Sadar upazila had the large and intermediate order of haats where transport facilities are good. Sultana (1986) has observed clear relationship between the transport system and the development of the haats. The present study is designed to show the interdependence between these two factors in respect of environment.

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2. Materials and Methods

2.1. Study Area

Nawabgonj Sadar Upazila stretches altitudinally between 24°25´N to 24°43´N and longitudinally between 88°05´E to 88°26´E. Nawabgonj upazila includes Nawabgonj Pourashava 14 union parishads and total number of 174 mauzas (BBS, 2011). In this Upazila, area is 451. 80 square km with population of 530592 and total 40 *haats* (Figure 1). Once, the Nawabgonj was with Gour, the famous capital of ancient Bengal.

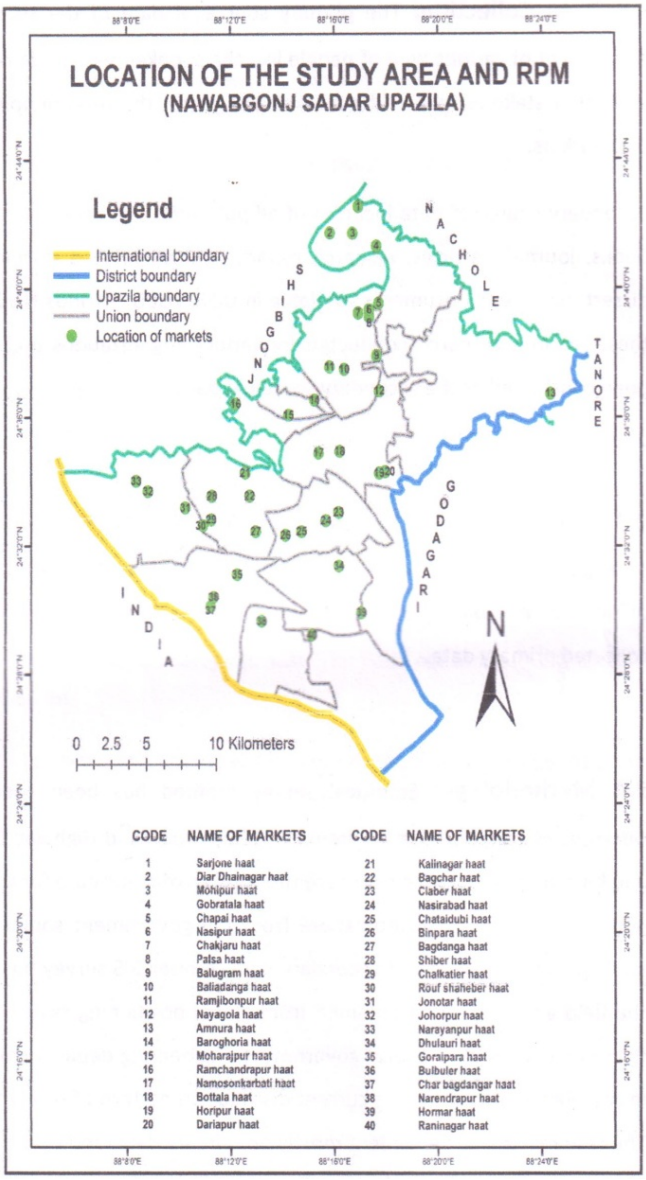

Figure 1. Markets in Nawabganj Sadar Upazila

2.2. Data Collection

The primary source of data are mainly the respondents like shopkeeper, customer, laborers and stakeholders of the market along with the rural people who live nearby the markets.

Secondary source of data includes published and reported materials including books, journals, articles, research reports, official printed documents, thesis, dissertations, and documents available in DOE, LGED and NGOs. Apart from these, research conducted by various organizations and people have also been considered as the secondary source of data.

2.3. Software Used

The computer software packages SPSS (statistical package for social science), Excels and GIS (geographical information system) are used for maps, diagrams and data analysis. A brief GIS survey has conducted during the field visit. The data obtained from global positioning system (GPS) survey was then compiled with the local government-engineering department (LGED) base map in Arc View GIS to show the current distribution pattern of rural market in this area.

