Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X

Volume 5	Number 2	December 2023

Published by

Ecological Society of Bangladesh

Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur

Website: https://journal.esbangladesh.org

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X

Volume 5 Number 2 December 2023

Subscription rate for each issue

	Bangladesh	Overseas
Individual	Tk. 100.00	US $ 10
Institutional	Tk. 250.00	US $ 20

Printed by : Sowrov Media Products, 18 Babupura, Kataban Dhal, Dhaka.
E-mail: sowrovmp@yahoo.com, sowrovmp@gmail.com, Mobile : 01718 419001, 01832 855227

Ecological Society of Bangladesh

ESTD. 2019

Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur

Executive Committee 2022-2024

President	**Prof. Dr. Md. Ruhul Amin** Department of Entomology, BSMRAU, Gazipur
Vice President	**Dr. Md. Fakhre Alam Ibne Tabib** Executive Director, Cotton Development Board, Dhaka
	Prof. Dr. Gopal Das Department of Entomology, Bangladesh Agricultural University, Mymensingh
General Secretary	**Prof. Dr. M. A. Mannan** Department of Agronomy, BSMRAU, Gazipur
Joint Secretary	**Prof. Dr. Md. Arifur Rahman Khan** Department of Agronomy, BSMRAU, Gazipur
	Prof. Dr. Md. Taimur Islam Department of Pathobiology, BSMRAU, Gazipur
Organizing Secretary	**Dr. Amina Khatun** Principal Scientific Officer, Rice Farming Systems Division, BRRI, Gazipur
Treasurer	**Dr. Md. Shamim Hossain** Assoc. Professor, Department of Entomology, BSMRAU, Gazipur
Assistant Treasurer	**Dr. Syeda Tasnim Jannat** Senior Scientific Officer, Training and Communication Wing, BARI, Gazipur
Publication Secretary	**Dr. Md. Nurealam Siddiqui** Assoc. Prof., Dept. of Biochemistry and Molecular Biology, BSMRAU, Gazipur
Assistant Publication Secretary	**Arifa Sultana Shipa** Assistant Registrar, Department of Co-operatives, Dhaka
Seminar Secretary	**Prof. Dr. Md. Ahsan Habib** Department of ICT, MBSTU, Tangail
Social Welfare Secretary	**Mohammad Abdul Aziz Khan** Head, Crop Protection Development, Syngenta, Dhaka
Members	**Prof. Dr. M. Abdul Karim** Department of Agronomy, BSMRAU, Gazipur
	Prof. Dr. Md. Abul Hossain Molla Department of Environmental Science, BSMRAU, Gazipur
	Prof. Dr. Md. Sharaf Uddin Dept. of Agroforestry and Environmental Science, SAU, Sylhet
	Mr. Ruman Hafiz Executive Director, Setu Corporation Limited, Dhaka
	Dr. Md. Sultan Ahmed Principal Scientific Officer, Entomology Division, BARI, Gazipur
	Dr. Md. Ataur Rahman Chief Scientific Officer and Head, Entomology Division, BSRI, Pabna
	Prof. Dr. Lam Yea Asad Dept. of Animal Nutrition and Breeding, SAU, Dhaka
	Prof. Dr. Md. Adnan Al Bachchu Dept. of Entomology, HSTU, Dinajpur

Ecology Journal

Ecological Society of Bangladesh

Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur

Editorial Board 2022-2024

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X

Volume 5 | Number 2 | December 2023

Contents

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 91-97

FALL ARMYWORM INFESTATION ON THE PERFORMANCE OF SWEET CORN VARIETIES

Tasfia Tasnim Moon[1], Md. Ramiz Uddin Miah[1], Md. Tofazzal Islam[2], Mansura Afroz[1] and Md Ruhul Amin[1]*

[1]Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. [2]Institute of Biotechnology and Genetic Engineering, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

***Corresponding email:** mramin@bsmrau.edu.bd

Received: 13 October 2023, revised: 18 October 2023, accepted: 20 October 2023, DOI: https: //doi.org/10.59619/ej.5.2.1

ABSTRACT

The study was conducted from November 2021 to April 2022 in the field and laboratory of Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to compare the morphological, developmental, yield contributing characteristics and leaf infestation status by fall armyworm of four different maize varieties viz. BU Misti Vutta 1, BARI Hybrid Vutta 1, Mohona and Dola. Among the varieties, Dola was the tallest plant having height of 156.9±6.1 cm with the highest internode length (16.0±0.2 cm), and the highest number of internodes (12.8±0.2), number of leaves per plant (11.9±0.3), leaf length (82.0±2.7 cm), and leaf width (10.5±0.2 cm). The maximum base diameter (1.9±0.1 cm) was observed in BU Misti Vutta 1. The lowest duration for seedling emergence was observed in BARI Hybrid Vutta 1 (17.6±0.3 DAS) while the lowest durations for tassel initiation (75.2±0.4 DAS), silk emergence (87.1±0.4 DAS) and earliest harvesting maturity (111.9±0.3 DAS) was observed in BU Misti Vutta 1. There was no leaf infestation (0.0±0.0%) in BU Misti Vutta 1 at 100 DAS. The highest cob length (16.4±0.5 cm), cob diameter (4.0±0.1 cm), cob weight (196.6±22.1 g), number of kernel/ cob (537.2±32.1) and yield (12.6±0.1 t/ha) were also recorded in BU Misti Vutta 1.

Keyword: BU Misti Vutta 1, morphological characters, fall armyworm, infestation, yield

Introduction

Maize (*Zea mays*) is a cereal crop belonging to the family Poaceae and the order Cyperales. It is a good source of carbohydrate, protein, starch, vitamins and minerals which is consumed as popcorn or can be eaten with soup or noodles and also in raw form or by boiling. The kernel can be consumed raw, in salads, or as a vegetable. Additionally, the corn husk and young green leaves are also popular as fodder in our country. The main types of maize are sweet corn, flint corn, popcorn, dent corn and pod corn. The sugar-rich varieties are called sweet corn. Maize is one of the most adaptable field crops to a wide range of agro-climatic conditions. It is grown in both Rabi and Kharif seasons in Bangladesh. The cultivation area and total production of Rabi and Kharif maize, in the fiscal year 2020-2021, was 979210.77 acre, 3563.7 thousand MT and 206440.73 acre, 552.7 thousand MT respectively (BBS 2021).

Sweet corn (*Zea mays* convar. *saccharata* var. *rugosa*) is a subspecies of the variety *Zea mays*. It is also called sugar corn or pole corn. It arises from a naturally occurring recessive mutation in the genes that regulate the conversion of sugar to starch within the corn kernel's endosperm (Erwin 1951). Field corn is harvested when the kernels are dry and mature (the dent stage) but the sweet corn is chosen when it is still immature (the milk stage). Hundred grams of raw yellow sweet corn contain 3.43 grams of glucose, 1.94 grams of fructose, and 0.89 grams of sucrose, according to the USDA (Wikipedia). Besides moderate levels of protein, vitamin and potassium, sweet corn contains 5-6% sugar, 10-11% starch, 3% water soluble polysaccharides and 70% water (Oktem and Oktem 2005). Sugar corn kernels are moderately high in calories in comparison to other vegetables. Sweet corn plays an important role in the human diet because of its health- promoting nutritional characteristics (Swapna *et al*. 2020).

BU Misti Vutta 1 is a sweet corn variety which was registered on 15 May, 2023 by National Seed Board and released by BSMRAU. BU Misti Vutta 1 was first introduced from South Korea. Only 14 inbreed seed was introduced in the country followed by in the field of the

department of Entomology, BSMRAU where it was grown and a fruitful outcome were noted. BU Misti Vutta 1 can be cultivated round the year but higher yield is obtained in Rabi season compared to Kharif season due to higher insect infestation especially of fall armyworm in Kharif season. Sandy-loam and silty-clay loam soil is suitable for cultivating this variety (Amin *et al*. 2023).

Although the soil and climatic conditions are suitable for maize cultivation in Bangladesh, the yield potentiality is low due to several abiotic and biotic constraints. The biotic factors include the attack of different insect pests, which cause serious damage to maize crops every year resulting huge yield loss (Sarker and Dutta 2022). The invasive insect fall armyworm (FAW) was recognized as being harmful to maize crops (Prodhan *et al*. 2020). Among several insect pests of maize, the cutworm (*Agrotis ipsilon*), fall armyworm (*Spodoptera frugiperda*), shoot fly (*Atherigona* sp.), stem borer (*Sesamia inferens* and *Chilo partellus*), aphid (*Rhopalosiphum maidis*), and the pod borer or earworm (*Helicoverpa armigera*) are important (Banglapedia 2023). Fall armyworm is a new invasive pest in our country that severely damages the maize plants and thus reduces yield severely. Without adequate management measures, the fall armyworm (FAW), which has already spread to 44 countries in Africa, has the potential to reduce annual maize production by 8 to 20 million tons in 12 African maize growing countries (Kumbhar *et al.* 2022). In Bangladesh, nearly 30-35% maize field is infected by fall armyworm which caused 5% cob infestation in the year 2019 (CIMMYT 2020).

Fall armyworm larvae damage the crop at different stages of growth, from early vegetative to physiological maturity. It cuts down young plants and also causes damage to the leaves, giving them a ragged, torn appearance. The caterpillar, which feeds inside whorls, is capable of destroying developing tassels and silks. It can also eat growing kernels, which can lower yields by causing direct losses, exposing cobs to secondary infections, and reducing the quantity and quality of grain (Sarker and Dutta 2022).

The infestation of the insect pests depends on the morphological and developmental characteristics of any plant. The insect attack also depends on temperature, humidity and other environmental condition and it needs optimum environment to thrive. So the infestation status of FAW is different in different varieties. The yield also varies greatly among different varieties. Varietal studies are necessary to compare is the insect attack. Therefore, the present study was undertaken to study the morphological, developmental, yield contributing characteristics and FAW infestation status in four different sweet corn varieties.

Materials and Methods

The study was conducted from November 2021 to April 2022 in the field and laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The study conducting site is located at 25°25′ North latitude and 89°5′ East longitude, which is almost in the middle of Bangladesh. The research area's yearly mean maximum and minimum temperatures, relative humidity, and rainfall amounts are 36.0°C and 12.7°C, 65.8% and 237.6 cm, respectively (Amin *et al*. 2015).

Experimental design and cultivation of sweet corn varieties: Four sweet corn varieties namely BARI Hybrid Vutta 1, Mohona, Dola, and BU Misti Vutta 1 were cultivated in the experimental plots from November 2021 to April 2022. Seeds of the BARI Hybrid Vutta 1 and BU Misti Vutta 1 were collected from Bangladesh Agricultural Research Institute, Gazipur, and BSMRAU, Gazipur Respectively. Seeds of Mohona and Dola varieties were purchased from Siddique Bazar, Dhaka. The experiment was conducted following randomized complete block design with four replications. The studied varieties were cultivated in 8 rows in 4 m × 4 m plot size in Rabi season. Seeds were sown on 22 November, 2021. Each of the varieties was planted in 4 plots of same size. Both of plot to plot and block to block distance was 1 m. The plant to plant and row to row distance was 25 cm and 60 cm respectively. Fertilizers were applied according to Fertilizer Recommendation Guide (FRG 2018). Intercultural operations such as irrigation, weeding, thinning etc. were done whenever necessary in the experimental field.

Observation of plant characteristics: The various morphological, yield contributing and developmental characteristics of the four maize varieties were studied

every week. The vegetative stages (V1-V12) were considered from the development of branch to emergence of tassel. The reproductive stages (R1-R3) were considered on the development of reproductive structures such as tassel initiation, cob formation and grain maturation. The emergence of the plants, tassel, cob, silk and grain maturation period of the 4 varieties was observed. The plant height, base diameter of plants, length of internode, number of nodes per plants, number of leaves per plant, leaf length and width, cob length, weight and width, grain number and thousand grain weight were also observed of these 4 varieties. Four randomly selected plants of each treatment were observed for measuring the characteristics.

Observation of leaf infestation (%) by fall armyworm larvae: The total number of healthy and infested leaves of a single plant from 4 randomly selected plants was counted for each of the four varieties at 50, 80 and 100 days after sowing (DAS). For assessment of insect infestation, data collections were started from the first sign of infestation, and were continued until final harvest. Number of infested leaves was counted and converted into percent leaf infestation using following formula-

$$\text{Leaf infestation (\%)} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves}} \times 100$$

Yield Assessment: The dried grains of each plot of four different treatments and control plot was separately weighed using a weighing machine and the yield of each variety was converted into t/ha by using the following formula:

$$\text{Yield (t/ha)} = \frac{\text{Weight of grains in kg/plot}\times 10000}{\text{Plot area in m2}\times 1000}$$

Statistical analysis: The statistical software package IBM SPSS 20.0 was used for data analysis. One way analysis of variance (ANOVA) followed by Tukey HSD posthoc test (at 5% level of significance) was done to determine the variation of morphological, yield contributing characters, yield and leaf infestation rate of the four different maize varieties.

Results and Discussion

Morphological characteristics of the maize varieties: Different varieties of maize varied in their morphological characteristics (Table 1). The study revealed that there was significant variation in the morphological characteristics such as plant height ($F_{3,12}$ = 18.0, <0.001), base diameter ($F_{3,12}$ = 3.8, <0.001), length of internode ($F_{3,12}$ = 84.0, <0.001), number of nodes per plant ($F_{3,12}$ = 34.7, <0.001), number of leaves per plant ($F_{3,12}$ =144.6, < 0.001), leaf length ($F_{3,12}$ = 33.9, <0.001), and leaf width ($F_{3,12}$ = 37.1, <0.001).

Dola was the tallest plant having height of 156.9±6.1 cm followed by BARI Hybrid Vutta 1 (134.4±4.8 cm) which was statistically similar with BU Misti Vutta 1 (121.4±3.8 cm). Mohona had the shortest plants having a height of 112.5±2.8 cm. Maximum stem diameter was observed in BU Misti Vutta 1 (1.9± 0.1 cm) followed by Mohona (1.8 ±0.1 cm) and Dola (1.7±0.0 cm). The lowest stem diameter was observed in BARI Hybrid Vutta 1 (1.6±0.0 cm).

Table 1. Morphological characteristics of the maize varieties

Varities	Morphological Characteristics						
	Plant height (cm)	Base diameter (cm)	Length of internode (cm)	Number of nodes/plant	Leaves/ plant	Leaf length (cm)	Leaf width (cm)
BU Misti Vutta 1	121.4±3.8bc	1.9± 0.1a	10.2±0.3c	10.4±0.2bc	9.4±0.2b	58.8±1.6c	7.9±0.1b
BARI Hybrid Vutta 1	134.4±4.8b	1.6±0.0b	12.9±0.1b	9.6±0.2c	7.3±0.1c	69.1±2.2b	10.5±0.4a
Mohona	112.5±2.8c	1.8±0.1b	13.5±0.4b	10.7±0.3b	5.7±0.3d	85.1±1.7a	6.8±0.4b
Dola	156.9±6.1a	1.7±0.0ab	16.0±0.2a	12.8±0.2a	11.9±0.3a	82.0±2.7a	10.5±0.2a

Data expressed as mean± S. E. Means within a column followed by no common letter(s) are significantly different by Tukey posthoc statistic at $P \leq 0.001$

Maximum length of internode was observed in Dola (16.0±0.2 cm) followed by Mohona (13.5±0.4 cm) which was statistically similar with BARI Hybrid Vutta 1 (12.9±0.1 cm). The least length of internode was observed in BU MistiVutta 1 (10.2±0.3 cm). Maximum number of nodes was observed in Dola (12.8±0.2) followed by Mohona (10.7±0.3) which is statistically similar with BU Misti Vutta 1 (10.4±0.2). The lowest number of nodes was observed in BARI Hybrid Vutta 1 (9.6±0.2). Maximum number of leaves per plant was observed in Dola (11.9±0.3) followed by BU Misti Vutta 1 (9.4±0.2) and BARI Hybrid Vutta 1 (7.3±0.1). The lowest number of leaves per plant was observed in Mohona (5.7±0.3). The highest leaf length was observed in Mohana (85.1±1.7cm) which was statistically similar with Dola (82.0±2.7cm). The lowest leaf length was observed in BU Misti Vutta 1 (58.8±1.6 cm). Maximum leaf width was observed in Dola (10.5±0.2 cm) which was statistically similar with BARI Hybrid Vutta 1 (10.5±0.4 cm). The lowest leaf width was observed in Mohona (6.8±0.4 cm) which was statistically similar with BU Misti Vutta 1 (7.9±0.1 cm). The morphological characteristics of the four maize varieties varied greatly may be due to their differences in various biochemical properties.

Developmental characteristics of the maize varieties: Different varieties of maize varied in their developmental stages (Table 2). The study revealed that there was significant variation in the developmental stages such as seedling emergence ($F_{3,12}$ = 23.46, P < 0.001), tassel initiation ($F_{3,12}$ = 38.80, P < 0.001), silk emergence ($F_{3,12}$ = 59.77, P<0.001), harvesting maturity ($F_{3,12}$ = 185.27, P<0.001). The fastest seedling emergence was observed in BARI Hybrid Vutta 1 (17.6±0.3 DAS) followed by BU Misti Vutta 1 (18.4±0.4 DAS), Dola (18.4±.4 DAS) and the slowest in Mohona (21.0±0.2 DAS). The lowest duration for tassel initiation was observed in BU Misti Vutta 1 (75.2±0.4 DAS) which is statistically similar to Dola (75.6±0.2 DAS). Mohana variety revealed the highest duration for tassel initiation (80.4±0.5 DAS). The lowest duration for silk emergence was observed in BU Misti Vutta 1 (87.1±0.4 DAS) followed by BARI Hybrid Vutta 1 (190.6±0.5 DAS). The highest duration for silk emergence was observed in Dola (93.3±0.1 DAS) which was statistically similar with Mohona (92.7±0.3 DAS). BU Misti Vutta 1 (111.9±.3 DAS) had the lowest duration for harvesting maturity followed by BARI Hybrid Vutta 1 (117.5±.4 DAS) and Mohona (119.5±.2 DAS). The highest duration for harvesting maturity was observed in Dola (123.5±0.5 DAS).

Leaf infestation (%) of different maize varieties: The leaf infestation (%) of different varieties of maize in different times of the growing period showed significant differences such as at 50 DAS ($F_{3,36}$ = 3.4, p<0.001), at 80 DAS ($F_{3,36}$ = 57.8, p<0.001) and at 100 DAS ($F_{3,36}$ = 4.0, p<0.001). Infestation rate at 50 DAS ranged from 9.2±4.0 to 38.2±12.0%. The highest infestation rate (38.2±12.0%) was observed in plots having Dola variety which was statistically similar with BARI Hybrid Vutta 1 (35.6±4.7%) and Mohana (30.0±4.3%). The lowest leaf infestation rate (9.2±4.0%) was observed in plots having BU Misti Vutta 1 (Table 3). Infestation rate at 80 DAS ranged from 0.0±0.0 to 43.9±3.4%. The highest infestation rate (43.9±3.4%) was observed in plots having Mohana variety which was statistically similar with BARI Hybrid Vutta 1 (36.4±3.2%). Infestation rate of Dola was 23.4±2.0%. No leaf infestation (0.0±0.0%) was observed in plots having BU Misti Vutta 1 at 80 DAS (Table 3).

Infestation rate at 100 DAS ranged from 0.0±0.0 to 16.6±4.8%. The highest infestation rate (16.6±4.8%) was

Table 2. Developmental stages of the maize varieties

Varieties	Developmental changes (DAS)			
	Seedling emergence	Tassel initiation	Silk emergence	Harvesting maturity of kernel
BU Misti Vutta 1	18.4±.4 b	75.2±.4 c	87.1±.4 c	111.9±.3 d
BARI Hybrid Vutta 1	17.6±.3 b	77.6±.4 b	90.6±.5 b	117.5±.4 c
Mohona	21.0±.2 a	80.4±.5 a	92.7±.3 a	119.5±.2 b
Dola	18.4±.4 b	75.6±.2 c	93.3±.1 a	123.5±.5 a

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey posthoc statistic at P ≤ 0.001 (DAS = Days after sowing)

Table 3. Leaf infestation (%) of different maize varieties by fall armyworm in Rabi season at different days after sowing.

Varieties	Days after sowing (DAS)		
	50	80	100
BU Misti Vutta 1	9.2±4.0 b	0.0±0.0 c	0.0±0.0b
BARI Hybrid Vutta 1	35.6±4.7 ab	36.4±3.2a	16.6±4.8a
Mohana	30.0±4.3 ab	43.9±3.4a	12.3±4.7ab
Dola	38.2±12.0 a	23.4±2.0b	9.7±1.6ab

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey posthoc statistic at $P \leq 0.001$ (DAS = Days after sowing)

observed in plots having BARI Hybrid Vutta 1. There was no leaf infestation rate (0.0±0.0%) was observed in plots having BU Misti Vutta 1. The leaf infestation was the higher in the mid vegetative stages and was the lower in the later stages. In BU Misti Vutta 1, the infestation was the least among all. It may be in the later stages the plants get strong enough to resist the pest attack. The plant epidermis got hard and thick so insect cannot attack the plants. The infestation was different may be due to the variations among the morphological characteristics i.e. variation of leaf size, width, leaf hair and various phytochemical and biochemical properties of the four different varieties. BU Misti Vutta 1 having the lowest leaf width and length and fast developmental characteristics may be the reason for least infestation by FAW.

Yield contributing characters of the maize varieties: There were significant variations in the yield contributing characteristics such as cob length ($F_{3,12} = 11.6$, <0.001), cob diameter ($F_{3,12} = 340.3$, <0.001), cob weight ($F_{3,12} = 35.3$, <0.001), number of grains per cob ($F_{3,12} = 113.6$, <0.001) and number of cobs per plant ($F_{3,12} = 14.3$, <0.001) (Table 4). The highest cob length was observed in Mohona (18.9±0.6 cm). The lowest cob length was observed in BARI Hybrid Vutta 1 (16.3±0.2 cm) which was statistically similar with BU Misti Vutta 1 (16.4±0.5 cm) and Dola (16.8±0.6 cm). Maximum cob diameter was observed in BU Misti Vutta 1 (4.0±0.1 cm) followed by BARI Hybrid Vutta 1 (3.5±0.0cm) and Mohona (3.0±0.0 cm). The lowest cob diameter was observed in Dola (1.8±0.1 cm).

Maximum cob weight was observed in BU Misti Vutta 1 (196.6±22.1 g). The lowest cob weight was observed in Dola (49.3±1.9 g) which was statistically similar with BARI Hybrid Vutta 1 (73.3±1.4 g), and Mohona (75.1±2.7 g).

Maximum number of grains was observed in BU Misti Vutta 1 (537.2±32.1) followed by Mohona (278.5±8.3) which was statistically similar with BARI Hybrid Vutta 1 (289.1±15.3). The lowest number of grains was observed in Dola (58.5±4.1). Maximum number of cobs per plant was observed in Mohona (2.7±0.3), Dola (2.7±0.2) and BARI Hybrid Vutta 1 (2.3±0.2) which were statistically similar. The lowest number of cobs was observed in BU Misti Vutta 1 (1.50±0.0). The study revealed that BU Misti Vutta 1 showed the best performance in yield contributing characteristics among the four varieties. Due to the lowest leaf infestation level and the lowest leaf width, length, plant height, the BU Misti Vutta 1 had the highest yield contributing characteristics among others.

Table 4. Yield contributing characters of the maize varieties

Varieties	Yield contributing characteristics				
	Cob length (cm)	Cob diameter (cm)	Cob weight (g)	Number of grains/cob	Cobs/ plant
BU Misti Vutta 1	16.4±0.5 b	4.0±0.1 a	196.6±22.1 a	537.2±32.1 a	1.5±0.0 b
BARI Hybrid Vutta 1	16.3±0.2 b	3.5±0.0 b	73.3±1.4 b	289.1±15.3 b	2.3±0.2 a
Mohona	18.9±0.6 a	3.0±0.0 c	75.1±2.7 b	278.5±8.3 b	2.7±0.3 a
Dola	16.8±0.6 b	1.8±0.1 d	49.3±1.9 b	58.5±4.1 c	2.7±0.2 a

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey posthoc statistic at $P \leq 0.001$

Seasonal leaf infestation of maize varieties: There was significant variation in the leaf infestation of the four maize varieties during Rabi season such as BU Misti Vutta 1 ($F_{6,21}$ = 531.2, <0.001), BARI Hybrid Vutta 1 ($F_{6,21}$ = 1095.2, <0.001), Mohona ($F_{6,21}$ = 511.3, <0.001), Dola ($F_{6,21}$ = 207.7, <0.001) (Figure 1). In BU Misti Vutta 1 the leaf infestation rate showed a slight increasing trend from 10 to 20 January and reached the peak (10.5±0.2%) on 20 January. Leaf infestation was found declined gradually from end of January. There was no infestation (0.0±0.0%) was found in beginning of January and end of February, during early vegetative stages and reproductive stages respectively.

In BARI Hybrid Vutta 1, the leaf infestation rate showed a slight increasing trend from midJanuary and reached at the peak (35.4±0.4%) on 10 January during growth stages and remained almost similar until 30 January. Leaf infestation rate started to decline from end of January. Lowest abundance (4.0±0.4%) was found in beginning of January followed by at the end of February during early vegetative stages and reproductive stages respectively. For Mohona, the leaf infestation rate showed a rapid increasing trend from January to 10 February and reached the peak (43.5±0.3%) on 10 February. Leaf infestation declined gradually from mid-February to the end of February. The lowest infestation (6.0±0.4%) was found in beginning of January followed by end of February during early vegetative stages and reproductive stages, respectively.

In Dola, the leaf infestation rate showed a rapid increasing trend from 10 January to 20 January and reached the peak (40.4±0.2%) on 20 January. Leaf infestation rate started to decline gradually from end of January. The lowest Infestation (6.4±0.5%) was found in beginning of January followed by end of February during early vegetative stages and reproductive stages, respectively. In all the varieties the lowest leaf infestation was observed at the beginning of January and end of February. When the temperature was too low, the infestation rate was also reduced. Fall armyworm thrives well in warm temperature.

Yield of the maize varieties: Different varieties of maize varied in their yield (Figure 2). The study revealed that there was significant variation in the yield ($F_{3,12}$ = 171.6, <0.001). The highest (12.6±0.1 t/ha) yield was observed in BU Misti Vutta 1 (10.9±0.1 t/ha) followed by BARI Hybrid Vutta 1 (9.9±0.1 t/ha), Mohona and the lowest in Dola (8.4 ±.0.1 t/ha). The study showed that BU Misti Vutta

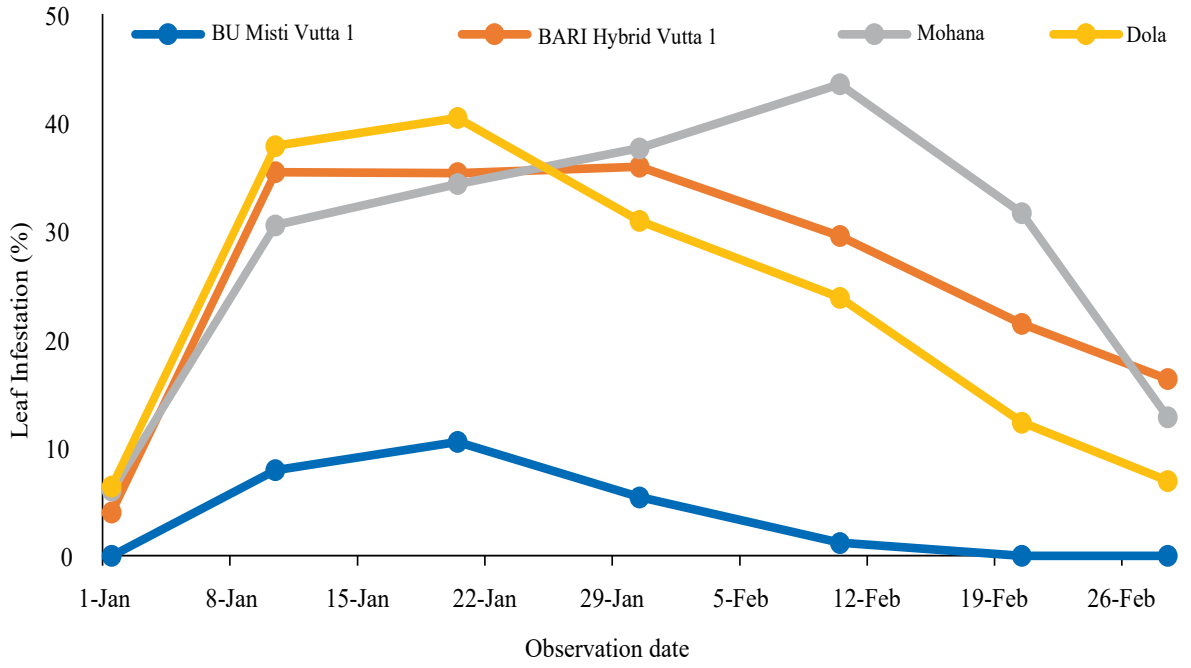


Figure 1. Seasonal leaf infestation (%) of fall armyworm in different varieties of maize during Rabi season.

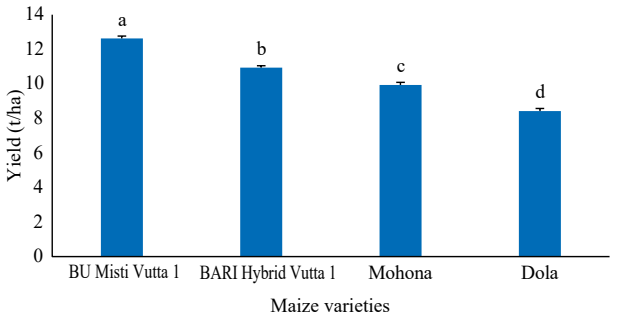


Figure 2. Yield of different maize varieties during Rabi season.

1 had the highest yield due to the lowest leaf infestation by fall armyworm. This variety was less susceptible to fall armyworm infestation compared to others. Islam and Hoshain (2022) reported that the yield of BARI Hybrid Vutta 1 in Rabi season was 7.5-8.5, in Kharif season it was 6.5-7.0 t/ha. In our study the yield of BARI Hybrid Vutta 1 was 12.75 t/ha in Rabi and 12.07 t/ha in kharif season. In the present study, the yield of BU Misti Vutta 1 was 12.6 t/ha which was at per BARI Hybrid Vutta 1.

In conclusion, among the four maize varieties BU Misti Vutta 1 showed the best performance. It had the highest yield with minimum leaf infestation rate by fall armyworm. From the present findings BU Misti Vutta 1 suggested to cultivate is for maximum production in Bangladesh during Rabi season.

References

Amin MR, Miah MRU, Afroz M and Moon TT. 2023. BU Misti Vutta 1. Leaflet (In Bengali). Department of Entomology, BSMRAU, Gazipur, Bangladesh.

Amin MR, Namni S, Miah MRU, Miah MG, Zakaria M, Suh SJ and Kwon YJ. 2015. Insect inventories in a mango-based agroforestry area in Bangladesh: foraging behavior and performance of pollinators on fruit set. Entomological Research, *45*: 217-224.

Banglapedia, National Encyclopedia of Bangladesh. Maize. Retrieved from https://en.banglapedia.org/index.php/Maize. Retrieved on 21 March, 2023.

BBS (Bangladesh Bureau of Statistics). 2021. Ministry of planning, Government of the Peoples' Republic of Bangladesh. www.bbs.gov.bd. 90-95.

CIMMYT. 2020. New project strengthens capacity to fight fall armyworm in Bangladesh. https://www.cimmyt.org/news/new-project-strengthens-capacity-to-fight-fallarmyworm-in-bangladesh/.

Erwin AT. 1951. Sweet corn-mutant or historic species? Economic Botany. *5*: 302. doi:10.1007/bf02985153. S2CID 28127396.

FRG (Fertilizer Recommendation Guide). 2018. Bangladesh Agricultural Research Council, Farmgate, Dhaka, p. 1215.

Islam MR and Hoshain S. 2022. A brief review on the present status, problems and prospects of maize production in Bangladesh. Research in Agriculture, Livestock and Fisheries, *9*: 89-96.

Kumbhar SC, Kulkarni SR and Shinde SS. 2022. Seasonal abundance of fall armyworm, *Spodoptera frugiperda* on maize in relation to abiotic factors. The Pharma Innovation Journal, *11*: 3881-3884.

Oktem A and Oktem A. 2005. Effect of nitrogen and intra spaces on sweet corn (*Zea mays Sachharata* Sturt) ear characteristics. Indian Journal of Plant Sciences, *4*: 361-363.

Prodhan MZH, Sarker D, Dutta NK Sarkar MA and Begum K. 2020. Insect pests of maize crop and their integrated management (in Bangla). Entomology Division, Bangladesh Agricultural Research Institute, Gazipur. p. 13.

Sarker D and Dutta NK. 2022. Fall Armyworm- Status, Challenges and Experiences in Bangladesh. In: Attaluri S, Gyeltshen K, Sultana N and Hossain BM (Eds.). Fall armyworm (FAW) *Spodoptera frugiperda* (Smith JE) - the status, challenges and experiences among the SAARC member states. SAARC Agriculture Centre, SAARC, Dhaka, Bangladesh, Pp. 11-22.

Swapna G, Jadesha G and Mahadevu P. 2020. Sweet corn-a future healthy human nutrition food. International Journal of Current Microbiology and Applied Science, *9*: 3859-3865. doi: https://doi.org/10.20546/ijcmas.2020. 907.452.

Wikipedia, The free Encyclopedia. Maize. Retrived from https://en.wikipedia.org/wiki/Maize. Retrieved on 12 March, 2023.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 99-104

ESTIMATION OF WOODY CARBON DENSITY BY ALLOMETRIC METHOD IN THE SELECTED SAL FORESTS OF BANGLADESH

Md. Habibur Rahman[1], Mohammad Ataur Rahman[1], Md. Abul Kashem[1], Md. Rabiul Islam[2] and Mohammad Zabed Hossain[1]*

[1]Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh. [2]Silviculture Research Division, Bangladesh Forest Research Institute, Chattogram 4000, Bangladesh

***Corresponding e-mail:** zabed@du.ac.bd

Received: 22 October 2023, revised: 05 November 2023, accepted: 12 November 2023, DOI: https: //doi.org/10.59619/ej.5.2.2

ABSTRACT

Estimation of Carbon (C) density in different Sal forests of Bangladesh has not yet been done for exploring their potentials in storing C. The present study compared the woody C density among three selected Sal forests located in Madhupur, Lalmai and Singra of Bangladesh in order to examine the effects of management intensities on C stocks. A total of 19 plots (each with 10 m × 10 m in size), 9 from Madhupur forest and each 5 from other two forests were placed to collect data on vegetation structure, plant diameter and woody C density. Allometric method was used to estimate C density for both aboveground and belowground parts of juvenile and adult tree plants of the selected plots. Woody biomass was converted into C content by multiplying the value with van Bemmelen factor (1.724). Results showed that woody C density was significantly (p = 0.0156) higher in Lalmai (552.46±64.09 ton/ha) and Singra forests (547.13±62.43 ton/ha) than the Madhupur Sal forest (354.03±38.43 ton/ha). Mean diameter of Sal tree plant at breast height was significantly (p = 0.022) higher in Lalmai (38.84±2.12cm) and Singra (37.36±1.97 cm) forests than Madhupur forest (30.72±1.93 cm). Results clearly demonstrated that forest trees with high average diameter had the high woody biomass content. This study thus suggested that long term forest conservation could be an effective approach to increase C stock in the forest ecosystems.

Keywords: Allometric method, biomass carbon, protected area, Sal forest

Introduction

Global warming has created enormous concerns for its multifaceted problems including climate change. Elevated concentrations of carbon dioxide (CO_2) in the atmosphere is playing the major role in global warming (Nunes 2023). Exploring the options for the mitigation of this environmental problem is, therefore, important to stop further deterioration of the current alarming situation. Among the various approaches, role of forest conservation in reducing CO_2 in the atmosphere is well recognized. As per UNFCCC (United Nations Framework Convention on Climate Change) and Kyoto Protocol, forest ecosystems can contribute to mitigating greenhouse gas emissions (Somogyi *et al*. 2008). Because, extant plant is one of the important pools that act as a sink for C storage. Therefore, reliable estimates of C density in woody plants is the fundamental to determine C stocks in forest ecosystems.

C storage by trees can be calculated from the biomass of the same species. Therefore, biomass estimation is a prerequisite to the calculation of C content stored by various tree species. As per the Kyoto Protocol, C should be assessed from different pools like aboveground and belowground biomass, dead wood, litter and soil (Santilli *et al.* 2005).

Several methods including destructive and non-destructive approaches and mean tree method are available for the estimation of biomass. Although destructive methods provide more accurate data, it has some limitations such as sacrifice of live plants and vast time. On the other hand, non-destructive method requires less time and labor. Allometric model is a non-destructive mathematical tool to estimate tree forest biomass (Picard *et al*. 2015). This model is the mathematical functions of tree variables including diameter at breast height, total height and wood density.

Estimating C content from the extant live plants in non-destructive approach is important from the aspects of conservation. Use of allometric regression models to convert forest inventory data to estimate aboveground biomass is commonly used method to quantify C stocks in the forest (Van Breugel *et al*. 2011). The use of allometric models implies decisions on the selection of extant models or the development of a local model, the predictor variables included in the selected model, and the number of trees and species for destructive biomass measurements.

Forests are predominant global C sinks as they restore 70-90% of biomass C (Houghton *et al*. 2009, Brienen *et al*. 2015). REDD (Reducing Emissions from Deforestation and Forest Degradation) under IPCC programs have also stressed on the importance of forest conservation and afforestation to scale back the atmospheric C levels (Skutsch *et al*. 2007; Angelsen 2008; Keith *et al*. 2009; IPCC 2003). In Bangladesh, Sal forests (dominated by *Shorea robusta* Gaertn.) cover an area of about 121,000 ha (Banglapedia 2021). These forests, distributed over different geographical locations, vary in management intensities such as protected, reserve and buffer forest zones.

Although some studies compared C density and stocks among several different forests of Bangladesh (Mukul *et al.* 2014; Mahmood *et al*. 2019), few attempts were taken so far to estimate biomass C in the Sal forests with different management intensities, though such information is very important for better management and conservation of forest for C storage. The specific objectives of the present study were to compare woody biomass C density among Singra Sal forest, Madhupur Sal forest and the Lalmai Sal forest with different management intensities in Bangladesh.

Materials and methods

Study site description: Three Sal forests namely Madhupur Sal forest, Lalmai Sal forest and the Singra Sal forest were selected in this study. Madhupur forest is situated in the Madhupur Sub-district under the district of Tangail. It is located at 24°41′22.0992″N to 24°41′22.1784″N latitude and 90°8′10.896″E to 90°8′10.4856″E longitude. The Lalmai forest, situated in the district of Cumilla, lies between the latitudes 23°25′18.8472″N to 23°25′20.9424″N and longitudes 91°8′12.0084″E to 91°8′12.444″E. Singra Sal forest, situated in the Birganj upazila of Dinajpur district, belongs to the tropical dry deciduous forest. Geographically, it is located from 25.8876682°N to 25.889277°N axis and 88.563593°E to 88.560535°E longitude. A part of this forest was declared as National Park in 2010. The area of Madhupur forest, Lalmai forest and Singra forest was 18,439.57 ha, 202.34 ha and 355 ha, respectively.

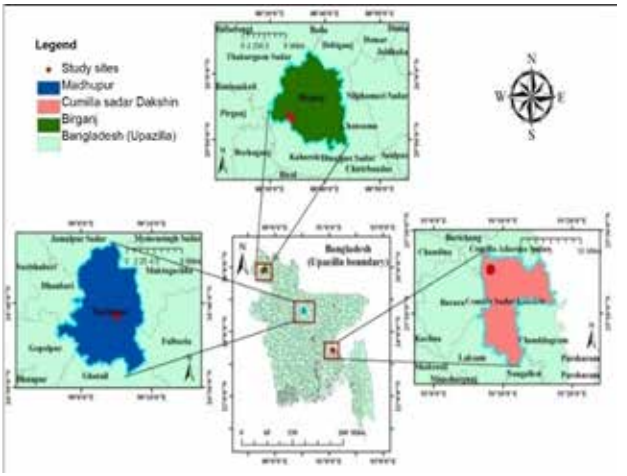


Figure 1. Map showing the study areas of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Vegetation analysis: Vegetation data were collected by following quadrat methods. A total of 19 quadrats (10 m × 10 m) were placed randomly at the three selected forests of which 9 were placed in the Madhupur forest while each 5 were in other two forests. Quadrats placed in the Singra forest were in the protected Area. Plant species were identified within the quadrat and recorded. The height of the tree species was determined by applying the general rules of trigonometry as follows:

Tree Height, h = Tan A x d, where h is the tree height, d is the distance from tree, and A is the angle to the top of the tree.

To measure the DBH (Diameter of Breast Height) of the tree species, GBH (Girth of a tree at Breast Height) was taken with a tape at a height of 1.37 m of a tree (Hossain 2022). DBH was determined from the GBH measurement using the formula $D = G / \pi$.

Determination of tree biomass and C density: Tree biomass and C density (ton/ha) of woody vegetation were assessed using the non-destructive allometric method. The aboveground biomass (AGB) of adult (≥30 cm GBH) tree species was estimated following the allometric equation of (Chave *et al.* 2005).

$AGB = \exp(-2.187+0.916 \times \ln(\rho \times D^2 \times H))$

Aboveground biomass of juvenile tree population (>10cm-<30 cm GBH) was estimated using allometric equation by following (Chaturvedi *et al*. 2012).

$AGB = 3.344+0.443 \times \ln(D^2)$

The wood specific gravity of each tree species was taken from the available published literature (Gisel *et al.* 1992; Cordero and Kanninen 2002; Mani and Parthasarathy 2007; Wiemann and Green 2007; Sundarapandian *et al*. 2014).

Belowground biomass (BGB) of trees was calculated following (Cairns *et al*. 1997).

$BGB = \exp(-1.0587 + 0.8836 \times \ln(AGB))$

The belowground biomass of juvenile tree population was calculated by multiplying the aboveground biomass value with 0.26 (Cairns *et al*. 1997, IPCC 2003).

Total carbon stock (TCS) was calculated by multiplying the Total biomass (AGB+BGB) value with 0.4453 (Prado-Junior *et al*. 2016).

$TCS = (AGB + BGB) \times 0.445$

For adult plants, GBH was considered >30 cm. The juvenile stage was considered when the sprout continued to grow but had not yet reached the stage of complete maturity and GBH was considered >10 cm to <30 cm.

Results and Discussion

There was no significant difference in species richness and Shannon's diversity index among the three selected forests although the values were relatively lower in Lalmai forest than the other two forests (data not shown). Mean DBH value of Sal plant was significantly (p = 0.022) higher in Lalmai (38.84±2.12cm) and Singra **(**37.36±1.97 cm) forests than that of the Madhupur **(**30.72±1.93 cm) forest (Figure 2). These results indicated that the trees of the Singra and Lalmai forests were older than the Madhupur forest. Dey *et al*. (2017) also reported that plant age and DBH were significantly positively correlated in a sugar-maple dominated forests of Menominee Indian Reservation in northeastern Wisconsin, the USA.

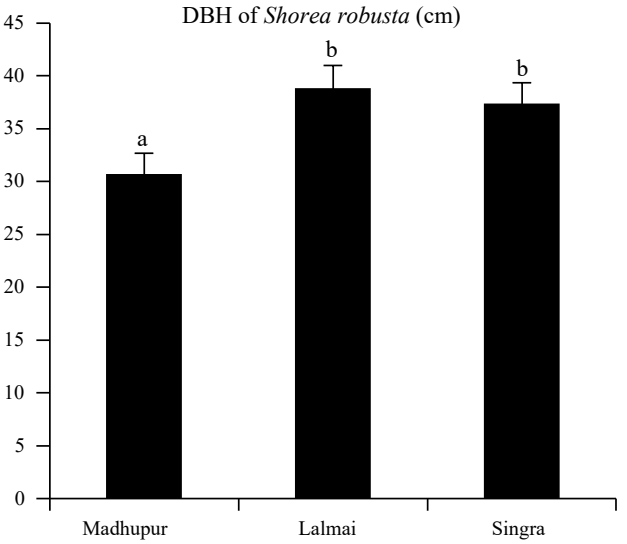


Figure 2. Diameter at Breast Height (DBH) of *Shorea rabusta* Gaertn. of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Significant differences appeared in aboveground (p = 0.0161), belowground (p = 0.0146) and total biomass (p = 0.0159) C density of the adult woody plants among the three selected forests (Figure 3). Aboveground, belowground and total biomass C density of the adult plants were significantly higher in Lalmai **(**547.8±63.6 ton/ha**)** and Singra **(**510.1±57.98 ton/ha**)** forests than Madhupur Sal forest. In case of juvenile tree, woody biomass C showed significant difference in aboveground (p = 0.0001), belowground (p = 0.0001) and total woody biomass (p = 0.0001) C density among the three selected forest (Figure 4). Data showed that the highest value was found in Singra forest **(**37.02±6.82 ton/ha**)** and the lowest in Lalmai forest **(**4.67±0.8 ton/ha**)** and the intermediate was in the Madhupur Sal forest **(**15.84±2.27 ton/ha**)** (Figure 4). When aboveground and belowground biomass C values were summed together then the woody C density was significantly (p = 0.0156) higher in Lalmai (552.46±64.09 ton/ha) and Singra forests (547.13±62.43 ton/ha) than that of the Madhupur Sal forest (354.03±38.43 ton/ha) (Figure 5).

Data of the present study clearly demonstrated that woody biomass C density was significantly higher in Singra and Lalmai Sal forests than the Madhupur Sal forest. Singra forest with an area of 305.7 ha was declared as Protected Area in 2010 by the government of Bangladesh. Wood logging and other disturbances were prohibited as per the Protected Area act. As a result forest tree plants could continue to grow till maturity. In Lalmai forest, Sal plants were found relatively taller and older. Mature and old plants could store more C than the relatively younger plants in the forest ecosystems. Other studies also reported similar results (Melillo *et al.* 2016; Tian *et al.* 2023). Estimation of woody C density is the fundamental and primary step in determining C stocks in forest ecosystems. The findings of the present study suggested that allometric method could be appropriate for determining woody C density. Results of the study are relevant for the estimation of C stocks of these forests by selecting more sampling sites.

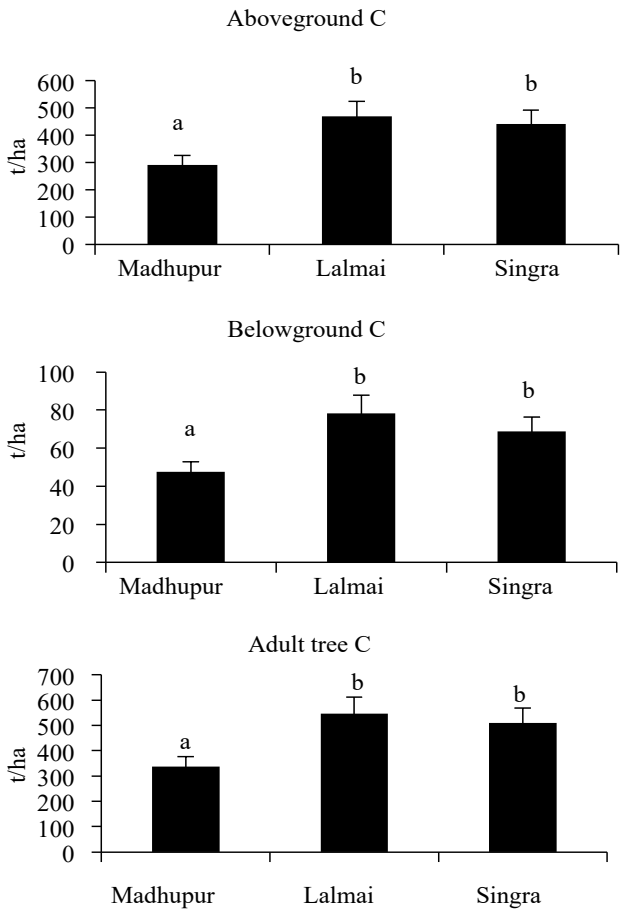


Figure 3: Carbon density (t/ha) of adult tree plants of the Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

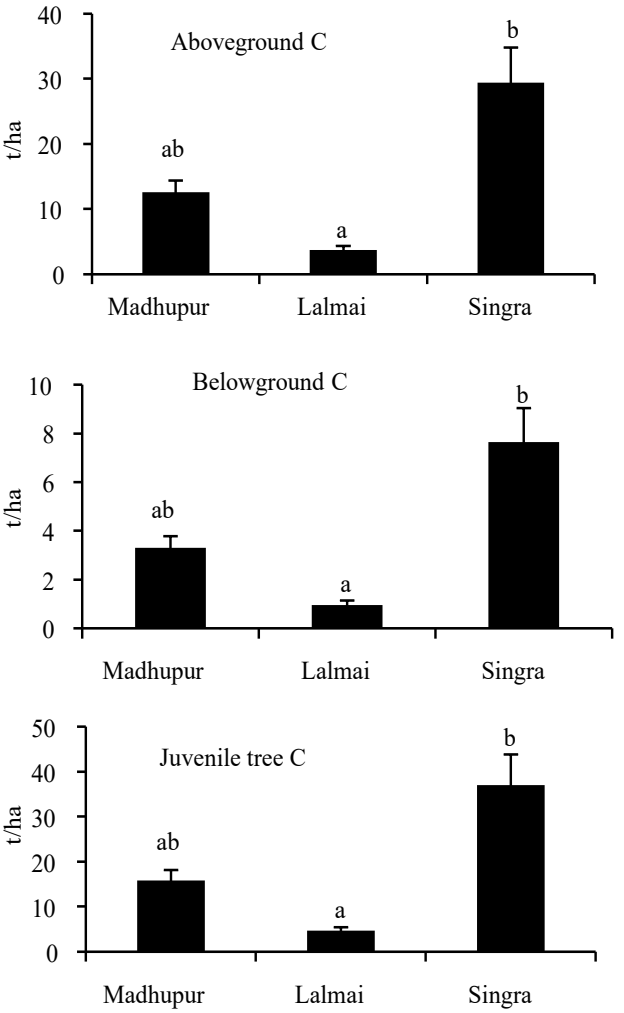


Figure 4: Carbon density (t/ha) of the aboveground, belowground and juvenile tree plants of the Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

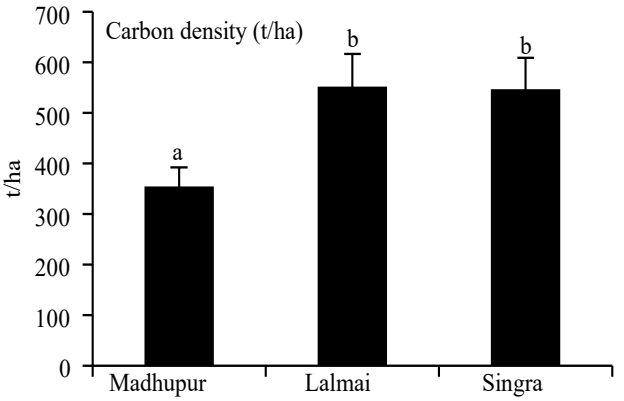


Figure 5: Carbon density (t/ha) of total woody plants of Madhupur Sal forest, Lalmai Sal forest and Singra Sal forest of Bangladesh.

Conclusion

The selected Sal forests differed significantly in woody C density where the values were higher in Singra and Lalmai forests than the Madhupur forest. Variation in plant growth as revealed by diameter of tree trunk at breast height might cause such difference in woody C density among the selected forests. Results of the study, therefore, suggested that long term forest conservation might have contributed to increase C stock in the forest ecosystem.

Acknowledgements

The authors gratefully acknowledge the financial support of the Bangladesh University Grants Commission through the University of Dhaka to conduct this piece of research during the fiscal year 2017-2018.

References

Angelsen A. 2008. REDD models and baselines. International Forestry Review, *10:* 465-475.

Banglapedia. 2021. National Encyclopedia of Bangladesh. Dhaka, Bangladesh: Banglapedia Trust, Asiatic Society of Bangladesh. ISBN 984-32-0576-6.

Brienen R, Phillips O, Feldpausch T. *et al.* 2015. Long-term decline of the Amazon carbon sink. Nature, *519:* 44-348.

Cairns MA, Brown S, Helmer EH and Baumgardner GA. 1997. Root biomass allocation in the world›s upland forests. Oecologia, *111*: 1-11

Chaturvedi RK, Raghubanshi AS and Singh JS 2012. Biomass estimation of dry tropical woody species at juvenile stage. The Scientific World Journal. Article ID 790219.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Riéra B and Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia *145*: 87-99.

Cordero LDP and Kanninen M. 2002. Wood specific gravity and aboveground biomass of *Bombacopsisquinata* plantations in Costa Rica. Forest Ecology and Management, *165*: 1-9

Dey DC, Dwyer J, Wiedenbeck J. 2017. Relationship between Tree Value, Diameter, and Age in High-Quality Sugar Maple (*Acer saccharum*) on the Menominee Reservation, Wisconsin. Journal of Forestry*, 115*: 397-405.

Gisel R, Sandra B, Jonathan C and Ariel LE. 1992. Wood densities of tropical species. US Department of Agriculture, Forest Service, South West Experimental Station. New Orleans, p. 15.

Hossain MZ. 2022. Methods for ecological studies. Ariban Public at in Tech, Qeensland, Australia, p. 306.

Houghton RA and Hall F. 2009. Importance of biomass in the global carbon cycle. Journal of Geophysical Research: Biogeosciences, *114*: G00E03.

IPCC 2003. Good practice guidance for land use. Land-use change and forestry. IPCC National Greenhouse Gas Inventories Programme. Kanagawa, Japan.

Keith DW. 2009. Why capture CO_2 from the atmosphere? Science, *325*: 1654-1655.

Mahmood H, Siddique MRH, Costello L, Birigazzi L, Abdullah SMR, Henry M, Siddiqui BN, Aziz T, Ali S, Mamun AA, Forhad MIK, Akhter M, Iqbal Z and Mondol FK. 2019. Allometric models for estimating biomass, carbon and nutrient stock in the Sal zone of Bangladesh. iForest - Biogeosciences and Forestry, *12*: 69-75.

Mani S and Parthasarathy N. 2007. Above-ground biomass estimation in ten tropical dry evergreen forest sites of peninsular India. Biomass and Bioenergy, *31*: 284-290

Melillo JM, Lu X, KicklighterDW, ReillyJM, Cai Y and Sokolov 2016.Protected areas' role in climate-change mitigation. *Ambio, 45:* 133-145.

Mukul SA, Biswas SR, Rashid AZMM, Miah MD, Kabir ME, Uddin MB, Alamgir M, Khan NA, Sohel MSI, Chowdhury MSH, Rana MP, Rahman SA, Khan MASA and Hoque MA. 2014. A new estimate of carbon for Bangladesh forest ecosystems with their spatial distribution and REDD+ implications. International Journal of Research on Land-use Sustainability, *1*: 33-41.

Nunes LJR. 2023. The rising threat of atmospheric CO_2: A review on the causes, impacts, and mitigation strategies. Environments, *10*: 66.

Picard N, Rutishauser E, Ploton P, Ngomanda A and Henry M. 2015. Should tree biomass allometry be restricted to power models? Forest Ecology and Management, *353*: 156-163.

Prado-Junior JA, Schiavini I, Vale VS, Arantes CS, van der Sande MT, Lohbeck M and Poorter L. 2016. Conservative species drive biomass productivity in tropical dry forests. Journal of Ecology, *104*: 817-827.

Santilli M, Moutinho P, Schwartzman S, Nepstad D, Curran L, Nobre C. 2005. Tropical deforestation and the Kyoto protocol. Climate Change, *71*: 267-276.

Skutsch M, Bird N, Trines E, Dutschke M, Frumhoff P, de Jong BHJ, van Laake P, Masera O and Murdiyarso D. 2007. Clearing the way for reducing emissions from tropical deforestation. Environmental Science and Policy, *10*: 322-334.

Somogyi Z, Teobaldelli M, Federici S, Matteucci G, PagliariV, Grassi G, and Seufert G. 2008. Allometric biomass and carbon factors database. Forest-Biogeosciences and Forestry, *1*: 107-113.

Sundarapandian SM, Amritha S, Gowsalya L, Kayathri P, Thamizharasi M, Dar JA, Srinivas K, Sanjay GD and Subshree D. 2014. Biomass and carbon stock assessments of woody vegetation in Pondicherry University campus, Puducherry. International Journal of Environment and Biology, *4*: 87-99.

Tian J, Feng C, Fu G, Fan L and Wang W 2023. Contribution of different types of terrestrial protected areas to carbon sequestration services in China: 1980–2020. Front. Ecol. Evol, *11*: 1074410

Van Breugel M, Ransijn J, Craven D, Bongers F and Hall JS. 2011. Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. Forest Ecology and Management, *262*: 1648-1657

Wiemann MC and Green DW 2007. Estimating Janka hardness from specific gravity for tropical and temperate species. Research Paper FPL-RP-643. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, p 21.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 105-113

TREE-SPECIFIC EQUATIONS FOR ACCURATE CARBON ESTIMATION OF MAJOR FRUIT TREES IN BANGLADESH

Mohammed Solaiman Talukder[1], Md. Main Uddin Miah[2*], Md. Giasuddin Miah[2]
Md. Mizanur Rahman[3] and Sohag Ahammed[4]

[1]Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh; [2]Department of Agroforestry and Environment, [3]Department of Soil Science, [4]Department of Forest Policy and Management, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh

***Corresponding e-mail:** mmumiahbsmrau@gmail.com

Received: 09 November 2023, revised: 14 November 2023, accepted: 25 November 2023, DOI: https: //doi.org/10.59619/ej.5.2.3

ABSTRACT

Tropical fruit trees play an important role in mitigating climate change by sequestering carbon from the atmosphere. However, estimating their carbon sequestration potential requires tree-specific equations. This study aimed to develop such equations for five major fruit tree species in Bangladesh *i.e.* Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*), Litchi (*Litchi chinensis*), Guava (*Psidium guajava*), and Jujube (*Ziziphus jujuba*). The study was conducted in four major ecosystems of Bangladesh namely, the Coastal ecosystem, Barind ecosystem, Terrace ecosystem, and Hill ecosystem. Vegetation data were randomly collected from each ecosystem. The equations were derived for Jackfruit W (lb) = 0.26 × D^2 × H (for diameter <11 inches) and W (lb) = 0.14 × D^2 × H (for diameter >11 inches); for Mango W (lb) = 0.26 × D^2 × H (for diameter <11 inches) and W (lb) = 0.13 × D^2 × H (for diameter >11 inches); for Litchi W (lb) = 0.23 × D^2 × H (for diameter <11 inches) and W (lb) = 0.13 × D^2 × H (for diameter >11 inches); for Guava W (lb) = 0.22 × D^2 × H (for diameter <11 inches), and for Jujube W (lb) = 0.22 × D^2 × H (for diameter <11 inches) and W (lb) = 0.12 × D^2 × H (for diameter >11 inches). The equations will help in developing effective carbon management and climate change mitigation strategies in tropical agroforestry systems, aiding researchers, land managers, and policymakers in understanding tree growth and carbon sequestration.

Keywords: Agroforestry system, carbon estimation, tree-specific equation, and ecosystems.

Introduction

Tropical fruit trees, when integrated into agroforestry systems, play a vital role in mitigating climate change by effectively capturing and storing carbon dioxide from the atmosphere. The significance of agroforestry systems, which involve the integration of tree growing with agricultural practices, is increasingly recognized as a crucial approach to addressing the issue of global climate change (Smith *et al.* 2014, Griscom *et al.* 2019). Within these ecological systems, fruit trees have a multifaceted role by serving as an important source of income for the local population and as significant carbon sinks, contributing to both environmental sustainability and the economic well-being of rural people.

The process of carbon sequestration, in which carbon dioxide is assimilated from the atmosphere and retained in plant life, is a fundamental aspect of efforts to mitigate climate change (IPCC, 2018). The pressing necessity to address climate change, considering its extensive impacts on ecosystems, economies, and human civilizations, highlights the significance of assessing and enhancing carbon sequestration in many ecological contexts. Tropical regions are very potential owing to their substantial capacity for carbon sequestration.

The process of carbon sequestration in trees and forests is primarily influenced by the growth patterns that are distinctive to each species, as well as other environmental conditions (Le Quéré *et al.* 2018, Lewis *et al.* 2019). The development of robust allometric equations that account for fluctuations is necessary to accurately estimate carbon sequestration in tropical fruit plants. These equations serve as a tool for connecting various attributes of trees, such as diameter at breast height (DBH) and height (H), with tree biomass. Through this approach, researchers establish a scientific foundation for the estimation of carbon stocks and fluxes, thereby enhancing the development of climate change mitigation plans.

However, tropical fruit trees play a significant role in Bangladesh, a nation where agriculture serves as the foundation of the economy and agroforestry systems are closely interconnected with rural livelihoods (Sultana *et al.* 2021). The fruit tree species that hold significant prominence in Bangladesh include Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*), Litchi (*Litchi chinensis*), Guava (*Psidium guajava*), and Jujube (*Ziziphus jujuba*). These species collectively play a crucial role in ensuring food security, nutrient sufficiency, generating income and conserving biodiversity within the country (Khan *et al.* 2017).

Nevertheless, the precise evaluation of carbon sequestration in these particular kinds of fruit trees has proven to be a formidable task. The applicability of existing equations designed for other areas or ecosystems may be limited due to differences in growth conditions, genetic diversity, and management practices (Chave *et al.* 2014). In order to bridge this gap in knowledge, the present study aims to develop tree-specific allometric equations that are specifically adapted to the five primary agroforestry fruit tree species found in Bangladesh. The utilization of these equations plays a crucial role in quantifying the capacity of carbon sequestration, hence enhancing the accuracy in assessing the extent to which these trees contribute to mitigating climate change, taking into account the specific ecological circumstances of the country.

The study consists of four primary ecosystems in Bangladesh, which are distinguished by unique environmental conditions and land use patterns. The coastal ecology, which encompasses the Khulna and Satkhira districts, has challenges related to saline intrusion and susceptibility to cyclones. The Barind ecosystem, which encompasses the Rajshahi and Dinajpur districts, is confronted with the dual difficulties of water scarcity and land degradation. The Terrace ecosystem, as exemplified by the Gazipur and Narsingdi districts, is currently grappling with challenges associated with the processes of urbanization and agricultural intensification. The Hill ecosystem, which encompasses the Rangamati and Khagrachari districts, is currently confronted with challenges pertaining to the preservation of forests and the sustenance of indigenous communities. The extensive geographic scope of the established allometric equations guarantees their ability to encompass a wide range of development patterns and ecological factors that are unique to each ecosystem.

The main objective of this research is to establish a strong scientific foundation for the estimation of tree biomass and, consequently, carbon sequestration in Jackfruit, Mango, Litchi, Guava, and Jujube plants of different ecosystems in Bangladesh. It is hoped that policymakers can employ the findings to establish policies and strategies with the goal of simultaneously attaining ecological and economic objectives within the framework of climate change mitigation and rural development.

Materials and Methods

Site selection: The research was carried out in four prominent agro-ecosystems in Bangladesh, including Coastal ecosystem, Barind ecosystem, Terrace ecosystem, and Hill ecosystem. The selection of these ecosystems was determined by considering their climatic zones, soil types, topography, and land use patterns (Islam *et al.* 2018). Mangrove trees, low-lying plains, saline soils, and a humid tropical climate are some of the characteristics that set the coastal environment apart. A semi-arid climate, sandy loam soils, undulating topography, and dry deciduous trees are some of the unique characteristics of the Barind ecosystem. The Terrace ecosystem is characterized by damp deciduous forests, clay loam soils, flat plains, and sub-humid tropical temperatures. The Hill environment exhibits a humid subtropical climate, sandy clay loam soils, undulating hills, and evergreen forests. Two districts were chosen within each habitat based on the presence and variety of the desired fruit tree species. The districts chosen for the study encompassed each ecosystem, including Khulna and Satkhira for the coastal environment, Rajshahi and Dinajpur for the Barind ecosystem, Gazipur and Narsingdi for the terrace ecosystem, and Rangamati and Khagrachari for the hill ecosystem. Three villages were chosen at random within each district, taking into consideration the occurrence and quantity of the specific fruit tree species.

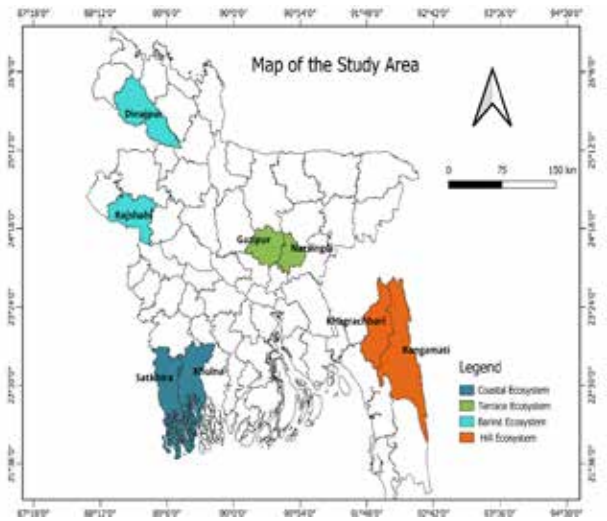


Figure 1. Map of the study area.

Data collection: The data was collected from January to December 2020. The fruit tree species included in the present study were Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*), Litchi (*Litchi chinensis*), Guava (*Psidium guajava*), and Jujube (*Ziziphus jujuba*). The selection of these species was determined by their economic significance, ecological adaptability, and presence in various habitats throughout Bangladesh (Lin 2011). The process of sampling was conducted in accordance with the ethical principles of informed consent and active collaboration, involving the local farmers who either owned or managed the trees.

Data was collected for each tree sample, including measurements of height (H) in feet (ft), diameter at breast height (D) in inches (in), as well as weights for the stem (SW), branches (BW), leaves (LW), roots (RW), fruits (FW), and seeds (SW), all measured in pounds (lb). The height of the tree was determined by using a measuring tape, which was extended from the tree's base to its highest point. The diameter was determined by employing a caliper positioned at a height of 4.5 feet above the ground. For the calculation of total stem weight, a sample (a short portion of the stem) weight for a particular volume was measured first then unit volume weight was calculated. Accordingly, total weight of the stem was calculated by multiplying unit volume weight and whole volume of the stem. The estimation of branch weight was conducted by removing all branches from the tree and thereafter measuring their weight on a digital scale. The estimation of leaf weight was conducted by gathering all the leaves from the tree and measuring their mass using a digital scale. The determination of root weight involved the extraction of all roots from the soil, followed by a thorough rinsing with water to eliminate any extraneous matter or soil particles. The roots were afterward measured in terms of weight on a digital scale. The estimation of fruit weight was conducted by harvesting all the fruits from the tree and afterward measuring their weight using a digital scale. The estimation of seed weight was conducted by extracting all seeds from the fruits and afterward measuring their mass with the use of a digital scale.

Development of tree-specific equations: The destructive method (clear-cut) was used for developing species-specific equations. For this, the model equation, $W = K \times D^2 \times H$ was used. Where W is above-ground biomass (lb), D is the diameter at breast height (inch), H is the total height of the tree (ft), and K is the factor. The biomass equations were developed on the basis of diameter class D < 11 inches and D > 11 inches (Chavan and Rasal, 2010; Chavan and Rasal, 2012). From the above equation, the K value was determined species-wise. The above-ground materials of the trees were sorted into stems, branches, and leaves. The roots of sampled trees were dug out and examined. Fresh weight for each component of the sample tree was measured separately on-site. Then, randomly selected representative samples of stems, branches, leaves, and roots were taken back to the laboratory and oven-dried at 75°C to constant weight after recording their fresh weight in the field (Baishya *et al.* 2009, Chen *et al.* 2015). The dry weight for each component was calculated according to the total fresh weight of the corresponding component. Above-ground dry biomass refers to the sum of the dry weight of stems, branches, and leaves; below-ground dry biomass refers to dry root weight and the total carbon storage refers to the sum of the tree›s total carbon storage in this study. The bark was not removed from stems or branches, and all branches were included in above-ground biomass. The amount of carbon in the plant was calculated as 50 percent of the plant›s dry weight (Poorter *et al.* 1990).

Data analysis: The data analysis was performed using Microsoft Excel and software R. The data were analyzed using correlation analysis, regression analysis, and

analysis of variance (ANOVA). The regression analysis was used to develop the tree-specific equations for estimating the weight (W) in pounds (lb) of the trees based on the diameter (D) in inches (in) and height (H) in feet (ft) of the trees. The regression coefficients were estimated using the nonlinear least squares method. The equation development was done separately for each species and each diameter class (<11 inches and >11 inches). The equation performance was evaluated using the coefficient of determination (R^2), root mean square error (RMSE), and mean absolute error (MAE). The study area map was constructed by using QGIS software.

Results and Discussion

The height and diameter of the trunk of a tree influence the carbon stock of the species. The maximum height and diameter of a tree represent the maximum amount of carbon stock by the species. Carbon stock by different trees varied significantly with respect to plant height, the diameter of the trees, and years after plantation. Among the five species, the tallest plant height was recorded in mango followed by jackfruit, Litchi, guava, and jujube, whereas the average shortest plant height was recorded in guava (Table 1). However, the diameter of the trees was significantly different from each other where the highest diameter was recorded in mango, whereas a tree with minimum diameter was observed in guava (Table 1).

The fresh weights of the stem of a tree influence the carbon stock of the species. The maximum fresh weight of the stem of a tree represents the maximum amount of carbon stock by the species. Among the five species, the highest fresh weight of stem was recorded in mango followed by jackfruit, Litchi, and jujube, whereas the average shortest plant height was recorded in jujube (Table 2) in case of above 11-inch diameter. Accordingly, the highest fresh weight of stem was recorded in mango followed by jackfruit, Litchi, and jujube, whereas the average shortest plant height was recorded in guava (Table 2) in case of the below 11-inch diameter of stem.

Among the agroforestry species, the highest fresh weight of the branch was recorded in mango followed by jackfruit, litchi, and jujube, whereas the average shortest plant height was recorded in jujube (Table 3) in case of above 11-inch diameter. Accordingly, the highest fresh weight of the branch was recorded in mango followed by jackfruit, litchi, and jujube, whereas the average shortest plant height was recorded in guava (Table 3) in case of the below 11-inch diameter of stem.

The highest fresh leaf weight was recorded in mango followed by jackfruit, litchi, and jujube, whereas the average shortest plant height was recorded in jujube (Table 4) in case of above 11-inch diameter. Accordingly, the highest fresh leaf weight was recorded in mango followed by jackfruit, litchi, and jujube, whereas the average shortest plant height was recorded in guava (Table 4) in case of the below 11-inch diameter of stem.

Table 2. Fresh weight of stem based on diameter class

Species name	Stem (kg)	
	>11 inch	<11 inch
Jackfruit	938.43b	201.37b
Mango	1143.30a	215.60a
Litchi	467.36c	132.44c
Guava	-	16.08e
Jujube	72.51d	47.12d
CV (%)	1.57	2.22

Table 1. Plant height and diameter of fruit tree species

Species name	Height class (ft)		Diameter class (inch)	
	Tall	Short	>11	<11
Jackfruit	40.65	35.72	28.45	10.89
Mango	42.48	38.75	31.12	10.96
Litchi	26.22	23.67	24.84	10.78
Guava	-	8.13	-	6.18
Jujube	14.33	11.85	12.99	8.92

The highest fresh root weight was recorded in mango (806.01 kg plant^{-1}) followed by jackfruit, litchi, and jujube, whereas the average lowest root was recorded in jujube (Table 5) in case of above 11-inch diameter. Accordingly, the highest fresh root weight was recorded in mango followed by jackfruit, litchi, and jujube, whereas the average shortest plant height was recorded in guava (Table 5) in case of the below 11-inch diameter of stem.

Among the following species, factors were calculated. In the case of jackfruit and mango, the factors were found same in diameter (<11 inches). But in the case of a diameter of above 11 inches, the factors were found 0.14 and 0.13 in jackfruit and mango, respectively. On the other hand, the factors of litchi were found 0.13 (> 11-inch diameter) and 0.23 (< 11-inch diameter), respectively. But in the case of guava, a diameter above 11 inch was not found and for below 11 inch diameter 0.22 factor was determined. Lastly, 0.12 (> 11-inch diameter) and 0.22 (< 11-inch diameter) factors were calculated for jujube (Table 6).

The relationship between biomass and the diameter and height of the tree is expressed by biomass equations. The model $W = K \times D^2 \times H$ is used to examine how height and diameter affect the tree›s above-ground biomass. Where W is above-ground biomass (lb), D is the diameter at breast height (inch), H is the total height of the tree (ft), and K is the factor that was identified before. For jackfruit, the biomass equations developed on the basis of diameter class < 11 inches and >11 inches (Table 7). The biomass equations were developed for aboveground biomass with height and diameter of jackfruit tree on the diameter class viz. diameter below 11 inches, diameter above 11 inches (Table 7). The developed biomass equations for total above-ground biomass (AGB) of jackfruit as a function of diameter at breast height and height showed a high correlation for the equation for < 11 inches (95.3%), equation > 11 inches (93.6%). Comparison and application of the proposed pan-tropic general models (Chave *et al.* 2014) with observed biomass data sets for each forest type revealed the significance of site-specific equations for precise biomass estimation in both primary and secondary forests in Southeast Asia (Basuki *et al.* 2009, Kenzo *et al.* 2009). The previously examined species-specific formulas

Table 3. Fresh weight of branch based on diameter class

Species name	Fresh weight of Branch (kg)	
	>11 inch	<11 inch
Jackfruit	841.22b	180.51b
Mango	1024.87a	193.26a
Litchi	418.94c	118.71c
Guava	-	14.42e
Jujube	64.99d	42.24d
CV (%)	0.96	3.42

Table 4. Fresh leaves weight based on diameter class

Selected species	Fresh leaves weight (kg)	
	>11 inch	<11 inch
Jackfruit	315.35b	67.67b
Mango	384.19a	72.44a
Litchi	157.05c	44.51c
Guava	-	5.42e
Jujube	24.36d	15.83d
CV (%)	3.18	4.22

Table 5. Fresh-weight roots based on diameter class

Selected species	Roots (kg plant^{-1})	
	>11 inch	<11 inch
Jackfruit	590.89b	126.79b
Mango	806.01a	151.99a
Litchi	277.34c	78.59c
Guava	-	6.34e
Jujube	35.53d	23.09d
CV (%)	2.86	1.95

Table 6. Determination of k values for tree-specific equation based on height and diameter

Selected species	Diameter (>11 inch)	Diameter (<11 inch)
Jackfruit	0.14	0.26
Mango	0.13	0.26
Litchi	0.13	0.23
Guava	-	0.22
Jujube	0.12	0.22
CV (%)	1.78	2.16

are helpful in precisely estimating the above-ground biomass of jackfruit (Nam *et al.* 2016, Manuri *et al.* 2014).

Mango trees are modeled using $W = K \times D^2 \times H$ to examine the impact of height and diameter on the tree›s aboveground biomass. where W stands for aboveground biomass (pounds), D for breast height diameter (inches), H for tree height (feet), and K for the previously determined factor. The biomass equations for mango were created based on two diameter classes: less than 11 inches and more than 11 inches (Table 8). The biomass equations were developed for aboveground biomass with height and diameter of a mango tree on the diameter class viz. diameter below 11 inches, diameter above 11 inches (Table 8). The developed biomass equations for total above-ground biomass (AGB) of mango as a function of diameter at breast height and height showed a high correlation for the equation for < 11 inches (92.4%), equation > 11 inches (98.6%). The significance of site-specific equations for precise biomass estimation based on application and/or comparison of the suggested pan-tropic general models (Chave *et al.* 2014) and observed biomass data sets for each forest type was highlighted by studies conducted in both primary and secondary forests in Southeast Asia (Basuki *et al.* 2009, Kenzo *et al.* 2009).

The model $W = K \times D^2 \times H$ is used to examine how height and diameter affect the tree›s above-ground biomass for litchi. where W stands for above-ground biomass (pounds), D for breast height diameter (inches), H for tree height (feet), and K for the previously determined factor. The biomass equations for litchi were derived based on two diameter classes: <11 inches and >11 inches (Table 9). The diameter class of litchi trees—diameter below 11 inches and diameter above 11 inches—was taken into consideration when developing the biomass equations for above-ground biomass (Table 9). The total above-ground biomass (AGB) of litchi as a function of height and breast height was calculated using biomass equations. The results indicated a strong correlation for the equations for < 11 inches (88.98%) and > 11 inches (92.2%).

The model $W = K \times D^2 \times H$ is used to examine how height and diameter affect the tree›s aboveground biomass for guava. where W stands for aboveground biomass (pounds), D for breast height diameter (inches), H for tree height (feet), and K for the previously determined factor. The biomass equations for guava were created based on the diameter classes of less than 11 inches and more than 11 inches (Table 10). The diameter class of guava trees—diameter below 11 inches and diameter above 11 inches—was taken into consideration when developing the biomass equations for aboveground biomass (Table 10). The developed biomass equations for the total above-ground biomass (AGB) of guava as a function of height and diameter at breast height revealed a strong correlation (86.78%) for the equation for diameters less than 11 inches.

For jujube, the model $W = K \times D^2 \times H$ is used to examine how height and diameter affect the tree›s aboveground biomass. Where W represents aboveground biomass (pounds), D is the diameter at breast height (inches), H is the tree›s total height (feet), and K is the previously identified factor. Based on diameter classes of less than 11 inches and more than 11 inches, the biomass equations

Table 7. Regression analysis of the variables

Diameter class	Biomass equations	R^2	RMSE	MAE
<11 inch	$W\ (lb) = 0.26 \times D^2 \times H$	95.3%	23.6	18.4
>11 inch	$W\ (lb) = 0.14 \times D^2 \times H$	93.6%	36.7	28.9

Table 8. Regression analysis of the variables

Diameter class	Biomass equations	R^2	RMSE	MAE
<11 inch	$W\ (lb) = 0.26 \times D^2 \times H$	92.4%	14.6	10.5
>11 inch	$W\ (lb) = 0.13 \times D^2 \times H$	98.6%	18.3	13.2

Table 9. Regression analysis of the variables

Diameter class	Biomass equations	R^2	RMSE	MAE
<11 inch	W (lb) = 0.23 × D^2 × H	88.98%	22.6	14.3
>11 inch	W (lb) = 0.13 × D^2 × H	92.2%	24.6	16.8

for jujube were developed (Table 11). The height and diameter of jujube trees on the diameter class—diameter below 11 inches, diameter above 11 inches—were used to develop the biomass equations for aboveground biomass (Table 11). The total above-ground biomass (AGB) of jujube as a function of height and breast height was calculated using biomass equations. The results showed a strong correlation between equations for < 11 inches (95.66%) and equations for> 11 inches (92.98%).

The presence of precise and tree-specific allometric equations holds considerable implications for the management of carbon and the mitigation of climate change in tropical agroforestry systems (Van Breugel *et al.* 2011). The utilization of these equations enables more accurate evaluations of the potential for carbon sequestration, hence assisting in the formulation of efficient approaches for carbon accounting and monitoring (Tabal *et al.* 2020). These equations can be employed by researchers to enhance the accuracy of carbon cycling models in agroforestry landscapes, hence facilitating more precise forecasts of carbon stocks and fluxes (Chave *et al.* 2014).

According to Hairiah *et al.* (2006), the utilization of these equations provides local communities and land managers with valuable tools to enhance the optimization of agroforestry practices. Farmers and landowners can make well-informed decisions regarding tree planting, trimming, and harvesting by acquiring knowledge about the correlation between tree dimensions and biomass (Ashraf *et al.* 2015). The acquisition of this knowledge has the potential to enhance livelihoods and augment carbon sequestration in these ecologically significant habitats (Nunes *et al.* 2020).

Conclusion

Tropical fruit trees heavily integrated into the agroforestry systems of Bangladesh can sequestrate carbon from the atmosphere and contribute to reducing global warming. Five tree-specific allometric equations were developed for major fruit tree species to precisely evaluate their carbon sequestration capacity in Bangladesh's unique ecological contexts. Our findings show that correct biomass predictions must encompass both diameter categories, i.e., trees with a DBH of less than 11 inches and those with a DBH of more than 11 inches. These equations can help researchers refine carbon models in agroforestry systems to anticipate carbon stocks and fluxes. The accuracy and adaptability of these equations allow researchers, land managers, policymakers, and local populations to make educated decisions. It also supports sustainable carbon management and climate change mitigation approaches for Bangladesh.

Table 10. Regression analysis of the variables

Diameter class	Biomass equations	R^2	RMSE	MAE
<11 inch	W (lb) = 0.22 × D^2 × H	86.78%	10.3	9.4
>11 inch	-	-		

Table 11. Regression analysis of the variables

Diameter class	Biomass equations	R^2	RMSE	MAE
<11 inch	W (lb) = 0.22 × D^2 × H	95.66%	16.3	10.5
>11 inch	W (lb) = 0.12 × D^2 × H	92.98%	17.4	15.3

Acknowledgment

The author would like to acknowledge Krishi Gobesona Foundation (KGF) for financial support under the project "Modelling climate change impact on agriculture and developing mitigation and adaptation strategies for sustaining agricultural production in Bangladesh."

References

Ashraf J, Pandey R, de Jong W and Nagar B. 2015. Factors influencing farmers' decisions to plant trees on their farms in Uttar Pradesh, India. Small-scale forestry, *14*: 301-313.

Baishya R, Barik, SK and Upadhaya K. 2009. Distribution pattern of aboveground biomass in natural and plantation forests of humid tropics in northeast India. *Tropical Ecology*, *50*: 295.

Basuki TM, Van Laake PE, Skidmore AK and Hussain YA. 2009. Allometric equation for estimating the above-ground biomass in tropical low-land dipterocarp forests. *Forest Ecology and Management*, *257*: 1684-1694. https://doi.org/10.1016/j.foreco.2009.01.027.

Chavan BL and Rasal GB. 2010. Sequestered standing carbon stock in selective tree species grown in the University campus at Aurangabad, Maharashtra, India. International Journal of Engineering Science and Technology, *2*: 3003-3007.

Chavan B and Rasal G. 2012. Total sequestered carbon stock of Mangifera indica. Journal of Environment and Earth Science, *2*: 37-49.

Chave J, Réjou-Méchain M, Búrquez A, Chidumayo E, Colgan MS, Delitti WB and Vieilledent G. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology, *20*: 3177-3190. https://doi.org/10.1111/gcb.12629.

Chen Y, Liu Z, Rao X, Wang X, Liang C, Lin Y and Fu S. 2015. Carbon storage and allocation pattern in plant biomass among different forest plantation stands in Guangdong, China. Forests, *6*: 794-808. https://doi.org/10.3390/f6030794.

Di Sacco A, Hardwick KA, Blakesley D, Brancalion PH, Breman E, Rebola CL and Antonelli A. 2021. Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. Global Change Biology, *27*: 1328-1348. https://doi.org/10.1111/gcb.15498.

Griscom BW, Lomax G, Kroeger T, Fargione JE, Adams J, Almond L and Kiesecker J. 2019. We need both natural and energy solutions to stabilize our climate. Global Change Biology, *25*: 1889-1890. https://doi.org/10.1111/gcb.14612.

Hairiah K, Sulistyani H, Suprayogo D, Purnomosidhi P, Widodo RH and Van Noordwijk M. 2006. Litter layer residence time in forest and coffee agroforestry systems in Sumberjaya, West Lampung. Forest Ecology and Management, *224*: 45-57. https://doi.org/10.1016/j.foreco.2005.12.007.

IPCC. 2018. Global Warming of 1.5°C. Special Report Intergovernmental Panel on Climate Change. https://doi.org/10.1017/9781009157940.

Islam K, Jashimuddin M, Nath B and Nath TK. 2018. Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh. The Egyptian Journal of Remote Sensing and Space Science, *21*: 37-47. https://doi.org/10.1016/j.ejrs.2016.12.005.

Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, Sakurai K and Ninomiya I. 2009. Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. Journal of Forest Research, *14*: 365-372. https://doi.org/10.1007/s10310-009-0149-1.

Khan SH, He X, Porikli F and Bennamoun M. 2017. Forest change detection in incomplete satellite images with deep neural networks. IEEE Transactions on Geoscience and Remote Sensing, *55*: 5407-5423. DOI: 10.1109/TGRS.2017.2707528.

Le Quéré C, Andrew RM, Friedlingstein P, Sitch S, Hauck J, Pongratz J and Zaehle S. 2018. Global carbon budget 2018. Earth System Science Data Discussions. https://doi.org/10.5194/essd-10-2141-2018.

Lewis SL, Wheeler CE, Mitchard ET and Koch A. 2019. Restoring natural forests is the best way to remove atmospheric carbon. Nature, *568*: 25-28. https://doi.org/10.1038/d41586-019-01026-8.

Lin BB. 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. Bio-Science, *61*: 183-193. https://doi.org/10.1525/bio.2011.61.3.4.

Manuri S, Brack C, Nugroho NP, Hergoualc'h K, Novita N, Dotzauer H and Widyasari E. 2014. Tree biomass equations for tropical peat swamp forest ecosystems in Indonesia. Forest Ecology and Management, *334*: 241-253. https://doi.org/10.1016/j.foreco.2014.08.031.

Nam VT, Van Kuijk M and Anten NP. 2016. Allometric equations for aboveground and belowground biomass estimations in an evergreen forest in Vietnam. PloS one, *11*: e0156827. https://doi.org/10.1371/journal.pone.0156827.

Nunes LJ, Meireles CI, Pinto Gomes CJ and Ribeiro ANM. 2020. Forest contribution to climate change mitigation: Management oriented to carbon capture and storage. Climate, *8*: 21. https://doi.org/10.3390/cli8020021.

Poorter H, Remkes C and Lambers H. 1990. Carbon and nitrogen economy of 24 wild species differing in relative growth rate. Plant Physiology, *94*: 621-627. https://doi.org/10.1104/pp.94.2.621.

Smith MM, Bentrup G, Kellerman T, MacFarland K, Straight R, Ameyaw L and Stein S. 2022. Silvopasture in the USA: A systematic review of natural resource professional and producer-reported benefits, challenges, and management activities. Agriculture, Ecosystems & Environment, *326*: 107818. https://doi.org/10.1016/j.agee.2021.107818.

Smith P, Bustamante M, Ahammad H, Clark H, Dong H, Elsiddig EA and Bolwig S. 2014. Agriculture, forestry and other land use (AFOLU). In Climate change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Pp. 811-922.

Sultana N, Limon SH, Rahman MS, Akther A, Salekin S., Meason, DF and Bloomberg M. 2021. Germination and growth responses to water stress of three agroforestry tree species from Bangladesh. Environmental Challenges, *5*: 100256. https://doi.org/10.1016/j.envc.2021.100256.

Tabal EP and Mendoza TC. 2020. Accounting the net carbon sequestered of various agroforestry systems (AFSs) in Zamboanga City, Philippines. International Journal of Agricultural Technology, *16*: 457-474.

Van Breugel M, Ransijn J, Craven D, Bongers F and Hall JS. 2011. Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. Forest Ecology and Management, *262*: 1648-1657. https://doi.org/10.1016/j.foreco.2011.07.018.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 115-125

VEGETABLE PRODUCTION ON THE DYKES OF BRACKISH WATER GHERS: STATUS AND CHALLENGES

Mohammad Bashir Ahmed* and Md. Matiul Islam

Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh

***Corresponding e-mail:** mbaatku@gmail.com

Received: 20 November 2023, Revised: 25 November 2023, Accepted: 30 November 2023, DOI: https: //doi.org/10.59619/ej.5.2.4

ABSTRACT

The embankments (Dykes) of the shrimp farms (Ghers) have been taken under vegetable production which deserves to be expedited for further implications. The aims of the study were to identify the status and problems of vegetable production on dykes in brackish water Ghers along with its impact on food security. Data were collected from purposively selected 67 respondents following accidental random sampling of the Dacope upazila of Khulna district in Bangladesh from July to November, 2017. The average area of the dykes was 8.89±4.69 decimals, and the average width was 1.73±0.34 m. The dykes were prepared either by spading or by preparing pits. The farmers grew vegetables in Kharif-2 season (July 01 to October 15). The farmers usually grew 16 types of vegetables as mixed crops, among which bitter gourd was dominant followed by cucumber and pumpkin, following two cropping patterns: vegetable-fallow-fallow and vegetable-vegetable-fallow. The cropping intensity was 162%. The majority of the respondents harvested vegetables four times. In terms of yield, the tomato (60 t ha^{-1}) was dominant, followed by brinjal (57.09 t ha^{-1}) and cabbage (55.41 t ha^{-1}). The dykes are occupying an area of 4,149.75 ha which would be able to produce 1, 04,438.83 tons of vegetables. Twenty-nine associated problems were identified, among those "rats attack" was the most severe problem. The confronted problems should be overcome through appropriate measures, and a typical model should be developed through research for dyke vegetable production to make it more resilient and profitable.

Keywords: Dyke vegetable production, status, food security, and problems.

Introduction

Ghers are low embankments or dikes constructed to control the inflow of brackish water into the coastal areas, creating pockets of land suitable for agriculture. Vegetable production on the dykes of brackish water Ghers has been practiced in the regions where these structures are common, such as coastal areas in South and Southeast Asia. The southwest part of Bangladesh is one of those regions. Nowadays, Bangladesh is facing the multidimensional effects of climate change in the forms of floods, cyclones, rising sea levels, drainage congestion, salinity in freshwater systems, etc. The existing literature (Habib-Ur-Rahman *et al.* 2022, Hossain *et al.* 2013, Minhas 2012, Lin 2011, Rahman 2011) suggests that crop production could be highly vulnerable in the face of climate change scenarios, thereby posing a potential threat to the country's food security.

Brackish water is water with salinity levels between seawater and freshwater. It occurs there where surface or groundwater mixes with seawater, in deep fossil aquifers. Usually, brackish water has been undervalued. Hillel (2000) defined brackish water as the water where 500-2,000 ppm salts are dissolved. In the coastal areas of Bangladesh, plenty of brackish to saline water are available. Thus, shrimp farming got a tremendous boom during the early 1980s. Salinity intrusion in agricultural land is increasing because of sea level rise due to climate change. Thus, the practice of agriculture, particularly vegetable production, has been almost stopped in the coastal areas, except for shrimp farming. The introduction of high-value crops on the dykes of brackish water shrimp Ghers could be an important innovation, although it has been practiced a while back.

The production practice of vegetables on the dykes of Ghers is termed Dyke vegetable production (DVP). DVP is an indigenous knowledge-based practice that is environment-friendly. In-depth knowledge about the present scenario i.e., area (in decimal) of the dyke, the

method of cultivation, preparation technique of pond and dyke, the season of dyke vegetable production, materials required, name of crops grown, use of manures and fertilizers on dyke vegetable production, an intercultural operation done, insect-pest and diseases attack dyke vegetables, crop rotation followed cropping intensity, time and frequency of harvest, the yield of vegetables and fish etc., and problems faced by the farmers in DVP, are merely available. To have a comprehensive idea about the above-mentioned issues it has been considered essential to study the present scenario and confronted problems related to DVP.

Vegetable production on the dykes of brackish water ghers represents a promising avenue for enhancing food security and economic prosperity in coastal regions. While celebrating its successes, it is crucial to address the identified challenges to establish a resilient and profitable model for dyke vegetable production. Continued research and community involvement will play a vital role in ensuring the long-term sustainability of this innovative agricultural practice.

Dyke area creates an avenue for increasing vegetable production in the water-logged areas of the southwest region of Bangladesh. In view of the above-cited facts, the present study was conducted with the following specific objectives: to identify the status and problems of vegetable production on dykes in brackish water Ghers along with its potential impacts on food security. Besides, the relationship of the selected characteristics of the respondents with their problem confrontation in brackish water dyke vegetable production was also explored.

Materials and Methods

Design of the study, source, method, instrument, and time of data collection: Descriptive and diagnostic research design postulated by Kothari (2004) was followed in conducting the study. All the dyke vegetable producers of Pankhali and Tildanga unions of Dacope upazila of Khulna district in Bangladesh were treated as the population of the study. Data were collected from sampled 67 dyke vegetable producers out of 87 (20 producers were excluded as they were included for pre-testing). Data were collected through face-to-face interviews by the Research Assistant from July to November, 2017. A number of 29 problems related to DVP were listed and identified through focus group discussion (FGD). After that, each of the respondents was asked to identify the problems indicating their extent of severity.

Status and impact of dyke vegetable production (DVP) on food security: The present status of DVP was determined based on following parameters (total 14) viz. area of the dyke, method of cultivation, preparation technique, materials required, season of DVP, types of vegetables grown, use of manures and fertilizers for DVP, intercultural operations done in dyke vegetables, insect-pests and diseases attack in dyke vegetables, crop rotation or cropping pattern followed, cropping intensity, time and frequency of harvest, yield of vegetables, and expenditure of and income from dyke vegetable production. Food security was measured in terms of dyke area and potential production of vegetables on the dykes in the study area during the survey period. The evaluation of food security in the study area was intricately tied to both the physical extent of dyke areas allocated for vegetable cultivation and the anticipated production of vegetables from these areas. This comprehensive approach provides a nuanced understanding of the region's capacity to meet food needs through the cultivation of vegetables on dykes.

Selection and measurement of the variables of the study: The selected 13 personal and socioeconomic characteristics (Table 11) of the dyke vegetable growers were treated as independent issues while the problem confrontation in dyke vegetable production was considered the focus issue of the study. The selected characteristics of the respondents were measured following standard procedure (Nishi *et al.* 2019).

Measurement of problem confrontation: A number of 29 problems (Table 9) were incorporated into the interview schedule (identified through FGD) to determine the problem confrontation of the respondent farmers in DVP. A 4-point rating scale, such as 'highly severe', 'moderately severe', 'negligible', and 'not at all' were employed to indicate the intensity of each of the faced problems by the respondents. A score of 3, 2, 1, and 0 were assigned against the scales respectively. The

problem confrontation score (PCS) of a respondent was calculated by summing up all the scores obtained against the 29 problems. Hence the PCS could range from 0-87. Based on PCS, the respondents were classified into three categories, such as low problem confrontation (1-29), medium problem confrontation (30-58), and high problem confrontation (58-87). Besides, a "Problem Confrontation Index Score" (PCIS) was calculated using the formula used by Akter *et al.* (2019) to understand the severity and magnitude of the faced problems.

Data processing, interpretation, and statistical analysis: Statistical treatments such as range, means, standard deviation, maximum, minimum, rank order, etc. were used to interpret data. To explore the relationship between the concerned variables Pearson's Product Moment Coefficient of Correlation (r) for normalized variables, and Spearman's Rank Order Coefficient (ρ) of Correlation for rank data, were employed.

Results and Discussion

Most (92.5%) of the respondents possessed medium to large dyke areas (Table 1). This finding is similar to that of Akter *et al.* (2019). They also found that most (86.9%) of the respondents had medium to large size of dykes.

The width of the dykes of the Ghers is usually decided by considering the convenience of intercultural operations (weeding, earthling-up, fertilizing, etc.). The respondents followed nine types of width (Table 2) in preparing dykes. More than half (55.2%) of the respondents considered the width of dykes as 1.82m (6ft), followed by 1.52 m (5 ft) (13.4%) and 1.37 m (4.5 ft) (11.9%). The respondents followed 67 different lengths depending on land size.

The farmers of the study area cultivated vegetables either by seeding (sowing/dibbling) or by planting method. Farmers produced climber types of vegetables such as bottle gourd, cucumber, bitter gourd, bean, etc., on a net or loft. The pumpkin and wax gourd were produced as creepers.