3. Results and Discussion

3.1. Commodities Assembled with Types

In general, perishable food comes from two sources viz. animal and plant. Animal source includes milk, meat, fish and egg. On the other hand, plant sources include vegetables and pulses beans along with some fruits. In Bangladesh, urban dwellers usually collect perishable food from nearby markets almost every day in a week. These market centers are usually grown spontaneously within or near the settlements, mostly beside a river or major road. So distribution pattern of these markets is related to the settlement pattern as well as communication facilities of the study area.

It is also evident that in this upazila the number of perishable food markets and the volume of goods are increasing very rapidly. In this study Nawabganj Upazila area which has been delineated after field investigation is shown in the map (Figure 1).

From the observation and questionnaire survey, it is found that various types of commodities are assembled in the rural periodic market. This selling commodities and types of commodities are divided into five categories in the study area. The classification and the details items of the goods are presented in Table 1.

Table 1. List of all classes of selling commodities

Selling types	Name of Commodities
Grocery /Grocer's Shop	Rice, wheat, pulse, oil, shop, pest, shampoo, biscuits, fried rice, sugar, molasses, confectionary items, stationary commodities, oilcake , cows feed, poultry feed, etc.
Vegetable Seller	Various type of fresh vegetables, cauliflower, potatoes, brinjal, cabbage, tomato, chili, gourd, pumpkin, papaya, onion, garlic, beans, carrot, lemon, etc.
Fruit Seller	Banana, apple, orange, grape, watermelon, litchi, mango, coconut, lemon, green coconut, wood apple, palm, jack fruit, pineapple, etc.
Butcher	Beef, buffalo meat, mutton, birds, duck and pigeon meat.
Miscellaneous	Tea stall, bag, brass, poly-thin paper bag, jute bag, etc.

Table 1 shows that various type of food items are selling by five types sellers in the market. Some RPMs are used as a few items trading centre but some RPMs have many types of items. So it is depended on its type's quality and accessibility of goods products. Most of the things get easier access in the RPM that is why these perish goods is not destroyed. But these goods are very often perished when taken to the urban market like upazila sadar of Chapai Nawabganj or elsewhere of the country.

3.2. Consumer Travel Distance

There is a direct relation between consumer travel distance and location of market. In fact, the consumer's travel distance has a close relationship with the spacing of market centers which in term is influenced by the density of population and the topography of geographical area of the locality. In the study area, most of the unions are thickly populated namely Namosankarbati, Baroghoria, Moharajpur, Ranihaati, Sundarpur and Municipal areas. The average travel distance is not more than 100 km that is the first order haat and some RPMs have consumer travel distance of under 50 km. The sparse population and rugged topography of the *Barind* and *Diar* areas have resulted in the higher consumer travel distance. Amnura haat and Gobratala haat in the *Barind* areas and Debinagar, Chataidubi, Kalinagar, Char Bagdanga *haat* and Narayanpur haat in the Diar areas have all consumer travel distance of 4 km. Bottala haat and Ramchandrapur haat are the two higher order haats and hence their consumer travel distance is higher, 8 km. and 6 km, respectively.

From the analysis, it is clearly that the close spatio-temporal spacing of market centers gives rise to wide latitude to any consumer to visit a number of rural markets in a week according to his will, necessity and capability. On the *Barind* and *Diar* lands the actual consumer walking distance is accentuated by intervening rugged topography in case of the *Barind* land and sandy tracts in case of *Diar* area (Altaf and Sheikh, 1998).

3.3. Transport and Environmental Impediments

Development of transport and communication system and trade has been evolving as complements to each other since long ago (Sultana, 1988). Christaller (1933) found a promulgated the epoch making influence of transport system on various economic activities. Therefore, development of transport system has tremendous impact on rural marketing and thereby on rural development. But some environmental impediments are related to the transport system of the rural periodic market. The transportation of rural markets and thereby the environmental impediments is closely interlinked with transport system. It is assumed that most of the larger haats are situated where the transport facilities are good which shows that good transport system is positively correlated with environmental factors. Haque (1986) found that Nawabganj Sadar upazila has the large and intermediate order haats are situated where transport facilities are good. Sultana (1980) found a clear relationship between the transport system and the development of the haats.