Before starting the season, the farmers first prepare their dykes for vegetable production either by spading or by preparing pits for creepers and climbers. For climbers, the vegetable growers of the study area prepared a netting loft (মাচা-platform) with the help of plastic ropes and bamboo over the water body of the Ghers.

Table 1. Distribution of the respondents according to the dyke area

Categories	Score (Decimal)	Respondent (N=67)		Mean±SD	Range	
		Number	Percentage		Min.	Max.
Small	<4.2	5	7.5			
Medium	4.20-13.59	53	79.1	8.89±4.69	1.85	26.85
Large	>13.59	9	13.4			

Table 2. Distribution of the respondents according to the width of the dykes of brackish water Ghers

Categories (Width)		Respondent (N=67) Min.		Mean±SD Max.	Range	
Meter	Feet	Number	Percentage (%)			
0.91	3.00	3	4.5			
1.21	4.00	1	1.5			
1.37	4.50	8	11.9			
1.52	5.00	9	13.4	(1.73±0.34) m or (5.75±1.13)ft	0.91m or 3ft	2.74m or 9ft
1.82	6.00	37	55.2			
2.13	7.00	2	3			
2.20	7.25	1	1.5			
2.28	7.50	4	6			
2.74	9.00	2	3			

In preparing dykes, the farmers used spades for land tillage operations and for pit preparations. Bamboo and synthetic ropes were used for preparing the loft. Hand-hoe (খুরপি) and small shovels were used for intercultural operations.

Mostly the farmers grew vegetables in the Kharip-2 season (July 01 to October 15). The farmers perform various activities for growing vegetables on the dykes. Some of the operations are mentioned below along with timings:

a) Old dyke repair or new dyke preparation: April-May
b) Net setting or loft preparation: April-May
c) Seeds/seedlings collection: April-May
d) Sowing / Planting: May-June
e) Harvesting: June-August and lasts up to November

The farmers of the study area grew 16 types of vegetables on the dykes of the brackish water Ghers. Most (86.56%) of them grew bitter gourd in their dykes followed by cucumber (82.08%), pumpkin (76.11%), and bottle gourd (64.17%) (Table 3). However, a few (2.98%) of them grew cabbage, Indian spinach, and potato. Akter *et al.* (2019) found that most (92.85%) of the respondents cultivated cucumber and bitter gourd on dykes of freshwater Ghers.

In preparing the pit, the farmers used compost. Besides, farmers used Urea, TSP, DAP, and MoP for increased production and quality of the produce.

All (100%) of respondents practiced weeding, irrigation, and setting trailers (বাউনি) followed by soil loosing (98.5%), mulching (97.01%), and control of insect-pests (88.05%) and diseases (70.14%) in their dykes of the Ghers (Table 5).

Highest proportion (29.9%) of the respondents cited that their dyke vegetables were infested by mosaic virus followed by downey (19.40%) and powdery (13.43%) mildews. A few respondents (11.9%, 4.5%, and 1.5%) also reported that their field was infested by wilt, root rot, and blight respectively (Table 6). The highest proportion (26.90%) of them addressed that fruit fly attacked their dyke vegetables followed by red pumpkin beetle (25.37%), caterpillar (13.43%), and aphids (11.94%). A few of the respondents cited that *epilachna* beetle (5.97%) and brinjal shoot and fruit borer (4.5%) also attacked their dyke vegetables (Table 6).

All of the respondents grew vegetables as mixed crops following two cropping patterns viz. vegetable-fallow-

Table 3. Types of vegetable crops grown in the dykes of brackish water Ghers

Sl.No.	Name of the vegetables	Respondents (N=67)	
		Citation	Percentage (%)
1.	Bitter gourd	58	86.56
2.	Cucumber	55	82.08
3.	Brinjal	22	32.83
4.	Pumpkin	51	76.11
5.	String bean	30	44.77
6.	Wax gourd	26	38.80
7.	Snake gourd	10	14.92
8.	Bottle gourd	43	64.17
9.	Bean	06	08.95
10.	Cabbage	02	02.98
11.	Knolkhol	13	19.40
12.	Tomato	27	40.29
13.	Indian spinach	02	02.98
14.	Potato	02	02.98
15.	Okra / Lady's finger	14	20.89
16.	Ribbed gourd	04	05.96

Table 4. Distribution of the respondents according to their use of manure and fertilizers in the dykes

Name of fertilizers	Respondents (N=67)	
	Citation	Percentage (%)
Cowdung	61	91.04
Urea	66	98.50
Triple Super Phosphate (TSP)	65	97.01
Di Ammonium Phosphate (DAP)	60	89.55
Muriate of Potash (MoP)	64	95.52

Table 5. Distribution of the respondents according to their intercultural operations practiced in the dykes during vegetable production

Name of intercultural operations	Respondents (N=67)	
	Citation	Percentage (%)
Weeding	67	100.00
Irrigation	67	100.00
Mulching	65	97.01
Setting Trailers (বাউনি)	67	100.00
Soil loosing	66	98.50
Control of diseases	47	70.14
Control of insects-pest	59	88.05

fallow and vegetable-vegetable-fallow. A number of 65 combinations of the crops were practiced under the two cropping patterns by the 67 respondents in the study area. Two combinations, viz. Bottle gourd+Bitter gourd+Pumpkin—Knolkhol+Tomato—Fallow and Cucumber+Bitter gourd+Bottle gourd+String bean+Pumpkin+Wax gourd—Fallow were repeated in the case of two and two respondents respectively.

The net dyke area covered by vegetables in the study area was 2.1755 ha, while the total area under dyke vegetable production was 3.5245 ha. The cropping intensity was 162 percent.

Irrespective of the types of vegetables, the harvesting time ranged from 40 to 75 days after seeding or planting (Table 7). The majority (76.1%) of the respondents harvested vegetables four times followed by three times (16.4%) and five times (7.5%) irrespective of types of vegetables (Table 8).

Highest amount of yield was obtained by the farmers in the case of tomato (60 t ha^{-1}) followed by brinjal (57.09 t ha^{-1}), cabbage (55.41 t ha^{-1}) and bottle gourd (40.68 t ha^{-1}) (Figure 1). The lowest yield was observed in the case of Indian spinach (6.75 t ha^{-1}) followed by cucumber (8.48 t ha^{-1}), pumpkin (8.57 t ha^{-1}), and potato (10.88 t ha^{-1}).

Irrespective of the types of vegetables, the yield obtained from one ha of dyke area was 25.12 t ha^{-1}. But Akter *et al.* (2019) found less yield (6.45833 t ha^{-1}). Rai *et al.* (1992) stated that the pond dyke yielded 5,626.5 kg of vegetables which worked out to 85.9 t $ha^{-1}y^{-1}$.

The cost (without considering the types of vegetables) involved laborers' wages for land preparation, netting (loft), intercultural operations, fertilizing, irrigation, pest control, harvesting, etc. The per hectare cost incurred for vegetable production on the dykes ranged from 30,000 to 1,10,000 BDT (353.03 to 1,294.44 USD) with a mean and standard deviation of 79,531.25 BDT (935.90 USD) and 18,943.30 BDT (222.92 USD), respectively. Besides, a huge amount of recurring expenditure incurred for de-weeding and cleaning of farm areas reduces the profitability of aquaculture practices (Roy *et al.* 1996).

Table 6. Distribution of the respondents according to diseases and insect-pest infestations in the produced vegetables

Name of diseases and insect-pests	Respondents (N=67)	
	Citation	Percentage (%)
Diseases		
Powdery mildew	9	13.43
Downey mildew	13	19.40
Mosaic virus	20	29.90
Blight	1	01.50
Wilt	8	11.90
Root rot	3	04.50
Insect-pests		
Brinjal shoot & fruit borer	3	04.50
Fruit fly	18	26.90
Jassids	2	02.98
Aphids	8	11.94
Red pumpkin beetle	17	25.37
Mealy bug	2	02.98
Epilachna beetle	4	05.97
Thrips	1	01.49
Fruit borer	1	01.49
Caterpillars	9	13.43

Table 7. Harvesting time of vegetables grown on the dykes of brackish water Ghers

Name of vegetables	Time of harvesting (DAS/DAP) *
1. Bitter gourd	40-50
2. Cucumber	40-50
3. Brinjal	55-65
4. Pumpkin	60-75
5. String bean	40-50
6. Wax gourd	45-50
7. Snake gourd	40-50
8. Bottle gourd	50-60
9. Bean	50-60
10. Cabbage	45
11. Knolkhol	40 -45
12. Tomato	45-50
13. Indian spinach	40
14. Potato	60
15. Okra / Lady's finger	45-55
16. Ribbed gourd	45

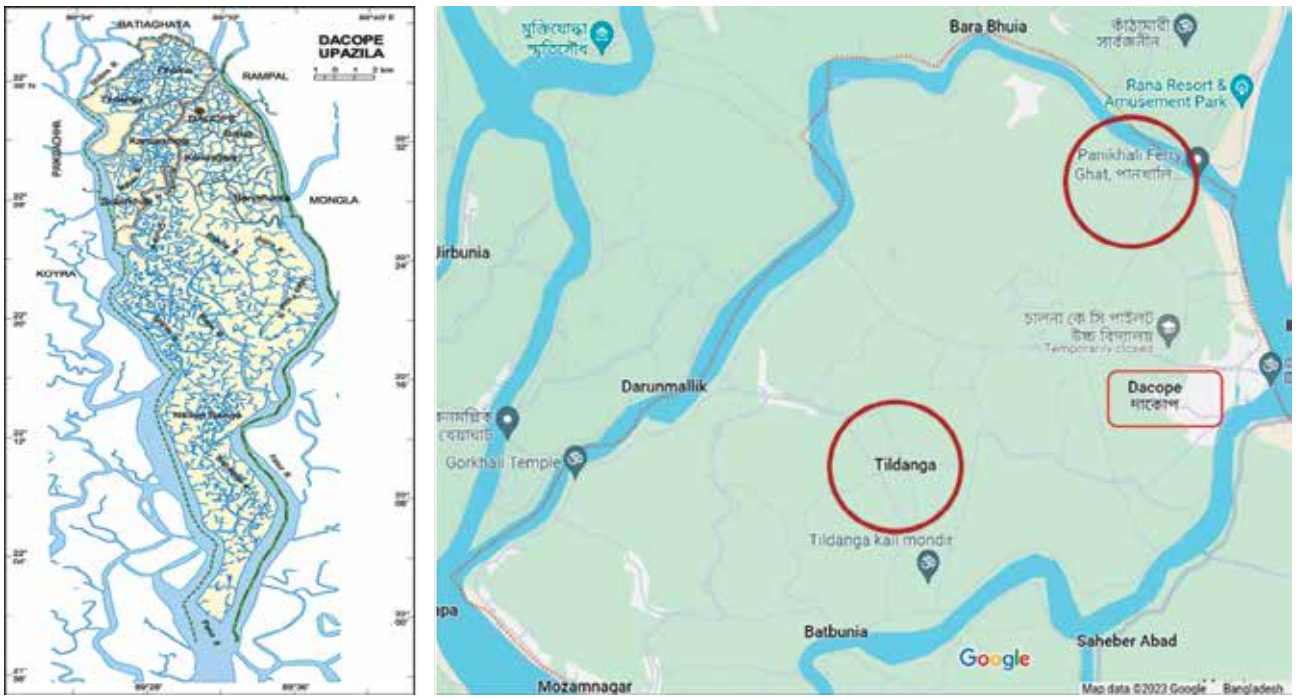
* DAS= Days After Seeding, DAP= Days After Planting

Table 8. Distribution of the respondents according to their frequency of harvest of the grown vegetables

Harvesting Times (frequency)	Respondents (N=67)	
	Citation	Percentage (%)
3	11	16.4
4	51	76.1
5	5	7.5

The average gross income from vegetable production in one ha of dyke area ranged from 1, 28,550 to 4, 75,000 BDT (1,512.73 to 5,589.64 USD) with a mean and standard deviation of 3, 20,293 BDT (3,769.10 USD) and 1,11,518.50 BDT (1,312.31 USD), respectively. The average net income from vegetable production in one ha of dyke area ranged from 73,550 to 3,77,000 BDT (865.51 to 4,436.41 USD) with a mean and standard deviation of 2,40,762.5 BDT (2,833.21 USD) and 9,940.44 BDT (116.98 USD) respectively. The findings of the present study indicate that the average income from one hectare of land for dyke vegetable cultivation was considered higher than that of Akter *et al.* (2019) who obtained BDT 30,093.02 (USD 354.12) ha^{-1}. Akter *et al.* (2019) conducted their study in Mollarhat upazila of the Bagerhat district in 2017. During that year the freshwater Ghers of that area were inundated due to heavy rainfall, and consequently, the dyke vegetables were damaged, and the production was less which contributed to low income.

According to Ahmed (2011), there are 3,594 brackish water shrimp farms (Khulna 1,425, Bagerhat 1,249, Satkhira 920) in the southwestern coastal region of Bangladesh, which covers an area of 82,995 ha (Khulna 25,485 ha, Bagerhat 33,214 ha, Satkhira 24,296 ha). The dykes covered 5% area (on average) of total shrimp Gher areas. The dykes of 3,594 brackish water shrimp farms (i.e., brackish water Ghers) in the southwestern coastal region (greater Khulna) of Bangladesh occupy an area of 4,149.75 ha. If we are able to undertake these dyke areas (4,149.5 ha) under vegetable production, we would be able to produce (25.16 t ha^{-1}×4,149.75 ha) = 104438.83 tons of vegetables. The increased amount of vegetables produced in this way, from the dykes, would definitely be added to the present amount of produced vegetables. Moreover, the vegetables produced during the lean period (transition time of seasonal changes when vegetables are merely available in the field and market) would add extra security to the required food as vegetable supplements.



Map 1. Administrative map of Dacope upazila of Khulna district.

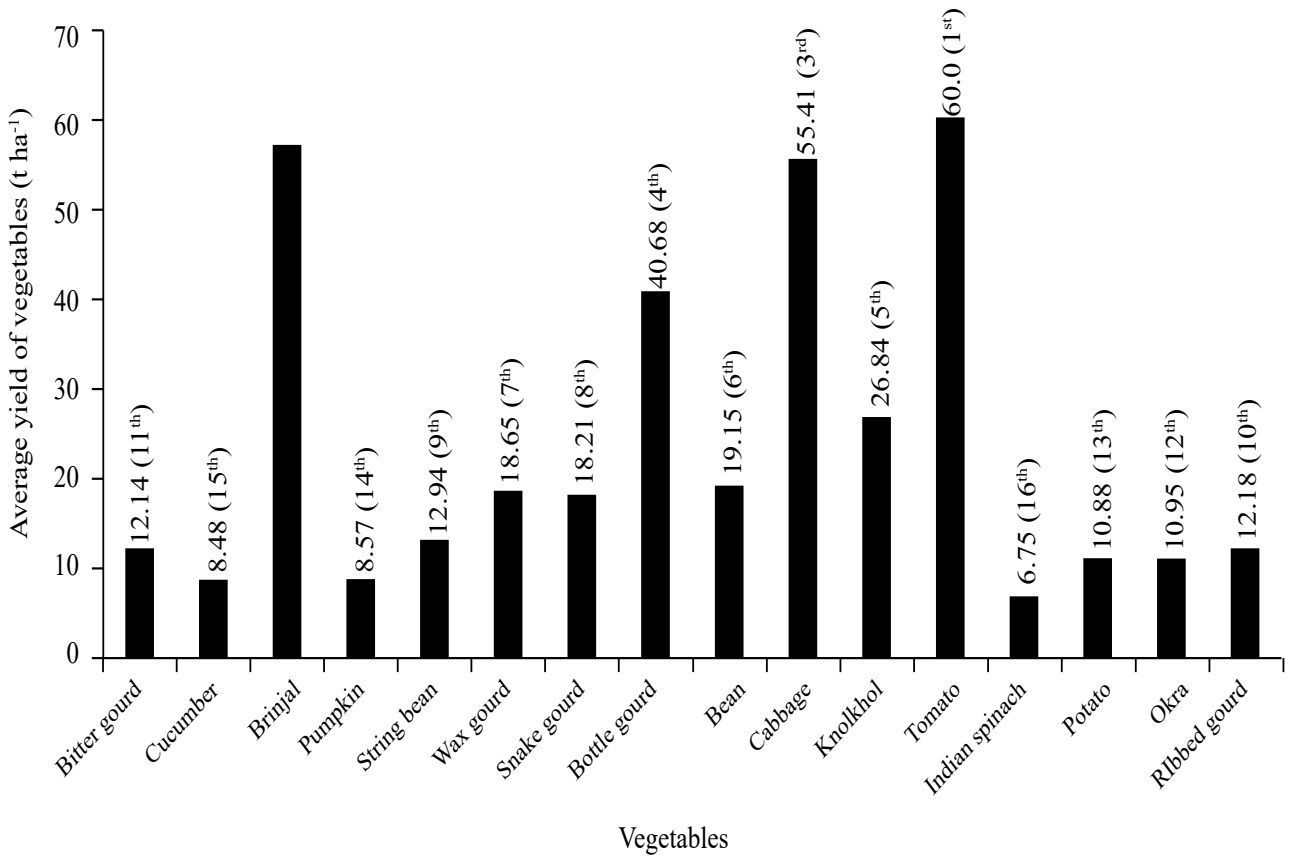


Figure 1. Yield of vegetables grown on the dykes on brackish water ghers in the study area (value in the parenthesis indicates the rank order based on yield).

Vegetable production on Ghers can contribute significantly to local food security. By utilizing otherwise challenging environments, communities can diversify their agricultural activities and enhance their resilience to changing environmental conditions. Vegetables are rich in essential nutrients, and their cultivation can provide a valuable source of nutrition for local populations. Additionally, successful vegetable production can have positive economic impacts by creating opportunities for local farmers to generate income through the sale of their produce.

Farmers confronted a total of 29 problems to different extents of severity. 'Rats attack' was the highly severe problem while 'Shortage of laborer' and 'High wage of laborer' were the least severe problems (Table 9). The other major problems were 'Lack of preservation facilities', 'Lack of technical knowledge for identification of diseases', 'Lack of technical knowledge for identification of insect-pests', and 'High percentage of insect-pests attacks'. Akter *et al.* (2019) also reported that lack of technical knowledge for the identification of diseases (1st) and insect pests (2nd)" had been the two most severe problems of dyke vegetable production at freshwater Ghers. About three-fourths (74.6%) of the respondents had confronted medium problems followed by high (25.4%) problemsi.e., all of the respondents (100%) fell into medium to high problem confrontation categories. None of the respondents belonged to the low problem confrontation category (Table 10). Akter *et al.* (2019) and Rashid *et al.* (1992) found that all of the respondents belonged to low to medium categories of problem confrontation and none of them confronted high problems.

Among the 13 selected characteristics of the respondents, experience in farming and experience in fish farming showed a positive significant relationship with the problem confrontation (Table 11). It means that the higher the experience in farming and experience in fishing, the higher the ability of the farmers to identify the problems in dyke vegetable cultivation. The statement suggests

Table 9. Rank order of problems based on problem confrontation index

Types of problems	Severity of the problems (N = 67)					PCI		Rank order
	HS (3)	MS (2)	LS (1)	NAA (0)	Total	Score	%	
1. Unavailability of seed and/ seedlings	10	46	11	0	67	133	66.16	10th
2. High price of seed / seedlings	22	44	22	0	67	176	87.56	7th
3. Problem of seed germination	11	50	6	0	67	139	69.15	9th
4. Purity of seed	23	39	5	0	67	130	64.67	11th
5. Lack of knowledge for selecting appropriate vegetables	0	17	50	0	67	84	41.79	19th
6. Unavailability of fertilizer in season	5	44	17	1	67	120	59.70	14th
7. High demand and high price of Fertilizer	17	40	10	0	67	124	61.69	12th
8. Lack of good quality fertilizer	36	24	7	0	67	163	81.09	8th
9. Lack of knowledge of balanced fertilizer	2	13	52	0	67	84	41.79	19th
10. Fertilizer enhance insect attack	58	7	2	0	67	190	94.52	6th
11. Lack of technical knowledge of Fertilizer application	1	24	42	0	67	93	46.26	17th=
12. Deficiency of irrigation water in season	3	10	53	1	67	83	41.29	20th=
13. Contamination of salinity in irrigation water	2	8	56	1	67	79	39.30	21th
14. High percentage of insect attack	58	6	3	0	67	189	94.02	5th
15. High percentage of diseases	54	7	6	0	67	182	90.54	6th
16. High price of insecticide or pesticide	58	8	1	0	67	191	95.02	4th=
17. Lack of technical knowledge for identification of Insects	59	6	2	0	67	191	95.02	4th=
18. Lack of technical knowledge for identification of Diseases	59	7	1	0	67	192	95.52	3rd
19. Poor productivity	5	26	34	2	67	101	50.24	16th
20. Low market price in respect of production cost	0	22	44	1	67	89	44.27	18th
21. Lack of marketing facilities	9	3	50	5	67	83	41.29	20th=
22. Lack of preservation facilities	64	1	2	0	67	196	97.51	2nd
23. Lack of loan facilities	8	38	21	0	67	121	60.19	13th
24. Lack of information	8	19	40	0	67	102	50.74	15th
25. Salinity reduce the productivity	8	10	49	0	67	93	46.26	17th=
26. Rats attack	67	0	0	0	67	201	100	1st
27. Security of products	0	7	56	4	67	70	34.82	22th
28. Shortage of labor	0	0	64	3	67	64	31.84	23th=
29. High wage of labor	0	2	64	1	67	64	31.84	23th=

HS=Highly severe, S= Severe, LS= Less severe, NAA= Not at all, PCI= Problem confrontation index

that individuals with more experience in both farming and fishing are more likely to possess enhanced skills in identifying issues related to dyke vegetable cultivation. In other words, the accumulated knowledge and expertise gained from practical involvement in farming and fishing activities contribute to a higher ability to recognize and address problems specific to cultivating vegetables in dyke areas. The implication is that hands-on experience in these related fields can enhance problem-solving capabilities in the context of dyke vegetable cultivation. The rest of the characteristics of the respondents did not show any significant relationship with their problem confrontation. Rashid *et al.* (1992) and Ahmed *et al.* (2007) reported similar types of findings. Ahmed *et al.* (2007) and Rashid *et al.* (1992) found that experience in poultry farming and experience in crop farming had a positive significant relationship with problem confrontation in poultry farming and Agroforestry practices respectively.

Conclusions

The dykes, averaging 8.89±4.69 decimals in area and 1.73±0.34 m in width, are prepared using spading or pits. Vegetable cultivation occurs during the Kharif-2 season (July 01 to October 15). Farmers grow 16 types of vegetables, predominantly bitter gourd (86.56%), cucumber (82.08%), and pumpkin (76.11%), employing two cropping patterns. The cropping intensity is 162%, with 76.1% of respondents harvesting vegetables four times. Top yields include tomato (60 t ha^{-1}), brinjal (57.09 t ha-1), and cabbage (55.41 t ha^{-1}). The average expenditure and net income per hectare for vegetables are 79,531.25 BDT (935.90 USD) and 2,40,762.5 BDT (2,833.21 USD), respectively. The dykes cover 4,149.75 ha, potentially producing 1,04,438.83 tons of vegetables. The study identifies 29 problems, with “rats attack” being the most severe (100%).

Table 10. Distribution of respondents based on confronted problems scores

Categories of problem confrontation	Score	Respondent (N=67)		Mean±SD	Range	
		Number	Percentage (%)		Min.	Max.
Low	1-29	0	0			
Medium	30-58	50	74.6	55.91±4.7	40	67
High	>58	17	25.4			

Table 11. Relationship between the selected socioeconomic characteristics of the respondent farmers and their problem confrontation regarding dyke vegetable production

Focusissue	Characteristics (measuring unit)	Correlation coefficient	Correlation type
Problem confrontation of dyke vegetable production	1. Age (year)	0.190^{NS}	PPCC (*r*)
	2. Level of Education (year ofschooling)	-0.002^{NS}	PPCC (*r*)
	3.Experience in farming (year)	0.308^{*}	PPCC (*r*)
	4.Experience in fishing (year)	0.281^{*}	PPCC (*r*)
	5.Experience in Dyke vegetable cultivation (year)	0.019^{NS}	PPCC (*r*)
	6. Family Size (number)	0.014^{NS}	PPCC (*r*)
	7. Farm Size (hectare)	0.083^{NS}	PPCC (*r*)
	8. Annual family income (‘000’ BDT)	0.216^{NS}	PPCC (*r*)
	9. Organizational participation (score)	-0.133^{NS}	SRCC (ρ)
	10. Loan from organization (0’000’ BDT)	0.114^{NS}	PPCC (*r*)
	11.Cosmopoliteness (score)	0.006^{NS}	SRCC (ρ)
	12. Training experience (number)	0.081^{NS}	PPCC (*r*)
	13. Extension media contact (score)	-0.025^{NS}	SRCC (ρ)

NS= Non-significant; ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed); PPCC – Pearson’s Product Moment Correlation Coefficient (*r*); SRCC – Spearman’s Rank Order Correlation Coefficient (ρ)

Acknowledgement

The authors are grateful to the University Grants Commission (UGC) of Bangladesh for selecting and issuing grants for conducting the research project.

References

Ahmed MB, Biswas S, Mannan MA and Amin MR. 2007. Problem confrontation of poultry farmers of Dumuria upazila under Khulna district. South Asian Journal Agriculture, *2*: 15-20.

Ahmed MB. 2011. Shrimp farming: Impact on socioeconomic, agriculture and environmental conditions in the southwestern coastal region of Bangladesh. LAP LAMBART Academic Publishing GmbH & Co., Germany, p. 174.

Akter J, Ahmed MB, Mannan MA, Islam MM and Mondal AB. 2019. Present status and problem confrontation of dyke vegetable production at freshwater gher in Bagerhat district of Bangladesh. Research in Agriculture, Livestock and Fisheries*, 6*: 69-78. https://doi.org/10.3329/ralf.v6i1.41387

Habib-Ur-Rahman M, Ahmad A, Raza A, Hasnain MU, Alharby, HF, Alzahrani YM, Bamagoos AA, Hakeem KR, Ahmad S, Nasim W, Ali S, Mansour F and El Sabagh A. 2022. Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. Front Plant Science, *10*: 13:925548. doi: 10.3389/fpls.2022.925548.

Hillel D. 2000. Salinity management for sustainable irrigation: Integrating science, environment and economics. The World Bank, Washington DC, p. 24.

Hossain MS, Uddin MJ and Fakhruddin ANM. 2013. Impacts of shrimp farming on the coastal environment of Bangladesh and approach for management. Reviews in Environmental Science and Biotechnology, *12*: 313-332.

Kothari CR. 2004. Research Methodology: Methods and Techniques. 2nd Edition. New Delhi: N*ew* Age International Publishers.

Lin BB. 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. Bio-Science*, 61*: 183-193. https://doi.org/10.1525/bio.2011.61.3.4.

Minhas PS. 2012. Sustainable management of brackish-water agriculture. National Institute of Abiotic Stress Management, Maharashtra, 413115, India.

Nishi NY, Islam MM and Ahmed MB. 2019. Participation of rural women in organic farming. Asian Journal of Agricultural Extension, Economics & Sociology *33*: 1-14. https://doi.org/10.9734/ajaees/2019/v33i330178

Rahman MM. 2011. Country report: Bangladesh, ADBI-APO Workshop on Climate Change and its Impact on Agriculture. Ministry of Agriculture, Bangladesh.

Rashid HA, Ali MY, Ahmed MB, Islam MM and Majumdar I. 1992. The economics of horticulture on fish pond dykes, 2-31. In: Tripathi SD, Ranadhirand M and Purushottarnan CS (Eds.), Aquaculture Economics Proceedings of the Workshop on Aquacultural Economics, 20 November 1992.

Roy AK, Rai SP, Saha BK, Sen PR, Datta AK, Das CR and Rai SP, Roy AK, Datta AK, Das CR and Ghosh JK. 1996. A record production from an integrated farming system utilizing sewage enriched water. Journal of the Indian Fisheries Association, 26 (Proc.Nat.Symp. Aquacrops): 33-40.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 127-133

EVALUATION OF MEAT PROCESSING KNOWLEDGE, ATTITUDE, AND PRACTICE WITH SOCIO-ECONOMIC CONDITION OF BUTCHERS

Md. Arafat Jaman[1*], Ayesha Khatun[2], Tahera Yeasmin[3] , Begum Fatema Zohara[1], Md. Faruk Islam[1]

[1]Department of Medicine Surgery & Obstetrics , Faculty of Veterinary & Animal Science; Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. [2]Department of Animal Science and Nutrition, Faculty of Veterinary & Animal Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur. [3]Department of Dairy and Poultry Science, Faculty of Veterinary & Animal Science ;Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh

Corresponding e-mail: arafatjaman.hstu@gmail.com

Received: 29 November 2023, revised: 07 December 2023, accepted: 12 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.5

ABSTRACT

The present research set out to assess Bangladesh's socioeconomic situation, meat processing knowledge, attitudes, and practices (KAP), and the state of the nation's butcher shops. The investigation of 200 butcher shops was carried out between June 2022 and July 2023 using an organized questionnaire. The interview schedule addressed the butchers' socioeconomic situation, the meat market's infrastructure, their educational attainment and other characteristics. Seventy two percent of butchers chose agriculture as their secondary career, 98% were men, and 16% were illiterate. Each week the percentage of slaughter animals with the highest ratio (1-2) was 49%, and the percentage of animals with the lowest ratio (>5) was 23%. The butchers incomes per month ranged between 30000 and 40000 (BDT), 34% had the highest proportion, and for those >40000 (BDT), 16% had the lowest. The roofs of the butcher shops were tin sheds (90%). The drainage system is an important issue for butcher shops, which were subdivided into no sewerage (45%), soil made (26%), cannel (15%), and concrete (14%). It was concerning to learn that 27% of butchers were aware of an antibiotic withdrawal period. The meat shop's biosecurity is currently appropriately managed to a 43% extent. 31% of butchers were knowledgeable about animal welfare and animal enjoyment. The negative effects of steroid use were known to 38% of butchers. Only 23 % of butchers knew about antibiotic resistance. In terms of meat handling and hygiene procedures, only 34% have training. The r_s value of knowledge of quality meat, known as diseased animals, known as life-threatening zoonotic diseases, parasitic infestation knowledge, environmental pollution concern, knowledge of the antibiotic withdrawal period, knowledge of animal welfare, knowledge of the harmful effects of steroid use, knowledge of microbial resistance, and training on meat handling negatively correlated with the educational level and had a significant ($p<0.01$) negative strongly ($r_s > 0.3$) relationship with the educational level. It indicates that the educational level increased with the improved awareness of knowledge about the health hazards of meat, which was significant ($p<0.01$). To solve current challenges, the government and the appropriate authority in the livestock industry should take necessary action.

Keywords: Butcher, socioeconomic situation, knowledge, biosecurity, livestock

Introduction

A meat marketing chain can be defined as the full range of activities required to bring a product (e.g., live cattle) to final consumers passing through the different phases of production, processing, and delivery. Only 2% of the farmers in the research sold their cattle directly to the marketplace; the majority sold to local dealers (70% to village traders, 15% to sub-district traders, 3% to district traders, 10% to other farms, and 2% to butchers). According to Patrick (2010), rather than selling their cattle to butchers directly, the majority of farmers in Bali and Lombok prefer to sell them to collectors, either on-farm or in a local market. According to Priyanti's (2012) research, live weight, body condition, breed, and sex all affected farm-gate cow prices. This suggests that price information about market demands is effectively transmitted. The sellers who were interviewed stated that the primary buyers of beef from the traditional market were restaurants, street vendors, homes, and companies that produced meatballs, in that order of significance. According to Priyanti and Putu (1999), wet markets control the majority of the beef industry and provide a tiny amount of the prime-grade meat

that restaurants and hotels need. Still, the majority of large hotels, eateries, and supermarkets would rather purchase their imported meat from meat distributors (Patrick *et al.* 2010). Beef cattle from neighboring provinces may travel through East Java before arriving in Jakarta as the major end-market, according to Deblitz *et al.* (2010). He noted in Hadi *et al.* (2002) that livestock are transported by land and sea from East Java to Jakarta. Farmers in West Nusa Tenggara have a tendency to sell and slaughter unhealthy cattle, as stated by Hermansyah and Mastur (2008). According to Alam *et al.* (2009), there were no government regulations pertaining to slaughterhouses that were followed there. The Bangladeshi government introduced the "Slaughterhouses Act 2011," a new law pertaining to animal slaughter and meat quality control, with the goal of improving meat safety through facility modernization. The slaughter of animals is a rather taboo topic; no one wants to know about it. noted anthropologist Noelle Vialles (Vialles 1994).

There isn't much information in the literature regarding the hygienic conditions and working conditions in Bangladesh's meat industry. Rahman (2001) claims that Bangladeshi livestock is treated carelessly during the handling of slaughtered animals. Large-scale slaughterhouses and meat processing facilities in emerging nations are not the same as those located in rural areas with smaller-scale slaughterhouses (Clottey 1985). From this point of view, the present study was undertaken to assess the present status of the beef markets in the selected Rangpur & Dinajpur district, to determine the meat processing knowledge, attitude, and practice (KAP) analysis of butchers and to evaluate the socioeconomic condition of butchers.

Materials and Methods

Study area: The investigation proceeded for an entire year, from June 2022 to July 2023. Interviews with butchers and slaughterhouse employees were conducted in Bangladesh's Dinajpur and Rangpur districts in order to acquire the information. The respondents were chosen to finalize passing through the different phases of production, processing, and delivery of meat. A randomly chosen respondent who worked in a meat shop was interviewed in each upazila.

Process of data collection: The survey was performed using socioeconomic and knowledge, attitude, and practice (KAP) data about meat processing that were gathered through in-person interviews and the observational synthesis of a common pre tested standard questionnaire. Data from respondents was collected through in-person interviews. The majority of the time, interviews were conducted at the respondents' houses and fields when they had free time. The observation of slaughterhouses and butcher shops was carefully done. Government livestock authorities were questioned during key informant interviews (KII). A total of 300 meat shop data points were collected.

Parameters studied: The socioeconomic standing of the butchers, the infrastructure of the meat market, the relationship between educational attainment, and other factors were all covered in the interview schedule. Identification of problems and recommendations during marketing.

Computing and statistical analysis of data: Descriptive analysis was done, like average and percentages as well as Spearman correlation coefficient (r_s) and level of significance through SPSS Statistics 25.0.

Spearman correlation coefficient is measured by following the formula,

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}.$$

Where ,

- $d_i = \mathrm{rg}(X_i) - \mathrm{rg}(Y_i)$, is the difference between the two ranks of each observation.
- n is the number of observations

Results and Discussion

The socio-economic conditions of butchers were categorized into five distinct categories: level of education, sex, occupations other than beef trading, work experiences, and attendance at training on meat handling. The level of education of the butchers was classified into five groups: illiterate, primary, SSC, HSC, and above SSC, respectively.

The outcomes reveal that the highest proportion (55%) of the butchers studied at the primary level, followed by SSC (20%), illiterate (16%), HSC (7%), and 2% who had a level of education above the graduate level. The state of education is currently getting better in Bangladesh. About 80.5% of kids in 2017 finished their primary education, with 98% of them attending school. 59.6% of secondary school students nationwide and 50.5% of postsecondary students are enrolled in secondary education (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021). 98% of the butchers were male, and 72% of butchers had taken agriculture as their secondary occupation. The highest proportion of the butcher`s work experience was between 5 and 10 years. Smigic *et al.* (2016) discovered that the majority of the employees in a study on Serbian meat establishments had between two and eight years of work experience. Every week the ratio of slaughtered animals (1-2) with the highest percentage was 49%, and the one with the lowest percentage (>5) was 23%. The largest percentage of income (31000–40000 BDT) was 34%, while the lowest percentage (>40000 BDT) was 16%. Only 34% of those who attended training on meat handling found this study. Meat handlers gain more understanding from training programs (Ansari-Lari *et al.* 2010). Food borne illness prevention mostly depends on the training of meat workers (Nel *et al.* 2004, Shojaei *et al.* 2006). It is assumed that workers in slaughterhouses have received training (Nel *et al.* 2004).

In this study the infrastructure of the meat shop was divided into three broad categories (floor type, type of roof and drainage system) which were further sub divided into various parameters. Floor type was further classified into bricks, concrete and soil respectively. The highest ratio was bricks made floor (48%) and then concrete (35%) and soil (17%) respectively. The highest percentage of roofs of the shops were tin sheds (90%). As reported by Cook *et al*. (2017), in western Kenya, 72% of slaughterhouses had solid walls, 89% had cement floors, and 65% had roofs. The drainage System is an important issue for butcher shop which was sub divided into no sewerage (45%), soil made (26%), cannel (15%) and concrete (14%). According to research done in 2007 by Alam *et al.* (2009) and Mahendri *et al.* (2012), 40% of the slaughterhouses in

Table 1. Socio-economic characteristics of the butcher/seller in butcher shops

Parameters	Categories	Frequency	Percentage
Level of Education	Illiterate	32	16%
	Primary	110	55%
	SSC	40	20%
	HSC	14	7%
	Graduate &Over	4	2%
Sex	Male	196	98%
	Female	4	2%
Other occupations than beef trading	Agriculture	144	72%
	Business	56	28%
Work experiences	< 5 years	64	32%
	5–10 years	116	58%
	> 10 years	20	10%
Monthly income (BDT)	10000-20000	44	22
	21000-30000	56	28
	31000-40000	68	34
	40000<	32	16
Slaughter animal (Weekly)	1-2	98	49
	3-5	56	28
	>5	46	23
Attended training on meat handling	Yes	68	34%
	No	132	66%

the Gazipur area lacked suitable lighting, 40% had poor ventilation, and 50% lacked drainage facilities. Alam *et al.* (2020) found the same condition in Mymensingh and Gazipur in 2017. The necessary utilities that were found in the butcher shops were tabulated in Table 2. The water supply system was tube well (80%), pond (13%) and tap water (7%) respectively. Electricity supply was sub-divided into no electricity (63%), grid (35%) and non grid (2%). The waste disposal system of the meat shops was categorized into offer to dog (37%), pit (32%) and open field (31%). The exact process by which diseases spread from one animal to another and from humans to animals was hotly debated in the late 19th and early 20th centuries (Rosenkrantz, 1985).

Table 3 from this study reveals that 77% of butchers knew what quality meat was. Identified diseased animals—about 72% butchers. Slaughterhouses and meat markets disclosed that 10% of their operations involved the slaughtering of sick animals and the same results found by Cook *et al.* (2017). There were about 39% of butchers known to have life-threatening zoonotic diseases. This is an unacceptable situation that may lead to the spread of zoonotic diseases such as cysticercosis (Mann *et al.* 1983). In the study by Cook *et al.* (2017), just 34% of employees in slaughterhouses were aware of the zoonotic illness. Only 43% of butchers were aware of parasite infections. 36% of butchers were aware of the dangers of pollution. It was concerning to learn that 27% of butchers had knowledge of the antibiotic withdrawal period. The meat market's biosecurity is only properly maintained in 43% of its areas. 31% of butchers were knowledgeable about animal welfare and enjoyed it. 38% of butchers knew that using steroids had negative effects. The fact that only 23% of butchers were aware of antibiotic resistance was a very dangerous incidence. Only 34% of people received training on hygienic methods for handling meat. Both theories have traditionally been applied to federal meat inspection legislation, such as the Meat Inspection Acts of 1891 and 1906 [Kolko, (1963), FAO (CAC/RCP 58-2005)]. Legal authorities have set criteria that farmers must go by in order to guarantee the quality of their beef (Murphy *et al.* 2014).

Table 2. Infrastructure of meat shop

Parameters	Categories	Frequency	Percentage
Floor Type	Bricks	96	48%
	Concrete	70	35%
	Soil	34	17%
Type of Roof	Building	18	9%
	Straw made	2	1%
	Tin shed	180	90%
Drainage System	Cannel	30	15%
	Concrete	28	14%
	No sewerage	90	45%
	Soil made	52	26%
Water Supply	Pond	26	13%
	Tap water	14	7%
	Tube well	160	80%
Electricity	Grid	70	35%
	No electricity	126	63%
	Non grid	4	2%
Waste Disposal system	Offer to dog	74	37%
	Open field	62	31%
	Pit	64	32%

Table 3. Correlation between the Educational Level and other variables

Parameter	Categories	% of farmers	Spearman correlation coefficient (r_s)	Level of sig.
Knowledge of quality meat	Yes	77	-.766**	**
	No	23		
Known as diseased animal	Yes	72	-.850**	**
	No	28		
Known as life threating zoonotic diseases	Yes	39	-.644**	**
	No	61		
Parasitic infestation knowledge	Yes	43	-.652**	**
	No	57		
Environmental pollution concern	Yes	36	-.404**	**
	No	64		
Knowledge Antibiotic Withdraw period	Yes	27	-.642**	**
	No	73		
Biosecurity Maintain	Yes	43	-.654**	**
	No	57		
Knowledge of Animal Welfare	Yes	31	-.636**	**
	No	69		
Knowledge of Harmful effect of steroid use	Yes	38	-.642**	**
	No	62		
Knowledge of Antimicrobial Resistance	Yes	23	-.652**	**
	No	77		
Training on meat handling	Yes	34	-.637**	**
	No	66		

$r_{s,}$=Spearman correlation coefficient; NS, Non-significant ($p>0.05$); *= $p<0.05$, **= $p<0.01$

The r_s value of knowledge of quality meat, known as diseased animals, known as life-threatening zoonotic diseases, parasitic infestation knowledge, environmental pollution concern, knowledge of the antibiotic withdrawal period, knowledge of animal welfare, knowledge of the harmful effects of steroid use, knowledge of microbial resistance, and training on meat handling negatively correlated with the educational level and had a significant ($p<0.01$) negative relationship with the educational level. The r_s value of all parameters had a negative correlation but was strongly ($r_s > 0.3$) correlated (Table 3), which was significant ($p<0.01$). Here we can say that poor educational level and biosecurity are more suspected of using illegal ways to increase the risk of public health. It indicates that the educational level increased with the improved awareness of knowledge about the health hazards of meat, which was significant ($p<0.01$).

Conclusion

The goal of the current study was to determine the current state of the beef markets and the quality of the beef in the Dinajpur and Rangpur district of Bangladesh. This experiment was carried out to assess the state of the market using a survey. The outcome showed that the state and quality of the beef market are related to a number of internal and external factors. It is acceptable to use hygienic procedures while processing and management raw beef in order to manage dangerous bacteria that could endanger public health. To address present issues, the government and the appropriate livestock sector authorities have to step up.

Acknowledgement

The another acknowledge greatly Science and Technology Ministry (NST) for financial support to conduct the present study. The authors greatly acknowledge Ministry of Science and Technology for the financial support to conduct the present study.

References

Alam MK, Hossain MM, Islam R and Akhter S. 2009. Management of slaughterhouse and meat selling centres to supply quality goat meat for human consumption. Journal of the Bangladesh Society for Agricultural Science and Technology, *6*: 135-140.

Alam MK, Keiko Y and Hossain MM. 2020. Present working conditions in slaughterhouses and meat selling centres and food safety of workers in two districts of Bangladesh. Pertanika Journal of Social Sciences & Humanities, *28*: 867-881.

Ansari-Lari M, Soodbakhsh S and Lakzadeh L. 2010. Knowledge, attitudes and practices of workers on food hygienic practices in meat processing plants in Fars, Iran. Food Control, *21*: 260-263.

Clottey SJA. 1985. Manual for the slaughter of small ruminants in developing countries. FAO, Rome, Italy.

Cook EAJ, Glanville WAD, Thomas LF, Kariuki S, Bronsvoot BMDC and Fevre EM. 2017. Working conditions and public health risks in slaughterhouses in western Kenya. BMC Public Health, *17*: 14. https://doi. org/10.1186/ s12889-016-3923-y.

Deblitz C, Hadi PU, Teddy. 2010. A draft summary of the project benchmarking the beef supply chain in eastern Indonesia. Paper presented in benchmarking the beef supply chain in eastern Indonesia workshop, Jakarta.

Food and Agriculture Organization of the United Nations. 2005. Code of hygienic practice for meat (CAC/RCP 58-2005). FAO, Rome, Italy.

Hadi PU, Ilham A, Thahar B, Winarso D, Vincent and Quirke. 2002. Improving Indonesia's beef industry. ACIAR, Australia.

Hermansyah, M. 2008, November. Pemotonnegan ternak tidak tercatat, studi di Kota Mataram, Nusa Tenggara Barat. In: Proceedings of the seminar of nasional sapi potonneg.

Kolko G. 1963. The triumph of conservatism. Glencoe, IL: Free Press.

Mahendri IGAP, Priyanti A and Cramb RA. 2012. Characterizing the marketing chain for beef cattle in east Java, Indonesia. In: Proceedings of the 15th AAAP Animal Science Congress, Pp. 26-30.

Mann I, Koulikovskii A and Matyas Z. 1983. Guidelines on small slaughterhouses and meat hygiene for developing countries. Geneva, Switzerland: WHO.

Murphy KJ, Parker B, Dyer KA, Davis CR, Coates AM, Buckley JD and Howe PR. 2014. A comparison of regular consumption of fresh lean pork, beef and chicken on body composition: a randomized cross-over trial. Nutrients, *6*: 682-696.

Nel S, Lues JFR, Buys EM and Venter P. 2004. The personal and general hygiene practices in the de-boning room of a high throughput red meat abattoir. Food Control, *15*: 571-578.

Patrick IW, Graham R and Marshall IGAA, Ambarawati, Muktasam Abdurrahman. 2010. Characterising the marketing chain for beef cattle in east Java, Indonesia, AGRARIS: Journal of Agribusiness and Rural Development Research, *7*: 176-190

Priyanti A and Putu. 1999. Processing and marketing of livestock products in Indonesia in livestock industries of Indonesia prior to the Asian Financial Crisis. Food and Agriculture Organization of the United Nations Regional Office For Asia and The Pacific, Pp. 63-76.

Priyanti A, Mahendri IGAP, Cahyadi F and Cramb R. 2012. Factors affecting the farm-gate selling price of smallholder beef cattle in East Java, Indonesia. In Proceedings of the 15th AAAP Animal Science Congress, Pp. 26-30.

Rahman MM. 2001. Fundamentals of Meat Hygiene. Department of Microbiology and Hygiene, Bangladesh Agriculture University of Mymensingh.

Rosenkrantz B. 1985. The trouble with bovine tuberculosis. Bulletin of the history of medicine, *59*: 155-175.

Shojaei H, Shooshtaripoor J and Amiri M. 2006. Efficacy of simple hand-washing in reduction of microbial hand contamination of Iranian food handlers. Food Research International, *39*: 525-529.

Slaughterhouse Act. 2011. Ministry of Law, Justice and Parliamentary Affairs, Government of the people's republic of Bangladesh. Retrieved August 30, 2018, from http://bdlaws.minlaw.gov. bd/bangla_all_ sections.php?id=1079.

Smigic N, Antic D, Blagojevic B, Tomasevic I and Djekic I 2016. The level of food safety knowledge among meat handlers. British Food Journal, *118*: 9-25.

United Nations Educational, Scientific and Cultural Organization. 2021. Country profile, Bangladesh. Montreal, Canada: UNESCO Institute for Statistics. Retrieved March, 2023, from http://uis.unesco.org/country/BD.

Vialles N. 1994. *Animal to edible.Cambridge*, England: Cambridge University Press.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 135-143

VARIATION IN THE MACRO-MORPHOLOGICAL TRAITS OF LEAVES IN RESPONSE TO AUTOMOBILE POLLUTION IN SELECTED URBAN TREE SPECIES IN THE CITY OF DHAKA

Md Abul Kashem*, Mohammad Ataur Rahman, Sirajum Munira Hussaini, Md Morsalinur Rashid and Mohammad Zabed Hossain

Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh

***Corresponding e-mail:** kashembotany@du.ac.bd

Received: 08 October 2023, revised:09 December 2023, accepted: 10 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.6

ABSTRACT

The present study was carried out at National Botanical Garden, Dhaka, considered as control site and Motijheel-Sayedabad roadside areas as polluted site to compare the impact of automobile pollution on leaves macro-morphological traits of selected ten plants growing in the polluted areas with those growing in control sites. Leaf morphological characteristics including leaf abnormalities of both young and mature leaves were assessed. Variations in leaf color such as light green, dark green, browning, yellowing and change in the leaf's shape either normal or deformed were also assessed for both the sites. All the selected plant species showed highly significant ($p<0.0001$) reduction at polluted site in their all leaf macro-morphological traits (leaf length, leaf breadth, leaf area, leaf perimeter, specific leaf area and petiole length) when compared with control site. The findings of this study revealed that the automobile pollution stress influenced tree morphological features in the Dhaka city. This study also indicated that plants go through adaptive processes in order to survive in automobile polluted environments.

Keywords: Air pollution, leaf characteristics, urban areas

Introduction

Automobile pollution refers to the emissions from cars and other vehicular traffic, which mostly include carbon monoxide, nitrogen oxides, carbon dioxide, sulfur oxides, hydro carbon, particulate matter and heavy metals. These harmful gaseous and particle pollutants affects negatively on roadside trees (Joshi and Swami 2009). Due to the stress of car exhaust pollution and high traffic intensity in urban roadside areas, leaf length, leaf breadth, petiole length, leaf area, and specific leaf area are some among the most prominent macro-morphological parameters of leaf have been observed to be significantly altered in plant species (Rodríguez-Alarcón *et al.* 2022, Montes-Pulido 2014, Rai and Mishra 2013). In order to preserve balance and ecological flexibility, plants have a variety of features. In particular, leaf macro- and micro-morphology plays a significant role in the ecosystem benefits which the plant species bring to urban environmental dynamics (Hanisch *et al.* 2020, Matasov *et al.* 2020). Trees are essential to preserving the natural balance in metropolitan areas, and their importance cannot be ignored. Through the absorption of pollutants, the capture of particulate matter, and the release of oxygen, urban trees also help to reduce air pollution levels (Escobedo *et al.* 2006)

The use of motor vehicles is growing fast globally at large and with a far faster rate in developing nations including Bangladesh. In Bangladesh, Dhaka is one of the largest urban areas where the population and vehicles are increasing day by day. The air quality in Dhaka is unhealthy and recently, it has even reached at dangerous levels (Kashem *et al.* 2022) due to our automobiles emit a high level of air polluting gases for their old age, poor performance, and lack of maintenance. Moreover, the situation is made worse by narrow roads, poor geometry, and regular traffic jams. The significant growth in vehicle density in the Dhaka city causes negative consequences on the vegetation growing closest to busy roads. Depending on the pollutant and the species' tolerance, the nature of the negative effects can vary to some extent (Seyyednezhad *et al.* 2013). Therefore, the present work was designed to analyze the effects of automobile exhaust gases on the leaves macro- morphology of different plant species that growing at the road sides in the Dhaka city.

Materials and Methods

Study sites: As control site, the study was conducted at the National Botanical Garden at Dhaka in Bangladesh with an area of around 204 acres. It is located at 23.81660° North and 90.34875° East and divided into 57 sections based on predominant flora and is managed by Forest Department under the Ministry of Environment and Forests, Government of Bangladesh (Al-Kaium *et al.* 2022). It is one of the largest botanical gardens of Bangladesh and a center of knowledge for nature lovers and botanists and a tourist destination. On the other hand, huge amount of petrol driven three wheelers vehicles with diesel driven four stroke engines vehicles are mostly found on the road at Motijheel-Sayedabad areas. These areas were selected as polluted site due to the heavy traffic congestion and emission of significant amounts of pollutants and dangerous substances such as small particles and lead (Kashem *et al.* 2022).

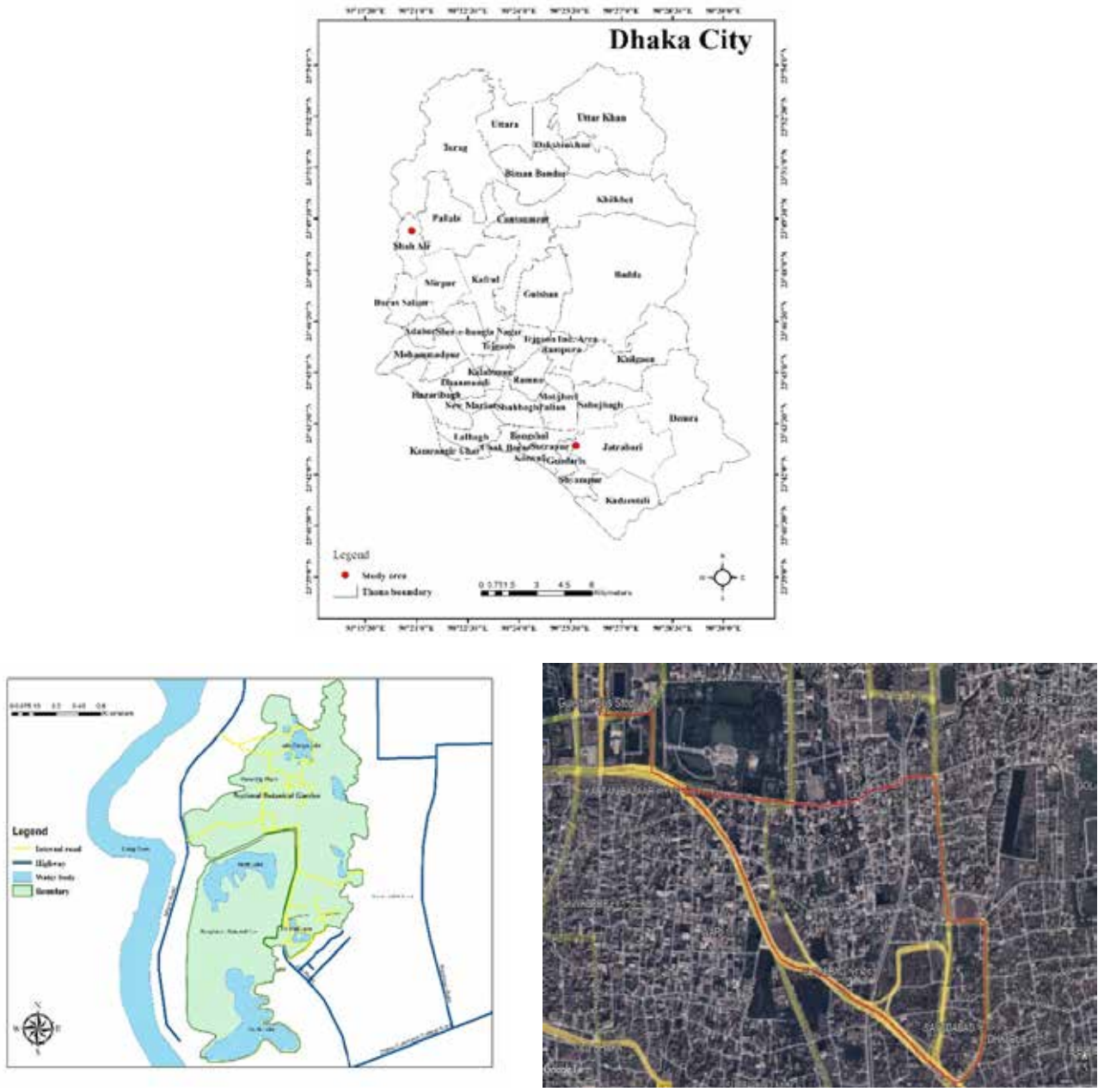


Figure 1: Map showing the control (left side) and polluted site (red marked at the right side) of the study areas in Dhaka city.

Plants material collection: The most frequently common species were considered for both sites and the study was conducted in october 2022. Fresh samples of leaves of jackfruit tree (*Artocarpus heterophyllus*), banyan tree *(Ficus benghalensis*), sacred fig tree *(Ficus religiosa),* spanish cherry (*Mimusops elengi*), false ashoka *(Polyalthia longifolia),* black plum tree (*Syzygium cumini*), mahogany (*Swietenia mahagoni*), arjun tree (*Terminalia arjuna*), indian almond (*Terminalia catappa*) and mango tree (*Mangifera indica*) were collected and then they were brought to the Ecology and Environment Laboratory at the Department of Botany, University of Dhaka. The diameter at breast height (DBH) of selected species varied largely across polluted and control locations, ranging from 18.26 to 189.45 cm, demonstrating variation in growth from site to site. Ten fully expanded youngest leaves were taken from each of the ten tree species where three individuals were selected per species. Thus, a total of 300 young leaves per sampling site were collected for the analysis of color, shape and macro-morphological traits of leaf. Mature leaves were also collected from both sites for the identification of color and shape.

Analysis of macro-morphological traits: Ten leaf attributes were studied to determine the effects of traffic on macro-morphological traits. Table 1 lists these parameters as well as their abbreviations. Six leaves from each tree were taken to examine macro-morphological traits. The macro-morphological parameters such as leaf length, leaf breadth, leaf perimeter, leaf area, specific leaf area and petiole length were measured using photography and ImageJ software (Kashem *et al.* 2022). Specific leaf area (cm^2g^{-1}) was obtained by dividing the leaf area of the sampled leaves by the leaf's dry weight (Jake *et al.* 2020). Changes in color (chlorosis, browning, yellowing, spotting, or change in the leaf's normal pigment) and shape (normal shape or deformed/modified) were also observed on plants from both control site and polluted site. The percentage increase or decrease of leaf traits was calculated using the technique developed by Syed and Iqbal (2008).

Table 1. Macro-morphological traits studied for leaves of selected tree species

Macro-morphological traits	Scale	Abbreviation
Leaf length	Cm	LL
Leaf breadth	Cm	LB
Petiole length	Cm	PL
Leaf area	cm^2	LA
Leaf perimeter	Cm	LP
Specific leaf area	cm^2g^{-1}	SLA

Statistical analysis: ANOVA was used to compare the macro-morphological features of ten plant species from both polluted and control sites. Turkey's HSD was applied to determine the level of significance among the means. JMP 4.0 software (SAS Institute, Carry, NC, USA) was used to analyze the data.

Results and Discussion

The macro-morphological characteristics of *A. heterophyllus, F. benghalensis, F. religiosa, M.elengi, P. longifolia, S. cumini, S. mahagoni, T. arjuna, T. catappa* and *M. indica* leaves were observed and measured in both control and polluted environments. Trees serving as bio-contaminant absorbents can filter poisonous and hazardous compounds through the surface of their leaves and roots, resulting in variations in leaf size during this process (Squires 2016). The leaves sampled from polluted areas exhibited highly significant ($p<0.0001$) reductions in all parameters (length, breadth, area, perimeter, petiole length and specific leaf area) when compared to control site (Table 2). These results were found in the studied polluted site due to different pollutants such as ozone, sulfur dioxide, nitrogen dioxide, and peroxyacetyl nitrate can induce leaf damage and plant harm. Pollution related particulate matter also can cause reduced leaf size, chlorotic and necrotic leaf patches, and decreased chlorophyll concentration. Furthermore, environmental contamination can cause a decline in growth as well as a drop in stomatal frequency and size in leaves. These findings imply that plants are stressed by automobile pollution and have developed adaptive systems to deal with the consequences and these results are also similar to other works (Seyyednezhad *et al.* 2013, Rai and Mishra 2013, Ianovici*et al.* 2011, Laghari and Zaidi 2013).

Table 2. Leaf macro-morphological traits of selected plants in polluted and control sites

Species	Sites	LL	LB	LA	LP	PL	SLA
A. heterophyllus	Polluted	12.23±0.57	6.26±0.38	58.77±2.53	40.19±1.15	1.64±0.06	15.91±0.74
	Control	15.16±0.97	7.05±0.58	79.13±11.36	51.27±7.45	1.68±0.17	25.39±1.92
F. benghalensis	Polluted	14.76±0.39	8.73±0.68	101.13±8.76	54.28±2.07	2.94±0.087	17.39±1.55
	Control	15.38±0.16	9.14±0.66	112.46±8.05	56.21±6.95	4.16±0.09	19.18±2.72
F. religiosa	Polluted	12.34±0.9	7.23±0.85	59.24±13.82	52.49±7.51	5.63±0.97	24.1±0.16
	Control	15.18±0.57	10.2±0.75	91.45±8.66	67.06±1.63	8.45±0.67	32.03±3.68
M. elengi	Polluted	10.81±1.11	4.86±0.35	40.07±6.57	33.09±2.96	1.32±0.31	19.58±1.23
	Control	12.88±1.65	4.96±0.23	46.11±7.52	35.94±5.03	1.48±0.096	20.65±0.46
P. longifolia	Polluted	14.1±0.95	2.48±0.11	26.33±2.85	34.97±1.76	0.61±0.075	17.85±7.44
	Control	25.67±2.58	4.85±0.79	89.7±20.95	70.01±12.6	0.94±0.09	31.59±3.03
S. cumini	Polluted	15.5±0.89	5.19±0.53	59.97±9.43	44.17±2.35	1.07±0.1	12.27±0.18
	Control	18.4±0.29	5.73±0.05	73.94±0.92	50.91±1.01	1.69±0.087	15.46±2.09
S. mahagoni	Polluted	13.54±0.31	4.38±0.02	44.28±1.6	35.64±0.96	0.44±0.023	14.34±1.91
	Control	22.55±1.85	7.28±0.53	115.68±15.3	58.08±5.22	0.8±0.04	22.24±0.6
T. arjuna	Polluted	10.13±0.64	3.84±0.37	32.2±1.58	30.05±2.89	0.42±0.017	16.18±0.63
	Control	11.96±0.98	3.89±0.05	36.55±6.47	30.85±3.03	0.46±0.07	19.18±1.15
T. catappa	Polluted	19.04±2.25	9.32±1.23	131.97±30.5	59.05±6.4	1.52±0.08	15.16±2.58
	Control	20.15±1.3	12.57±0.94	214.36±27.5	71.25±4.73	2.18±0.72	25.08±0.76
M. indica	Polluted	17.25±0.64	4.08±0.31	51.98±4.95	56.08±4.29	2.61±0.17	15.53±1.1
	Control	21.73±2.16	8.35±0.94	98.1±13.34	86.47±8.54	4.66±0.9	16.4±1.7
F ratio		33.58	50.66	38.85	24.79	62.57	5.47
P value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

The statistical t-test revealed that there was highly significant ($p<0.0001$) difference in leaf length data in both two studied sites. *T. arjuna* had the shortest leaf length (11.96±0.98 and 10.13±0.64 cm) at the control and polluted sites, while *P. longifolia* and *T. catappa* had the longest (25.67±2.58 and 19.04±2.25 cm). Figure 2 showed that, the overall average decreasing percentage of leaf length at polluted site compared to control site was found to be in the range of 4.03-45.07%, lowest to highest, in the leaves of *F. benghalensis* and *P. longifolia,* respectively. Kashem *et al*. (2022) found in their study that the overall average leaf length of all studied species except *F. religiosa*was recorded higher at Ramna park site than its adjacent polluted roadside areas. The slow increase in the percentage of leaf length at polluted sites compared to non-polluted sites could be attributed to the effect of air pollution at that site, which affects gas exchange for photosynthesis and leaf productivity. Aribal*et al.* 2016, Keskin and Ili (2012), Makbul *et al.* (2006), and Gielwanowska *et al*. (2005), all made observations that supported these points of view. They discovered that plants growing along the city's major

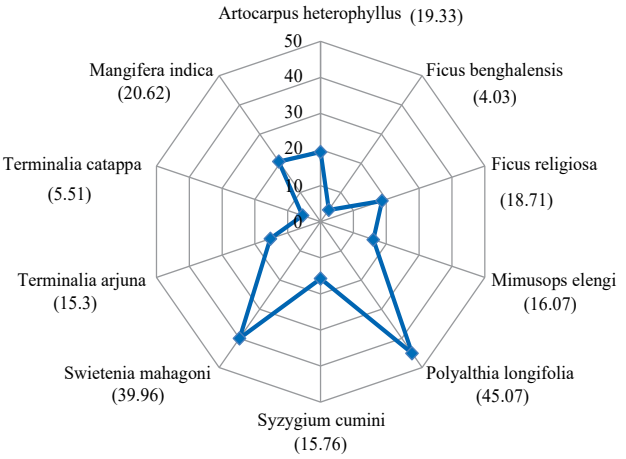


Figure 2. Average decreasing (%) of the leaf length of different plant species at the polluted site compared with the control site.

road are substantially influenced by auto-emission. The presence of hazardous substance in auto-emission causes the inhibitory effects on plant growth.

There were reductions in leaf breadth in all plants among the selected plants in polluted areas from the control site. Table 2 showed that *P. longifolia* and *T. arjuna* had the smallest leaf breadth at polluted and control sites (2.48±0.11 and 3.89±0.05 cm, respectively), while *T. catappa* had the largest (9.32±1.23 and 12.57±0.94 cm). The statistical t-test also revealed a highly significant ($p<0.0001$) difference in the leaf breadth of all plant species between the two sites. *P. longifolia* (48.87%) reduced leaf breadth the most in all selected plant species at polluted site, followed by *S. mahagoni* (39.84%), *M. indica* (35.75%), and *F. religiosa* (29.12%) (Figure 3). Similarly, there were reduction in the breadth of leaf in the polluted plants where *Tabernaemontana divricata* showed the highest reduction in leaf breadth followed by *Nerium olender*, *Azadirachata indica* and *Catharanthus roseus* (Madhumonisa and Saradha 2021). In addition, except *F. religiosa,* leaf breadth was recorded higher in all studied tree species at Ramna park site than its adjacent polluted roadside areas (Kashem *et al*. 2022). Squires (2016) also found that *F. rotundifolia* and *M. alba* showed a significant decrease in the size of leaf length and leaf breadth. These findings also support the study results of Rodríguez-Santamaría *et al.* (2022), Seyyednezhad *et al.* (2013), Laghari and Zaidi (2013) and Ianovici *et al.* (2011), who demonstrated that air pollution can inhibit the growth of leaf size specially leaf length and breadth.

Leaf of all ten plant species used in the study showed a significant difference ($p<0.0001$) in leaf area between two studied sites. The average leaf area of all selected species was found to be greater at the control site than at the polluted location (Table 2). *T. arjuna* and *P. longifolia* had the smallest leaf area at the control and polluted sites (36.55±6.47 and 26.33±2.85 cm^2), whereas *T. catappa* had the largest (214.36±27.5 and 131.97±30.5 cm^2). Polluted plants *P. longifolia* (70.65%) showed the biggest reduction in leaf area, followed by *S. mahagoni* (61.72%), *M. indica* (42.74), and *T. catappa* (38.44%), where *F. benghalensis* showed the lowest reduction (10.07%) (Figure 4). This finding was consistent with the results of Myers (2015) and Ekpemerechi *et al.* (2014), who found that reduced leaf area is the most common observation when assessing the interaction of plants and pollutants. In general, the findings of this study are consistent with the outcomes of previous studies on changes in leaf area in *Acer saccharum*, *Ginkgo biloba* (Sianping *et al.* 2009), *Albizia lebbeck* and *Callistemon citrinus* (Seyyednejad *et al*. 2009a, Seyyednejad *et al.* 2009b) and *Tilia begonifolia* (Yousefzadeh *et al.* 2011).

The ANOVA results demonstrated a highly significant ($p<0.0001$) change in the values of petiole length between control and polluted areas in all plant species (Table 2). The leaves collected from polluted areas showed decrease in petiole length in all selected plant species. The total average decrease in petiole length at the polluted

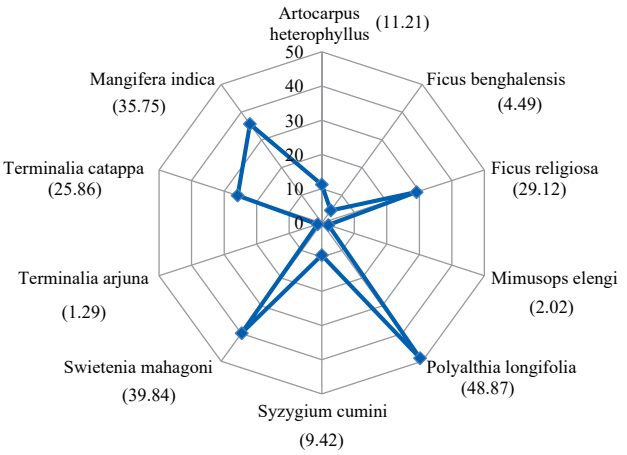


Figure 3. Average decreasing (%) of the leaf breadth of different plant species at the polluted site compared with the control site.

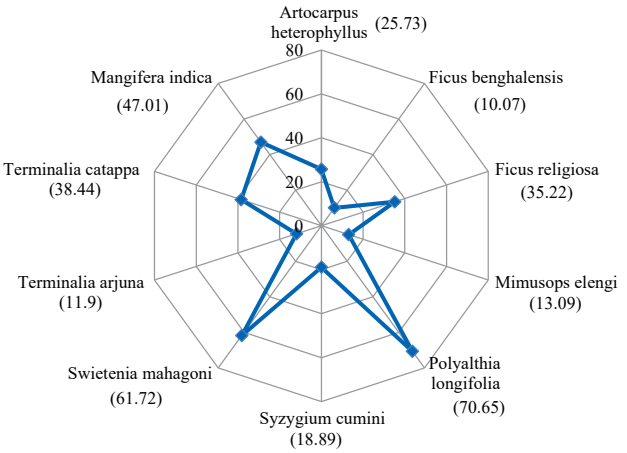


Figure 4. Average decreasing percentage (%) of the leaf area of different plant species at the polluted site compared with the control site.

site compared to the control site was 2.38-45% in *A. heterophyllus* and *S. mahagoni*, respectively. Minimum petiole length at control and polluted site (0.42±0.017 and 0.46±0.07 cm) was found in *T. arjuna*, while maximum (5.63±0.97 and 8.45±0.67 cm) was recorded in *F. religiosa*. The findings of the other study showed similar type of results where petiole length in *Parrotia persica*, *Celtis australis* and *Tilia begonifolia* lower in polluted sites compared to the control sites (Yousefzadeh *et al.* 2009, Zarafshar *et al.* 2010, Akhondnezhad *et al.* 2010). The pollution of the city resulted in significant effects on petiole length of *C. siamea* and *P. pterocarpum* compared to control areas (Zaidi and Leghari, 2004, Shafiq *et al.* 2009).

The statistical t-test revealed a highly significant ($p<0.0001$) variance in the values of specific leaf area between the two selected locations. As indicated in Figure 6, the polluted plants *P. longifolia* (43.49% decrease) had the highest loss in specific leaf area, whereas *M. elengi* (5.18% decrease) had the least reduction. Other remaining plant species, on the other hand, showed reductions ranging from 5.3-39.55% low to high. The specific leaf area of all species was greater at the control site than at the polluted site (Table 2). *S. cumini* had the lowest specific leaf area at the control and contaminated sites (15.46±2.09 and 12.27±0.18 cm^2/g, respectively), whereas *F. religiosa* had the highest (32.03±3.68 and 24.1±0.16 cm^2/g). This finding corresponded with the findings of others, who noticed an identical decrease in leaf area in several

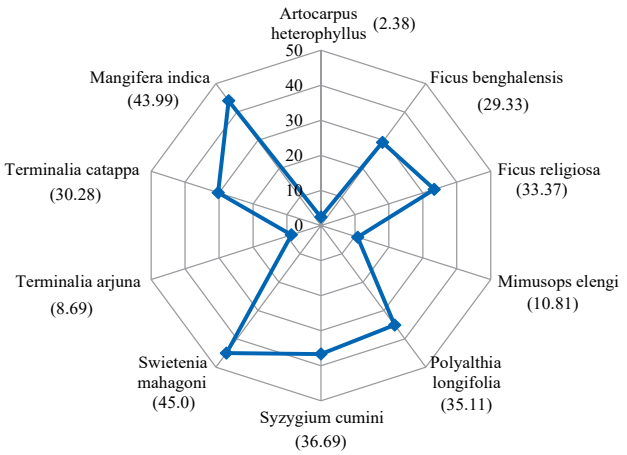


Figure 5. Average decreasing percentage (%) of the petiole length of different plant species at the polluted site compared with the control site.

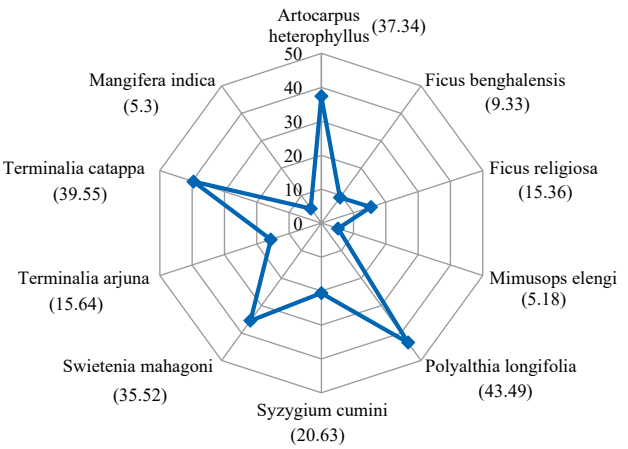


Figure 6. Average decreasing percentage (%) of the specific leaf area of different plant species at the polluted site compared with the control site.

other plant species growing in roadside areas or close proximity to heavy pollutants (Rodríguez-Santamaría *et al.* 2022, Kashem *et al.* 2022, Yousefzadeh *et al.* 2011, Akhondnezhad *et al.* 2010). As a result of the above findings, it is clear that air pollutants have had a negative impact on the leaf surface, as its area remains small at polluted sites compared to control sites.

ANOVA results showed that there was highly significant ($p<0.0001$) variation in the values of leaf perimeter of polluted and control site in all the plant species (Table 2). The overall average decreasing % of leaf perimeter at polluted site with respect to control site was 2.59-50.05% in *T. arjuna* and *P. longifolia*, respectively (Figure 7). The leaves collected from polluted areas showed reduction in leaf perimeter in all studied tree species. Minimum perimeter at control and polluted site (30.85±3.03 and 30.05±2.89 cm) was found in *T. arjuna*, while maximum (71.25±4.73 and 59.05±6.4cm) was recorded in *T. catappa*. Kashem *et al.* (2022) also found in their study that all of the selected plants at the adjoining roadside areas of Ramna park showed decrease in perimeter of leaf with the exception of *F. religiosa*.

Table 3 shows the leaf shape and color of the species under study in both polluted and non-polluted area. Species in polluted area showed significant difference compared to species found in the non-polluted area. The color of leaves vary from light green in polluted site to generally dark green in control site at young and mature growth stage for

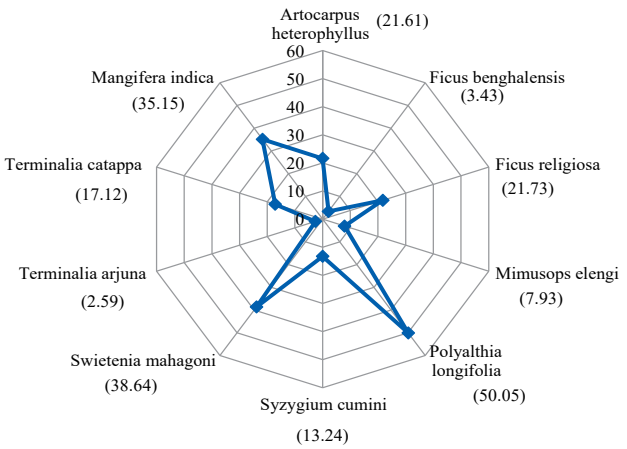


Figure 7. Average decreasing percentage (%) of the leaf perimeter of different plant species at the polluted site compared with the control site.

F. benghalensis and *F. religiosa* while most of the leaves of other species at young stage in polluted area were light green and at mature stage were dark green but in control site the leaves of all species were generally dark green. Moreover, majority of the leaves of *F. benghalensis, F. religiosa, P. longifolia, S. cumini , T. arjuna* and *T. catappa* were deformed at young and mature stage in polluted site while those found in control site exhibited typical leaf shape. For both sites, *A. heterophyllus, M. elengi, S. mahagoni* and *M. indica* at young growth stage had typical leaf shape for both sites, but those found in polluted areas at mature stage were deformed (Table 3). Leaf colors of a plant could be used to identify stress level due to its adaptation to environmental change. Leaves of most the species under study in control site at both young and mature stages were dark green, while the species found in polluted area are relatively lighter. This implies that the chlorophyll pigment on leaves in polluted area might be affected by automobile pollution. According to Giri *et al.* (2013), the photosynthetic pigments are the most likely to be damaged by air pollution and further explained that under stress they may underwent reduction in size and changes in color and shape. Laghari and Zaidi (2013) found in their study that the consequences

Table 3: Leaf morphological changes of selected plant species and growth stages growing in polluted and control sites

Plants name	Family	Growth stage	Color		Shape	
			Polluted site	Control site	Polluted site	Control site
A. heterophyllus	Moraceae	Young	Lg	Dg	T	T
		Mature	Dg	Dg	D	T
F. benghalensis	Moraceae	Young	Lg	Dg	D	T
		Mature	Lg	Dg	D	T
F. religiosa	Moraceae	Young	Lg	Dg	D	T
		Mature	Lg	Dg	D	T
M. elengi	Sapotaceae	Young	Dg	Dg	T	T
		Mature	Dg	Dg	D	T
P. longifolia	Annonaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
S. cumini	Myrtaceae	Young	Lg	Dg	D	T
		Mature	Dg	Dg	D	T
S. mahagoni	Meliaceae	Young	Lg	Lg	T	T
		Mature	Dg	Dg	D	T
T. arjuna	Combretaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
T. catappa	Combretaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
M. indica	Anacardiaceae	Young	Lg	Lg	T	T
		Mature	Dg	Dg	D	T

Lg: Light green; Dg: Dark green; T: Typical; D: Deformed

of macro-morphological features found in the studied species at polluted site were as a significant reduction in the size of leaves and the leaves turned into pale green. Moreover, Plants from polluted areas exhibit significant morphological alterations, particularly in terms of their colors, forms, leaf length, width, area, and petiole length (Seyyednezhad *et al.* 2013, Madhumonisa and Saradha 2021, Hanisch *et al.* 2020, Kashem *et al.* 2020). Overall, the study found that auto-emission has a negative impact on all plant species flourishing in the city's polluted environment.

Conclusion

Urban trees provide a variety of environmental advantages, including improved air quality due to the retention of atmospheric particulate matter on their leaves. In this study, all the selected tree species showed highly significant reduction at polluted site in all macro-morphological traits of leaf when compared with the control site. The findings imply that reducing automobile pollutant emissions is the best technique to maintain air quality and health of tree species in urban contexts. However, constant population increase, urbanization, and consumer demand make this impractical. To ensure the reduction of roadside pollution that affects plants, Bangladesh needs a reliable monitoring system and stronger environmental protection laws.

Acknowledgement

The authors are thankful to the University of Dhaka for providing financial support to conduct this study as part of the Centennial Research Grant (CRG), 2nd phase, 2020-2021.

References

Akhondnezhad S, Nejadsattari T, Sattarian A, Asri Y and Bageriehnajar *Carpinus betulus* M. 2010. The survey of diversity in leaf, branch and fruit morphological characters of in various geographical conditions. Plant Science Researches, *5*: 64-72.

Al-Kaium A, Hosen S and Shamsi S. 2022. Frequency, abundance and distribution of lichen in National Botanical Garden, Mirpur, Dhaka, Bangladesh. Dhaka University Journal of Biological Sciences, *31*: 273-280.

Aribal LG, Llamos EJN, Bruno AGT and Medina MAP. 2016. Comparative leaf morphometrics of two urban tree species: an assessment to air pollution impacts. Journal of Biodiversity and Environmental Sciences, *9*: 106-115.

Ekpemerechi S, Lala M, Jimoda L, Odiwe A and Saheed S. 2014. Effect of air pollution on the foliar morphology of some species in the family Euphorbiaceae in southwestern Nigeria. Journal of Science and Technology, *34*: 21-29.

Escobedo FJ, Nowak DJ, Wagner JE, La Maz CL, Rodriguez DE and Hernandez J. 2006. The socio-economics and management of Santiago de Chile's public urban forests. Urban Forestry and Urban Greening, *4*: 105-114.

Gielwanowska I, Szczuka E, Bednara J, and Gorecki R. 2005. Anatomical features and ultra-structure of *Deschampsia antarctica* (Poaceae) leaves from different growing habitats. Annals of Botany, *96*: 1109-1119.

Giri S, Shrivastava D, Deshmukh K and Dubey P. 2013. Effect of air pollution on chlorophyll content of leaves. Current Agriculture Research Journal, *1*: 93-98.

Hanisch M, Schweiger O, Cord AF, Volk M and Knapp S. 2020. Plant functional traits shape multiple ecosystem services, their trade-offs and synergies in grasslands. Journal of applied Ecology, *57*: 1535-1550.

Ianovici N, Andrei M, Feroiu B, Muntean HE, Danciu R and Pupăză E. 2011. Anatomical peculiarities and ecological adaptations of the leaves of species of the genus *Plantago*. Natura-Biologie. Seria III, *53*: 163-194.

Jake FA, Rahman MH, Kashem MA and Hossain MZ. 2020. Spatio-temporal variation in leaf traits of Sal (*Shorea robusta* Gaertn.) populations in Bangladesh. Tropical Plant Research *7*: 452-459.

Joshi PC and Swami A. 2009. Air pollution induced changes in the photosynthetic pigments of selected plant species. Journal of Environmental Biology, *30*: 295-298.

Kashem MA, Rahman MA, Hussaini SM and Hossain MZ. 2022. Effects of air pollution on the leaf morpho - physiological traits of some common tree species of Ramna park and its adjacent roadside areas in Dhaka city, Bangladesh. Mol, *22*: 9.

Keskin N and Ili P. 2012. Investigation of particular matters on the leaves of *Pinus nigra* Arn. Subsp. *Pallasiana* (Lamb.) Holmboe in Denizli (Turkey), Pakistan Journal of Botany, *44*: 1369-1374.

Laghari SK, Zaidi MA. 2013. Effect of air pollution on the leaf morphology of common plant species of Quetta city. Pakistan Journal of Botany, *45*: 447-454.

Madhumonisa AS and Saradha M. 2021. Effect of air pollution on leaf properties of selected plants. International Journal of Scientific Development and Research, *6*: 233-235.

Makbul S, Coskuncelebi K, Turkmen Y and Beyazoglu O. 2006. Morphology and anatomy of *Scrophularia* L. (Scrophulariaceae) taxa from NE Anatolia. Acta Biologica Cracoviensia, *48*: 33-43.

Matasov V, Marchesini LB, Yaroslavtsev A, Sala G, Fareeva O, Seregin I, Castaldi S, Vasenev V and Valentini R. 2020. Monitoring of urban tree ecosystem services: possibilities and challenges. Forests, *11*: 775

Montes-Pulido CR. 2014. Use of plant functional traits as estimators of carbon stored in aboveground biomass. Ambient, *5*: 237-243.

Myers C. 2015. The effects of air pollution on plants. http://www.livestrong.com.ph. Accessed on 08 March 2016.

Rai P and Mishra RM. 2013. Effect of urban air pollution on epidermal traits of road side tree species, *Pongamia pinnata* (L.) Merr. Journal of Environmental Science, Toxicology and Food Technology, *2*: 2319-2402.

Rodríguez-Alarcón SJ, Pinzón-Pérez L, López-Cruz J and Cabrera-Amaya D. 2020. Functional traits of woody plants in green areas of Bogota, Colombia. Biota Colombiana, *21*: 108-133.

Rodríguez-Santamaría K, Zafra-Mejía, CA and Rondón-Quintana HA. 2022. Macro-Morphological traits of leaves for urban tree selection for air pollution biomonitoring: A review. Biosensors, *12*: 812.

Seyyednejad SM, Niknejad M and Yusefi M. 2009a. Study of air pollution effects on some physiology and morphology factors of *Albizia lebbeck* in high temperature condition in Khuzestan. Journal of Plant Sciences, *4*: 122-126.

Seyyednejad SM, Niknejad M and Yusefi M. 2009b. The effect of air pollution on some morphological and biochemical factors of *Callistemon citrinus* in petrochemical zone in South of Iran. Asian Journal of Plant Sciences, *8*: 562-565.

Seyyednezhad SM, Ypusefi M, Zaezi J and Karamizade F. 2013. The effect of air pollution on physiological characteristics, anatomy and morphology of two species *Malva parviflora* and *Hordeum glaucum* in the region of Ahvaz steel industry. Scientific Journal of Agriculture, *35*: 105-116.

Shafiq M, Iqbal MZ, Athar M and Qayyum M. 2009. Effect of auto exhaust emission on the phenology of *Cassia siamea* and *Peltophorum pterocarpum* growing in different areas of Karachi. African Journal of Biotechnology, *8*: 2469-2475.

Sianping P, Sun BN and Yan DF. 2009. Altitudinal variation in *Ginkgo* leaf characters: Clues to paleoelevation reconstruction. Science in China Series D Earth Sciences, *52*: 2040-2046.

Squires V. 2016. Dust particles and aerosols: impact on biota "a review" Snejana B. variation in Kudzu (*Pueraria lobata* Willd.). Annals of Botany, *45*: 77-80.

Syed A and Iqbal MZ. 2008. Level of heavy metals in the foliage of naturally growing plants collected from korangi and Landhi industrial areas of Karachi city. Pakistan Journal of Botany, *40*: 785-789.

Yousefzadeh H, Akbarian MR and Akbarinia M. 2009. Variation in leaf morphology of *Parrotia persica* along an elevational gradient in eastern Mazandaran Province (N. Iran). Botanical Journal of Iran, *9*: 178-189.

Zaidi MA and Leghari S. 2004. Levels of pollution along the road side trees of Quetta city due to traffic exhaust. Botany Conference, May 20-23, 2004; Government College University Lahore.

Zarafshar M, Akbarinia M, Yousefzadeh H and Satarian A. 2009. The survey of diversity in leaf and fruit morphological characters of *Celtis australis* in various geographical conditions. Iranian Journal of Rangelands and Forests Plant Breeding and Genetic Research, *17*: 88-99.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 145-153

IMPACTS OF INDUSTRIAL EFFLUENT ON CROP PRODUCTION IN MOKESH BEEL AREAS OF GAZIPUR DISTRICT

Abul Hossain Molla*, Rupa Saha and Md. Manjurul Haque

Department of Environmental Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706

Corresponding e-mail: ahmolla@bsmrau.edu.bd

Received: 12 October 2023, revised: 04 December 2023, accepted: 05 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.7

ABSTRACT

Industrial discharge is the prominent impediment of maintaining a congenial aquatic and terrestrial habitat. The present study was undertaken to evaluate the status of crop cultivation before and after industrial development in Mokesh beel area, where composite effluent of different industries are discharged intensively. Face-to-face interview was conducted among local relevant respondents to achieve the aforesaid objectives. Water quality of Mokesh beel was severely deteriorated and its usages were restricted mostly after industrial development. Remarkably decreased cultivation of rice, all vegetables, mango and jackfruit after industrial development were cited by maximum percent of respondents. Increased percentage of respondents (39 and 20%) mentioned that deformed fruit size and abnormal taste were maximized after industrial development than before, respectively. Besides decreased yield of rice and jackfruit was reported by majority of the respondents (75 and 84%, respectively). Maximum deterioration was reported of rice (27%) and jack fruit (25%) cultivation after industrial development. Industrial development in Mokesh beel area remarkably decreased crop production practices.

Keywords: Crop deterioration, industrial effluent, respondent, water quality, yield

Introduction

The economy of Bangladesh depends mostly on agricultural enterprises but recently different industrial growth plays significant roles on it. In recent years about 80% of total foreign currency is being earned through exporting of textiles goods and at the same time it creates huge number of employment opportunities (Chowdhury 2015). Therefore, the textile industries development has reached significant level in Bangladesh within last 15 to 20 years. The highest number of textile industries present in Gazipur district, near capital city of Dhaka. Mostly these are dyeing, knitting, spinning, finishing and textile accessories (Haque *et al.* 2022). Besides, there are ample number of pharmaceuticals, tannery, chemicals, footwear and other industries existing in Gazipur district also. Perhaps the Kaliakair upazila (an administrative unit of the district) of Gazipur district, Bangladesh has achieved the top ranked of industrial development than the others. Increased industrial development usually generates vast amount of industrial effluent. Hossain *et al.* (2018) reported that only colored industrial effluent was discharged 217 m^3 in 2016 and it is projected that the textile dyeing industries of Bangladesh will discharge 203,000 million liters of effluent in each year since 2021 and onward (Haque *et al.* 2021a). Careless and indiscriminate disposal of effluents are being carried directly to the surface water reservoirs, agricultural fields, irrigation channels, canals and rivers etc (Sultana *et al.* 2009, Jaganathan *et al.* 2014), which might have negative impact in agronomic practices.

Industrial effluents comprise different chemicals of both organic and inorganic pollutants which are toxic, carcinogenic and highly prone of causing damage to the central nervous system of human, aquatic and terrestrial lives (Arefin and Mallik 2017, Wang *et al.* 2020, Fouda *et al.* 2021, Sultana *et al.* 2009, Haque *et al.* 2021a,b, Markandeya *et al.* 2022). The textile effluent is recognized as the top ranked pollutants among all industrial sectors considering both volume and composition (Roy *et al.* 2010, Hossain *et al.* 2018, Haque *et al.* 2021a). Indiscriminate disposal of industrial effluents induces serious negative impacts on surface water, damage aquatic ecosystem, soil health and losses crop yield. It may cause significant alteration of qualities and habitat environment which might give rise to dwindling biodiversity of different

flora and fauna and enhance food toxicities by destroying whole ecosystems and ecosystem services (Tüfekci *et al.* 2007, Dudgeon 2019). Generally, the industrial effluents contain different heavy metals, among them cadmium, chromium, mercury, lead and nickel are remarkable, have no useful biological function but impose toxic effects to plants and animals even in low concentration (He *et al.* 2005, Tchounwou *et al.* 2012). The biotic components of aquatic ecosystem might be affected by carcinogenic, mutagenic and genotoxic effects of these metals leading to damage biodiversity and ecosystem services (Kheirallah *et al.* 2019, Haque *et al.* 2021a). Indiscriminate disposal of effluents may have great chance to intake of these toxic metals by human and animal body through different food chains. Therefore, due to health hazards the industrial effluents are not encouraged for irrigation. Because it may pose detrimental effect for both the crops and crop consumers (Ogedengbe and Akinbile 2011). Besides, discharge/application of industrial effluent to crop field might alter the physical, chemical and biological properties of soil which impair the production of crop yield.

Therefore, the present study was undertaken to evaluate the crop cultivation status before and after of industrial development in Mokesh beel area which is severely polluted due to indiscriminate discharged of industrial effluent.

Materials and Methods

The study was conducted in Mokesh beel, [the 'beel' denotes the natural water reservoir, approximate area 1000 acres of land and 15 km far in north-east direction from Upazila head quarter of Kaliakair, Gazipur district of Bangladesh] is being intensively polluted by discharging of composite industrial effluent generally in the months of January and February each year. The necessary data were collected from studied area through face-to-face interview by pre tested questionnaire.

Questionnaire preparation and respondent selection for interview: Before preparation of questionnaire a survey was done for preliminary assessment to achieve the targeted objectives. Next a questionnaire was prepared in local language based on initial survey for collecting relevant information from the studied area. Randomly 80 respondents of both male and female were selected from respective area, who was minimum 25 years of old and had minimum primary education.

Survey and data collection: Prepared questionnaire was used to collect the necessary information. Face-to-face interview was conducted for collecting necessary information considering useful necessary questions. The information on water, crop biodiversity and cultivation status were collected on two different aspects such as before and after establishment of industries.

Results and Discussion

Due to indiscriminate disposal of industrial effluents from several industries (mostly textiles) to Mokesh beel, it has lost its previous aesthetic beauty. In Table 5, it was cited clearly that 100% of the respondents mentioned that the beel's water was used for cooking, bathing, irrigation, several domestic activities, boating and recreational purposes etc before establishment of industries. Interchangeably, due to severe pollution of Mokesh beel's water, none of the above activities (except irrigation) was carried out now were expressed by 100% respondents (Table 1). The obtained results conveyed that the water of the Mokesh beel lost its color, taste and aesthetic scenery. Odor was too much pungent and color was grey to black based on opinion of 100% respondents. Excessive pollutants loading and significant discharges of industrial effluents to surface water (rivers/canals) decreased the water quality as well as lost the aesthetic values (Rahman *et al.* 2012). Almost similar fact i.e. river water pollution by discharges of industrial effluent was described by Hafizur *et al.* (2017).

Among the cereals crop, mostly rice and wheat were grown by farmers in Mokesh beel area. Maize was cultivated there but not in higher scale. Barley and millets were not well-known crop there. Based on the present survey, 90% respondents expressed their opinion that rice was intensively cultivated in Mokesh beel area before establishment of the industries but at present i.e. after establishment of industries only around 54% respondents shared the same opinion (Table 6). On the other hand, earlier wheat was intensively cultivated there shared by 91% respondents but at present none responded the same as before. Perhaps wheat crop could not sustain at industrial wastewater irrigated environment but rice

Table 1. Respondent's response to water quality and usages status of Mokesh beel wastewater discharged with industrial effluent [Based on responses of (N) =80 respondents]

	Contents	Before establishment of industries		After establishment of industries	
		Comments	RP (%)	Comments	RP (%)
Water quality	Appearance	Excellent	100	Dirty and ugly	100
	Taste	Good	100	Bad and people could not use it.	100
	Odor	None any pungent odor	100	Pungent odor. Smell seems to chemicals from water.	100
	Color	Fresh water color	100	Grey to black color. Dying & washing are the main reasons.	100
Usages of water	Cooking	Yes	100	No	100
	Bathing	Yes	100	No. Skin diseases can occur if they used this water.	100
	Irrigation	Yes	100	Yes	70
	Domestic activity	Yes	100	No	100
	Animal's bathing	Yes	100	No	100
	Boating	Yes	100	Boating occurred but it was very rare.	62.5
				Boating could not happen.	37.5

Note: RP=Respondent perception

plants do not face problem to sustain at that environment too much. In Bangladesh wheat is grown in winter (dry and cold) season, no rain at that time and the discharges effluents became more concentrate because of no raining in winter. Perhaps these situations may impair the wheat cultivation. Rice is mostly grown in rainy season, which does not face similar situation as wheat. But at industrial wastewater irrigated situation sterility of rice was enhanced reported by Hossain *et al.* (2015). In case of cash crop, jute and sugarcane were not cultivated in Mokesh beel area but bamboo was there. Bamboo was cultivated as intermediate scale before establishment of industries were responded by maximum respondents but later the scale of bamboo cultivation was dropped expressed by above 71% respondents (Table 2). In industrial area, the disposal of effluents not only pollutes the water and soil of the disposed area, but also the surrounding air and soil become polluted by volatile gases and acid rains, which are common facts in industrial areas. Obviously, these environments impose negative impacts on living beings including plants and animals. None respondents expressed their opinion on growing of pulse crop in Mokesh beel area before and after establishment of industries there. Toxic soil and water by industrial discharges enforce negative impacts on crop seed germination. Total germination of mustard seeds (*Brassica juncea* L.) failed while it was irrigated with textile effluent (Molla and Khan 2018). Heavy metals exerted the most adverse effects on seed germination of different crops (Mahmood *et al.* 2007). Excessive heavy metals were noticed in rice grown near the disposed area of polluted wastewater (Uddin *et al.* 2016). Decreased crop cultivation in industrial areas was reported by Hossain *et al.* (2010, 2015).