3.4. Transport Conditions of the Rural Periodic Market

Turten (1974) observed that waterways play an important role in the economic development of the underdeveloped countries and it is quite applicable for Nawabganj Sadar upazila. Most of the *haats* of Nawabganj Sadar upazila are connected by pucca roads, 7 haats are connected by water ways and 14 by seasonal water way. The *haats* are connected by permanent water ways are Baliadanga, Bagchar, Baroghoria, Gobratala, Nayagala, Kalinagar and Hormer. These haats are seasonal water ways connected. Transport linkage condition includes both the transport network and transport mode. In this study, 5 networks and 5 modes have been defined to analyze the status of the rural market. In this study transport network includes 5 variables and transport mode includes 5 variables (Table 2). All these variables are allotted points on the basis of their importance: rail way 5, bus 4, truck 3, pucca road 3, semi pucca road 2, pick up 2, permanent water ways 2, *kucha* road 1, seasonal water1 and cart 1 according to Haque (1988). These points are then summed up and made the ranking order for rural periodic market (RPM). Various types of transport systems are presented in Table 2.

Table 2. Transport conditions of the RPM of Nawabganj Sadar Upazila

Types of RPMs	Sl. N0	Name of the Haat	Pucca	Semi pucca	Kucha road	Perm anent water ways	Seasonal water ways	Railway	Bus all time	Truck	Pick up	Cart	Total point	Percentage
First order	01	Ramchandrapur haat	3	2	1	-	1	-		3	2	1	13	32.08
	02	Bottala haat	3	2	1	-	1	-		3	2	-	12	
	03	Namosankarbati haat	3	2		-	-	-		3	2	-	10	
	04	Moharajpur haat	3	2	1	-	1	-	4	3	2	-	16	
	05	Baroghoria haat	3	2	1	2	-	-	4	3	2	-	17	
	06	Dhulauri haat	-	-	1	-	1	-	-	-	2	1	5	
	07	Kalinagar haat	3	2	1	-	1	-	4	3	2	1	17	
	08	Amnura haat	3	2	1	-	-	5	4	3	2	1	21	
First order haat total point			**21**	**14**	**7**	**2**	**5**	**5**	**16**	**21**	**16**	**4**	**111**	
Second order	09	Gobratala haat	3	2	1	2	-	-	4	3	2	1	17	26.30
	10	Mohipur haat	3	2	1	-	-	-	4	3	2	-	15	
	11	Nayagala haat	3	2	1	2	-	-	4	3	2	-	16	
	12	Chataidubi haat	-	-	1	-	-	-	-	-	2	1	4	
	13	Noranthropur haat	-	-	1	-	-	-	-	-	-	1	2	
	14	Horipur haat	3	2	1	-	-	-		3	2	-	11	
	15	Bagchar haat	-	2	1	2	1	-	-	-	2	1	9	
	16	Baliadanga haat	3	2	1	2	-	-	-	3	2	-	13	
	17	Bulbul haat	-	-	1	-	-	-	-	-	-	1	2	
Second order haat total point			**15**	**12**	**09**	**08**	**01**	**00**	**12**	**15**	**14**	**5**	**91**	
Third order	18	Char Bagdanga haat	-	2	1	-	-	-	-	-	2	1	6	17.63
	19	Naraynpur haat	-	-	1	-	1	-	-	-	-	1	3	
	20	Diar Dhainagar haat	-	2	1	-	1	-	-	-	2	1	7	
	21	Bagdanga haat	-	-	1	-	-	-	-	-	2	1	4	
	22	Roufshaheb haat	-	2	1	-	1	-	-	-	2	1	7	
	23	Dariapur haat	3	2	1	-	-	-	4	3	2	-	15	
	24	Binpara haat	-	-	1	-	-	-	-	-	-	1	2	
	25	Cluber haat	-	-	1	-	-	-	-	-	-	1	2	
	26	Palsa haat	3	2	1	-	-	-	4	3	2	-	15	
Third order haat total point			**6**	**10**	**9**	**00**	**3**	**00**	**8**	**6**	**12**	**7**	**61**	
Fourth order	27	Janotar haat	-	-	1	2	-	-	-	-		1	4	23.98
	28	Shibber haat	-	2	1	-	-	-	-	-	2	1	6	
	29	Ramjibonpur haat	-	2	1	-	1	-	-	-	2	1	7	
	30	Chapai haat	3	2	1	-	-	-	4	3	2	-	15	
	31	Chalkathir haat	-	-	1	-	-	-	-	-	-	1	2	
	32	Johorpur haat	-	-	1	-	1	-	-	-	-	1	3	
	33	Balugram haat	3	2	1	-	-	-	4	3	2	-	15	
	34	Goraipara haat	-	-	1	-	-	-	-	-	-	1	2	
	35	Sarjan haat	-	2	1	-	-	-	-	-	2	1	6	
	36	Chakjharu haat	-	2	1	-	1	-	-	-	2	1	6	
	37	Nasirabad haat	-	-	1	-	-	-	-	-	-	1	2	
	38	Nashipur haat	-	2	1	-	1	-	-	-	2	1	7	
	39	Hormer haat	-	-	1	2	-	-	-	-	-	1	4	
	40	Raninagar haat	-	-	1	-	1	-	-	-	-	1	3	
Fourth order haat total point			**6**	**14**	**14**	**4**	**5**	**00**	**8**	**6**	**14**	**12**	**83**	
Grand total			**48**	**50**	**39**	**14**	**14**	**5**	**44**	**48**	**56**	**28**	**346**	100.0