In case of vegetable production in Mokesh beel area, the obtained results implied that high scale production practice of maximum vegetables except red amaranth, radish, sweet potato, potato, cauliflower and carrot were mentioned by higher percent of respondents before establishment of industries. But that situation was drastically changed after establishment of industries. The highest percent of respondent's perception was diverted to low production of all vegetable crops except amaranth (Table 3). Moreover, the lowest respondent's perception was recorded against the high scale production of vegetable after establishment of industries. However, the present results implied that the majority vegetable crops (Carrot, Amaranth, Ash gourd, Sweet gourd, Cauliflower, Brinjal etc.) were grown in Mokesh beel area and its production was high at prior establishment of industries. Existing environment impedes in some extent the production of all vegetables and the obtained reports present that some were under threatened and endangered situation. Bangladesh is the country, where plenty of vegetables growing are being practiced including the areas are located near the source of

Table 2. Respondent's perception (%) on crop cultivation intensity in Mokesh beel area polluted by industrial effluent discharges [Based on responses of (N) =80 respondents]

Crop		Before establishment of industries								After establishment of industries							
		None		Low		Medium		High		None		Low		Medium		High	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Cereal	Rice	-	-	-	-	8	10	72	90	-	-	14	17.50	23	28.75	43	53.75
	Wheat	-	-	-	-	7	8.75	73	91.25	-	-	75	93.75	5	6.25	-	-
	Maize	-	-	10	12.50	30	37.50	40	50.00	-	-	50	62.50	25	31.25	5	6.25
	Barley	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Millets	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
Cash	Jute	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Sugarcane	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Bamboo	-	-	20	25	45	56.25	15	18.75	-	-	57	71.25	18	22.50	5	6.25
Pulse	Lentil	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Mung bean	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Black gram	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Chick pea	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Grass pea	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Pea	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-
	Pigeon pea	80	100	-	-	-	-	-	-	80	100	-	-	-	-	-	-

Table 3. Respondent's perception (%) on production of vegetable in Mokesh beel area polluted by industrial effluent discharges [Based on responses of (N) =80 respondents]

Crops	Before establishment of industries						After establishment of industries					
	Low		Medium		High		Low		Medium		High	
	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent
Brinjal	18	22.50	26	32.50	36	45.00	43	53.75	23	28.75	14	17.50
Sweet gourd	12	15.00	23	28.75	45	56.25	38	47.50	30	37.50	12	15.00
Bean	15	18.75	30	37.75	35	43.75	49	61.25	18	22.50	13	16.25
Rib gourd	10	12.50	21	26.25	49	61.25	52	65.00	23	28.75	5	6.25
Ash gourd	5	6.25	17	21.25	58	72.50	40	50.00	32	40.00	8	10.00
Red amaranth	17	21.25	36	45.00	27	33.75	37	46.25	33	41.25	10	12.50
Amaranth	15	18.75	26	32.50	39	48.75	32	40.00	39	48.75	9	11.25
Snake gourd	2	2.50	27	33.75	51	63.75	52	65.00	24	30.00	4	5.00
Radish	8	10.00	45	56.25	27	33.75	56	70.00	22	27.50	2	2.50
Sweet potato	30	37.50	50	62.50	-	-	65	81.25	15	18.75	-	-
Cabbage	14	17.50	32	40.00	34	42.50	45	56.25	22	27.50	13	16.25
Cauliflower	12	15.00	44	55.00	24	30.00	45	56.25	25	31.25	10	12.50
Carrot	20	25.00	55	68.75	5	6.25	44	55.00	36	45.00	-	-
Pointed gourd	55	68.75	25	31.25	-	-	66	82.50	14	17.50	-	-
Potato	37	46.25	40	50.00	3	3.75	56	70.00	24	30.00	-	-

heavy metals pollution like industrial areas (Ahmad and Goni 2010). Vegetables growing in industrial effluents discharged areas were high of heavy metals and it has high influence on carcinogenic risks of consumed people (Haque *et al.* 2021c).

All common fruits are grown in Mokesh beel area but mango, jack fruit, litchi, black berry and guava were the most common cultivated fruit crops there. Before establishment of industries production of mango and jack fruit received the highest respondent's perception (86 and 91%, respectively), which was dropped to 10 and 11% after establishment of industries (Table 4). It indicated that fruit production magnitude was decreased drastically after industrial development. The fruit production scale of black berry, litchi and guava was comparatively lower than the mango and jack fruit.

The fruit shape and texture of Mokesh beel area was influenced by industrial development. Before industrial development 83 and above percent respondents expressed their opinion in favor of normal shape and texture of all studied fruits in Mokesh beel area (Table 5). It indicated that before industrial development all fruits shape and texture was normal expressed by 83 and above percent of respondents and only 8-16% respondents shared their opinion that there were deformed fruits. The obtained report in Table 5, before industrial development deformed jack fruit was reported by 16.25% respondents only but after industrial development, higher number (38.75%) respondents expressed their opinion on deformed jack fruit. It suggested that deformed jack fruit number was increased after industrial development. Almost similar observations were recorded in all studied fruit crops.

Conversely, abnormal fruit taste was enhanced after industrial development also (Table 5). The majority percent of respondents shared their opinion about normal fruit taste before industrial development but the percent respondents were decreased in respect of normal fruit taste after industrial development. In general, the taste of all studied fruits was deteriorated in some extent by discharging of industrial wastes to the environment. During expression of opinion, the most of the respondents conveyed the message about pungent and bad smell of the fruits. It might be induced by the different chemicals present in effluents.

Fruit quality parameters of citrus were monitored after three consecutive years irrigation with wastewater to young citrus plants. The used wastewater was rich in sodium, chloride and boron, but both growth and fruit quality parameters were unaffected by the high levels of sodium, chloride and boron in wastewater (Reboll *et al.* 2000). In another study, increased concentrations of Zn and Cu in pepper fruit were noticed while it was grown with the addition of sewage sludges (Pascual *et al.* 2010). Textile dyeing wastewater was used to grow tomato in pot, however the researchers reported the dramatically reduced yield and physiochemical attributes of tomato. They didn't investigate heavy metals accumulation pattern in different plant parts of the tomato grown by applying as irrigation of textile dyeing wastewater but increasing trends of heavy metals in irrigated soil were monitored (Hassan *et al.* 2022). Awad *et al.* (1995) stated that sewage sludge application significantly increased the growth of apple seedlings but the Pb and Ni contents of fruits and leaves were slightly increased. Fruit yield and cumulative

Table 4. Respondent's perception on fruit production in Mokesh beel area of Kaliakoir upazila in Gazipur district, Bangladesh

Crops	Before establishment of industries						After establishment of industries					
	Low		Medium		High		Low		Medium		High	
	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent	Res. no	Percent
Mango	-	-	11	13.75	69	86.25	55	68.75	17	21.25	8	10
Jack fruit	-	-	7	8.75	73	91.25	52	65.00	19	23.75	9	11.25
Black berry	8	10.00	28	35.00	44	55.00	45	56.25	24	30.00	11	13.75
Litchi	15	18.75	30	37.50	35	43.75	20	25.00	28	35.00	32	40.00
Guava	14	17.50	33	41.25	33	41.25	27	33.75	30	37.50	23	28.75

Table 5. Respondent's perception (%) on fruit shape & texture, and taste in Mokesh beel area discharged with industrial effluent [Based on responses of (N) =80 respondents]

Crop	Fruit shape & texture				Fruit taste			
	Before establishment of industries		After establishment of industries		Before establishment of industries		After establishment of industries	
	Normal	Deformed	Normal	Deformed	Normal	Abnormal	Normal	Abnormal
Mango	86.25	13.75	76.25	23.75	95.00	5.00	87.50	12.50
Jack fruit	83.75	16.25	61.26	38.75	96.25	3.75	82.50	17.50
Litchi	87.50	12.50	77.50	22.50	91.25	8.75	88.75	11.25
Black berry	91.25	8.75	73.75	26.25	96.26	3.75	80.00	20.00
Guava	88.75	11.25	81.25	18.75	95.00	5.00	86.25	13.75

Table 6. Respondent's perception on yield reduction of major crops in Mokesh beel area discharged with industrial effluent [Based on responses of (N) =80 respondents]

Crops	Percent respondent perception	Percent decrease of yield	Remarks
Rice	72.50	27	Due to sterility
Jack fruit	83.75	25	Deformed and reduced fruit size
Litchi	56.25	21	Deformed and infested
Cucurbits	62.50	18	Reduced fruit setting

yield efficiency of apple trees significantly increased with sewage sludge application (Bozkurt and Yarilgaç 2003). Application of wastewaters from domestic and industrial sources may have some positive effects on promotion of plant growth and fruit production but always it might not be true. Besides application of these wastewaters have great chance to enhance toxicity of consumable parts of the plants.

Decreasing yield of major crop was recorded in Mokesh beel area (Table 6). Majority respondents expressed their views that a remarkable percent of yield loss of rice, jack fruit, litchi and cucurbits was noticed in last few years i.e., after establishment of industries. In the present study 72.50% of respondents shared that the yield of rice was reduced about 27% in recent years. It was happened due to increase of sterility percent of spikelets in panicles, which was not noticed before (establishment of industries). Enhanced sterility percent of rice was recorded by Hossain *et al.* (2015) in their study on irrigation with industrial effluent to rice in pot cultivation. In Mokesh beel area jack fruit is the major fruit crop was affected in significant level after establishment of industries. The recorded report conveyed that 25% yield of jack fruit was deteriorated in recent years based on opinion of 83.75% of respondents (Table 6). A significant number of deformed and reduced sized fruits were remarked in maximum plants at present than the before. As like as rice and jack fruit incredible percent of yield loss was monitored at present in litchi and cucurbits also. No doubt the present situation is the output of changing of agro-ecosystems by disposal of different wastes from several industries. Decrease fertility, increase insect infestation and reduce yield of rice were reported from a study conducted in industrial areas (Afrad *et al.* 2020). Negative effect of industrial wastewater on crop yield was reported by Han-jie *et al.* (2022).

Conclusions

Aquatic habitat of Mokesh beel was drastically deteriorated by indiscriminate discharge of industrial effluents. The situations decreased the cultivation and yield of cereals, vegetables and fruits as well as fruit quality in the studied area.

References

Afrad MSI, Monir MB, Haque ME, Barau AA and Haque MM. 2020. Impact of industrial effluent on water, soil and rice production in Bangladesh: a case of Turag river Bank. Journal of Environmental Health Science and Engineering, *18*: 825-834.

Ahmad JU and Goni MA. 2010. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. Environmental Monitoring and Assessment, *166*: 347-357.

Arefin MA and Mallik A. 2017. Sources and causes of water pollution in Bangladesh: a technical overview. Bibechana, *15*: 97-112.

Awad F, Kahl L, Kluge R and Abadia J. 1995. Environmental aspects of sewage sludge and evaluation of super absorbent hydrogel under Egyptian conditions. In: Iron Nutrition in Soil and Plants. Proceedings of the Seventh International Symposium, Zaragoza, Pp. 53-62.

Bozkurt MA and Yarilgaç T. 2003. The Effects of Sewage Sludge Applications on the Yield, Growth, Nutrition and Heavy Metal Accumulation in Apple Trees Growing in Dry Conditions. Turkish Journal of Agriculture and Forest, *27*: 285-292.

Chowdhury AKA. 2015. Science, technology and innovation for economic growth and development: Bangladesh perspective. 23rd Bangladesh Science Conference, 17-18 Oct 2015, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh, Pp. 33-35.

Dudgeon D. 2019. Multiple threats imperil freshwater biodiversity in the Anthropocene. Current Biology, *29*: R960-R967.

Hafizur RM, Nuralam HM and Rumainul IM. 2017. Investigation of physicochemical parameter, heavy metal in Turag river water and adjacent industrial effluent in Bangladesh. Journal of Science, Technology and Environment Informatics, *5*: 347-360.

Han-jie W, Wang J and Yu X. 2022. Wastewater irrigation and crop yield: A meta-analysis. Journal of Integrative Agriculture, *21*: 1215-1224.

Haque MM, Haque MA, Mosharaf MK and Marcus PK. 2021a. Decolorization, degradation and detoxification of carcinogenic sulfonated azo dye methyl orange by newly developed biofilm consortia. Saudi Journal of Biological Sciences, *28*: 793-804.

Haque MM, Haque MA, Mosharaf MK, Islam MS, Islam MM, Hasan M, Molla AH and Haque MA. 2022. Biofilm-mediated decolorization, degradation and detoxification of synthetic effluent by novel biofilm-producing bacteria isolated from textile dyeing effluent. Environ Pollution, *314*: 120237.

Haque MM, Haque MA, Mosharaf MK and Marcus PK. 2021b. Novel bacterial biofilm consortia that degrade and detoxify the carcinogenic diazo dye Congo red. Archive Microbiology, *203*: 643-654.

Haque MM, Niloy NM, Khirul MA, Alam MF and Tareq SM. 2021c. Appraisal of probabilistic human health risks of heavy metals in vegetables from industrial, non-industrial and arsenic contaminated areas of Bangladesh. Heliyon, *7*: e06309.

Hassan J, Rajib MMR, Sarker U, Akter M, Khan MN, Khandaker S, Khalid F, Rahman GKMM, Ercisli S, Muresan CC and Marc RA. 2022. Optimizing textile dyeing wastewater for tomato irrigation through physiochemical, plant nutrient uses and pollution load index of irrigated soil. Scientific Reports, *12*: 10088.

He ZL, Yang XE and Stoffella PJ. 2005. Trace elements in agroecosystems and impacts on the environment. Journal of Trace Elements in Medicine and Biology, *19*: 125-140.

Hossain L, Sarker, SK and Khan MS. 2018. Evaluation of present and future wastewater impacts of textile dyeing industries in Bangladesh. Environmental Development, *26*: 23-33.

Hossain MA, Rahman GKMM, Rahman MM, Molla AH, Rahman MM and Uddin MK. 2015. Impact of industrial effluent on growth and yield of rice (*Oryza sativa* L.) in silty clay loam soil. Journal of Environmental Science, *30:* 231-140.

Hossain MA, Uddin MK, Molla AH, Afrad MSI, Rahman MM and Rahman GKMM. 2010. Impact of industrial effluents discharges on degradation of natural resources and threat to food security. The Agriculturists, *8*: 80-87.

Jaganathan V, Cherurveettil P, Chellasamy A and Premapriya MS. 2014. Environmental pollution risk analysis and management in textile industry: a preventive mechanism. European Scientific Journal, *2:* 332-329.

Kheirallah DAM, El-Samad LM, Mokhamer EHM, Abdul-Aziz KK and Toto NAH. 2019. DNA damage and oogenesis anomalies in *Pimelia latreillei* (Coleoptera: Tenebrionidae) induced by heavy metals soil pollution. Toxicology and Industrial Health, *35*: 688-702.

Mahmood T, Islam KR and Muhammad S. 2007. Toxic effects of heavy metals on early growth and tolerance of cereal crops. Pakistan Journal of Botany, *39*: 451-462.

Molla AH and Khan HI. 2018. Detoxification of textile effluent by fungal treatment and its performance in agronomic usages. Environmental Science and Pollution Research, *25:* 10820-10828.

Ogedengbe K and Akinbile CO. 2011. Comparative analysis of the impact and agricultural effluent on Ona stream in Ibadan, Nigeria. Journal of Science and Technology, *31*: 33-45.

Pascual I, Azcona I, Aguirreolea J, Morales F, Corpas FJ, Palma JM, Rellán-Álvarez R and Sánchez-Díaz M. 2010. Growth, Yield, and Fruit Quality of Pepper Plants Amended with Two Sanitized Sewage Sludges. Journal of Agriculture and Food Chemistry, *58*: 6951-6959.

Rahman AKML, Islam M, Hossain MZ and Ahsan MA. 2012. Study of the seasonal variations in Turag river water quality parameters. African Journal of Pure and Applied Chemistry*, 6*: 144-148.

Reboll V, Cerezo M, Roig A, Flors V, Lapeña L and García-Agustín P. 2000. Influence of wastewater vs groundwater on young Citrus trees. Journal of the Science of Food and Agriculture, *80*: 1441-1446.

Roy R, Fakhruddin ANM, Khatun R and Islam MS. 2010. Reduction of COD and pH of textile industrial effluents by aquatic macrophytes and algae. Bangladesh Academy of Science, *34*: 9-14.

Sultana MS, Islam MS, Saha R and Al-Mansur MA. 2009. Impact of the effluents of textile dyeing industries on the surface water quality inside D.N.D. embankment, Narayanganj. Bangladesh Journal of Scientific and Industrial Research, *44*: 65-80.

Tchounwou PB, Yedjou CG, Patlolla AK and Sutton DJ. 2012. Heavy metal toxicity and the environment. In: Luch, A. (Ed.), Molecular, Clinical and Environmental Toxicology. Springer Basel, Basel, Pp. 133-164

Tüfekci N, Sivri N and Toroz I. 2007. Pollutants of Textile Industry Wastewater and Assessment of its Discharge Limits by Water Quality Standards. Turkish Journal of Fisheries and Aquatic Sciences, *7*: 97-103.

Uddin MJ, Parveen Z and Hossain MF. 2016. Status of heavy metals in water and sediments of canals and rivers around the Dhaka city of Bangladesh and their subsequent transfer to crops. Advances in Plants & Agriculture Research, *5*: 593-601.

Wang ZY, Walker GW, Muir DCG and Nagatani-Yoshida K. 2020. Toward a global understanding of chemical pollution: a first comprehensive analysis of national and regional chemical inventories. Environmental Science and Technology, *54*: 2575-2584.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 155-161

PREVALENCE AND ALLELOPATHIC EFFECT OF *PARTHENIUM HYSTEROPHORUS* ON CROPS IN SOUTHWEST REGIONS OF BANGLADESH

Mst. Sharmin Khatun[1], Parimal Kanti Biswas[1], Mohammad Shamim Hasan Mandal[2], Marjana Yeasmin[1], Sharmin Sultana Akhi[1], Hasan Mehraj[3] and Sheikh Muhammad Masum[1*]

[1]Department of Agronomy, Sher-e-Bangla Agricultural University. [2]Japan International Research Center for Agricultural Sciences, Tsukuba, Ibaraki, JP. [3]Graduate School of Agricultural Science, Kobe University, JP

Corresponding e-mail: smmasum607@sau.edu.bd

Received: 15 October 2023, revised: 08 December 2023, accepted: 15 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.8

ABSTRACT

Periodical weed surveys were conducted during 2020-21 in Jashore, Jhenaidah, Chuadanga, Meherpur and Khustia districts of Bangladesh to observe the severity and allelopathic effect of *Parthenium hysterophorus* on field crops. Parthenium infected the crops differently as observed in rice (8.75), maize (11.45%), lentil (12.45%), chickpea (32.40%), field pea (57.63%), jute (57.63%), cotton (13.45%), mustard (63.85%), sesame (17.50%), groundnut (28.35%), pointed gourd (11.50%), pumpkin (8.45%), onion (30.47%), garlic (26.25%), turmeric (17.50%), potato (38.75%), banana (24.33%), sugarcane (60.25%), napiergrass (55.00%) and marigold (11.25%). Allelopathic effect was examined using 5% aqueous leaf extract of *P. hysterophorus* in germination test and results showed complete failure of germination in seeds of sesame, jute, pumpkin, red amaranth, chili, radish and tomato. Seeds of other crops germinated poorly in aqueous solution of parthenium with reduced radicle and plumule growth. Among the different crops, wheat had the highest reduction in radicle (96%) and plumule (94%) length compared to their control.

Keywords: Parthenium, infestation, allelopathy, aqueous extract, germination, seedling growth

Introduction

Parthenium hysterophorus L., known as Congress Weed, Carrot Weed, or White Top, is an alien invasive herbaceous weed that was once only found in the tropical and subtropical Americas but is now found across the tropics (Adkins and Shabbir 2014). In every instance, the weed has been unintentionally introduced and spreads quickly and forms mono-specific thickets that endanger cropland, rangeland, and the diversity of natural ecosystems. For instance, introduction of parthenium in India took place in the 1950s, and within a few years, it spread to almost the whole nation (Bajwa *et al*. 2016). Recently, it has been introduced to Bangladesh, presumably from India, as the weed populations are found mostly in the border districts specially on the road systems connecting the two countries. The weed has also been identified in Jashore, Narail, Magura, Kushtia, Meherpur, Chuadanga, Faridpur, Rajbari, Rajshahi, Natore, Pabna, Sirajgonj, Manikgonj, Gazipur, Dhaka and Mymensingh districts which supported the findings of other authors (Masum *et al*. 2013, Masum *et al*. 2022). This weed severely impacts on human health, agriculture, forestry, fisheries, wetlands, roadsides, natural areas, and animal productivity.

Globally and specifically in Bangladesh, climate change is currently a reality. There has been a noticeable increase in global temperature and changes in rainfall patterns. Such changes in temperature and rainfall are likely to modify the distribution and adaptation of plants including weeds. Parthenium weed is considered physiologically adaptable to climate change and it has been hypothesized that parthenium weed will become more vigorous and prolific in near future (Navie *et al*. 2005).

Although several studies on the effect of parthenium weed have been undertaken in many countries, very little work has been done in Bangladesh. Further, a few accounts of parthenium weed are available although most of the people never know anything about the emerging problem. Investigation on parthenium weed by assessing the severity of infestation and their effects on crop production is necessary to address this issue effectively. Therefore, the current research was conducted to identify the crops with parthenium

populations, to measure their number and level of infestation, and to determine the allelopathic effect of parthenium on crop productivity.

Materials and Methods

Crop infestation: Field surveys of parthenium weed infestations were conducted during April 2020 to March 2021 in 27 administrative regions (Upazila) within Jashore hub which encompasses Jashore, Jhenaidah, Chuadanga, Meherpur, and Khustia districts of Bangladesh. Jashore hub includes the western portion of the Ganges River floodplain with primarily high and medium elevations. This area is primarily calcareous dark grey and brown floodplain soils that are moderately alkaline. The organic matter content is high in dark grey soils but low in brown ridge soils. In this study, crop fields were measured using the list quadrat method. Photographs were taken by handheld GPS to integrate topography when parthenium at a density of at least one plant per 10 m^2 (Maszura *et al*. 2018).

The following equations were used to compute the percent prevalence and infestation of parthenium:

$$\text{Occurrence (\%)} = \frac{\text{No. of field having parthenium}}{\text{Total number of fields surveyed}} \times 100$$

$$\text{Infestation (\%)} = \frac{\text{Total no. of quadrates in which parthenium weed occurred}}{\text{Total number of quadrates used}} \times 100$$

The crop fields were chosen based on local crop production patterns and the seasons. The number of fields inspected for the various crops ranged from 20 to 200. Twenty quadrates measuring 50 × 50 cm^2 were randomly placed along each 50-meter length to count the amount of parthenium in each of the selected fields.

Allelopathic effects: For determination of allelopathic effect of parthenium, germination test of crop seeds was conducted with aqueous extract of parthenium. Fresh parthenium samples were collected from different infested parts of the country at their maximum vegetative stage. Leaf samples of parthenium were oven-dried at 60ºC until they reached a constant dry weight. The dried samples were blended into a fine homogeneous powder and preserved in glass jars. After being separated, the leaves were finely chopped by a sharp knife, weighed for an equal amount, crushed in a sterile mortar and pestle, and combined with sterilized water for 48 hours at room temperature. The aqueous stock extract was prepared by soaking 50 g of air-dried plant material for 24 hours at room temperature in 1000 mL of cold distilled water for making 5% concentration. Aqueous stock extract was filtrated firstly by three layers of muslin fabric to remove particles from aqueous leachate. The filtrate was re-filtered using one layer of Whatman No. 1 filter paper to get the final aqueous solution and preserve it in a dark and cool place. It was used for the plant aqueous extract bioassay. pH of the extracts was adjusted to 5.74 and used within a week.

Germination test was carried out in 2021 at the Central Laboratory, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. In this experiment, 5% aqueous leaf extracts of parthenium and control were followed with three replications of each crop seed in a completely randomized design. Ten seeds of each test crop were sown on Whatman 2 MM paper in a 9 cm Petri plate, and 6 mL of the aqueous extract or control solution was added to the Petri plate in a 48-hour interval. Germination was examined every 12 hours until no more seeds were germinated which was indicated by the appearance of the radicle and expressed in percentage.

Data analysis: Statistix 10 data analysis software was used and for each statistical comparison, the Type I error was set to 0.01. Microsoft Excel was used to compute the standard errors.

Results and Discussion

Crop fields were analyzed and the results revealed that cereal, pulse, fibre, oil, sugar, narcotic, spices, vegetables, fodder, fruit crops and flowering ornamental crop were infested by parthenium weed with the exception of cereal crop *aman* rice (Table 1). Only *aus* rice (upland rice) crop fields were infested although the infestation was lower (8.75%). Similarly, lower infestation was noticed on the vegetable crop pumpkin (8.45%). A severe infestation of parthenium weed (>50%) was recorded in pulse crop pea (57.85%), fiber crop tossa jute (57.63%), oil crop mustard (63.85%), sugar crop sugarcane (60.35%), and fodder crop napier grass (55.0%) fields . A moderate parthenium infestation was observed (10-40%) in cereal crops (wheat

Table 1. Parthenium prevalence and infestation percentages in various crops

Common name	Scientific name	No. of fields investigated	No. of infested fields	Occurrence (%)	Infestation (%)
Cereal crops					
Aus rice	*Oryza sativa*	180	6	3	8.75
Aman rice	*Oryza sativa*	50	3	sporadic	-
Maize	*Zea mays*	60	3	5	11.45
Wheat	*Triticum aestivm*	45	2	4	22.32
Pulse crops					
Lentil	*Lens culinaris*	20	1	5	12.45
Pea	*Pisum sativum*	25	6	24	57.85
Chickpea	*Cicer arietinum*	20	2	10	32.4
Fibre crops					
Tossa jute	*Chorchorus olitorius*	35	15	43	57.63
Cotton	*Gossipium hyrsutum*	12	1	8	13.45
Oil crops					
Mustard	*Brassica campestris*	37	9	24	63.85
Peanuts	*Arachis hypogaea*	3	1	33	28.35
Sesame	*Sesamum indicum*	10	1	10	17.5
Sunflower	*Helianthus annus*	6	1	16	10
Tuber crops					
Potato	*Solanum tuberosum*	20	7	35	38.75
Sugar crop					
Sugarcane	*Saccharum officinarum*	70	45	64	60.35
Narcotic Crops					
Tobacco	*Nicotiana tabacum*	16	1	6	13.45
Spices crops					
Onion	*Allium cepa*	28	4	14	30.47
Garlic	*Allium sativum*	26	2	8	26.35
Turmeric	*Curcuma longa*	14	3	21	17.5
Vegetables crops					
Bottle gourd	*Lagenaria siceraria*	22	3	14	11.5
Pumpkin	*Cucurbita maxima*	14	2	14	8.45
Hyacinth bean	*Lablab purpureus*	5	1	20	10.5
Tomato	*Solanum lycopersicum*	20	4	20	17.75
Fodder crops					
Napier grass	*Pennisetum purpureum*	15	8	53	55
Fruit crops					
Banana	*Musa acuminata*	33	2	6	24.33
Mango	*Mangifera indica*	20	11	55	12.45
Flowering ornamental crops					
Marigold	*Tagetes erecta*	6	1	16	11.25

– 22.32%, and maize – 11.45%), pulse crops (chickpea – 32.40%, and lentil – 12.5%), fibre crop cotton (13.45%), oil crops (peanuts – 28.35%, sesame – 18.5%, sunflowers – 10%), tuber crop potato (38.75%), narcotic crop tobacco (13.45%), spice crops (onion – 30.47%, turmeric – 17.5%, garlic – 26.35%), vegetable crops (bottle gourd – 11.5%, hyacinth bean – 10.5%, and tomato – 17.75%), fruit crop (banana – 24.33%, mango – 12.45%), and flowering ornamental crop marigold (11.25%) fields . Additionally, in various locations throughout the examined region, parthenium weed is a severe problem in pastures and rangelands (data not shown). Parthenium weed has been documented to harm agricultural output through resource competition and allelopathy in many Asian countries, Africa and Australia. In most of these countries, the weed has already infested susceptible crops, while in other countries, it is still moving from the areas it originally colonized into cropping lands. Parthenium infestations were recorded in rice, millet, soybean, sugarcane, maize, cotton, sorghum, onions, and citrus orchards. Compared to other crops, sugarcane had a substantially greater parthenium infestation. There is substantial evidence that parthenium can reduce sorghum and sunflower production. It can reduce pasture production by up to 90% and crop yield losses by up to 40%. It interferes with nodulation in legumes by inhibiting the activities of the nitrifying and nitrogen-fixing bacteria *Rhizobium*, *Actynomycetes*, *Azotobactor*, and *Azospirillum* (Gnanavel 2013). Due to parthenium weed infestations, Tamil Nadu lost almost 300 kg ha^{-1} of cotton seed. In contrast, rice had minimal parthenium infestation (Khan and Aneja 2016). Grain yield and the harvest index of maize were also dropped due to parthenium weed (Safdar *et al.* 2016).

Allelopathy activity of leaf extract of *P. hysterophorus* was examined against seed germination including radicle and plumule growth of twenty field crops. Crops included three major kinds of cereal (rice, wheat, maize), six pulse crops (chickpea, cowpea, green gram, blackgram, field pea, lentil), two oilseed crops (mustard, sesame), one fiber crop (tossa jute), two spice crops (onion, chilli), and six vegetable crops (bean, cucumber, pumpkin, red amaranth, radish, tomato). Leaf extract used for germination test had a more substantial inhibitory allelopathic effect than other vegetative parts of parthenium. Allelopathic effects of parthenium on crops were assessed by germination test, radicle and plumule length of seedlings (Anwar *et al*. 2016).

The osmotic and imbibitional absorption of water, which activates enzymes and increases metabolic activity is the first step of germination. Germination rates were lower in all seeds treated with 5% parthenium leaf extract than the control (Table 2). The failure of germination (0%) was observed in sesame, jute, pumpkin, red amaranth, chili, radish and tomato seeds due to allelopathic effect of parthenium extract, similarly, aqueous parthenium leaf extract completely prevented seed germination in *Eragostis tef* (Tefera 2002). Among the major cereals, wheat had the minimum germination (21.33%), followed by maize (33.33%) and rice (44.33%). Phenols, alkaloids and other allelochemicals of parthenium may cause failure or lower germination crop seeds. An imbalance in metabolism controlled by different enzyme activities may also cause the inhibitory impact of parthenium leaf extracts on seed germination. However, flavonoid compounds' herbicidal activity may contribute to the further decline in the germination percentage (Sorecha and Birhanu 2017).

All the species in germinated test showed significantly shorter radicle and plumule length when treated with aqueous parthenium extract (Table 2). Of the cereal species, the radicle and plumule of wheat decreased considerably due to parthenium extract. The results showed that the radicle and plumule length of rice became 75 and 74% shorter than that of the control. Similarly, radicle and plumule length of wheat were 96 and 94% shorter respectively than the control. Whereas in maize, radicle length was 43% and plumule length was 44% shorter from the control. Among pulses, the radicle and plumule length of lentil were reduced to 87 and 90%, respectively as compared to the control. The radicle and plumule length of mustard seedlings reduced to 45 and 66% the mustard seedlings in control condition. Similarly, the onion seedlings had 76 and 72% reduced radicle and plumule respectively, compared to seedlings of onion in control. Among the vegetables, cucumber had the higher reduction seedling growth (58 and 59% radicle and plumule, respectively, as compared to control seedling. Contrary, been had 45 and 43% reduced radicle and plumule, respectively than from control seedlings.

Table 2. Allelopathic effects of parthenium on germination, radicle and plumule length of various field crops

Name of the Crops	Germination (%)		Radicle length (cm)		Plumule length (cm)	
	Control	Aqueous extract	Control	Aqueous extract	Control	Aqueous extract
Cereal crops						
Rice	96.33 ± 0.88	44.33 ± 4.70	3.37 ± 0.11	0.85 ± 0.03	4.27 ± 0.15	1.04 ± 0.01
Wheat	97.43 ± 0.69	21.33 ± 2.03	4.47 ± 0.33	0.20 ± 0.06	8.83 ± 0.45	0.57 ± 0.17
Maize	94.57 ± 0.88	33.33 ± 3.28	12.42 ± 0.65	7.09 ± 0.21	12.72 ± 0.46	7.13 ± 0.51
Pulse crops						
Chickpea	87.33 ± 7.06	27.33 ± 4.67	10.46 ± 0.48	5.53 ± 0.70	3.54 ± 0.25	1.75 ± 0.19
Cowpea	92.00 ± 2.19	38.33 ± 4.41	6.68 ± 0.34	3.68 ± 0.26	9.32 ± 0.45	6.66 ± 0.29
Greengram	95.00 ± 1.15	70.60 ± 4.63	9.10 ± 0.35	4.33 ± 0.97	18.13 ± 0.64	13.33 ± 0.94
Blackgram	95.00 ± 1.82	81.33 ± 2.89	7.73 ± 0.33	5.13 ± 0.43	18.40 ± 0.36	15.60 ± 0.93
Fieldpea	94.20 ± 0.67	34.00 ± 3.21	63.78 ± 1.40	9.48 ± 0.52	59.00 ± 3.88	7.39 ± 0.66
Lentil	93.17 ± 1.73	37.00 ± 1.53	51.95 ± 8.50	6.54 ± 0.10	64.31 ± 3.12	6.43 ± 1.03
Oilseed crops						
Mustard	87.83 ± 4.04	38.96 ± 4.87	3.78 ± 0.12	2.08 ± 0.30	3.56 ± 0.81	1.21 ± 0.09
Sesame	85.33 ± 0.88	0.00 ± 0.00	3.22 ± 0.14	0.00 ± 0.00	3.64 ± 0.10	0.00 ± 0.00
Fiber crop						
Jute	80.67 ± 3.53	0.00 ± 0.00	1.32 ± 0.05	0.00 ± 0.00	2.64 ± 0.10	0.00 ± 0.00
Spices crops						
Onion	77.50 ± 1.73	14.67 ± 2.03	2.80 ± 0.70	0.67 ± 0.17	3.56 ± 0.80	0.98 ± 0.12
Chilli	76.33 ± 4.41	0.00 ± 0.00	3.12 ± 0.29	0.00 ± 0.00	3.38 ± 0.13	0.00 ± 0.00
Vegetables crops						
Bean	79.33 ± 0.58	42.33 ± 2.96	18.33 ± 0.24	10.04 ± 0.88	33.45 ± 0.16	19.15 ± 2.29
Cucumber	86.00 ± 1.76	41.67 ± 2.03	46.79 ± 2.98	19.79 ± 0.63	62.77 ± 1.20	25.82 ± 1.57
Pumpkin	75.67 ± 2.40	0.00 ± 0.00	17.72 ± 0.40	0.00 ± 0.00	10.37 ± 1.12	0.00 ± 0.00
Amaranth	74.33 ± 0.58	0.00 ± 0.00	11.42 ± 0.66	0.00 ± 0.00	20.43 ± 1.42	0.00 ± 0.00
Radish	92.33 ± 0.33	0.00 ± 0.00	8.33 ± 0.24	0.00 ± 0.00	16.45 ± 1.64	0.00 ± 0.00
Tomato	96.00 ± 1.73	0.00 ± 0.00	0.35 ± 0.03	0.00 ± 0.00	0.89 ± 0.03	0.00 ± 0.00

Radicle appeared more sensitive to allelopathic effect than plumule in most cases of test species. Similar findings have been reported for tomato (Mersie and Singh 1987), chickpea and sesame (Ashebir *et al*. 2012), maize, soybean, and cotton (Masum *et al*. 2012), blackgram and green gram (Parthasarathi *et al*. 2012), onion and bean (Demissie *et al*. 2013), bean (Tahseen *et al.* 2015), maize (Anwar *et al*. 2016), wheat, chickpea and mustard (Hassan *et al*. 2018), rice and wheat (Shrestha and Thapa 2018), cowpea and rice (Bhuvaneshwari *et al*. 2019). In this study, dicotyledonous plants showed more growth inhibitory effects than monocotyledonous plants. Khanh *et al.* (2006) also observed that *Passiflora edulis* aqueous extracts significantly inhibited the growth of dicot plants while having less of an impact on the growth of monocot plants.

Conclusion

Parthenium weed is identified in different field crops of southeast region of Bangladesh although degree of infestation varied significantly depending upon the

nature of crop growth. It also showed allelopathic effect on germination and seedling growth of crops. However, detailed study is necessary with crops in other regions of Bangladesh so that comprehensive management may be adopted to control the devasting weed. Further, appropriate laws, policy, and management options are required to reduce parthenium weed in Bangladesh.

Acknowledgment

The authors gratefully acknowledges the Special Allocation Project for the Year 2020-2021[BS-211/1547] for financial support of the Ministry of Science and Technology, Bangladesh, to conduct this research.

References

Adkins SW and Shabbir A. 2014. Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.). Pest Management Science**,** *70*: 1023-1029. https://doi.org/10.1002/ps.3708

Anwar T, Khalid S, Saeed M, Mazhar R, Qureshi H and Rashid M. 2016. Allelopathic interference of leaf powder and aqueous extracts of hostile weed: *Parthenium hysterophorus* (Asteraceae). Science International, *4*: 86-93. https://scialert.net/abstract/?doi=sciintl.2016.86.93.

Ashebir B, Sharma JJ and Lisanwork N. 2012. Allelopathic effects of aqueous extracts and plant residues of *Parthenium hysterophorus* L. on kabuli chickpea and sesame. Ethiopian Journal of Weed Management, *5*: 13-26. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=b032e9483aae0b9e03a21fe2c886477deeb43327.

Bajwa AA, Chauhan BS, Farooq M, Shabbir A and Adkins SW. 2016. What do we really know about alien plant invasion? A review of the invasion mechanism of one of the world's worst weeds. Planta, *244*: 39-57. https://doi.org/10.1007/s00425-016-2510-x.

Bhuvaneshwari K, Muniyappan C, Priyadharshini D, Sathyapriya P, Rathika S and Ramesh T. 2019. Allelopathic effect of *Parthenium hysterophorus* L. on germination and seedling growth of different field crops. The Pharma Innovation Journal, *8*: 257-261. https://www.thepharmajournal.com/archives/2019/vol8issue7/PartE/8-7-15-911.pdf

Demissie AG, Ashenafi A, Arega A, Etenash U, Kebede A and Tigist A. 2013. Effect of *Parthenium hysterophorus* L. on germination and elongation of Onion (*Allium cepa*) and Bean (*Phaseolus vulgaris*). Research Journal of Chemical and Environmental Sciences**,** *1*: 17-21. http://www.aelsindia.com/vol1june2013/3f.pdf.

Gnanavel I. 2013. *Parthenium hysterophorus* L: a major threat to natural and agroecosystems in India. Science International, *1*: 124-131. http://docsdrive.com/pdfs/scienceinternational/sciintl/2013/124-131.pdf.

Hassan G, Rashid HU, Amin A, Khan IA and Shehzad N. 2018. Allelopathic effect of *Parthenium hysterophorus* on germination and growth of some important crops and weeds of economic importance. Planta Daninha, v36:e018176372. https://doi.org/10.1590/S0100-83582018360100132.

Khan SA and Aneja KR. 2016. Parthenium infestation and yield losses in agricultural crops. Indian Journal of Weed Science, *48*: 428–431. http://dx.doi.org/10.5958/0974-8164.2016.00109.X.

Khanh TD, Chung IM, Tawata S and Xuan TD. 2006. Weed suppression by *Passiflora edulis* and its potential allelochemicals. Weed Research, *46*: 296-303. https://doi.org/10.1111/j.1365-3180.2006.00512.x.

Masum SM, Ali MH, Mandal MS, Haque MN and Mahto AK. 2012. Influence of *Parthenium hysterophorus*, *Chromolaena odorata* and PRH on seed germination and seedling growth of maize, soybean and cotton. Bangladesh Journal of Weed Science*, 3*: 83-90. https://www.researchgate.net/publication/269277785.

Masum SM, Halim A, Mandal MSH, Asaduzzaman M and Adkins S. 2022. Predicting current and future potential distributions of *Parthenium hysterophorus* in Bangladesh using Maximum Entropy Ecological Niche Modelling. Agronomy, *12*: 1592. https://doi.org/10.3390/agronomy12071592.

Masum SM, Hasanuzzaman M and Ali MH. 2013. Threats of *Parthenium hysterophorus* on agro-ecosystems and its management: a review. International Journal of Agriculture and Crop Sciences, *6*: 684-697. www.ijagcs.com IJACS/2013/6-11/684-697 ISSN 2227-670.

Mersie W and Singh M. 1987. Allelopathic effect of *Parthenium hysterophorus* extract and residue on some agronomic crop and weeds. Journal of Chemical Ecology, *13*: 1739-47. DOI: 10.1007/BF00980214.

Navie SC, Panetta FD, McFadyen RE and Adkins SW. 2005. The effect of CO_2 enrichment on the growth of a C3 weed (*Parthenium hysterophorus* L.) and its competitive interaction with a C4 grass (*Cenchrus ciliaris* L.). Plant Protection Quarterly, *20*: 61-66. https://weedinfo.com.au/ppq_abs20/ppq_20-2-61.html.

Parthasarathi T, Suganya V and Sivakumar R. 2012. Allelopathic effect of aqueous leaf extract of *Parthenium hysterophorus* L. on seed germination and seedling growth in greengram, blackgram and groundnut. Madras Agriculture Journal, *99*: 514-517. https://www.researchgate.net/publication/254559476.

Safdar ME, Tanveer A, Khaliq A and Maqbool R. 2016. Critical competition period of parthenium weed (*Parthenium hysterophorus* L.) in maize. Crop Protection, *80*: 101-107. https://doi.org/10.1016/j.cropro.2015.11.002.

Shrestha B and Thapa CB. 2018. Allelopathic effects of invasive alien species *Parthenium hysterophorus* L. on seed germination of paddy and wheat. Himalayan Biodiversity, *6*: 1-6. https://doi.org/10.3126/hebids.v6i0.33526.

Sorecha EM and Birhanu B. 2017. Allelopathic effect of *Parthenium hysterophorus* L. on germination and growth of peanut and soybean in Ethiopia. Advances in Crop Science and Technology, *5*: 285. DOI:10.4172/2329-8863.1000285.

Srivastava J, Raghava N and Ragha va RP. 2011. Allelopathic potential of parthenium to reduce water absorption in germinating cowpea seeds. Indian Journal of Scientific Research, *2*: 59-65. https://indianjournals.com/ijor.aspx.

Tahseen NK, Kumar H and Jagannath S. 2015. Assessment of allelopathic efficacy of *Parthenium hysterophorus* L. plant parts on seed germination and seedling growth of *Phaseolus vulgaris* L. Brazilian Journal of Biological Sciences, *2*: 85-90. http://revista.rebibio.net/v2n3/v02n03a09.pdf.

Tefera T. 2002. Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedling growth of *Eragrostis tef* (Zucc.) Trotter. Journal of Agronomy and Crop Science, *188*: 306-310. https://doi.org/10.1046/j.1439-037X.2002.00564.x.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 163-171

TAXONOMIC ACCOUNT OF SOME CRAB-SPIDERS GENUS *THOMISUS* WALCKENAER, 1805 (ARANEAE: MISUMENINAE: THOMISIDAE) FROM BANGLADESH

Vivekananda Biswas[1] and Dinendra Raychaudhuri[2]

[1]Department of Zoology, Khulna Government Women's' College, Khulna, Bangladesh. [2]Entomology Laboratory, Department of Zoology, University of Calcutta, Kolkata, India

Corresponding e-mail: vivekarach@gmail.com

Received: 19 October 2023, revised: 25 October 2023, accepted: 5 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.9

ABSTRACT

A taxonomic study on the crab-spiders genus *Thomisus* Walckenaer was carried out in different areas of coastal region of Khulna, Bangladesh. Two species were recorded in this study of which *T. bhagabati* n. sp. was identified as new to science and another one *T. cherapunjius* Tikader was recorded for the first time in Bangladesh. The generic diagnosis, description of the species, distribution and key to the species was provided.

Keywords: Taxonomy, morphology, crab-spider, Araneae, Misumeninae, Thomisidae.

Introduction

Crab-spiders (Family Thomisidae) of the genus *Thomisus* Walckenaer, 1805 are one of the common predatory members in the gardens and forests of Bangladesh. They are very colourful and attractive but cannot make any web and stay themselves spreading the first pair of legs on the leaves or flowers of plants for the preys. Some members show a degree of camouflage or mimicry during preying in the fields. The genus was first established by Walckenaer in 1805 with the type-species *T. onustus* Walckenaer. At present, the genus is represented by 145 species in the world fauna (World Spider Catalog 2023) and 45 species in the Indian Sub-continent (Tikader 1971, 1980, Majumder 2005, Majumder 2007, Keswani 2012) but their numbers are very poor in Bangladesh and till date, only 8 (eight) species are recorded (Chowdhury and Nagari 1981; Chowdhury and Pal 1984, Okuma *et al*. 1993, Biswas *et al.* 1993, Biswas 2009, Biswas 2019, Biswas 2023a, b). A good number of species are described in other Asian countries like - China (Chen and Zhang 1991, Zhao 1993) Japan (Song *et al.* 1999, Song and Zhu 1997, Shikai and Takano 1984, Yaginuma 1986, Ono 1988, Ono *et al.* 2009), Korea (Paik 1978, Kim and Lee 2012, Singapore Koh 1989, Koh *et al.* 2015) and in Philippines (Barrion and Litsinger 1995).

In Bangladesh, there is no taxonomic description of *Thomisus* species except Biswas (2023 a, b). Therefore, the present study was undertaken and it represents an illustrated description of 2 (two) species of the genus *Thomisus* Walckenaer of which one is described as new to science and another one is newly recorded from the areas of present study. Generic diagnosis, distribution and key to the species are also provided herewith.

Materials and Methods

Collection and Preservation: Specimens of the genus *Thomisus* Walckenaer were collected from the gardens and crop-fields of southern coastal districts Bagerhat, Khulna and Pirojpur of Bangladesh. Collection was made by jerking the branches of plants on the inverted umbrella placed underneath the plants (Tikader 1987). Specimens thus collected were then placed to a large glass jar filled with chloroform for paralyzing the specimens and make it easy for next step of study. These are then transferred to a petri-dish filled with 70% ethyl alcohol for sorting. After sorting, specimens were preserved in separate glass vials with 70% alcohol and put for identification and future study.

Identification and Study: The specimens thus preserved were identified following different books and journals of home and abroad. These are - Tikader (1971, 1980, 1987); Tikader and Biswas (1981), Ono (1988, 2009), Barrion

and Litsinger (1995), Song and Zhu (1997), Dondale and Redner (1978), Okuma *et al.* (1993), Koh (1989), Chen and Zhang (1991), Zhao (1993), Levy (1973, 1985), Yaginuma (1886), Kim and Gwon (2002), Biswas (2009), Tang and Li (2010) and Kim and Lee (2012).

After identification, the specimens were permanently preserved for future study (separate specimens in separate vials) in Audmans' Preservatives (90 parts 70% alcohol + 5 parts glycerene + 5 parts glacial acetic acid) following the method by Lincoln and Sheals (1985).

Necessary taxonomically important body-parts of identified specimens were dissected out under the Stereozoom Binocular Microscope placed on a petri-dish filled with 70% ethyl alcohol and sand grains. Male palp after dissection was boiled in 10% KOH for 3-5 minutes and female epigynum after dissection placed in clove oil for 12 to 18 hours (Levi 1965; Tikader 1987). After dissection, both male palp and female genitalia (epigynum) were placed in separate microvials and put it in a large vial along with the parent spider within Audmans' Preservative.

Illustrations and Photographs: Whole body of spider and its different body-parts were illustrated under a Stereozoom Binocular Microscope fitted with Camera lucida. Leg measurements were taken under the same condition in the following sequences: femur, patella, tibia, metatarsus, tarsus and total length. All measurements were taken in millimeters (mm). Photographs of the identified specimens were taken both in natural condition (in the field) by DSLR Camera fitted with 90 mm macrozoom lens and in the laboratory by the Camera fitted microscope (model SV8, Zeiss).

Type deposition: After completion of necessary drawings of different body-parts, with Camera lucida, the preserved specimens were put separately (single specimen in single vial) and then placed in a large glass jar full of 70% alcohol. Later, the types were preserved with the collection of the Department of Zoology, Khulna Government Womens' College, Khulna and will be deposited to the Museum of the Department of Zoology, University of Dhaka, in due course of time.

Results and Discussion

Systematics

Family: THOMISIDAE Sundevall, 1833

Subfamily: Misumeninae Sundevall, 1833

Genus: *Thomisus* Walckenaer, 1805

Type-species: *T. onustus* Walckenaer, 1805

1805. *Thomisus* : Walckenaer, *Tabl. Aran.,*: 28.

1869. *Thomisus* : Stoliczka, *J. Asiat. Bengal.,* 38: 225.

1895. *Thomisus* : Simon, *Hist, Nat. Arainees,* 1(4): 1023.

1935. *Thomisus* : Dyal, *Bull. Dept. Zool. Panjab Univ.,*1: 200.

1954. *Thomisus* : Roewer, *Catalogue der Araneae,* 2: 855.

1957. *Thomisus* : Commelini, *Rev. Zool. Bot. Afr*., LV (1-2): 1.

1962. *Thomisus* : Tikader*, J. Linn. Soc.,* London, 44 (300): 569.

1971. *Thomisus* : Tikader, *Mem. Zool. Surv. India*, 15 (3): 13.

1973. *Thomisus* : Levy, *Israel J. Zool.,* 22: 124.

1980. *Thomisus* : Tikader, *Fauna of India,* Araneae: Thomisidae, 1(1): 30.

1985. *Thomisus* : Levy, *Fauna Palaestina, Arachnida* II, Araneae, Thomisidae: 35.

1986. *Thomisus* : Yaginuma, *Spiders of Japan in colour*: 211.

1988. *Thomisus* : Ono, *Bull. Natn. Sci. Mus*., Tokyo: 193.

1991. *Thomisus* : Chen and Zhang, *Fauna of Zhejiang,* Araneida: 278.

1995. *Thomisus* : Barrion and Litsinger, *Riceland spiders of South and Southeast Asia*: 228.

1997. *Thomisus* : Song and Zhu, *Fauna Sinica,* Thomisidae and Philodromidae: 163.

1997. *Thomisus* : Mikhailov, *Cat. Spiders of territories of former Soviet Union*: 197.

1997. *Thomisus* : Platnick, *Advances in Spider Taxonomy*: 839.

1999. *Thomisus* : Song *et al*., *The Spiders of China*: 486.

2001. *Thomisus* : Kim and Gwon, *Korean Arachnol.,* **17** (1): 45.

2002. *Thomisus* : Buchar and Ruzicka, *Catalogue Spiders of Czech Republic*: 172.

2004. *Thomisus :* Gajbe, *Rec. Zool. Surv. India,* Occ. Pap. **227**: 112.

2005. *Thomisus :* Majumder, *Mem. Zool. Surv. India,* **20** (3): 51.

2006. *Thomisus :* Platnick, *World Spider Catalog*, Version 6.5: 2688.

2007. *Thomisus :* Dippenaar-Schoeman and Hrten, *Fauna of Arabia*, **23**: 171.

2009. *Thomisus :* Biswas, *Encyclopedia of Flora and Fauna of Bangladesh,* Arachnida, **18** (1): 355.

2010. *Thomisus :* Tang and Li, *Zootaxa, Monograph,* **2369**: 62.

2012. *Thomisus :* Kim and Lee, *Invertebrate fauna of Korea*, **21** (9): 45.

2015. *Thomisus* : Platnick, *World Spiders Catalog,* Version 15.0, http://www.research.amnh.org/iz/spider/catalog/intro.html

2023. *Thomisus :* *World Spider Catalog,* Version 23.0, Natural History Museum, Bern., online at – http://www.wsc.nmbe.ch (accessed on 7th Febr. 2023

Diagnosis: Spiders of the genus *Thomisus* Walckenaer with short, compact and robust bodies. Body bright in colour. Cephalothorax truncated in front, with the upper fore corners strongly and conically protruberant and divergent. All eyes very small, arranged in two rows, with lateral eyes on distinct eye tubercles; anterior row strongly recurved with medians nearer to laterals than the others. Leg long, relatively much longer in males; leg I and II much longer than III and IV.

Abdomen narrow and truncated in front, enlarging to a considerable width behind, where at either corner with a short, blunt, conical protruberance.

Females small to medium in size (2 mm – 11 mm). Carapace usually as wide as long, high and convex but posterior margin concave. Males are much smaller (1.9 mm – 3.6 mm) and most species darker in colour, with strong erect setae both on the carapace and abdomen. Eye tubercles in all species distinct and sharply pointed.

Biological Note: Spiders of the genus *Thomisus* are usually live in vegetation, mainly inside flower corollas. They cannot make any web and can consume small insects in the crop-fields and gardens. Some can change their colours to match the substratum (Levy 1985). They catch their prey lurking on the flowers with their legs spread widely.

Distribution: Africa, America, Asia, Australia and Europe.

Key to the species of genus *Thomisus*

1. Abdomen elongately oval, posteriorly narrowed, without any reticulation; cephalothorax with distinct radii; palpal cymbium elongate, inwardly curved and bluntly pointed; cheliceral margins without any teeth; labium anteriorly narrowed; sternum anteriorly broad and posteriorly narrowed .....……..……..……..…….. *T. bhagabati* n. sp.

- Abdomen rhomboid, posteriorly broad, with scally reticulation; cephalothorax without any radii but with alternately arranged yellow, black and white longitudinal bands; palpal cymbium short and sharply pointed ; only outer margin of chelicerae with one tooth; labium anteriorly broadly rounded ; sternum parallel sided, posteriorly pointed ….. *T. cherapunjius*

1. *Thomisus bhagabatii* n. sp. (Figure 1a-e; 3a)

Material examined: male, Chitalmari, Bagerhat, Bangladesh, 18. V. 1993, Coll. V. Biswas (Holotype); male, Batiaghata, Khulna, Bangladesh, 25. VII. 1992, Coll. V. Biswas (Paratype).

General: Body small, light brown in colour**.** Cephalothorax and legs brown; abdomen yellowish.

Male (Holotype): Total body length 8.30 mm. Carapace 2.50 mm long, 2.00 mm wide; abdomen 5.80 mm long, 1.80 mm wide and 1.20 mm height.

Female (Allotype): Unknown.

Cephalothorax: Male: broad, longer than wide, anteriorly convex and narrowing, posteromedially wide. Both anterior and posterior eyes recurved; anterior row of eyes shorter; posteromedian eyes distantly placed than the anteromedians; ocular quad wider than long; radii distinct. Chelicerae brown, moderately strong, wider basally, without any teeth on the margins, clothed with hairs and spines (Fig. 1b). Maxillae longer than wide, anteriorly wide and scopulate (Fig. 1c). Labium longer than wide, posteriorly wide, anteriorly narrow and scopulate (Fig.

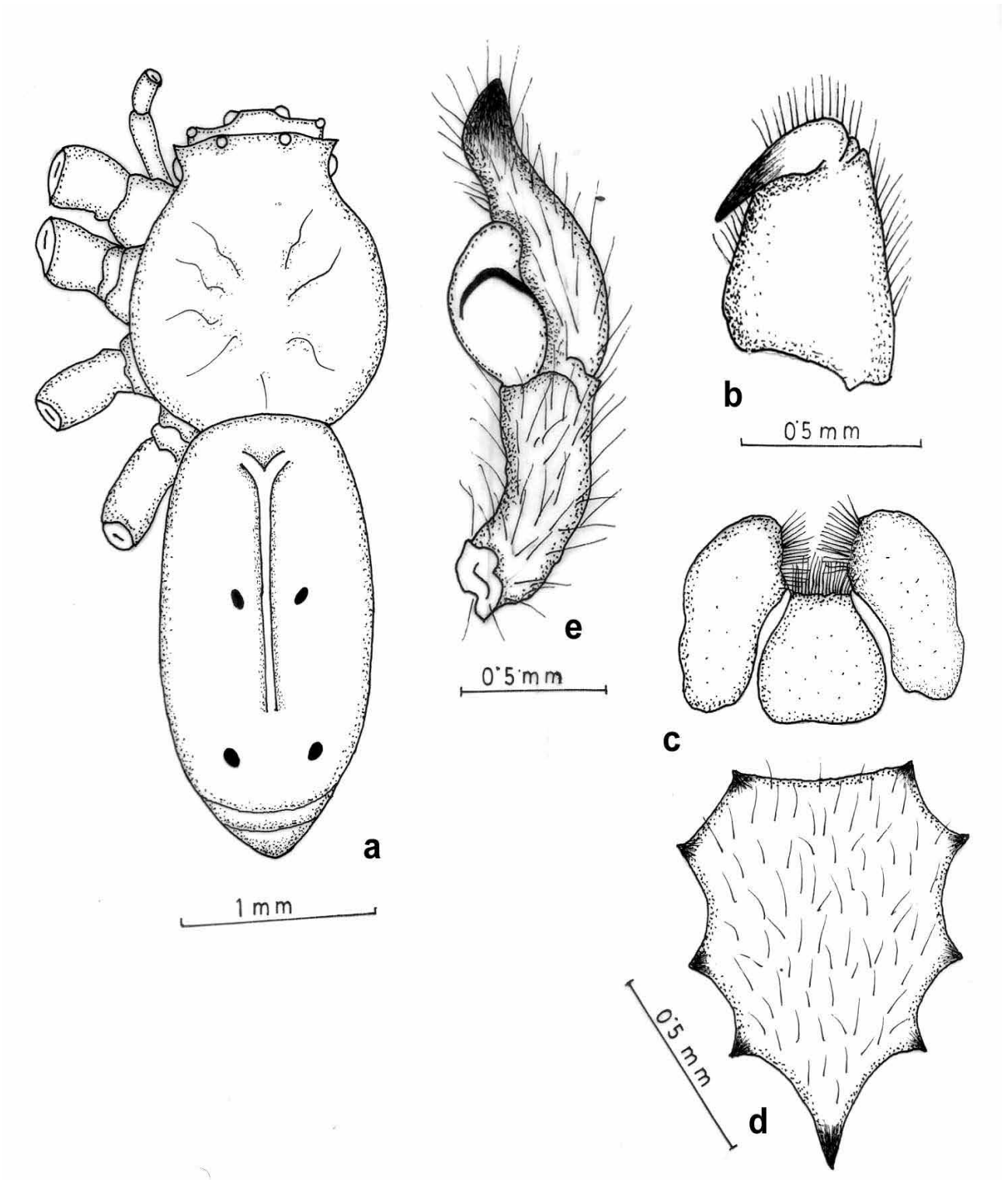


Figure 1. *Thomisus bhagabatii* n. sp. a. Whole body (dorsal view); b. Chelicerae; c. Maxillae and Labium; d. Sternum; e. Male palp

Table 1. Measurements (mm) of leg segments of *T. bhagabati* in. sp.

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	4.00/4.00	1.50/1.50	2.40/2.40	2.50/2.50	1.00/1.00	11.40/11. 40
II	3.90/3.90	1.00/1.00	2.10/2.10	2.10/2.10	1.00/1.00	10.10/10.10
III	2.00/2.00	0.90/0.90	1.80/1.80	1.80/1.80	0.70/0.70	7.20/7.20
IV	2.00/2.00	0.90/0.90	1.80/1.80	1.80/1.80	0.70/0.70	7.20/7.20

1c). Sternum heart-shaped, anteriorly wide, posteriorly produced and pointed, clothed with spines (Fig. 1d). Legs long and strong, clothed with spines; leg formula 1243 and the measurements (in mm) are shown in Table 1.

Abdomen: longer than wide, nearly dumbel shaped; dorsum with a median anteriorly bifurcated band; posterior half with 2 pairs of dark brown spots or sigillae.

Type-specimen: Holotype- male in spirit; **Paratype-** one male in spirit.

Type-locality: Bangladesh: districts Bagerhat and Khulna, southwestern part of the country near Sunderbans.

Etymology: The species is named after Professor Bhagabati Sarker, Department of Philosophy, Government Profulla Chandra College, Bagerhat, Bangladesh.

Type-locality: Bagerhat and Khulna of Bangladesh.

Remarks: By the shape of the abdomen the species *T. bhagabatii* n. sp. appears close to *T. elogatus* Stoliczka (Tikader, 1980) but it stands distinct in having cephalothorax wider than abdomen, band on ocular area straight, abdomen with an anteriorly bifurcate mid-longitudinal band, posteriorly with 2 pairs of dark brown spots or sigillae and typical male palp.

The species, is therefore, described as new to science.

Type deposition: The types are at present in the collection of the Department of Zoology, Khulna Government Womens' College, Khulna and will be deposited to the Museum of the Department of Zoology, University of Dhaka, Bangladesh, in due course of time.

2. *Thomisus cherapunjius* Tikader (Figs. 2a- f; Fig. 3b)

1966. *Thomisus cherapunjius* : Tikader, *Proc. Indian Acad. Sci*., 64 (1): 54.

1980. *Thomisus cherapunjius* : Tikader, *Fauna of India,* Thomisidae 1 (1): 54.

1992. *Thomisus cherapunjius* : Biswas and Biswas, *Fauna of West Bengal,* Araneae, Part-**3**: 408.

2005. *Thomisus cherapunjius* : Majumder, *Mem. Zool. Surv. India,* 20 (3): 52

2009. *Thomisus cherapunjius* : Biswas, *Encyclopedia of flora and fauna of Bangladesh,* Arachnida, 18 (1): 357.

2015. *Thomisus cherapunjius* : Platnick, *World Spider Catalog,* Version 15.0, http://www.research.amnh.org./iz/spider/catalog/intro.html

2023. *Thomisus cherapunjius* : *World Spider Catalog*, Version 23.0, Natural History Museum, Bern., online at– http://www.wsc.nmbe.ch (accessed on 7th Febr., 2023)

Materials examined: 1 female and 1 male, Bagerhat, Bangladesh, 18. V. 1990, Coll. V. Biswas; 1 female, Barisal, Bangladesh, 25. VI. 1991, Coll. V. Biswas; 1 female, Jashore, Bangladesh, 12. VI. 1990, Coll. V. Biswas; 2 female, Jhenaidah, Bangladesh, 28. VII. 1990 and 05. VIII. 1992, Coll. V. Biswas; 2 female and 1 male, BARI, Jashore, Bangladesh, 25. VII. 1990, Coll. V. Biswas; 2 females, Khulna, Bangladesh, 20. X. 1991, Coll. V. Biswas; 1 female, Satkhira, Bangladesh, 15. V. 1992, Coll. V. Biswas.

General: Body small to medium in size. Cephalothorax and legs green; abdomen mixed with brown and dirty

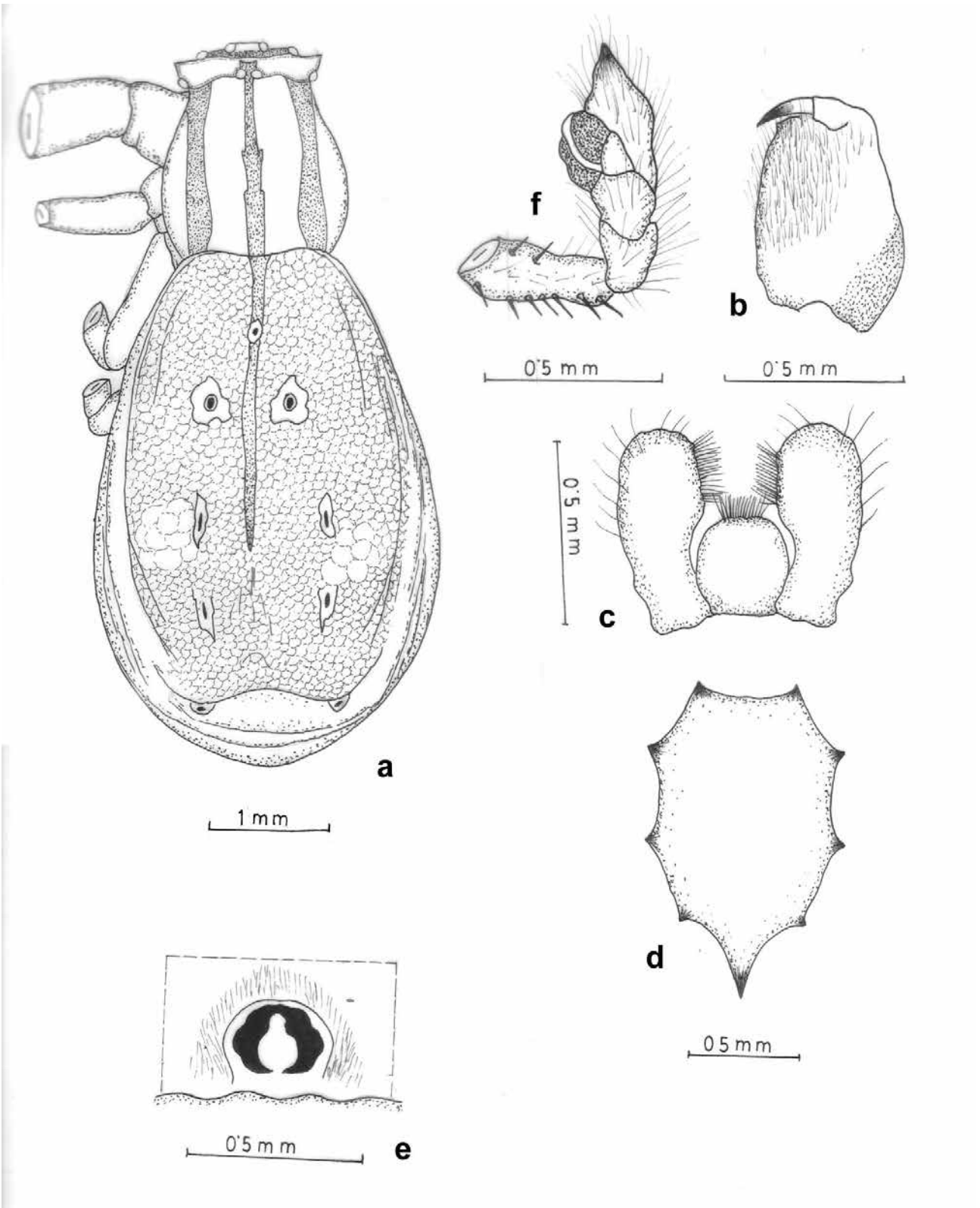


Figure 2. *Thomisus cherapunjius* Tikader a. Whole body (dorsal view); b. Chelicerae; c. Maxillae and Labium; d. Sternum; e. Epigynum; f. Male palp

Table 2. Measurements (mm) of leg segments of *T. cherapunjius* Tikader

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	2.00/2.00	0.80/0.80	2.00/2.00	2.00/2.00	0.80/0.80	7.60/7.60
II	2.00/2.00	0.80/0.80	1.90/1.90	2.00/2.00	0.80/0.80	7.50/7.50
III	1.00/1.00	0.30/0.30	0.80/0.80	0.80/0.80	0.30/0.30	3.20/3.20
IV	1.50/1.50	0.30/0.30	0.80/0.80	0.50/0.50	0.30/0.30	3.40/3.40

white. Total body length (female) 5.40 mm. carapace 2.00 mm long, 1.80 mm wide ; abdomen 3.40 mm long and 2.50 mm wide. Total body length (male) 5.00 mm. Carapace 2.00 mm long, 1.60 mm wide ; abdomen 3.00 mm long and 2.50 mm wide.

Cephalothorax: Slightly longer than wide, clothed with fine hairs ; cephalic region slightly raised, narrowing anteriorly ; dorsum with 2 dark brown, lateral longitudinal bands ; ocular tubercle chalk-white, high, produced laterally, pointed and transversely joined with an elevated ridge ; a narrow longitudinal chalk-white band extending mi-dorsally from ocular area to the base of thorax. Eyes black ; anterior row recurved and shorter than the straight posterior row ; lateral eyes placed on the base of lateral conical tubercle; posteromedians closer than the anteromedians, posterolaterals distinctly placed ; ocular quad longer than wide and narrowing posteriorly. Chelicerae thick, brownish, fang segmented, fang furrow with 1 tooth on inner margin (Fig. 2b). Maxillae longer than wide, anteriorly wide and scopulate (Fig. 2c). Labium globose, medially broad and anteriorly scopulate (Fig. 2c). Sternum elongate, wide medially, posteriorly produced and pointed, clothed with fine hairs (Fig. 2d). Legs long and slender, I and III very long; tibiae and metatarsi I with 5 and 8 pairs of strong ventral spines; leg formula 1243 and the measurements (in mm) are shown in Table 2.

Abdomen: Longer than wide, wider posteriorly, nearly brinjal – shaped, anteriorly narrowing; dorsum with 3 pairs of brownish markings on the either side of dorso-median longitudinal chalk-white band extending from the anterior margin upto the 2/3rd of abdomen, marginally with 3 or 4 longitudinal brown lines; ventrally pale green; epigyne as in fig. 2e.

Distribution: Bangladesh: Bagerhat, Barisal, Jashore, Jhenaidah, Khulna and Satkhira; India (Biswas, 2009; Tikader, 1966, 1980).

Conclusion

Spiders of the genus *Thomisus* Walckenaer are one of the important and attractive members in the crop-fields and gardens. From the taxonomic history of these spiders of Bangladesh (Chowdhury and Pal 1984; Okuma *et al.* 1993; Biswas 1995, 2009; Biswas *et al.* 1993; Begum and Biswas 1997), it is found that there is no previous record on these spiders and both the described species are the new record for the area of present study. From this study, it is also observed that there are some variable characters like- colour, shape, size etc. found in these species which varies with the Indian fauna.

In the behaviour, both these species are natural predators of the crop-fields and garden pest insects. They consume the preys by a peculiar manner both from the plant leaves and flowers. Majority of the members of this genus stay on petals of colourful flowers for the preys showing mimicry. Therefore, these are also called the 'flower spiders' and are considered as one of the important biological control agents of crop pests.

Acknowledgements

The authors are grateful to Dr. S. C. Majumder, Scientist – SD, Zoological Survey of India, Kolkata, for confirmation of the identity of the species and the Head, Department of Zoology, University of Calcutta, Kolkata, for kind permission during the study.

References

Barrion AT and Litsinger JA. 1995. *Riceland spiders of South and Southeast Asia.* CAB International, Wallingford, UK, XIX + 700 p.

Begum A and Biswas V. 1997. A list of spider fauna of Barisal division, Bangladesh (Araneae: Arachnida). Bangladesh Journal of Zoology, *25*: 207-210.

Biswas V. 2019. Checklist of the spider fauna of Bangladesh (Araneae: Arachnida). Bangladesh Journal of Zoology, *47*: 185- 227.

Biswas V. 2023a. A new species of crab-spider under the genus *Thomisus* Walckenaer, 1805 (Araneae: Thomisinae: Thomisidae) from Bangladesh. Journal Asiatic Society of Bangladesh (in press).

Biswas V. 2023b. First time report on the crab-spider species *Thomisus pugilis* Stoliczka, 1869 (Araneae: Thomisinae: Thomisidae) from two Southern districts of Bangladesh. Journal Asiatic Society of Bangladesh (in press).

BISWAS V. 1995. *Studies on the spider fauna* (*Araneae: Arachnida*) *of Bangladesh* Ph. D. thesis, Department of Zoology, University of Calcutta +50 plates, 622 p.

Biswas V. 2009. (In Ahmed ed.) Encyclopedia of flora and fauna of Bangladesh, Arachnida, *18*, Asiatic Society of Bangladesh, Dhaka, p. 437.

Biswas V, Khan HR, Kamal NQ and Begum A. 1993. A preliminary study of the rice-field spiders of Jhenidah, Bangladesh. Bangladesh Journal of Zoology, *21*: 85-92.

Chen ZF and Zhang ZH. 1991. *Fauna of Zhejiang, Araneida.* Zhejiang Science and Technology Publication House, p. 356.

Chowdhury SH and Pal SK. 1984. Further report on the rice-field spiders from Bangladesh. Chittagong University Studies, 2: 25-39.

Chowdhury SH and Nagari S. 1981. Rice-field spiders from Chittagong. Proceedings of Zoological Society of Bangladesh, 53-72.

Dondale CD and Redner JH. 1978. The crab-spiders of Canada and Alaska (Araneae: Philodromidae: Thomisidae). Biosystematic Research Institute, Agriculture, Canada, p. 255.

Keswani S, Hadole P and Rajoria A. 2012. Checklist of spiders (Arachnida: Araneae) from India – 2-12. Indian Journal of Archaeology, *1*: 1- 129.

Kim JP and Gwon SP. 2001. A revisional study of the spider family Thomisidae Sundevall, 1833 (Arachnida: Araneae) from Korea. Korean Archaeology, *17*: 13 - 78.

Kim ST and Lee SY. 2012. *Invertebrate fauna of Korea,* Thomisid spiders. National Institute of Biol. Resource, MO Education, *2*: 1-88

Koh JKH. 1989. *A Guide to Singapore Spiders.* Singapore Science Centre, p. 160.

Levi HW. 1965. Techniques for the study of spider genitalia. *Psyche, 72*: 152-158.

Levy G. 1973. Crab-spiders of six genera from Israel (Araneae: Thomisidae). Israel Journal of Zoology, *22*: 107 - 141.

Levy G. 1985. Fauna Palaestina, Arachnida – II, Araneae : Thomisidae. Israel Academy of Science and Humanities, Jerusalem, p. 111.

Lincoln RJ and Sheals JG. 1985. Invertebrate Animals: Collection and Preservation. British Museum (Natural History), London, p. 150.

Majumder SC. 2005. Studies on some spiders from eastern coastal region of India. Zoological Survey of India, *20*: 1- 57.

Majumder SC. 2007. Pictorial Handbook on Spiders of Sunderbans, West Bengal, India. Zoological Survey of India, Kolkata, p. 138.

Okuma C, Kamal NQ, Hirashima Y, Alam Z, and Ogata T. 1993. Illustrated Monograph on the rice-field spiders of Bangladesh. IPSA-JICA, Salna, Gazipur, p. 93.

Ono H. 1989. Revisional study on the spider family Thomisidae (Arachnida: Araneae) of Japan. Bulletin of the National Museum of Nature and Science, Tokyo, 17: 374-375.

Ono H. 2009. The spiders of Japan with key to the families and genera and illustrations of the species. Tokai University Press, Kanagawa, *16*: 739.

Paik KY. 1978. Araneae: Illustrated flora and fauna of Korea., *21*: 1-548.

Song DX and Zhu MS. 1997. Fauna Sinica, Arachnida: Aranae (Thomisidae: Philodromidae). Science Press, Beijing, p. 259.

Song DX, Zhu MS and Chen J. 1999. The Spiders of China. Hebei Science and Technology Publishing House, p. 640.

Tang G and Li SQ. 2010. Crab-spiders from Hainan Island, China (Araneae, Thomisidae). *Zootaxa*, 2369: 1-68.

Tikader BK. 1966. Studies on some crab-spider (Family: Thomisidae) from Khasi and Jaintia hills, Assam, India. Proceedings of the Indian Academy of Science, *64*: 53-61.

Tikader BK. 1971. Revision of Indian crab-spiders (Araneae: Thomisidae). Zoological Survey of India, *15*: 1- 90.

Tikader BK. 1980. *Fauna of India, Araneae* (Thomisidae), Zoological Survey of India, Kolkata, p. 247.

Tikader BK. 1987. *Handbook of Indian Spiders.* Director, Zoological Survey of India, Kolkata, p. 251.

Tikader BK and Biswas B. 1981. Spider fauna of Calcutta and Vicinity. Records of the Zoological Survey of India, *30*: 1-149.

World Spider Catalog, 2023. World Spider Catalog, Version 23.0, Natural History Museum, Bern., online at – http ://www.wsc.nmbe.ch (accessed on 7th February, 2023).

Yaginuma T. 1986. Spiders of Japan in Color. 2nd edition, Hoikusha Publishing Company Ltd., Osaka, p. 305.

Zhao JZ. 1993. Spiders in the Cotton Fields in China. Wuhan Press, China, p. 552.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 173-180

EFFICACY OF SOME PLANT OILS AND GROWTH REGULATORS ON TWO-SPOTTED SPIDER MITE

Most. Monsefa Aktar, Mst. Farjana Akter Nipu, Md. Nizam Uddin, Mohammad Mosharof Hossain Bhuyain and Md. Adnan Al Bachchu*

Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh.

Corresponding e-mail: adnan@hstu.ac.bd

Received: 24 November 2023, revised: 30 November 2023, accepted: 05 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.10

ABSTRACT

Two-spotted spider mite, *Tetranychus urticae* Koch, is one of the most damaging pests of many economically important crops. The acaricidal, ovicidal and nymphal activity of three essential plant oils viz. neem, mahagoni, castor and two insect growth regulators viz. buprofezin and lufenuron + Emamectin benzoate were evaluated against *T. urticae* under laboratory conditions and in the potted plants. Results showed that mahagoni oil (100%) and lufenuron + emamectin benzoate (100%) performed the most efficient acaricidal agent against *T. urticae* in the laboratory conditions. Mahagoni oil also showed the highest ovicidal efficacy (77.2%) and lufenuron + emamectin benzoate (74.6%) showed the second highest ovicidal efficacy against *T. urticae*. Castor oil showed the lowest percent of ovicidal efficacy (48.1%). In the case of the nymph, the highest average mortality was observed in mahagoni oil (55.4%) followed by lufenuron + emamectin benzoate (52.8%). The lowest nymphal mortality was observed in castor oil (31.3%). In potted bean plants, all the treatments showed a significant reduction in the adult population over control up to 21 days. The adult *T. urticae* population's survival rate progressively declined throughout the length of the days after treatment (DAT) for each treatment up to seven days, then slightly climbed up to 21 days. However mahagoni oil (77.8%) and lufenuron + emamectin benzoate (72.2%) showed the highest mite mortality compared to all other treatments. Therefore mahagoni oil and lufenuron + emamectin benzoate were found to be the most effective to control *T. urticae.*

Keywords: Country bean, *Tetranychus urticae*, mortality, plant oils.

Introduction

The two-spotted spider mite was originally described from European specimens. Since 1900 the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), has become an increasingly important agricultural pest and is a worldwide pest of many plant species including several economically important agricultural crops. It is one of the most damaging polyphagous pest and attacks more than 1000 plant species of vegetables, fruits, crops, and a wide variety of ornamentals are among its host plants belonging to about 140 plant families (Grbic *et al*. 2011). Some vegetables are grown year-round, while others are produced during specific growing seasons. They are important food considering the aspects of nutritional, financial as well as food security in Bangladesh. According to Rincon *et al.* (2019), the price of losses caused by this pest in crops like beans, citrus, cotton, avocado, apples, pears, plums, and many more horticultural and decorative crops is expected to be above 4500 USD per hectare.

The two-spotted spider mite prefers the hot, dry weather of the summer and fall months, but may occur anytime during the year (Fasulo and Denmark 2009). Overwintering females hibernate in ground litter or under the bark of trees or shrubs. Season and host plants have an impact on the longevity and fecundity of this mite (El-Taj *et al.* 2016). Adults and nymphs consume the sap from the underside of leaves, which causes yellowing and staining (Reddy and Kumar 2006). Feeding close to the midrib and plant veins typically results in a 50–100% yield loss (Kumar *et al*. 2010). In cases of severe infestation, the mite creates webbing on the leaves which causes the damaged leaves to dry out and fall off (Reddy *et al*. 2014). In greenhouse conditions, it causes economic damage to high value crops in severe infestation. The damaged

cells appear as yellowish white spots and chlorophyll is destroyed from the upper surface of the leaf. Continued feeding causes a stippled-bleached effect and later, the leaves turn yellow, grey or bronze. Mite not only causes direct damage to plants by leaf defoliation and burning but also causes indirect damage to plants due to decrease in photosynthesis and transpiration (Brandenburg and Kennedy 1987).

The control of spider mites is a challenge and difficult due to their short life cycle. Conventionally, spider mites have been controlled by different systemic chemical pesticides but quick development of pesticide resistance by the mite was reported (Van Leeuwen *et al*. 2010). Moreover, the use of synthetic chemicals has resulted in serious environmental problems and has been a threat to human life (Kim *et al*. 2005). Therefore, alternative strategies such as the use of different bio-control agents, essential plant oils and insect growth regulators need to explore for their acaricidal activity against the *T. urticae* in order to reduce the chemical acaricides that are currently being used.

The essential oils (EOs) had pesticidal activities due to the presence of monoterpenes, diterpenes and sesqui terpenes (Mohamed and Alotaibi 2023). Many plant derived essential oils can be a potential alternative for mite control, because some of them are selective, biodegradable, and have few effects on non-target organisms and the environment (Giunti et al. 2022). They usually exert multiple types of beneficial properties such as repellence, antifeedant activity, growth regulatory activity and toxicity to many insect and mite pests Alexenizer and Dorn 2007). Insect growth regulators (IGRs) are substances that adversely affect insect growth and development (Tunaz and Uygun 2004). Buprofezin and lufenuron, which are potential chitin synthesis inhibitors, were found effective against many arthropod pests including mites (Kavya *et al*. 2015). However, reports on the efficacy of plant oils and IGRs against the populations of *T. urticae* were rarely found. Considering that the plant oils and IGRs have been not focused on spider mites, or in their acaricidal properties, the present research work was under taken to search a potential plant oil and insect growth regulator with their acaricidal, ovicidal and nymphal efficacy against two-spotted spider mite.

Materials and Methods

The study on the efficacy of some plant oils and insect growth regulators against *Tetranychus urticae* was conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of July to December 2022.

Mite collection and rearing: The adult *Tetranychus urticae* was collected from an infested bean field of HSTU campus, Dinajpur, Bangladesh from August to September 2022. The colony was maintained without application of any acaricides or pesticides on country bean plants reared on the bean leaves in the laboratory.

Table 1. List of treatments used in bioassay

Treatments	Trade name	Active ingredients	Nature of chemical	Manufacturar/ sources	Recommended dose / L water
T_1	Neem oil	Azadirachtin	Antifeedant and repellent	Market	2.0 ml
T_2	Mahogany oil	saponin	Antifeedant and repellent	Market	2.0 ml
T_3	Castor oil	Ricicin	Antifeedant and repellent	Market	2.0 ml
T_4	Award 40 SC	Buprofezin	Contact and stomach	Square pharmaceuticals company Limited	0.5 %
T_5	Lumectin 10 WDG	Lufenuron (5%) + Emamectin Benzoate (5%)	Contact and systemic	Haychem (Bangladesh) Limited	0.5 ml
T_6	Control	-	-	-	-

Collection of plant oils and insect growth regulators: Plant oils namely neem, *Azadirachta indica* A. Juss, Mahogany, *Swietenia mahagoni* L, Castor, *Ricinus communis* L. and insect growth regulators were collected from local market at Dinajpur town, Bangladesh. Their detailed information is given in the Table 1. All the treatments were mixed with tap water at the concentrations recommended by the manufacturers. The acaricidal effect of these treatments against *T. urticae* was studied both in the laboratory and in the potted bean plants.

Topical application of treatments to adult females of *T. urticae*: A group of eighty *T. urticae* females (48 hours old) were randomly selected from culture and transferred equally to four fresh bean leaf discs (3 cm in diameter) placed adaxial side on moistened cotton in a Petri dish. Those mite-leaf discs were sprayed with the selected acaricidal suspension (2 mg cm^{-2}) using hand sprayer. The Petri dishes were left naked to avoid mite mortality due to any gassing effect of the tested treatments. A control test was maintained using tap water. Mites were considered dead as their appendages not move when prodded with a fine brush at 6, 12, 18, 24, 30, 36, 42 and 48 hours after treatment (HAT). An stereomicroscope was used to record the number of alive and dead mites. Four leaf discs serving as replicates were maintained for each treatment. Mortality data were corrected using the Abbott's correction formula (Abbott 1925).

Topical application of treatments to eggs of *T. urticae*: Bean leaf discs (3 cm diameter) were used as a substrate to ovipositor. Four leaf discs were used for each treatment and 20 female mites were placed on upside down leaf discs which were attached with wet cotton in a plastic Petri dish (9 cm diameter) and allowed to stand for 6 hours for laying eggs. After then, the adults were removed and the eggs were checked under a stereomicroscope to ensure that at least 20 eggs less than 24 hours old had been laid on each leaf disc. The leaf discs with eggs were treated with selected oils and growth regulators concentrations of 2% and 0.5ml/L with the help of a hand sprayer and allowed to dry. Control units were sprayed with tap water as a control. The number of hatched and non-hatched eggs was recorded after seven days. A stereomicroscope was used to record the number of hatched and non-hatched eggs. All females and eggs were tested under controlled conditions (25±2°C, 65±10% RH, and 16: 8 L: D).

Topical application of treatments to nymph of *T. urticae*: Bean leaf discs were placed on moistened cotton in a Petri dish. Ten moving nymphs were placed on the ventral surface of each leaf discs. The nymph with leaf discs was sprayed with the selected oils and growth regulators. A control group was maintained by spraying tap water only. Death individuals were recorded after 24, 48 and 72 hours of spraying.

Toxicity assessment in potted bean plants: The experimental area (300 L × 180 W × 300 H cm) was covered under a natural photoperiod with a thrips-proof (196 mesh) screening. The bean seeds variety of BARI seem 1 were sown in plastic containers (20 D ×20 H cm), filled with sandy loam soil and farm yard manure (1:1). Plants were allowed to grow with bamboo supported sticks. The bean plants have been fertilized and the water is supplied properly. No plant protection measures were applied throughout the study period. One month before the beginning of the study, a four-week old potted bean plants was infested with twenty adult gravid females of *T. urticae* obtained from the stock culture. All the treatments were applied at the field recommended concentration using knapsack sprayers (model ML10) under a fume hood until run off. Only water was sprayed in the control treatment. The spray volume per plant was 200 ml. Prior to treatment (day 0), randomly selected three infested leaves in each plant was observed as the typical signs of infestation (chlorotic spots). These leaves were marked, and the number of all *T. urticae* adult females on each was counted with a magnifying glass. On days 1, 3, 7, 14 and 21 after spraying, counting was repeated on those leaves. A complete randomized design (CRD) was used with six treatments and three replications.

Statistical analyses: The mortality percentage was calculated by using Abbott's corrected formula (Abbott 1925). Data were analyzed with ANOVA followed by LSD test at $p<0.05$ using statistix 10 software. Graphical works were done with excel program.

Results and Discussion

Acaricidal activity of neem, mahogany, castor oil, buprofezin and lufenuron + emamectin benzoate were tested against *T. urticae* at different time interval and are shown in Figure 1. Results showed that the mahogany

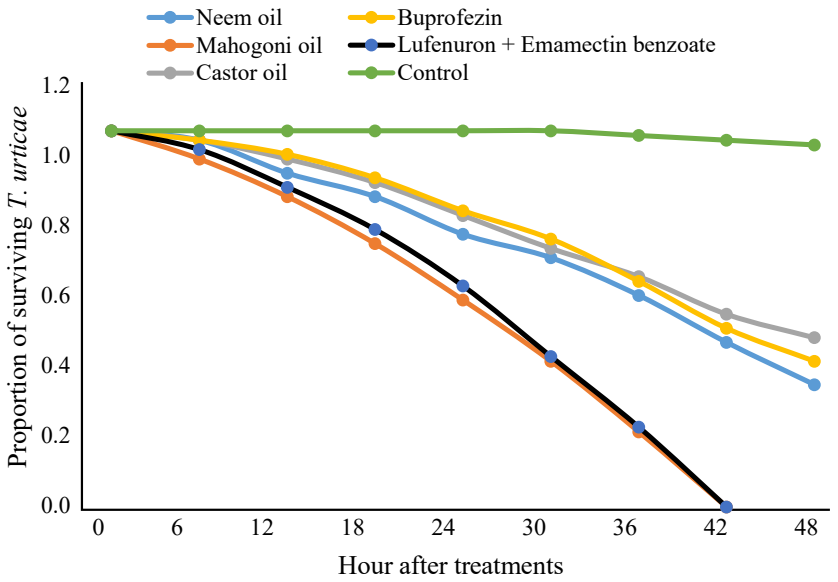


Figure 1. Survivorship of *T. urticae* adult females exposed to different treatments in topical application

oil and lufenuron + emamectin benzoate were the most potent miticide which caused the highest mortality to adults of *T. urticae* with 100% mortality within 42 hours of exposure. The second most toxic was found from neem oil with 67.5 % mortality in adult *T. urticae* (Figure 1). The mortality percentage was increased proportionally within hours after treatments. There was no mortality observed in control treatments up to 30 hours of exposure but low mortality (1.25%) was found after 48 hours of exposure. On the basis of adult mortality percentage, the order of the toxic effect of three botanical oils and two growth regulators against *T. urticae* adult were found as mahogany oil > lufenuron + emamectin benzoate > neem oil > buprofezin > castor oil.

From the above results, it is found that all the treatments showed a different level of adult mortality but mahogany oil and lufenuron + emamectin benzoate showed the best result with the highest performance. This finding is in agreement with the result of Uddin *et al.* (2014). They found that mahogany oil has the highest acaricidal activity followed by neem and eucalyptus oil. In another study, El-Zalabani *et al.* (2012) stated that ethanoic extracts of leaves and stem bark of *S. mahagoni* and *S. macrophylla* has strong acaricidal activity against *Varroa destructor* with 90% mortality.

The results presented in Table 2 that all the treatments showed significantly ($P<0.05$, $df=5$, $F=57.60$) different percent egg hatching over control. The lowest percent egg hatching (22.5%) was observed when the eggs were treated with mahogany oil which also showed the highest ovicidal efficacy (77.2%). The second lowest percent egg hatching (25.0%) was observed when the eggs were treated with lufenuron + emamectin benzoate and neem oil (33.7%) which was statistically similar. On the other hand, significantly the highest percent of egg hatching (51.2%) was found from the treatment of castor oil with showed the lowest percent of ovicidal efficacy (48.1%). In the control treatment significantly the highest percentage of egg hatching was observed (98.7%).

Above results from Table 2 indicated that mahogany oil showed the highest ovicidal efficacy which is significantly different from other treatments. Mahogany oil and lufenuron + emamectin benzoate significantly differ from control and other treatments. Based on the results, the effects of plant indicated the toxicity of the plant oils and growth regulators against the egg of *T. urticae* and the highest mortality percent (77.2%) was found in mahogany oil and castor oil showed the lowest mortality (48.1%).

The obtained results are in agreement with the results obtained by Abdelgaleil and Nakatani (2003). They stated that the limonoids in the mahogany products have also been found effective against cotton leaf worms. EI-Rahman *et al.* (2016) stated that oils of *A. indica* comes in

Table 2. Egg hatching of *Tetranychus urticae* exposed to different plant oils and insect growth regulators by direct spray and water- treated control with the corresponding efficacy.

Treatments	% Egg hatching (Mean±SE)	% Efficacy over control
Neem oil	33.7±5.5 cd	65.8
Mahogany oil	22.5 ±3.2 e	77.2
Castor oil	51.2±4.2 b	48.1
Buprofezin	38.7±2.4 c	60.7
Lufenuron (5%) + Emamectin Benzoate (5%)	25.0 ±4.1 de	74.7
Control	98.7±1.2 a	-
CV (%)	16.5	
Level of significance	0.01	
CD	11.07	

Means within a column followed by different letters are significantly different at 5% level of probability by LSD.

the category of the least effective compound on the eggs of *T. urticae* which conformed to the present findings. Abd EI-Wahab (2003) indicated that castor oil treatment appeared to be the most effective against the population of *T. urticae* than soybean oil on cucumber.

Effects of different oils and growth regulators at different time intervals on the mortality of the *T. urticae* nymph are presented in Table 3. Percent mortality at 24 HAT was statistically different among the treatments (*p <0.05%, df =5, F =17.4*). The highest nymphal mortality (25%) was observed when applied mahogany oil and the lowest mortality (10%) was found in castor oil. No mortality was observed at control treatment at 24 HAT. After 48 HAT, significantly the highest mortality was observed from the treatments of mahogany oil (55%) and lufenuron + emamectin Benzoate (55%) followed by neem oil (45%) which were found statistically similar. But the lowest mortality was observed from the treatment of castor oil (32.5%) followed by buprofezin (35%) which is statistically identical but statistically different from other treatments. There was no mortality observed in control treatment also at 48 HAT. At 72 HAT the highest mortality was found when applied mahogany oil (86.4%) and the lowest one was castor oil (51.4%). Average mortality indicated that significantly the highest mortality was observed in mahogany oil (55.4%) followed by lufenuron + emamectin Benzoate (52.8%) which was statistically similar between those two treatments. The lowest average mortality was observed in castor oil (31.3%). The mortality

Table 3. Percent mortality of *T. urticae* nymph exposed to different treatments in tropical application

Treatments	Percent mortality (Mean±SE)			
	24hr	48hr	72hr	Average
Neem oil	17.5 ±2.5 b	45.0 ±2.9 b	70.3±2.6 bc	44.2 abc
Mahogany oil	25.0 ±2.9 a	55.0 ±2.9 a	86.4±2.8 a	55.4 a
Castor oil	10.0 ±0.0 c	32.5 ±2.5 c	51.4±2.6 d	31.3 c
Buprofezin	15.0 ±2.8 bc	35.0 ±2.9 c	62.2±2.7 c	37.4 bc
Lufenuron (5%) + Emamectin Benzoate (5%)	25.0 ±2.9 a	55.0 ±2.9 a	78.3±4.5 ab	52.8 ab
Control	0.0 d	0.0 d	7.5 ±2.5 e	2.5 d
CD (p = 0.05)	6.7	7.6	9.1	
CV (%)	29.6	13.8	10.3	

Means within a column followed by different letters are significantly different at 5% level of probability by LSD. ±SE: indicates standard error, CD: critical difference test.

of neem oil and buprofezin was found 44.2% and 37.4% respectively. A little average of nymphal mortality was found in the control (2.5%) treatment.

From the above results, it is clear that different treatments showed remarkable nymphal mortality at a different level but mahogany oil showed the best performance. The present findings are in agreed with those of Uddin *et al.* (2014) who found that mahogany oil showed effective acaricidal activity against *T. urticae.* Satti and Elamimm (2012), conducted an experiment to evaluate the insecticidal activities of several extracts prepared from two meliaceous plants, viz., mahogany and neem, against the 3rd instar larvae of *T. granarium.* Mahogany leaves exerted better actions than those of neem leaves. In present study, mahogany oil showed better performance than neem oil. Mohammed *et al*. (2018) proved that castor oil has a moderate mortality proportion against *T. urticae* with high concentrations.

All treatments showed a significant reduction in the female population over control up to 21 days (Table 4). Survival of the population of female *T. urticae* decreased gradually with the progress of days after treatment (DAT) of each treatment as compared to control. Lufenuron + emamectin benzoate, mahogany oil, castor oil, buprofezin and neem oil showed less mortality effect on day 1 after treatment where the mortality percentage was 28.5%, 25.7%, 23.5%, 19.7% and 18.2%, respectively. One week later, lufenuron + emamectin benzoate (67.0%) and mahogany oil (62.5%) showed >50% mortality. At 14 DAT, all treatments showed significantly different mortality rates as compared with the untreated control. No significant difference was observed among neem oil (55.1%) and buprofezin (54.1%) (Table 4). At 21 DAT, the mortality caused by mahogany oil, lufenuron + emamectin benzoate and neem oil was 77.8%, 72.2%and 60.7%, respectively which was significantly different from the untreated control and considerably higher than the other treatments. However, mortality rate of buprofezin and castor oil was not significantly different from that of mahogany oil, lufenuron (5%) + emamectin benzoate (5%), and neem oil (Table 4).