Source: Field Survey, 2018

Table 2 shows that 16 *haats* are connected with pucca road, 25 *haat* with semi-pucca road, 39 with kucha road,7 with permanent water ways, 14 with seasonal water ways and only one haat is connected with railway. However, 10 *haats* are connected with bus, 16 *haats* with truck and 28 haats connected with pick up van. On the other hand, every haat facilities are not equal some haat are connected with pucca road, water ways, bus, truck, pick up and other means of transport facilities. But some *haats* are connected by only kucha road. So the RPMs are related to the environment impediments. Rural periodic markets (RPMs) which have good transport condition are environment friendly. If we look the total point of individual *haat*, Bottala got 12 points, Dariapur 15 points, Nayagala 17 points, Gobratala 17 points and Amnura 21 points. Thus it is clear that though the study area is very close to the Nawabganj Sadar there is a distinguish variations among *haats* of this area in term of location, transportation and communication.

3.5. Distance Decay and Perishability

There is a distinguished difference between north and southern side of Nawabganj Sadar upazila in terms of transportation and communication. North part is very developed regarding to transportation and communication on the other hand the south side is very poorly communicated. In south part most of the road is kucha and the number of vehicles are insufficient. There is no engine vehicle because there is no pucca road. However, in recent time a road is built on the Mahananda river barrage from Sundarpur to Char Bagdanga *haat* and a kucha road has been developed to communicate the Kalinagar *haat*.

In the South region, perishable food, especially fish, meat, vegetable, fruits and seasonal fruits, etc. transportation is very difficult as there is no metallic road or good means of transportation. These goods are going to the the RPM from the Nawabganj sadar, Godagari and Mohisalbari *mokam*. Most of the goods are carrying by head, bi-cycle, van and in some times with motorcycle.

It has been observed that the North and the South part transport system is remarkably different which is presented in Table 3 where some unions are very underdeveloped and transport system is also very poor. Nevertheless, in the Table 3, the means of transport in North side and Southern part of Nawabganj upazila is presented.

Table 3. Status of transportation means of transport system of North and South part of Chapai Nawabganj Upazila

Name of Union/Pourashava	Two sides of sadar upazila	Bus	Truck	Pickup van	Cart	Head-load	Bi-cycle	Motor Cycle
Nawabganj-sadar	North side	100	100	100	-	-	2	-
Baliadanga		50	50	100	10	-	1	-
Gobratala		75	75	100	-	-	2	-
Baroghoria		100	100	100	-	-	2	-
Jhilim		100	100	100	50	2	5	-
Ranihaati		100	100	100	-	-	2	-
Moharajpur		100	100	100	-	-		
Alatuli	South side	-	-	-	100	10	10	100
Islampur		-	-	-	100	10	10	100
Char Bagdanga		-	-	-	100	10	11	50
Debinagar		-	-	-	100	10	10	75
Narayanpur		-	-	-	100	12	12	100
Char Anupnagar		-	-	-	100	20	20	100
Shajahanpur		-	-	-	100	10	12	75
Sundarpur		-	-	-	100	10	13	30

Table 3 shows that bus, truck and pickup van are commonly used in carrying goods and people to the RPMs in the Northern side of the upazila. On the other hand, in Southern part all goods are transported by cart, head lorded, bi-cycle and motor cycle to the nearby RPMs but these transport facilities are totally out dated and time consuming as a result very often many valuable perishable goods are damaged on the way.