The effectiveness of three essential oils and two insect growth regulators varies among the treatments on the species of mites. However, we observed that from three oils the mahogany oil had the greatest direct effect on *T. urticae*, followed by neem and castor oils. From the two growth regulators, lufenuron + emamectin benzoate showed better performance than buprofezin. Our results are agreed with those of Bamaiyi *et al.* (2006) studied that mahogany seed oil for its effectiveness to control *Callosobruchus maculatus*on stored cowpea. Over the past 30 years, a large number of laboratory and field research have been carried out utilizing various plant extracts or products that have the potential to be used as botanical pesticides to control agricultural mites (Jia *et al.* 2011, Pavela 2016). Among the plant oils tested, mahogany oil was performed significantly better than neem and castor oils. The possible explanation for the superior performance of mahogany oil could be the inclusion of some unique natural elements, or phytochemical studies

Table 4. Mean density of *T. urticae* adult female before spraying (0 day) and after 1, 3, 7, 14 and 21 days after words and the corresponding efficacy

Treatments	Number of adult mites (±SE) survived per leaf					
	Day 0	Day 1	Day 3	Day 7	Day 14	Day 21
Neem oil	24.5±1.7 a	20.7±1.6 ab (18.2)	20.7±1.6 ab (25.1)	8.9±1.1 bc (36.7)	5.1±0.6 c (55.1)	4.1±0.5 c (60.7)
Mahogany oil	23.6±0.8 a	18.4±0.8 b (25.7)	12.3±1.1 bc (39.7)	5.3±0.8 d (62.5)	2.9±0.5 d (74.9)	2.2±0.2 d (77.8)
Castor oil	20.5±0.9 a	19.1±0.6 ab (23.5)	15.0±0.6 abc (28.6)	9.8±0.6 b (30.3)	7.7±0.6 b (32.7)	6.5±0.3 b (37.5
Buprofezin	23.3±1.1 a	20.1±0.7 ab (19.7)	14.4±0.6 abc (30.8)	7.8±0.1 c (44.4)	5.3±0.6 c (54.1)	4.5±0.4 c (56.1)
Lufenuron (5%) + Emamectin Benzoate (5%)	22.7±1.2 a	18.0±1.2 b (28.5)	12.1±1.2 c (42.0)	4.6±0.7 d (67.0)	3.0±0.5 d (74.4)	3.1±0.6 cd (72.2)
Control	21.9±2.2 a	22.8±2.1 a	16.1±1.1 a	14.1±0.3 a	11.5±0.2 a	10.6±0.9 a

Means within a column followed by different letters are significantly different at 5% level of probability by LSD. ±SE: indicates standard error. Values within parentheses are percentage over control.

that have made it possible to identify and isolate various secondary metabolites that are toxic to *T. urticae*, such as tannins, saponins, and phenolic acids (Sukardiman and Ervina 2020). El Zalabani et al. (2012) indicated that both leave and bark extracts of *S. mahogany* at 500 ppm were the most effective against varroa mite with 90% of mortality. The two insect growth regulators (IGRs), buprofezin and lufenuron were found moderately effective against *T. urticae*. However, IGRs are considered to be safe for beneficial organisms (Ishaaya *et al*. 2001), and the selected IGRs could be considered for the development of an IPM program for *T. urticae*.

Conclusion

Mahogany oil and lufenuron + emamectin benzoate were the most potent miticide which caused the highest mortality to adults of *T. urticae* with 100% mortality within 42 hours of exposure. The mortality percentage of *T. urticae* egg indicated that mahogany oil showed the highest mortality (77.2%) among all the treatments. In the potted been plants the highest mortality was found in mahogany oil (77.8%) and the lowest showed in castor oil (37.4%) at 21 days. Therefore, mahogany oil and lufenuron + emamectin benzoate were the most effective natural alternatives to synthetic chemical pesticides for the control of *T. urticae* in vegetable field.

References

Abbott WW. 1925. A method of computing the effectiveness of an insecticide. Journal of American Mosquito Control Association, *3*: 302-303.

Abd El-Wahab HA. 2003. Efficiency of leaves extracts of castor bean plant against *Aphis gossipi* (Glover) and *Tetranychus urticae* (Koch) on cucumber plant. Journal of Plant Protection and Pathology, *28*: 4029-4038.

Abdelgaleil SAM and Nakatani M. 2003. Antifeeding activity of limnoids from *Khaya senegalensis.* Journal of Applied Entomology, *127*: 236-239.

Alexenizer M and Dorn A. 2007. Screening of medicinal and ornamental plants for insecticidal and growth regulating activity. Journal of Pest Science, *80*: 205-215. DOI 10.1007/s10340-007-0173-x.

Bamaiyi LJ, Ndams IS, Toro WA and Odekina S. 2006. Effect of mahogany, *Khaya senegalensis* seed oil in the control of *Callosobruchus maculates* on stored cowpea. Plant Protection Science*, 42*: 130-134.

Brandenburg RL and Kennedy GG. 1987. Ecological and agricultural consideration in the management of two-spotted spider mite (*Tetranychus urticae* Koch). Agricultural Zoology Reviews, *2*: 185-236.

Copping LG and Duke SO. 2007. Natural products that have been used commercially as crop protection agents-a review. Pest Management Science, *63*: 524-554.

El- Rahman AHA and Keblawy MS. 2016. Toxicological studies of some compounds on two-spotted spider mite *Tetranychus urticae* on different host plants. Journal of Plant Protection and Pathology, *7*: 519-524.

El Zalabani SM, Hesham I. El-Askary OM, Mousa MY, Issa AA. and Zaitoun EAS. 2012. Acaricidal activity of *Swietenia mahogani* and *Swietenia macrophylla* ethanolic extracts against Varroa destructor in honeybee colonies. Experimental Parasitology, *130*: 166-170. doi.org/10.1016/j.exppara.2011.10.013.

El-Taj HF, Hossain KF, Arifunnahar M, Alim MA and Bachchu MAA. 2016. Effects of host plants and seasons on the biology of the two-spotted spider mite, *Tetranychus urticae* (Koch). African Entomology, *24*: 188-196.

El-Zalabani MS, El-Askary IH, Mousa MO, Issa YM, Ahmed A, Zaitoun AA and Abdel-Sattar E. 2012. Acaricidal activity of *Swietenia mahogani* and *Swietenia macrophylla* ethanolic extracts against *Varroa destructor* in honeybee colonies. Experimental Parasitology, *130*: 166-170.

Fasulo TR and Denmark HA. 2009. Twospotted spider mite, *Tetranychus urticae* Koch (Arachnida: Acari:Tetranychidae): EENY150/IN307, doi. org/10.32473/edis-in307-2000.

Giunti G, Benelli G, Palmeri V, Laudani, F, Ricupero, M, Ricciardi R, Maggi F, Lucchi A, Guedes RNC, Desneux N and Campolo O. 2022. Non-target effects of essential oil-based biopesticides for crop protection: Impact on natural enemies, pollinators, and soil invertebrates. Biological Control, *176*: 105071.

Grbic M, Van Leeuwen T, Clark RM, Rombauts S, Rouze P, Grbic V, Osborne EJ and Dermauw W. 2011. The genome of *Tetranychus urticae* reveals herbivorous pest adaptations. Nature, *479*: 487-492.

Ishaaya I, Kontsedalov S, Masirov D and Horowitz AR. 2001. Biorational agents – mechanism, selectivity and importance in IPM programs for controlling agricultural pests. Mededelingen Faculteit Land bouwwetenschappen Rijksuniversiteit Gent, *66*: 363-374.

Jia FL, Chen YJ, Chen J, Wang DD and Dai GH. 2011. Biological activity of extracts from 8 species of plants against *Tetranychus cinnabarinus*. Chinese Agricultural Science Bulletin, *27*: 286-291.

Kavya MK, Srinivasa N, Ravi GB and Vidyashree AS. 2015. Relative toxicity of selected acaricides on two spotted spider mite (*Tetranychus urticae*) of brinjal. The Bioscan, *10*: 605-608.

Kim DI, Park JD, Kim SG, Kuk H, Jang MS and Kim SS. 2005. Screening of some crude plant extracts for their acaricidal and insecticidal efficacies. Journal of Asia-Pacific Entomology, *8*: 93-100.

Kumar SV, Chinniah C, Muthiah C and Sadasakthi A. 2010. Management of two spotted spider mite *Tetranychus urticae* Koch a serious pest of brinjal, by integrating biorational methods of pest control. Journal of Biopesticides, *3*: 361-368.

Mohamed AA and Alotaibi BM. 2023. Essential oils of some medicinal plants and their biological activities: a mini review. Journal of Umm Al-Qura University for Applied Sciences, *9*: 40-49. https://doi.org/10.1007/s43994-022-00018-1

Mohammed RAA, Bashir NHH and Assad YOH. 2018. Efficacy of selected seed oils against two-spotted spider mite, *Tetranychus urticae* Koch, in the field. Agriculture Research Journal, *55*: 370-373.

Pavela R. 2016. Acaricidal properties of extracts of some medicinal and culinary plants against *Tetranychus urticae* Koch. Plant Protection Science, *52*: 54-63.

Reddy SGE and Kumar NKK. 2006. Integrated management of two spotted spider mite, *Tetranychus urticae* (Koch) on tomato grown under polyhouse. Pesticide Research Journal, *18*: 162-165.

Reddy SGE, Chauhan U, Kumari S, NaddaG and Singh MKK. 2014. Comparative bioefficacy of acaricides against two spotted spider mite, *Tetranychus urticae* (Koch) on chrysanthemum in polyhouse. International Journal of Research in Chemistry and Environment, *4*:15-19.

Rincon RA, Rodríguez D and Coy-Barrera E. 2019. Botanicals against *Tetranychus urticae* Koch under laboratory conditions: A survey of alternatives for controlling pest mites. Plants, *8*: 272. DOI: 10.3390/plants8080272

Roobakkumar A, Subramaniam MSR and Babu A. 2010. Bioefficacy of certain plant extracts against the red spider mite, *Oligonychus coffeae* Nietner (Acarina : Tetranychidae) infesting tea in Tamil Nadu, India. International Journal of Acarology, *36*: 255-258.

Sukardiman and Ervina M. 2020. The recent use of *Swietenia mahagoni* (L.) Jacq. as antidiabetes type 2 phytomedicine: A systematic review. Heliyon, *6*: e03536. doi.org/10.1016/j.heliyon.2020.e03536

Tehri K and Gulati R. 2014. Field efficacy of some biorationals against the two spotted spider mite *Tetranychus urticae* Koch (Acari : Tetranychidae). Journal of Applied and Natural Science, *6*: 62-67.

Tunaz H and Uygun N. 2004. Insect growth regulators for insect. Turkish Journal of Agriculture and Forestry, *28*: 377-387.

Uddin MN. 2014. Bioecology and management of two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) infesting country bean. Ph.D. thesis. Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh, p. 150.

Van Leeuwen T, Vontas J, Tsagkarakou A, Dermauw W and Tirry L. 2010. Acaricide resistance mechanisms in the two-spotted spider mite *Tetranychus urticae* and other important Acari: a review. Insect Biochemistry and Molecular Biology, *40*: 563-572.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 181-186

FLOWER QUALITY AND VASE LIFE OF GLADIOLUS AS AFFECTED BY HORMONES

Nusrat Nawreen Orpa[1], Kabita Anzu-Man-Ara[2*], Farjana Nasreen Khan[2] and Khairul Kabir[3]

[1]Hajee Mohammed Danesh Science and Technology University, Dinajpur, Bangladesh. [2]Floriculture Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. [3]Department of Horticulture, Sher-e- Bangla Agricultural University, Dhaka, Bangladesh

***Corresponding e-mail:** dr.kabita2009@yahoo.com

Received: 13 November 2023, revised: 09 December 2023, accepted: 10 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.11

ABSTRACT

An experiment was conducted at the Floriculture field of Horticulture Research Centre, Gazipur during Rabi season of 2021-22 to find out the effect of preharvest spray of different hormones (GA_3, SA and BA) at different concentrations on flower and vase life of gladiolus. The experiment was laid out in a Randomized Complete Block design with three replications. The treatments were T_1=GA_3 @ 100 ppm, T_2=GA_3 @ 200 ppm, T_3=GA_3 @ 300 ppm, T_4=SA@ 100 ppm, T_5=SA @ 200 ppm, T_6=SA @ 300 ppm, T_7=BA @ 100 ppm, T_8=BA @ 200 ppm, T_9 =BA @ 300 ppm and T_{10}= Control (fresh water). Healthy corms of gladiolus having a diameter of about 5.0 cm were used as planting material. The aqueous solution of GA_3 (100, 200 and 300 ppm), SA (100, 200 and 300 ppm) and BA (100, 200 and 300 ppm) along with control (fresh water) were applied twice on the flower plants at three and six leaves stage. Flowering parameters of plants as well as vase life of flowers were significantly influenced by the application of hormones. Among all the treatments, application of SA @ 100 ppm was recorded to be an outstanding treatment in improving floral and vase quality attributes i.e. highest spike (78.5 cm) and rachis length (52.8 cm), maximum floret number/spike (14.5), biggest floret diameter (10.0 cm) and early spike initiation (65 days) were observed as compared to control. The maximum floret opening (90%), highest water uptake (45.0 g) and maximum vase life (12 days) were also noted with SA @ 100 ppm in gladiolus.

Keywords: Gladiolus, preharvest spray, gibberellic acid, benzyl adenine, salicylic acid, vase life

Introduction

Gladiolus (*Gladiolus grandiflorus*) is a flower of glamour and perfection which is known as the queen of bulbous flowers belongs to family Iridaceae. The gladiolus gained popularity in Bangladesh and different parts of the world due to its unsurpassed beauty and economic value. Now the flower is in high demand due to attractive spikes, big florets, dazzling colours and long vase life (Khan *et al*. 2011). The agro-ecological conditions of Bangladesh are very much conducive for the successful cultivation of gladiolus (Ara *et al*. 2010). The aesthetic value of flowers in the daily life is increasing with the advancement of civilization. Gladiolus is mainly used as cut flower in Bangladesh. The major production belts of this flower in the country are Jashore sadar, Sharsha, Chowgacha, Kushtia, Chuadanga, Satkhira, Khulna, Chittagong, Mymensingh, Dhaka, Savar, Narayangonj, Rangpur and Gazipur regions. Due to higher economic return the flower growers are also very much interested in cultivating this flower (Hoque *et al.* 2022). Therefore, gladiolus is becoming attractive to the growers as well as users now a day. The cut flowers of gladiolus are highly perishable due to high respiration rate and excessive weight loss (Kumar and Gupta 2014,).

Enhancement of vase life of gladiolus cut flower is an important area in horticultural research. The post-harvest quality and longevity of cut flowers is dependent on several pre-and post-harvest factors (Bose *et al*. 2003). Senescence of cut flowers mainly depends on hormonal control and related to the changes in carbohydrate status of the petal (Pal *et al*. 2015). The growth conditions of the plant before harvest would affect the quality of the cut flowers by about 30 - 70% (Marandi *et al*. 2011). It has been reported that pre-harvest spray of salicylic acid has shown a significant difference in morphological, physical parameters and vase life in the flowers like gladiolus (Abdou *et al*. 2007), lilium (Hajizadeh and Aliloo 2013), cut rose (Kazemi *et al*. 2018) and tuberose (Anwar *et al*. 2014). The use of gibberellic acid and benzyl adenine

as pre-harvest sprays has shown promising results in improving the flower quality (Hoque *et al*. 2022, Devi *et al*. 2007, Emami *et al*. 2011) and vase life (Khan *et al*. 2011, Kapri *et al*. 2018 and Kumar and Gupta 2014.) in home and abroad. Therefore, the objective of this research is to study the effect of preharvest foliar spray of different hormones on flower quality and vase life of gladiolus.

Materials and Methods

The experiment was carried out at the Floriculture field of Horticulture Research Centre, BARI, Gazipur during Rabi season of 2021- 2022. The experimental land was prepared with deep ploughing. Manure and fertilizers were applied @ 5 ton, 200.0 kg, 225.0 kg, 190.0 kg, 20.0 kg, 2.0 kg, 3.0 kg per hectare of Cowdung, Urea, TSP, MoP, S, B and Zn, respectively

(Anon, 2018). Cowdung, TSP, MoP, S, B and Zn were applied as basal and urea was top-dressed in two equal splits at 4 leaf stage and spike initiation stage. Healthy corms of BARI Galdiolus-4 having a diameter of about 5.0 cm were used as planting material. The aqueous solution of GA_3 (100, 200 and 300 ppm), SA (100, 200 and 300 ppm) and BA (100, 200 and 300 ppm) along with control (fresh water) were applied twice on the flower plants at three and six leaves stage to study their effect on the quality and vase life of cut gladiolus. They were GA_3 @ 100ppm (T_1), GA_3 @ 200ppm (T_2), GA_3 @ 300 ppm (T_3), SA @ 100 ppm (T_4), SA @ 200 ppm (T_5), SA @ 300 ppm (T_6), BA @100 ppm (T_7), BA @ 200 ppm (T_8), BA @ 300 ppm (T_9) and control (T_{10}).The unit plot size was 2.5 m ´ 2.0 m and spacing was maintained at 20 cm x 20 cm. The experiment was laid out in Randomized Complete Block design with 3 replications. Management practices like irrigation, weeding, mulching etc were same for all treatments during entire period of study to get a healthy crop.

Various quality parameters of flowers were recorded at the time of harvest from five tagged plants. Cut flowers obtained from all the treatments were subjected to vase life studies. The spikes were cut when lower 2-3 florets showed their blushes of colour. The spikes were brought to the laboratory within ½ hour after harvest. The spikes length was uniformly maintained i.e. 50 centimeter and all the leaves were removed to avoid contact with the solution. Cut flowers of gladiolus were placed in glass jar containing 150 ml of water and kept in laboratory at room temperature (20-25^{O}C) and relative humidity (RH) of 65-80% with adequate aeration. The observation of vase life was recorded at daily interval until the flower petal faded and they were not suitable for vase. Floret opening (%) recorded from the day when the first floret opening till the spike was discarded and expressed in percentage. The data recorded on different parameters were statistically analyzed with the help of MSTAT-C software. The difference between treatments means were compared by Duncan's Multiple Range Test (DMRT) according to Steel *et al*. (1997).

Results and Discussion

The data pertaining to the effect of preharvest foliar application sprays of hormone significantly influenced the flower quality parameters and the data are presented in Table 1. When comparing early appearance of spike, it was found that SA @ 100 ppm (T_4) caused early initiation of spike (65.0 days), which might be due to early flower primordial development, cell differentiation and early utilization of nutrients; whereas control plant (T_{10}) took the maximum days for spike initiation (75.0 days). The present results are agreed with the findings of Padmapriya and Chezhiyan (2002) who stated that SA stimulate early flowering in chrysanthemum. SA induces flowering in a range of plants, controls ion uptake by roots and stomata conductivity (Alaey *et al*. 2011). Spike and rachis length increased with application of SA and maximum was found in 100 ppm treated plants (78.5 cm and 52.8 cm, respectively). Similar observations have also been found previously by Tamrakar *et al.* (2021) in gladiolus at 100 ppm SA. The possible reason for increasing spike length and rachis length might be due to increase in the cell division and cell elongation of intercalary meristem resulting in rapid internode elongation (Shankar *et al*. 2011). Results indicated that number of florets per spike of gladiolus were increased by all concentrations of hormones compared to the untreated plants. However, among all the concentrations of hormones studied SA at 100 ppm gave the highest number of florets per spike

Table 1. Effect of preharvest sprays of hormones on floral parameter gladiolus

Treatment	Spike initiation (days)	Spike length (cm)	Rachis length (cm)	Floret no./spike	Floret diameter (cm)
GA_3@100ppm (T_1)	70.0 b	75.0 ab	47.0b	14.0 ab	9.7 ab
GA_3@200ppm (T_2)	72.0 ab	72.0 b	49.5 ab	13.5 ab	9.6 ab
GA_3@300ppm (T_3)	73.0 ab	71.5 bc	45.8 bc	12.8 ab	9.5 ab
SA@100ppm (T_4)	65.0 c	78.5 a	52.8 a	14.5a	10.0 a
SA@200ppm (T_5)	72.0 ab	74.0 ab	50.0 ab	13.6 ab	9.7 ab
SA@300ppm (T_6)	73.0 ab	71.4 bc	49.0 ab	13.0 ab	9.5 ab
BA@100ppm (T_7)	73.0 ab	70.3 bc	46.0 b	13.5 ab	9.4 ab
BA@200ppm (T_8)	72.0 ab	69.5 bc	45.3 bc	13.0 ab	9.3 ab
BA@300ppm (T_9)	73.0 ab	69.0 bc	45.4 bc	12.8 ab	9.2 ab
Control (T_{10})	75.0 a	67.0 c	42.0 c	10.5 b	8.5 b
Level of Significance	*	*	*	*	*
CV %	9.5	8.6	8.4	7.9	7.5

T_1 = GA_3 @100 ppm, T_2= GA_3 @ 200 ppm, T_3 = GA_3 @ 300 ppm, T_4 =SA @ 100 ppm, T_5 =SA @ 200 ppm, T_6 =SA @ 300 ppm, T_7 =BA @ 100 ppm, T_8=BA @ 200 ppm, T_9 =BA @ 300 ppm and T_{10} =Control Means followed by same letter(s) in a column do not differ significantly at 5% level by DMRT.

(14.5) followed by GA_3 at 100 ppm (14.0).

The results of present study are similar to results of Anwar *et al*. (2014) who stated that exogenous application of SA promoted floret number. These results are also accordance with those of (Kaur *et al*. 2007) who found salicylic acid (100 ppm) has influence on growth and photosynthesis and net photosynthesis rate is positively associated with the crop yield in chickpea. Floret diameter was significantly affected by the growth hormone treatments. The diameter of the floret was maximum (10.0 cm) with spraying of SA (100 ppm) while the lowest was (8.5 cm) was obtained in control. The present study is in conformity with the findings of (Anwar *et al*. 2014) who observed that SA (100 ppm) increased the flower diameter of tuberose. SA might have altered the biophysical properties of cell wall. According to Padmapriya and Chezhiyan (2002), salicylic acid has positive effect on photosynthesis in leaves and carbohydrate in leaves and stem due to this reason flower size increased.

The effect of different hormones on vase quality of gladiolus were investigated in this study. Findings of the study are presented in Table (2) and Figure (1 & 2). Floret opening in spikes for a period of 12 days differed with different treatments (Figure 1). Spikes held in T_4 treatment (100 ppm SA) recorded the highest percent of floret opening (90%), while only 70% floret opened in T_{10} (control). The extension of floret opening as observed in the present investigations, accords with previous results obtained in gladiolus by Padamlatha *et al*. (2014) and Sunita *et al.* (2018) in lilium.

T_1 = GA_3 @100 ppm, T_2= GA_3 @ 200 ppm, T_3 = GA_3 @ 300 ppm, T_4 =SA @ 100 ppm, T_5 =SA @ 200 ppm, T_6 =SA @ 300 ppm, T_7 =BA @ 100 ppm, T_8=BA @ 200 ppm, T_9 =BA @ 300 ppm and T_{10} =Control

Means followed by same letter(s) in a column do not differ significantly at 5% level by DMRT.

Total water uptake and water loss for a period of 12 days by the spike differed significantly in case of different hormone solutions (Table 2). Spikes held in solution T_4 (SA @100 ppm) had the highest water absorption (45.0 g) and water loss (43.0 g) whereas, the spikes held in solutions without hormones (control) having the lowest water uptake (21.0 g) and water loss (28.5 g). In Table 2, it was observed that the water loss uptake ratio was lowest (0.8) for the spikes held in solution T_4 (SA @ 100 ppm) and it was the highest value (1.4) for the spikes held in control (T_{10}). Similar results were reported by Marandi *et al*. (2011) in gladiolus. It was observed that days taken by

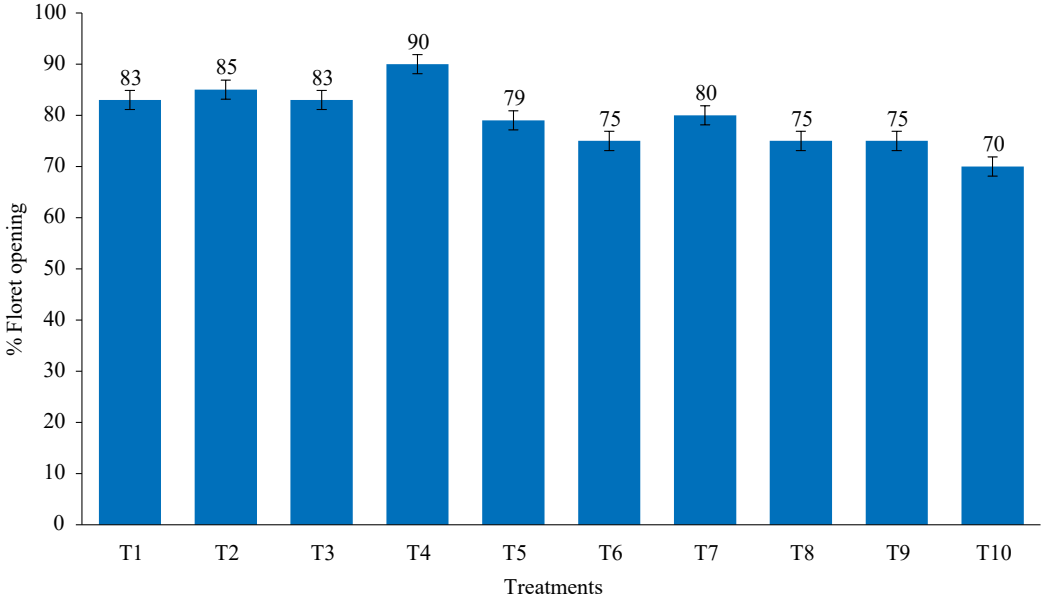


Figure 1. Effect of hormones on %floret opening in gladiolus

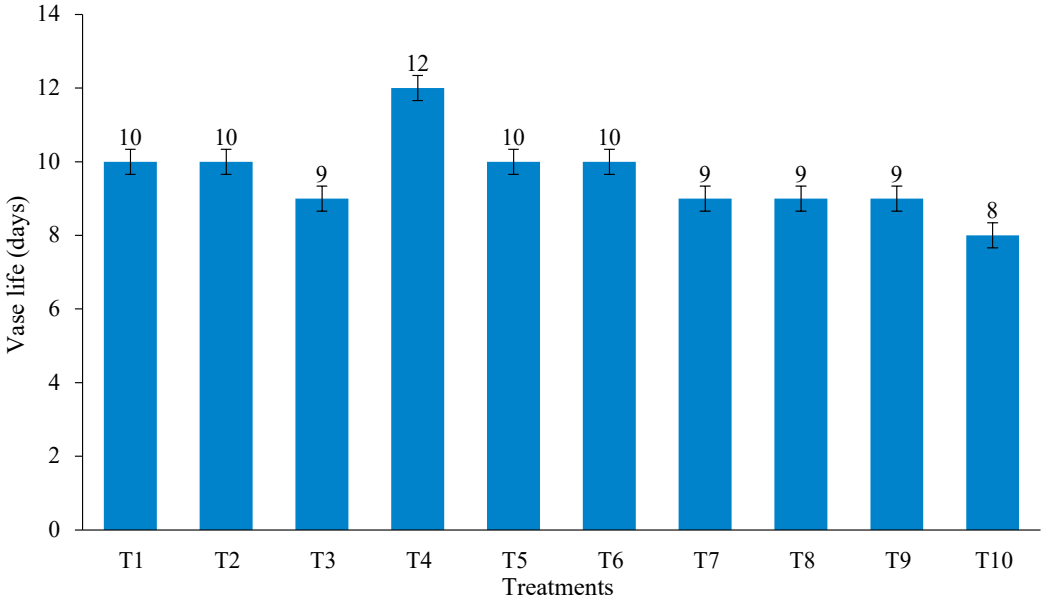


Figure 2. Effect of hormones on vase life of gladiolus

the flowers for deterioration were significantly influenced by different concentrations of hormone level (Table 2). Higher days (10.0 days) were recorded for deterioration started of flowers recorded in T_4 (SA @ 100 ppm). The lowest days (6.0 days) was recorded in control i.e. without hormone solution (T_{10}). At T_4 (SA @ 100 ppm) solution showed better performance because in this treatment water uptake increased and pathogen development reduced. The findings of the experiment are further supported by those of Tawar *et al*. (2003) in gladiolus.

In Figure 2, it was observed that vase life differed with different vase solutions. Spikes held in solution T_4 (100 ppm SA) maintained a maximum vase life for 12 days which was closely similar (11 days) with those held in solution T_2 (200 ppm GA_3) compared with the control and other treatments. It was clear from the above results

Table 2. Effect of different hormones on vase quality of gladiolus

Treatments	Water uptake (g/spike)	Water loss (g/spike)	Water loss uptake ratio	Days taken to deterioration started
T_1	41.0 b	38.5 a	0.9 ab	8.0 ab
T_2	36.4 bc	37.7 bc	1.0 ab	8.0 ab
T_3	34.0 c	34.5 b	1.0 ab	7.0 ab
T_4	45.0 a	43.0 a	0.8 b	10.0 a
T_5	39.0 b	36.0 bc	0.9 ab	8.0 ab
T_6	35.0 bc	37.5 bc	1.1 ab	8.0 ab
T_7	36.5 bc	37.2 bc	1.0 ab	7.0 ab
T_8	28.0 d	32.0 bc	1.2 ab	7.0 ab
T_9	30.0 cd	31.0 bc	1.1 ab	7.0 ab
T_{10}	21.0 e	28.5 c	1.4 a	6.0 b
Level of significance	*	*	*	*
CV%	10.5	9.2	9.6	9.8

T_1 = GA_3 @100 ppm, T_2= GA_3 @ 200 ppm, T_3 = GA_3 @ 300 ppm, T_4 =SA @ 100 ppm, T_5 =SA @ 200 ppm, T_6 =SA @ 300 ppm, T_7 =BA @ 100 ppm, T_8=BA @ 200 ppm, T_9 =BA @ 300 ppm and T_{10} =Control Means followed by same letter(s) in a column do not differ significantly at 5% level by DMRT.

that 100 ppm SA proved to be effective in increasing the water uptake resulting prolongation of vase life. These might be due to salicylic citric acid inhibits the microbial growth, reduce moisture stress in cut flowers by affecting stomatal closure, preventing transpiration and water loss (Alaey *et al.* 2011).

T_1 = GA_3 @100ppm, T_2= GA_3 @ 200ppm, T_3 = GA_3 @ 300ppm, T_4 =SA @ 100ppm, T_5 =SA @ 200ppm, T_6 =SA @ 300ppm, T_7 =BA @ 100ppm, T_8=BA @200 ppm, T_9 =BA @ 300ppm and T_{10} =Control

Means followed by same letter(s) in a column do not differ significantly at 5% level by DMRT.

The findings of the experiment are further supported by those of Anwar *et al.* (2014) in tuberose and Suneetha *et al*. (2017) in lilium. Similar results were also reported by Marandi *et al*. (2011) in gladiolus.

Conclusion

Flowering parameters of plants as well as vase life of flowers were influenced by the application of hormones, namely GA_3, SA and BA in gladiolus. SA @ 100 ppm was superior regarding all flowering parameters and reduced time to spike initiation by 10 days for early bloom. The same treatment also increased vase life of flowers by 4 days. Furthermore, SA @ 100 ppm concentration also exhibited the best results in % floret opening and water uptake of gladiolus. From the present study, it might be stated that preharvest application of SA @ 100 ppm was superior for obtaining the maximum number of flowers with longest stalk as well as biggest flower size and prolonged vase life in gladiolus.

References

Abdou MH, El-Sayed AA, Attia FA and Khalil AR. 2014. Effect of compost, salicylic and ascorbic acids treatments on vegetative growth and flowering of *Gladiolus grandiflorus* cv. White Prosperity. Scientific Journal of Floriculture and Ornamental Plants, *1*: 223-31. https://doi.org/10.21608/ sjfop.2014.4133

Alaey M, Babalar M, Naderi R and Kafi M. 2011. Effect of pre and postharvest salicylic acid treatment on physiochemical attributes in relation to vase life of rose cut flowers. Postharvest Biology and Technology, *61*: 91-94.

Anonymous, 2018. Fertilizer Recommendation guide-2018, Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215, p. 143.

Anwar M, Hakim AS, Imran H, Nadeem AA., Hafiz AA, Muhammad AB, Ansar H, Zaffar I and Azmat HA. 2014. Effect of pre harvest treatment of salicylic on growth and vase life of tuberose with aroma environment. Wudpecker Journal of Agricultural Research, *3*: 50-57.

Ara KA, Sharifuzzaman SM and Ahmed MS. 2010. Floriculture Development in Bangladesh. A paper presented on Expert Consultation Meeting on Floriculture Development in Asia held on 07-09 January, 2010 at Kunming, China, Pp. 1-10.

Bose TK, Yadav LP, Pal PV, Pathasarathy A and Das P. 2003. Gladiolus. Commercial Flowers. Vol-2. 2nd Rev.ed. Nayaprokash, Calcutta, India, Pp. 163-202.

Devi DU, Sekhar RC and Baba JD. 2007. Effect of growth regulators on flowering and corm production of gladiolus. Journal of Research ANGRAU, *35*: 6-14.

Emami H, Saeidnia M, Hatamzadeh A. Bakhshi D and Ghorbani E. 2011. The Effect of gibberellic acid and benzyladenine on growth and flowering of lily *(Lillium longiflorum*). Advances in Environmental Biology, *5*: 1606-1611.

Emongor VE. 2004. Effect of gibberellic acid on post-harvest quality and vase life of gerbera cut flowers. Journal of Agronomy, *3*: 191-195.

Hoque MA, Khan MA, Miah MMU and Biswas MS. 2022. Gladiolus growth and flowering: Impact of chemicals and plant growth regulators. Annals of Bangladesh Agriculture, *25*: 67-78.

Kapri M, Singh AK, Sisodia A and Padhi M. 2018. Influence of GA_3 and BA (Benzyl adenine) on flowering and postharvest parameters in lily. Journal of Pharmacognosy and Phytochemistry, *7*: 1916-1918.

Kaur G, Singh P, Kaur J and Sandhu JS. 2007. Response of abscisic acid and salicylic acid on morphophysiological traits of chickpea *(Cicer arietinum* L.) cultivars. Ecology, Environment and Conservation, *13*: 589-591.

Kazemi M, Abdossi V, Kalateh Jari S, Ladan Moghadam AR. 2018. Effect of pre-and postharvest salicylic acid treatment on physio-chemical attributes in relation to the vase life of cut rose flowers. The Journal of Horticultural Science and Biotechnology, *93*: 81-90.

Khan FN, Rahman MM, Hossain MM and Hossain T. 2011. Effect of benzyladenine and gibberellic acid on dormancy breaking and growth of gladiolus cormels. Thai Journal of Agricultural Science, *44*: 165-174.

Kumar, S and Gupta AK. 2014. Postharvest life of *Gladiolus grandiflorus* L. cv. Jessica as influenced by preharvest application of gibbrellic acid and kinetin. Journal of Postharvest Technology, *2*: 169-176.

Marandi RJ, Hassani A, Abdollahi A and Hanafi S. 2011. Improvement of the vase life of cut gladiolus flowers by essential oils, salicylic acid and silver thiosulfate. Journal of Medicinal Plants Research, *5*: 5039-5043.

Padamlatha T, Satyanarayana RG, Chandrasekhar R, Siva SA and Anurag C. 2014. Effect of pre planting treatment of corms with chemicals and plant growth regulators on vegetative growth, flowering and post-harvest life in gladiolus. Indian Journal of Agricultural Research. *48*: 301-308.

Padmapriya S and Chezhiyan N. 2002. Influence of gibberellic acid and certain other chemicals on flowering character of chrysanthemum cultivars. South Indian Horticulture, *50*: 437-443.

Pal V, Ram M and Kumar M. 2015. Effect of various levels of spacing and salicylic acid treatment on vegetative growth and flowering of gladiolus (*Gladiolus grandiflora* L) cv. White prosperity. South Asian Journal of Food Technology and Environment, *1*: 101-104. https://doi.org/ 10.46370/sajfte.2015. v01i01.14

Shankar K, Singh AK. and Singh HK.. 2011. Effect of plant growth regulators on spike yield and bulb production of tuberose (*Polianthes tuberosa* Linn.) cv. double. Plant Archive, *11*: 169-171.

Steel RGD, Torrie JH and Dickey DA. 1997. Principles and procedures of statistics. A Biometric Approach 3rd ed. Mc Graw Hill Book Co. Inc., New York, Pp. 107-109.

Sunita K, Santhosh K and Singh, CP. 2018. Effect of preharvest sprays of hormones of spike quality and vase life of Asiatic liliumcv. Tresor. The Pharma Innovation Journal, *7*: 470-473.

Tamrakar SK, Singh P, Vijay, K and Tirkey T. 2021. Effect of pre-harvest foliar spray of plant growth regulators, vermiwash and cow urine on the vase life of gladiolus flower. The Pharma Innovation Journal, *10*: 937-941.

Tawar RV, Sable AS and Giri MD. 2003. Effect of growth regulators on growth and flowering of gladiolus cv. jester. Annals of Plant Physiology, *17*: 109-111.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 187-198

STATUS OF FOREST GOVERNANCE IN BANGLADESH: A CASE STUDY ON BHAWAL NATIONAL PARK

Md. Shamim Hossain[1], Asib Ahmed[2*] and Anik Ahmed[3]

[1]Department of Geography and Environmental Science, Begum Rokeya University, Rangpur, Bangladesh. [2]Department of Geography and Environment, University of Dhaka, Bangladesh. [3]Post-graduated, National University of Bangladesh, Bangladesh.

***Corresponding e-mail:** asib01geo@du.ac.bd

Received: 24 November 2023, revised: 30 November 2023, accepted: 10 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.12

ABSTRACT

The present study assessed the status of forest governance of Bhawal National Park (BNP) in Bangladesh. The research employs both qualitative and quantitative methods to identify and analyze data. The study identified that the BNP authority adhered to well-defined and coherent forest policies and laws of forest governance, having highest score (i.e., about 4.27) in five-points rating scale. However, the enforcement of forest laws and regulations by the jurisdictional authority is hindered due to insufficient resources, including budgetary constraints, shortage of forest officials and staff, inadequate tools and technology, and delayed implementation resulting less effective influence on the forest governance. The involvement of stakeholders in decision-making processes and access to information is limited. Additionally, there is not always a high enough level of transparency and accountability, sometimes leading to misconduct and corruption among forest officials, secured the lowest score of forest governance (i.e., 1.15). Overall, the composite score is nearly 1.90 represents less significant influence of forest governance for BNP resulting in one-third of the park is completely under encroachment. The findings of this study are crucial for policymakers to determine the priority areas within the various components and pillars of forest governance.

Keywords: Bhawal national park, forest policies, governance, implementation

Introduction

Over the last few decades, the pressure on global forests has intensified due to the conflicting and growing needs of societies for food, timber production, bio-energy, and environmental services, particularly in the context of climate change (Ziegler *et al.* 2012, IPCC 2014). Therefore, forest resources have been decreasing at a constant rate and nearly one-third of population of the world is affected by forest degradation due to poor forest governance (UNEP 2007). However, governance of forest resource carry essence since its economic, ecological and social values. Forest governance is the regulatory structures (i.e., institutional rules, norms, principles and decision-making procedures) developed by government and civil society for the conservation and utilization of forests (Giessen and Buttoud 2014). Forest governance encompasses rules (e.g., formal and informal), organizations and processes, which binds the decisions about the management, use and conservation of forest resources (Davis *et al.* 2013). It comprises the processes, norms, instruments and organizations that regulate the way people act together with forests (Kishor and Robenbaum 2012). The emergence of concept of forest governance is also explained by Arts (2014) by using the term 'Triple G' which includes government (state forestry), governance (participatory forestry) and governs mentality (state to the market and to society). Governance through decentralization is always significance for forest resource management (Agrawal *et al.* 2008). It can be considered as an operational way to govern forest management. This strategy has led to reduce the fast degradation and decline of forests in many developing countries (Balooni *et al.* 2008). Good governance could lead to achieve sustainability of forest resources in many aspects of operations and procedures (FAO 2012). However, industrialization, encroachment, overexploitation, illegal logging, corruption, and various crimes debilitate the governance of forests.

Bangladesh is losing its forests at an alarming rate. For instance, the country lost approximately 2600 ha of forest land annually from 1990 to 2015 because of poor forest governance (Begum 2022). Currently, Bangladesh has only 9.5% (17.4 % in Department of Forest's record)

forest land (Reddy *et al.* 2016, BFD and IUCN 2023). Despite its environmental and livelihood significance, Bangladesh has low per capita area of forest land (i.e., 0.009 ha per person) compared to Asia (i.e., 0.145 ha per person) and the world (0.597 ha per person) (Sarker and Rodrigo 2014, Nath *et al.* 2016, Giessen *et al.* 2016). The annual rate of deforestation in Bangladesh is around 0.77% from 2006 to 2014 (Reddy *et al.* 2016). This results in deforestation, biodiversity loss as well as reduction of environmental services. Therefore, it is crucial to safeguard the remaining forests and increasing forest coverage in the country through forest governance since, governance is the keystone of sound environmental resource management especially forest resources. The perspective plan of Bangladesh (2010-2021) and Bangladesh Vision 2021 have proposed good governance as one of the strategic pillars of economic development in Bangladesh (GoB 2012). Further, forest policy of 2016 in Bangladesh has already been set an agenda of good governance in policy statement (Mollick *et al.* 2018).

Bhawal National Park (BNP) is one of the most endangered ecosystems in Bangladesh which has been degrading constantly through the process of industrialization, establishment of settlement, encroachment, overexploitation, agricultural expansion, plantation with invasive species, pollution, pasturing of domestic cattle, illegal cut down of trees, fragmentation of forest land by road construction as well as existing population pressure (Islam and Sato 2012). Moreover, a significant number of visitors come to BNP for pleasure trip during the winter season (Alauddin *et al.* 2020). Therefore, more than two-thirds of forest habitat has been spoiled during the last 50 years (Chowdhury 2013). Besides, around 2284 ha. area of the forest has been depleted from 2005 to 2020 only because of new settlements in privately owned lands within the BNP jurisdiction (Rahman *et al.* 2022).

Some studies have been conducted on different aspects of forest resources in Bangladesh. For instance, the study by Rahman and Miah (2017) highlighted the implementation of REDD (Reducing Emissions from Deforestation and Forest Degradation) in the protected forest area of Bangladesh. Moreover, the study by Jashimuddin *et al.* (2021) emphasized the local level forest governance in a co-managed protected area of Bangladesh. Both the studies considered the wildlife sanctuary in their assessments. The study by Khan *et al.* (2021) conducted on the dynamics of forest governance considering policy and institutional dimensions. Mollick *et al*. (2018) evaluated good governance in a forest area by using three indicators that includes participation, transparency and efficiency. The existing literature did not cover all the relevant dimension, pillars and variables in assessing forest governance in a precise and in-depth manner. However, present study evaluated the status of forest governance in BNP of Bangladesh. This study would be helpful for the policy and decision makers in the forest sectors, environmental managers, researchers as well as for the academicians.

Materials and Methods

Study Area: The study selected Bhawal National Park (BNP) as a case to assess the status of sustainable forest governance in Bangladesh (Figure 1). It covers an area of 5022 ha. in Sreepur upazila of Gazipur district. The selected forest area is the Tropical Moist Deciduous Forests where Sal is the main tree species. The BNP is the largest belt of Sal Forest in Bangladesh (Masum *et al.* 2015). The park was full with flora as well as fauna. However, the biodiversity of the park is continuously degraded very rapidly due to human invasion through setting up of settlements, and industries (Rahman *et al.* 2009, Masum *et al.* 2015).

Study design: The present study identified a range of variables by reviewing relevant literature (Kishor and Rosenbaum 2012, Satpathy *et al.* 2013, FAO 2011). The study takes into account the framework for assessing and scaling-up the existing status of forest governance of BNP proposed by Food and Agriculture Organization (FAO 2011). The framework of FAO identified three (03) pillars and thirteen (13) different components of forest governance. Finally, the present study adopted twenty-two (22) variables under six (06) components and three pillars (Table 1) from the FAO framework by conducting a reconnaissance survey with the stakeholders of the area and taking experts' opinion.

To identify the potential variables that illustrate the governance of forest, a reconnaissance survey was conducted with 10 respondents in BNP. Several on-

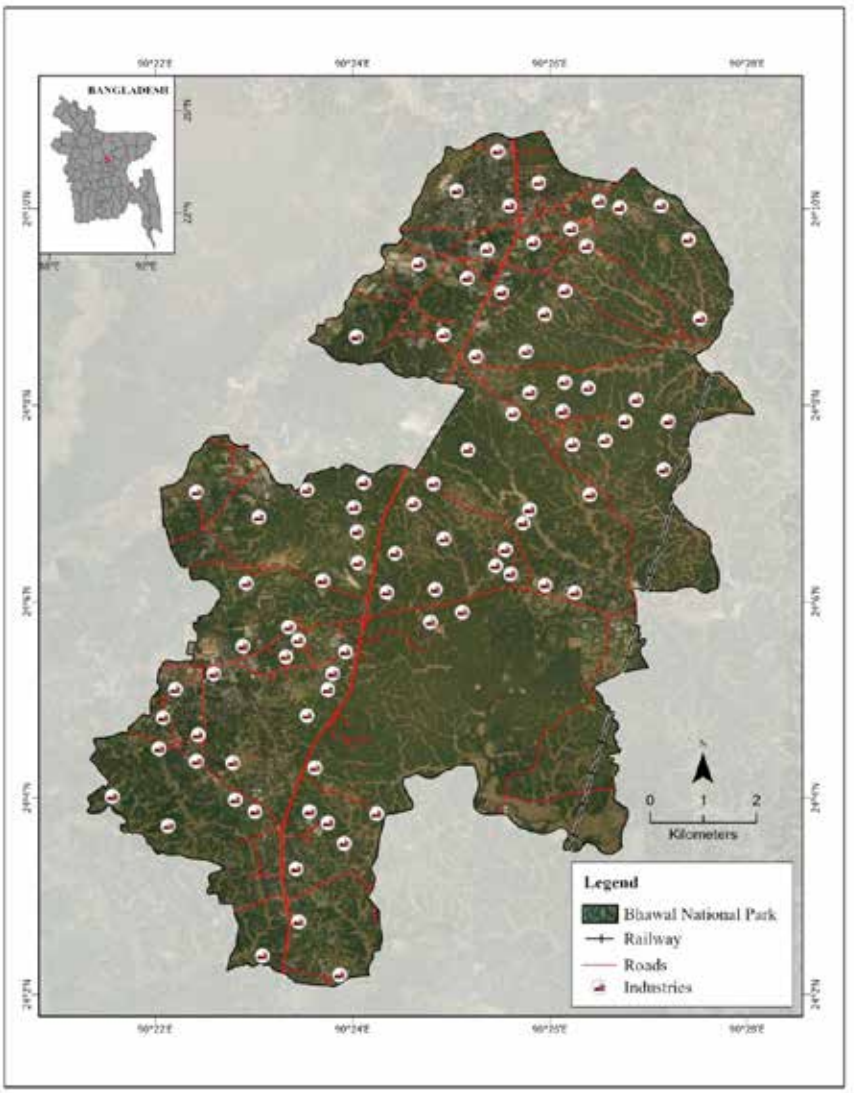


Figure 1. Map of Bhawal National Park of Bangladesh (Source: The Authors 2023)

site visits were conducted during the study to observe first hand the real-world conditions associated with the variables identified by the participants. Since then, common variables were identified for assessing the actual scenario of BNP's governance. This study followed quantitative approach of collecting and analyzing data. The data were collected through structured questionnaire following a structured interview using a purposive sampling technique. The questionnaire used five points rating scales whereas every question were ranked from 1 to 5 (whereas 1= very low, 2= low, 3= moderate, 4= high and 5= very high forest governance in the scale) to measure the components of forest governance.

Secondary data such as, laws of forest including the forest act 1927, the Bangladesh wildlife preservation (amendment) act 1974, and wildlife conservation and safety act 2012 were collected from Bangladesh Forest Department (BFD). Besides, different article, book chapter and unpublished thesis were used. These relevant literatures were collected through Google scholars. Moreover, Landsat satellite images were used to prepare Land Use and Land Cover (LULC) maps of BNP using ArcGIS (version 10.5). Ethical considerations took precedence in this study, with participants providing verbal consent.