3.6. Distance and Cost

In Southern part of the study area, the sandy road does not permit engine run transport other than motor cycle. Thus there is no alternative means of quick transport for carrying perishable goods in this region. Consequently the transport cost become very high and very often valuable goods are damaged due to lack of quick transfer facilities. It is noted that fifty percent area of this upazila is deprived of effective transport facility through the south part of the study area enjoy good transport facility. The details picture of the transport system is presented in Table 4.

Table 4. Communication and transport system of southern part of the study area

Name of the Union	Total Number of Motor Cycle	Carrying Goods and People in Fare	Number of Passenger
Alatuli	20	10	35
Islampur	55	35	150
Char Bagdanga	50	68	120
Debinagar	140	110	300
Narayanpur	30	20	100
char Anupnagar	11	5	30
Shajahanpur	40	25	100
Sundarpur	75	50	120

Table 4 shows that 8 unions have no effective means of transportation consequently the people of this area bound to carry their perishable goods through motor–cycle and even they have to hire motor-cycle in emergency cases which is costly. Most of the families (50% above) have motor cycle, and rest does not have motor cycle and they used to rent motorcycle for transport (Table 5).

Table 5. Status of rent of motor cycle

Sl.No.	Name of the Union	Fare (Tk.)/Person/Km
01	Alatuli	15
02	Islampur	14
03	Char Bagdanga	15
04	Debinagar	14
05	Narayanpur	20
06	Char Anupnagar	18
07	Shajahanpur	15
08	Sundarpur	16

From Table 5 it is clear that the fare of rent of motor cycle is not convenient and most of the people in the southern part of sadar upazila have to use rented motor cycle for their emergency transportation and communication

However, there is a variation in fare in terms of distance and number of passenger. Single passenger with short distance, fare is very high compare to double or triple passengers in long distance. Moreover, fare may high in case of muddy and sandy road. So the commutation system of this region is difficult and expensive. In this region passengers, goods and commodities are also carried by the rented motor cycle from some commercial points like Nawabganj sadar, Godagari and Mohisalbari *haat*.

Table 6. Status of transportation of perishable food like as fish, meat, fruit and vegetables in the southern region

Sl. No.	Means of Transport	Transport Numbers		
		Fish/meat	Fruit	Vegetables
01	Cart	-	10	70
02	Head loaded	30	40	10
03	Rickshaw van	5	10	10
04	Engines van	15	20	-
05	Cycle	15	10	10
06	Motor cycle	25	-	-
07	Truck	-	-	-
08	Pickup van	10	10	-
	Total	100	100	100

From the Table 6, it is found that perishable goods are carried by some vehicles which is very costly though the people of northern part of the sandy area enjoy affordable cost in carrying their goods through available public transport like bus, truck, train and van. But the people of southern part have to spend huge amount of money for transporting their necessary goods particularly perishable items like fish, meat, fruit and vegetables.

4. Conclusion and Recommendation

The study area has total 40 RPMs, 16 RPMs under revenue collection and 18 are non-governments RPM. It is observed that 07 *haat*s are connected by water ways and 18 *haat*s are connected by pucca road. Most of the *haat*s are situated in flood-free area but some *haat*s are affected by flood.

Bus, truck and pickup van are commonly used in carrying goods and people to the RPMs in the Northern side of the Chapai Nawabganj upazila. On the other hand, in Southern part, goods are transported by cart, head loaded, bi-cycle and motorcycle to the nearby RPMs but these transport facilities are totally out dated and time consuming as a result very often many valuable perishable goods are damaged on the way. People of southern part have to spend huge amount of money for transporting their necessary goods particularly perishable items like fish, meat, fruit and vegetables.

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