Table 1. Pillars, components and associated variables of forest governance used for the present study

Pillars	Components	Variables
Policy, legal, institutional and regulatory framework	Forest-related policies and laws	Coherence
		Clarity
		Applicable
	Institutional framework	Organizational resources
		Financial mechanisms
		Availability of information
		Adequacy of modern technology
		Public awareness
		Participation of civil society, indigenous peoples and forest officials
Planning and decision-making processes	Stakeholder participation	Opportunity in decision making process
		Access to justice through effective resolution of conflict and grievance
		Performance based rewards and penalties
	Transparency and accountability	Accessibility to information
		Obligation to disclose information
Implementation, enforcement and compliance	Forest law enforcement	Appropriateness and consistency in the implementation of laws
		Penalties for breaking of laws
		Jurisdictional authority
		Capacity of law enforcement
	Measures to address corruption	Conducts of stakeholders
		Effective role of private sector
		Function of courts and arbitrators
		Follow-up action

Sample size determination: The study followed purposive sampling technique whereas questionnaire was structured in nature. The research used the following equation (Equation 1) to determine the sample size from the unknown population.

$$n = \frac{z^2pq}{d^2} \qquad (1)$$

Where, z denotes the normal variant

p is the target proportion. In this case, the study assumed p= 0.50

p + q = 1, therefore, q= 0.50

d is the desired error which is 0.1

Based on this equation, different possibilities could be explored to determine the suitable sample size. The study considered 90% confidence level where the value of normal variant (z) is 1.65 and 10% maximum error (d) where the value is 0.1. Hence, the value of n calculated as:

$$n = \frac{(1.65)^2 \times 0.50 \times 0.50}{(0.1)^2} = \frac{0.6806}{0.01} \quad n = 68$$

A total number of 75 respondents (i.e., the local people whose livelihood depends on forest) were selected for the survey. However, at the end, present study considered about 68 respondents due to some exclusion criteria such as inadequate data, misleading information during the survey etc. Moreover, the study found approximately 15 forest officials including managers and staffs through purposive sampling using a checklist. The responses were cross-checked with local people and forest officials to ensure validity of information. This research did not consider socio-demographic information such as age,

income, gender, or religion when choosing participants. Instead, the selection process focused on the respondents' level of knowledge and maturity regarding forest resources and their governance issues.

Validation and assignment of weights to ratings: To assign ratings for each variable, respondents were tasked to assign weights to individual variables, components, and pillars using the same rating scale (i.e., 1 to 5). The study incorporated these weights to ensure that the indicators accurately reflected local conditions. The assigned weights for variables were determined based on perceived influences of variables on governance to forest resources in the study site, particularly under the components (e.g., forest related policies and laws, institutional framework etc.) using a five-point rating scale. The researchers' observations were also taken into account during the final weighting of the indicators. However, the final calculations for the indicators employed a methodology involving the weighted mean index and aggregate weighted index, analogous to the approach adopted by Gupta and Shaw in 2015. Equations 2, 3, and 4 outline the procedures for calculating the weighted scores of individual variables, components, and composite governance scores in the study. Initially, to compute the weighted scores for individual variables, this study applied Equation 2.

$$\text{Score}_{\text{Forest-related policies and laws}} = \frac{W_1V_1 + W_2V_2 + \ldots\ldots\ldots\ldots\ldots + WnVn}{W_1 + W_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + Wn} \quad (2)$$

Where,

Wn= the assigned weights for each variable

Vn= the scores of the variables

Subsequently, the study determined the weighted mean scores for each of the three pillars using Equation 3.

$$\text{Weighted Mean Score}_{\text{Policy, legal, institutional and regulatory framework}} = \frac{W_1c_{\text{Forest-related policies and laws}} + W_2c_{\text{Institutional framework}}}{W_1 + W_2} \quad (3)$$

Where,

Cn= the scores of components obtained from Equation 2

Wn= the assigned weights for each component

The composite governance scores for the study area were then calculated using Equation 4.

$$\text{Composite Governance Score} = \frac{W_1p_{\text{Policy, legal, institutional and regulatory framework}} + W_2p_{\text{Planning and decision-making processes}} + W_3p_{\text{Implementation, enforcement and compliance}}}{W_1 + W_2 + W_3} \quad (4)$$

Where,

Pn= the weighted mean scores of each of the three pillars

Wn= the assigned weights for each pillar

Besides gathering quantitative survey data, three Focus Group Discussions (FGDs) were conducted across the study site to qualitatively validate the ratings and weighting of the indicators. Each FGD consists of five (05) respondents including male and female. Additionally, five (05) Key Informants Interviews (KIIs) were conducted during the qualitative data collection phase. To depict the impact of variables on forest governance, the mean weightages were grouped into five categories: very less effective (0.00-1.00), less effective (1.01-2.00), moderate effective (2.01-3.00), high effective (3.01-4.00), and very high effective (4.01-5.00).

Results and Discussion

The study identified that the policies and laws related to forest governance is very clear, coherence as well as applicable and secured the highest scores (i.e., 4.27) among the components of forest governance (Table 2).

There are a number of forest related policies and laws adopted for forest governance in the country. For instance, no one is allowed to enter into the forest area without the permission of forest authority. Besides, building any settlement is prohibited inside the forest (The Forest Act 1927, Section 30; The Bangladesh Wildlife (Preservation) (Amendment) Act 1974, Section 23, Sub-section 3). In accordance with law, no one is allowed to hunt, kill or seize any kinds of wild animal inside national park and within the radius of 1 mile outside of its territory. Moreover, no one is allowed to kill native birds or migratory birds. Laws of forest do not allow anyone to cut down or remove or destroy trees or collect any parts of trees from the forest without the permission of forest authority. Moreover, no one has right to fell, tape, and burn, destroy or remove trees from the national park (The Forest Act 1927, Section 30 and Section 32; The Bangladesh Wildlife (Preservation) (Amendment) Act 1974, Section 23, Sub-section 3; Wild life Conservation and Safety Act 2012, Section 6, Sub-section 1). The study revealed that the authority of BNP knows all the mentioned policies and laws.

Institutional framework holds second highest score (i.e., 1.96) of forest governance of BNP in five points rating scale (Table 2). It involves different elements including organizational resources (i.e., human and technical resources) and financial mechanism (e.g., budget and finance), information, technology, public awareness and education etc. However, there is a lack of adequacy and stability of financial funds, logistics support as well as manpower. On an average per range office has more or less 41 manpower and all of them are male. About 50% of total manpower (i.e., 21 out of 41) are used for patrolling the forest resource of range area.

The study found at the time of filed survey that a range office uses only one car and six motor cycles for patrolling forest. Therefore, they do not patrol forest regularly as the shortage of forest officers and staffs and technical resources. Sometimes they are patrolling the forest and the forest resources on foot due to scarcity of vehicles. On an average, a range office has 3 short guns, and 17 Chinese Rifle use if necessary, during patrolling the forest. The field survey identified that there is a need of permanent boundary to protect the forest area. Forest authority only use pillar (Forest department pillar) to mark forest area. As a result, private land holders are grabbing the forest lands day by day. Further, appropriate tools and modern technology are seldom available. Consequently, the concern authority does not have adequate and timely information of the different issues of the forest such as, harvesting, conservation measures, illegal activities etc. On the other hand, nearby residents are not getting training on awareness and education regarding management of forest and conservation forest resources. Among the three pillars used to assess forest governance, the policy, legal, institutional and regulatory framework secured the maximum scores (i.e., 3.12) (Table 3).

Stakeholder participation influences less on the forest governance which secured a score of 1.41 in five points rating scale (Table 2). It is identified that at present no environmental organization is working actively with the authority of BNP for the betterment of the forest and its environment. On the other hand, civil society including local people is the active agent for the sustainable use of resources. However, the participation of public from civil society and indigenous community for the sake of forest management is not sufficient. Recently, Bhawal National Park management authorities are trying to increase public engagement in forest management through social forestry. Forest range officer organized weekly and monthly meeting for discussions with the people of social forestry program. It is also identified that people often have limited access in decision-making process for forest management and access to justice by the effective resolution of the existing conflict and grievance.

Table 2. Components-wise weighted governance scores in a five-points rating scale

Components	Scores
Forest-related policies and laws	4.27
Institutional framework	1.96
Stakeholder participation	1.41
Transparency and accountability	1.15
Forest law enforcement	1.33
Measures to address corruption	1.26

Source: The Authors 2023

Transparency and accountability component achieved the lowest score (i.e., around 1.15) among the all components of forest governance (Table 2). It is identified that there is not always a high enough level of transparency within the forest officials. However, forest authority suspends corrupted officers, cutoff their 2 or 3 increments and stop their salary as well. On the other hand, accountability of forest officials and staffs are not in a satisfactory level. For instance, the forest manager and his employees are not successful in informing the public about their conducts by giving various types of information about annual budget, revenue collection, expenditure of used resources, accounting etc. Moreover, forest officials seldom provide information of administrative policy, legal action etc. to the general people who live in and around the forest. However, accountability from the individual level to institutional level is effective within the different wings of forest authority. Forest officials submit monthly report and annual report to the higher authority of forest on the usage of resources. Besides, they must be accountable to concern authority for failing to meet performances. Consequently, the pillar (i.e., Planning and decision-making processes) has obtained low score (i.e., 1.28) on the forest governance (Table 3).

The study identified a weak enforcement of laws for the forest governance. The component obtained only 1.33 scores of forest governance in five points rating scale (Table 2). The typical land use of BNP is rapidly changed due to lack of appropriateness and consistency in the implementation of forest laws and regulations (Figure 2). There is an irregularity in the application of penalties for the violation of forest laws. However, the authority of BNP struggled to execute the forest laws regulations because of insufficiency of resources including budget, forest officials and staffs, tools and technology. Consequently, Bhawal National Park is occupied with permanent settlements, agricultural land and industries (Table 4, Figure 1 and Figure 2).

There are a number of human settlements and other infrastructures including grocery shops, auto repair garages and hair cutting salons are present inside the park area. Moreover, the settlements and man-made structures are also increasing day by day. Presently, about 20% forest area is covered by settlements and man-made structures (Table 4). Besides, it is found that several trees of forest have cut down by the grabbers. Therefore, number of Sal trees is decreasing constantly which is currently occupied by only 23% of the forest area (Table 4).

Different measures for the prevention of corruption are not adequate in the BNP which scored only 1.26 in five points rating scale. Officials of forest department struggled to manage the people who live inside the forests. Forest authority would like to take help from the courts and arbitrators. However, in most of the cases, courts and arbitrators do not work in a timely manner. For instance, last fiscal year 2019-20 Sreepur Range office filed 137 cases against the offenders. About 32,078 cases were pending in the courts until June 2015 (Sreepur Range Office 2020). Though 90 days are fixed for completing each case but completing a case need more than four years. There are some reasons for this delay such as, improper prosecution submissions, absence of plaintiffs and witnesses, non-submission of evidence, and weak arguments. It is also noticed that, effective follow up action on corruption, revenue collection, expenditure, budgeting and audit are not in optimum level. The study identified that the implementation, enforcement and compliance pillar secured score roughly 1.30 in five points rating scale (Table 3). The composite score is 1.90 in five points rating scale that indicates less effective governance of Bhawal

Table 3. Pillar-wise weighted governance scores for the study area in a five-points rating scale

Pillars	Scores
Policy, legal, institutional and regulatory frameworks	3.12
Planning and decision-making processes	1.28
Implementation, enforcement and compliance	1.30
Composite Governance Score	1.90

Source: The Authors 2023

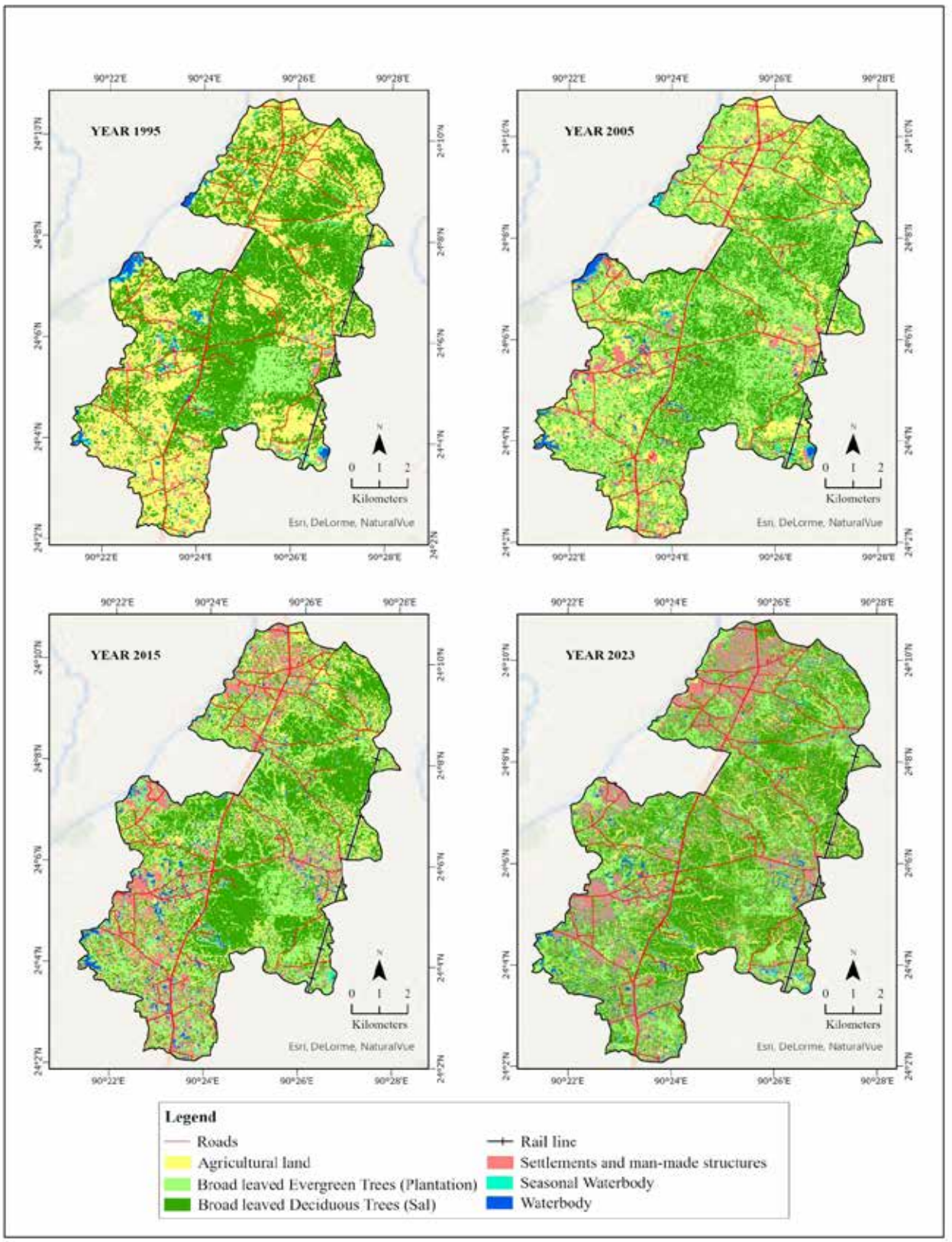


Figure 2. The trend of land use change inside the BNP (Source: The Authors 2023)

Table 4. The trend of land use change inside the BNP

Year	1995		2005		2015		2023	
Class	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Agricultural land	4229.17	44.39	1910.18	20.05	1342.92	14.09	1078.61	11.32
Settlements and man-made structures	212.27	2.23	711.852	7.47	1618.89	16.99	1858.56	19.50
Broad leaved Deciduous Trees (Sal)	4193.9	44.02	2765.23	29.02	2798.52	29.36	2148.46	22.54
Broad leaved Evergreen Trees (Plantation)	560.62	5.88	3899.41	40.92	3349.16	35.14	3831.68	40.20
Seasonal Water body	219.61	2.30	116.25	1.22	154.41	1.62	374.44	3.93
Water body	112.08	1.18	125.77	1.32	267.17	2.80	239.78	2.52

Source: The Authors 2023

National Park (BNP).

Bhawal National Park is a protected forest area and hence, is strictly accessible area (The Forest Act 1927, Section 30 and Section 33, Sub-section 1A; The Bangladesh Wildlife Preservation (Amendment) Act 1974, Section 23, Sub-section 3). However, number of permanent settlements and industries are present inside the core area of the park avoiding laws of the forest. Considering the situation, the Ministry of Environment and Forest, Bangladesh had imposed a ban on the construction of any kinds of infrastructure (e.g., industries) at the Bhawal National Park under the environmental law of 1999. However, the gazette of notification was published after 7 years (i.e., 2006). As a result of delayed enforcement, local people had taken advantages. Thus, lands of the park grabbed by the local people and industries that are posing a great threat to the forest ecosystem. Therefore, about 66% forest areas were covered by vegetation in 1985, which is reduced to 45% in 2009 (Rahman *et al.* 2009). On the other hand, approximately 26.44% lands of the park are now under total encroachment (Masum *et al.* 2015) due to the lack of proper implementation of the forest laws.

In 2008, the government issued environmental clearance certificates for industries on privately owned lands within the park (Masum *et al.* 2015). Therefore, more or less 354 industries have been legalized and the clearance certificates have opened the door of the park for future industrial setup on privately owned lands inside the park. Consequently, 255.3 ha of forest land have already grabbed and 0.72 ha/industry are grabbed every year (Masum *et al.* 2015). Besides, in 2009, government withdrew the gazette notification of banning industrialization in and around the BNP (Roy 2010 cited in Masum *et al.* 2015). Hence, industrialists and puissant people started building industries in the park on a regular basis. On the other hand, private land within the park is causing a great threat to the ecosystem of the forest.

Coordination among local people and forest officials is essential for the development and management of forest resources of BNP. Moreover, increasing participation and satisfaction of participants are both relevant in forest resource governance (Thompson *et al.* 2005). Accountability and transparency are some of the important values for the individuals and these are obvious to ensure forest governance. Local people expect from officers to govern the forest resources properly and contributing to suitable environment. According to Nath and Inoue (2008) forest governance of Bangladesh has been obstructed by low level of accountability and transparency in decision-making and access to information. Similarly, Bhawal National Park governance needs to increase accountability and transparency.

It is important to have enough institutional arrangement and resources including physical, financial and human resources for the governance of forest resources. However, the Forest Department of Bangladesh lacks enough physical, financial and human resources to give full safeguard to the forests (Mitchel *et al.* 2004, BFD and IUCN 2023). Very often forest resource users (e.g., local

people and forest authority) are involved with conflict. There are various reasons including rejections of cultural values and attachment to tradition (Thondhalana *et al*. 2016), policy intervention (Agrawal and Redford 2007), inadequate livelihood support for resource users, partiality in benefit sharing and top-down nature of participatory forest programs are responsible for forest dispute (Nath and Inoue 2010; Islam and Sato 2013). Forest court adjudicates legal disputes between forest authority and offender including forest land grabber, thief of the forest trees etc. (Hasan and Bahauddin 2014). However, conflicts among local people and forest officials can be solved by the community management approach.

Conclusions

The present study identified that forest related policies and laws such as the forest act (1927), the Bangladesh wildlife preservation (amendment) act (1974), wildlife conservation and safety act (2012) are very clear, coherence and applicable. However, the process of implementation was found as weak due to lack of sufficient and skill manpower in the BNP and insufficient financial support from the forest authority. Besides, inappropriate demarcation of the forest boundaries has made the situation worse, resulting less effective influence of forest governance for BNP. The situation might be largely responsible for the encroachment of one-third area of the park. Moreover, the access of general people to information, decision making and justice needs to be widen. Additionally, conflict between forest user arise because of in inequitable benefit sharing by the actors, imposing new practices or development activities, introducing new rules and regulations that restrict the subsistence activities of the inhabitants. However, to safeguard the BNP with proper governance, forest authority needs to implement the existing forest policies and laws very strongly. The authority should provide sufficient and skill manpower and sufficient financial support to every beat office of the BNP. Moreover, to save the forest from the land grabbers it is urgent to make permanent boundary on the border of the area.

Acknowledgement

The authors are thankful to Begum Rokeya University, Rangpur for financial support of the study (Budget Code-3632104).

References

Agrawal A and Redford K. 2007. Conservation and Displacement: An Overview. In: Protected Areas and Human Displacement: A Conservation Perspective, World Conservation Society, New York.

Agrawal A, Chhatre A and Hardin R. 2008. Changing governance of the world's forests. Science, *320*: 1460-1462.

Alauddin M, Hossain MN, Islam MB, Islam S and Islam M. K. 2020. Management strategies for sustainable forest biodiversity conservation in protected areas of Bangladesh: a Study of Bhawal National Park, Gazipur. Grassroots Journal of Natural Resources, *3*: 56-72.

Arts B. 2014. Assessing forest governance from a triple G perspective: government, governance, governmentality. Forest Policy and Economics, *49*: 17-22.

Balooni K, Pulhin JM and Inoue M. 2008. The effectiveness of decentralisation reforms in the Philippines's forestry sector. Geoforum, *39*: 2122-2131.

Begum N. 2022. Participatory forest governance for sustainable forest management: opportunities and challenges in Bangladesh. Doctoral dissertation, Macquarie University.

BFD and IUCN. 2023. Bangladesh National Conservation Strategy: Forest Resources, Government of People's Republic of Bangladesh. Retrieved from, https://bforest.portal.gov.bd.

Chowdhury RI. 2013. Attitudes towards Co-management: Is Satchari National Park a Suitable Model for Bhawal National Park ? USAID.

Davis C, Williams L, Lupberger S and Daviet F. 2013. Assessing Forest Governance: The Governance of Forests Initiative Indicator Framework. https://www.wri.org.

FAO (Food and Agriculture Organization). 2011. Framework for Assessing and Monitoring Forest Governance. https://www.fao.org.

FAO (Food and Agriculture Organization). 2012. Strengthening effective forest governance monitoring practice. FAO, Rome.

Giessen L and Buttoud G. 2014. Defining and assessing Forest Governance. Forest Policy and Economics, 49: 1-3.

Giessen L, Sarker PK and Rahman MS. 2016. International and domestic sustainable forest management policies: distributive effects on power among state agencies in Bangladesh. Sustainability, *8*: 335.

GOB. 2012. Perspective Plan of Bangladesh 2010-2021: Making Vision 2021 a Reality. Planning Commission, Government of Bangladesh.

Gupta RD and Shaw R. 2015. An indicator based approach to assess coastal communities' resilience against climate related disasters in Indian Sundarbans. Journal of Coastal Conservation. 19, Pp. 85-101.

Hasan E and Bahauddin KM. 2014. Community's Perception and Involvement in Co-management of Bhawal National Park, Bangladesh. Journal of Natural Sciences Research, *4*: 60-67.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate change 2014: synthesis report. Contributions of working groups I, II and II to the fifth assessment report of the intergovernmental panel on climate change. Core writing team, IPCC, Geneva, Switzerland (2014), p. 151.

Islam K and Sato N. 2012. Deforestation, land conversion and illegal logging in Bangladesh: the case of the Sal (Shorea robusta) forests. Forest-Biogeosciences and Forestry, *5*: 171.

Jashimuddin M, Islam KN and Nath TK. 2021. Local level forest governance and conservation outcomes in a co-managed protected area of Bangladesh. Journal of Sustainable Forestry, *41*: 302-318.

Khan NA, Al Srijohn A and Aziz N. 2021. Forest governance in Bangladesh: a probe into selected policy and institutional dimensions. The Malaysian Forester, *84*: 313-335.

Kishor N and Rosenbaum K. 2012. Assessing and monitoring forest governance: a user's guide to a diagnostic tool The World Bank, Pp. 1-124.

Masum KM, Islam MN, Saha N, Hasan MZ and Mansor A. 2015. Assessment of land grabbing from protected forest areas of Bhawal national park in Bangladesh. Landscape Research, *41*: 330-343.

Mitchell AH, Alam MK and Bari MA. 2004. Assessment of the forest department's institutional organization and capacity to manage the protected area system of Bangladesh. Nishorgo Support Project Report.

Mollick AS, Rahman MK, Khan MNI and Sadath MN. 2018. Evaluation of good governance in a participatory forestry program: A case study in Madhupur Sal forests of Bangladesh. Forest Policy and Economics, *95*: 123-137.

Nath TK and Inoue M. 2008. How does local governance affect project outcomes ?

Experience from a Participatory Forestry (PF) project in Bangladesh. International journal of agricultural resources, governance and ecology, *7*: 491-506.

Nath TK and Inoue M. 2010. Impacts of participatory forestry on livelihoods of ethnic people: experience from Bangladesh. Society and Natural resources, *23*: 1093-1107.

Nath TK, Jashimuddin M and Inoue M. 2016. Community-based forest management (CBFM) in Bangladesh. Switzerland: Springer.

Rahman MM, Nishat A and Vacik H. 2009. Anthropogenic disturbances and plant diversity of the Madhupur Sal forests (*Shorea robusta* CF Gaertn) of Bangladesh. International Journal of Biodiversity Science and Management, *5*: 162-173.

Rahman MH and Miah MD. 2017. Are protected forests of Bangladesh prepared for the implementation of REDD+? A forest governance analysis from Rema-Kalenga Wildlife Sanctuary. Environments, *4*: 43.

Rahman MU, Dey T and Biswas J. 2022. Land-use change and forest cover depletion in Bhawal National Park, Gazipur, Bangladesh from 2005 to 2020. Environmental Monitoring and Assessment, *195*: 201.

Reddy CS, Pasha SV, Jha CS, Diwakar PG and Dadhwal VK. 2016. Development of national database on long-term deforestation (1930-2014) in Bangladesh. Global and Planetary Change, *139*: 173-182.

Sarker PK and Rodrigo R. 2014. A review of the status and trends of forest cover in Bangladesh and Philippines. In: Proceedings of the 4th International DAAD Workshop on The Ecological and Economic Challenges of Managing Forested Landscape in a Global Context from.

Satpathy B, Muniapan B and Dass M. 2013. UNESCAP's characteristics of good governance from the philosophy of Bhagavad-Gita and its contemporary relevance in the Indian context. International Journal of Indian Culture and Business Management, *7*: 192-212.

Sreepur Range Office. 2020. Annual Report, Sreepur Range Office of Bhawal National Park, Gazipur, Bangladesh.

The Bangladesh Wildlife (Preservation) (Amendment) Act. 1974. Act No. 23 of 1973, Laws of Bangladesh, Government of People's Republic of Bangladesh. http://bdlaws.minlaw.gov.bd/act-details-452.html.

The Forest Act. 1927. Act No. XVI of 1927, Department of Forest, Government of People's Republic of Bangladesh. http://www.bforest.gov.bd.

Thompson JR, Elmendorf WF, McDonough MH and Burban LL. 2005. Participation and conflict: lessons learned from community forestry. https://academic.oup.com/jof/article-abstract/103/4/174/4598619.

Thondhlana G, Cundill G and Kepe T. 2016. Co-management, land rights, and conflicts around South Africa's Silaka Nature Reserve. Society & Natural Resources, *29*: 403-417.

UNEP. 2007. Global Environment Outlook GEO4: Environment for Development, United Nations Environment Programme. https://www.unenvironment.org.

Wildlife Conservation and Safety Act. 2012. Act No. 30 of 2012, Department of Forest, Government of People's Republic of Bangladesh. http://www.bforest.gov.bd.

Ziegler AD, Phelps J, Yuen JQ, Webb EL, Lawrence D, Fox JM, Bruun TB, Leisz SJ, Ryan CM, Dressler W and Mertz O. 2012. Carbon outcomes of major land-cover transitions in SE Asia: great uncertainties and REDD+ policy implications. Global Change Biology, *18*: 3087-3099.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 199-205

GROWTH, WATER RELATION, LEAF PIGMENTS AND YIELD OF SESAME AS INFLUENCED BY SIMULATED SALINE ENVIRONMENT

Masuma Akter, Most. Tanjina Akter, Kaniz Fatema Jui, Md. Nasimul Bari and MA Mannan*

Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh

***Corresponding e-mail:** mannanagr@bsmrau.edu.bd

Received: 30 November 2023, revised: 05 December 2023, accepted: 12 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.13

ABSTRACT

Salt stress is a significant environmental problem that restricts crop productivity. Despite being an important oilseed crop in Bangladesh, little is known about the phenotypic and physiological responses of sesame (*Sesamum indicum*) to salinity. In order to measure the plant height, number of leaf plant^{-1}, dry matter accumulation capability, leaf water uptake capacity, leaf chlorophyll content, and yield response six sesame genotypes viz., BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, and BD-6999 were grown in pots and exposed to a 7.5 dS m^{-1} simulated salty environment. These genotypes were chosen for this investigation from 86 genotypes according to the relative germination percentage at 10 dS m^{-1} salinity. Results revealed that plant height, number of leaf plant^{-1}, dry matter accumulation capability, leaf chlorophylls a and b content, and yield were reduced in all the genotypes, but reduction rate was lower in genotype BD-7011. On the other hand, water uptake capacity in sesame leaf was increment in all the genotypes under salinity but increasing rate was lower in the same genotype BD-7011. These results suggest that the sesame genotype BD-7011 may be able to withstand salt stress with little detrimental effects on the growth, physiological traits, seed yield.

Keywords: Abiotic stress, oilseed crop, physiological traits

Introduction

One of the main abiotic stressors that have a major impact on plant growth and output is salinity (Gharsallah *et al*. 2016). Salinity reduces the amount of water available to plants. When salt concentrations are excessively high and plants are unable to absorb water, physiological drought takes place. No matter how much water may be in the soil, plant roots are unable to absorb it due to the negative osmotic pressure. By the middle of the twenty-first century, over half of all arable land would disappear due to the ongoing salinization of arable land caused by climate change (Islam *et al*. 2019). A multitude of factors contribute to the annual increase of saline areas, such as salts' capillary rise, rivers carrying seawater into freshwater during the dry season, tornado-induced inland floods, and more (Mannan *et al.* 2012). Different salinity levels have affected 26.7% of newly created land over the last 40 years in Bangladesh.

According to Zhang *et al*. (2013) and Rahneshan *et al*. (2018), a high concentration of salt causes ionic imbalance and osmotic stress in plants, which negatively affects their morphology, biomass, physiology, and biochemical activity and eventually causes damage to the plants. In addition to chlorosis, leaf senescence, slowed development, decreased dry weight, decreased carbon fixation, increased stomatal closure and photosynthetic rate, decreased water content, and changed osmolytes, salinity has detrimental effects on plant morphology, physiology, and yield. Numerous plants have developed a variety of strategies to address these issues like less degradation of chlorophyll content and lower water uptake capacity in their leaves. Sesame is one of the world's greatest crops at withstanding droughts, although it cannot grow in too salinized soil (Langham *et al.* 2008). Since there might be variations across cultivars of the same species and between phenological stages of the same genotype, plants' responses to salt stress can vary greatly overall (Sánchez-Blanco *et al*. 2004). Abbasdokht *et al*. (2012) stated that sesame is a plant with a moderate salt resistance. This study focused on the agronomic responses of several sesame genotypes to salt stress and sought to identify genotypes that were sensitive to and tolerant of salt based on agronomic and physiological markers. The

objective of this research is to study the effects of salinity on sesame growth, leaf water and chlorophyll content, and yield under saline environment.

Materials and Methods

Thepot experiment was carried out in a vinyl house in the Agronomy Department's research field at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh in the Kharif 1 season (February to June, 2023). Each pot was 30 cm in diameter and 24 cm in height. It was filled with 14 kg of air-dried soil and a 4:1 mixture of soil and cow dung. 0.64g, 0.62g, 0.52g, and 0.20g of urea, TSP, MoP, and gypsum @) 50.0-20.0-40.0-14.0 kgN-P-K-S ha^{-1} were applied to the pot soil, respectively (FRG 2018). All fertilizers, with the exception of half of urea, were applied as basal and the remaining half at 15 DAE (days after emergence). The study employed a completely randomized design with three replications. In this experiment, six sesame genotypes like BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, and BD-6999 were employed. In our earlier work, these genotypes were eliminated from 86 genotypes under 10 dS/m salinity during the germination stage. On February 5, 2023, ten healthy seeds were sown in a pot and covered with soil. To guarantee consistent germination, mild irrigation was administered following seed sowing. Three plants were kept 14 days after they emerged, and they received salt treatment (irrigation with 7.5 dS m^{-1} saline water) for the duration of the growing season. Conversely, tap water was used to irrigate the control pots. Plant parameters such as height, leaf count, dry weight of the entire plant, water uptake capacity (WUC), and leafchlorophyll content were measured at flowering stage, and yield parameter was measured at the maturity stage. Water uptake capacity (WUC): Water uptake capacity quantifies the capacity of plants to absorb a greater quantity of water per unit of dry weight in relation to turgid weight. It was measured by using the following formula:

$$WUC = \frac{TW - FW}{DW}$$

Where, TW = Turgid weight of the leaf, FW = Fresh weight of the leaf, DW = Dry weight of the leaf

Chlorophyll content:

Chlorophyll content was estimated from the fully expanded uppermost leaf samples at 15, 30, 45 and 60 days after saline treatment imposed using the method described by Witham *et al.* (1986). The fresh leaf sample of 20 mg were taken in small vials containing 20 ml of 80 % acetone and covered with aluminium foil, and preserved in the dark for 72 hours. Then reading was taken at 663 nm and 645 nm wave lengths by a double beam spectrophotometer (Model 200-20) and the result was expressed as mg g^{-1} fresh weight. The formula for computing chlorophyll a, b and total chlorophyll were-

mg Chlorophyll a g^{-1} fresh weight = [12.7 (D_{663}) - 2.69 (D_{645})] X [V/1000 X W]

mg Chlorophyll b g^{-1} fresh weight = [22.9 (D_{645}) - 4.68 (D_{663})] X [V/1000 X W]

Where, D (663, 645) = Optical density of the chlorophyll extract at wave length of 663 and 645 nm, = Final volume (ml) of the 80 % acetone with chlorophyll extract, W = Weight of fresh leaf sample in g.

Statistical analysis: The statistical tool MSTAT-C was used to analyze the data. The least significant difference (LSD) test was used to compare the means of the different treatments (Gomez and Gomez 1984). An Excel program was used to create the table and graph.

Results and Discussion

In sesame, salinity reduced plant height, with genotype-specific variations in the rate of decline (Table 1). BD-7009 had the highest plant height at control, whereas BD-6980 had the lowest. The genotypes' differences in plant height reduction at 7.5 dS m^{-1} salinity varied from 11.73% to 25.56%. Salinity-induced reduction in plant height was less pronounced in the BD-7011 genotype (11.73%). With the largest percentage loss (25.56%) in plant height, genotype BD-6999 had the most detrimental effects of salinity. Salinity-induced reduction in plant height was found to be mild in genotypes BD-6980 and BD-7009. The BD-7011 genotype's apparent resistance to salt in relation to plant height has been ascribed to their capacity for rapid growth and for reducing the concentration of salt in plant tissue. Wahome *et al*. (2001) reported that high salinity

Table 1. Growth attributes of sesame genotypes influenced by salinity at flowering stage

Genotypes	Plant height (cm)		Number of leaf plant^{-1}		Dry weight (g) plant^{-1}	
	Control	Saline	Control	Saline	Control	Saline
BD-6980	61.43	52.67 (14.27)	29.00	23.67 (18.39)	4.13	3.39 (17.92)
BD-7009	69.00	55.07 (20.19)	28.00	19.33 (30.95)	4.63	2.89 (37.70)
BD-7011	64.80	57.20 (11.73)	22.67	18.00 (20.59)	3.25	2.90 (10.67)
BD-6994	68.97	57.60 (16.48)	27.33	18.67 (31.71)	3.66	2.67 (27.02)
BD-6983	66.83	54.93 (17.81)	28.00	20.00 (28.57)	4.43	2.74 (38.18)
BD-6999	68.60	51.07 (25.56)	24.33	18.33 (24.66)	362	2.51 (30.76)
Level of significance	*		*		*	
LSD (0.05)	7.18		6.34		1.15	

Values in parenthesis indicates percent reduction in saline stress compare to control. *A significant difference at $p < 0.05$.

in the growing media negatively affects plant growth and development, which is consistent with our finding that salinity limits the growth of sesame plants. Hasanuzzaman *et al.* (2012) stated that these impacts could result in changed levels of growth regulators, membrane damage, nutritional imbalance, inhibition of certain enzymes, and metabolic inefficiencies, including photosynthesis. While soil salts such as Na and Cl disrupt normal plant growth and development, accumulating soil salts seem to shorten plant height under conditions of salt stress (Tunçtürk *et al*. 2011). Gaballah *et al.* (2007) found that high salinity levels reduced sesame height, with significant cultivar-to-cultivar variability in this characteristic. Plant tissues and cell size can alter as a result of salinity stress, which is caused by salt in water.

Salinity dramatically lowered the number of leaves produced per plant for sesame genotypes. In saline conditions, fewer leaves per plant were discovered (Table 1). The genotype BD-6994 had the largest reduction (31.71%), followed by BD-7009 (30.95%), BD-6983 (28.57%), BD-6999 (24.66%), and BD-7011 (20.59%). The genotype BD-6980 (18.39%) had the lowest reduction. A mean value of 21.56 leaves per plant in a sesame plant study by Janivan *et al.* (2017) showed that the number of leaves was unaffected by saline levels. In our study, however, we found that the salinity caused less leaves per plant than the control. Similar results were seen in tomatoes under salt stress by Romeroaranda *et al*. (2001). The number of leaves per plant is negatively impacted by salinity stress. This could be as a result of the decreased cell elongation and division, which inhibits the physiological and biochemical activities of the plants (Kumari and Parida 2018).

Table 1 shows the reduction in total dry matter (DM) output as well as the variation in DM production among genotypes as a result of salt. In every sesame genotype under investigation, salinity had a considerable impact on the overall dry matter production. The variations in the reduction of root, leaf, stem, and pod dry matter over their control were the reason for the salinity-induced disparities in total dry matter production across the genotypes. BD-7011 had the lowest percentage reduction in total dry matter (10.67%), whereas BD-6983 had the highest percentage reduction (38.18%). Because BD-7011 produces leaf and stemdry matter more efficiently than other genotypes, its total dry matter was less influenced by salinity stress. Koca *et al*. (2007) found that as salt levels rose, the shoots and roots of some sesame cultivars shrunk, however there were significant differences amongst the cultivars. They concluded that salt-tolerant cultivars produced higher dry matter than salt-sensitive cultivars. Reduced plant biomass, leaf area, and growth have been seen in a variety of vegetable crops that have been subjected to salt stress (Giuffrida *et al.* 2013).

A higher water uptake capacity (WUC) indicates that a plant is under more moisture stress, as the plant must absorb more water to reach turgid weight (Sangakkara *et al.* 1996). The water uptake capacity of plants quantifies their ability to absorb water per unit dry weight in comparison to turgid weight.In all the sesame genotypes examined, salinity had a notable impact on WUC. Figure

1 show that all genotypes showed an increase in WUC when exposed to salinity, but the increase was greater in genotype BD-6983 (0.91) and lower in genotype BD-7011 (0.68). This suggests that genotype BD-7011 was less affected by water stress when exposed to salinity. Increased soluble salts slow down the uptake of nutrients and water, leading to osmotic effects and toxicity, which has a negative impact on plant-water relations (Yang *et al*. 2009, Jiang *et al*. 2014).

Six genotypes of sesame plants showed different levels of chlorophyll in their leaves depending on salinity. All genotypes showed a significant drop in chlorophyll a and b content at 7.5 dS m^{-1} salinity level (Table 2). The genotype with the lowest chlorophyll a and chlorophyll b decrease was 17.03%and 17.86%, respectively in BD-7011, while the genotype with the highest predicted reduction was in genotype BD-6983. In salinity conditions, genotype BD-7011 showed a greater quantity of chlorophyll a and chlorophyll b than the other genotypes, suggesting that this genotype is comparatively salt tolerant. In the current study, salinity treatments considerably decreased the pigments involved in photosynthesis, such as chlorophyll a and chlorophyll b, in sesame genotypes. Chlorophyll content has been proposed in a number of studies as a biochemical indicator of plant salt tolerance. It is well known that while salt-sensitive plants exhibit a high decrease in chlorophyll contents, salt-tolerant plants exhibit less decreased or unchanged levels of chlorophyll under salinity conditions (Stepien and Johnson 2009, Ashraf and Harris 2013).

The relative (% of control) seed yield of six genotypes varied under salinity environment, ranging from 21% to 5.31 47% (Figure 2). BD-7009 had the largest loss in seed output per plant (79%) whereas BD-7011 had the lowest (53%). The highest relative seed yield of genotype BD-7011 was mostly caused by the highest relative pod number/plant and individual seed weight of this genotype. Plants undergo morphological, physiological, and biological changes under salt stress. This reduces plant yield and negatively affects reproductive characteristics (Hasanuzzaman *et al*. 2021). Rapid water loss from plant cells caused by salt stress have a significant impact on the reproductive stages of sesame plants, which require water for flower and capsule growth. Plant growth characteristics negatively affected by salinity include fresh weight, dry weight, leaf size, leaf area, and leaf number. Furthermore, osmotic stress caused by salinity in plants changes the overall nutritional status of plants and negatively affects hydraulic conductivity (Babu and Thirumurugan 2001). Therefore, growth retardation, ion and nutrient imbalance, changes in water conditions, and inhibition of photosynthesis affect the yield characteristics of sesame plants.

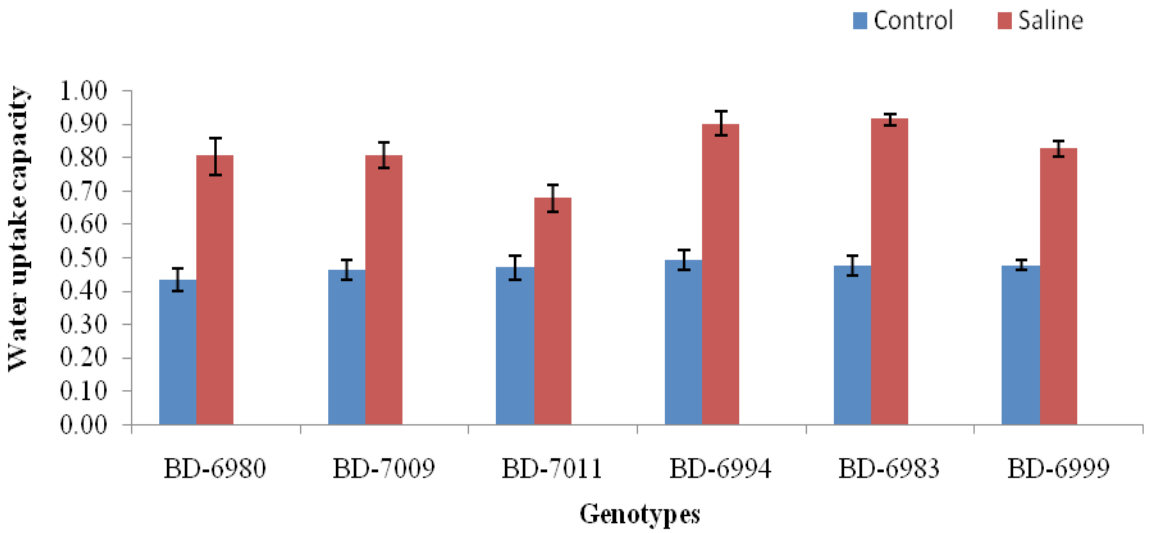


Figure 1. Water uptake capacity of sesame leaf as influenced by salinity. Bars indicate (±SE)

Table 2. Leaf chlorophylls of sesame genotypes as influenced by salinity at flowering stage

Genotypes	Chlorophyll a (mg g^{-1}FW)		Chlorophyll b (mg g^{-1}FW)	
	Control	Saline	Control	Saline
BD-6980	0.72	0.53 (73.61)	0.43	0.32 (74.41)
BD-7009	0.78	0.51 (65.38)	0.40	0.31 (77.50)
BD-7011	0.94	0.78 (82.97)	0.56	0.46 (82.14)
BD-6994	0.59	0.46 (77.96)	0.53	0.20 (37.73)
BD-6983	0.65	0.41 (63.06)	0.55	0.19 (34.54)
BD-6999	0.65	0.43 (66.15)	0.53	0.15 (28.30)
Level of significance	*		*	
LSD (0.05)	0.14		0.17	

Values in parenthesis indicates percent reduction in saline stress compare to control. *A significant difference at $p < 0.05$.

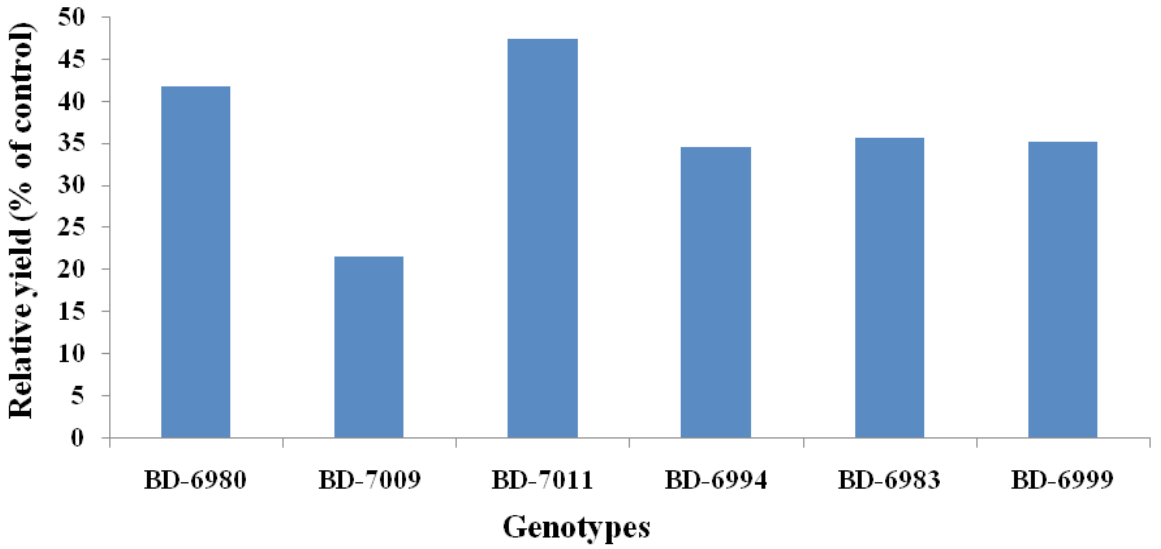


Figure 2. Effect of salinity on yield of sesame under salinity stress

Therefore, the reduction in height, yield, composition and seed yield of sesame when exposed to salt is due to cell division, hypertrophy, differentiation and growth, wilting and stomata caused by the removal of water from the cells by osmotic pressure. It can be explained by decreased closure and decreased water withdrawal from the cells. Similar results were obtained from Shani and Dudley (2001), who reported that the yield caused by impaired cellular function, increased consumption of energy and carbohydrates in osmoregulation, and decreased photosynthetic activity due to saline conditions. Ghadiri *et al.* (2006) expressed concern about decreased water intake due to salt. Salinity is caused by high osmotic potential and high concentrations of certain ions in the soil, which can cause physiological problems in plant tissues and lead to reduced yields, are in agreement with these findings.

Conclusion

The plant height, dry matter accumulation, chlorophyll a and b content in sesame leaf, and yield parameters of sesame genotypes to salt stress showed wide variation. Genotype BD-7011 has high tolerance to salt stress due to high low water uptake capacity, higher chlorophylls, which significantly contribute to high seed yield of this genotype.

Acknowledgement

The authors are grateful to Ministry of Science and Technology, Government of Bangladesh for funding the research.

References

Abbasdokht H, Ashrafi E and Taheri S. 2012. Effects of different salt levels on germination and seedling growth of sesame (*Sesamumindicum* L.) cultivars. Technical Journal of Engineering and Applied Sciences, *2*: 309-313.

Ashraf M and Harris PJC. 2013. Photosynthesis under stressful environments: an overview. Photosynthetica, *51*: 163-190

Babu S and Thirumurugan T. 2001. Effect of NaCl priming for increased salt tolerance in sesame (*Sesamumindicum*). Journal of Ecobiology, *13*: 309-312.

FRG (Fertilization Recommendation Guide). 2018. Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka 1215, Pp: 84-264.

Gaballah MS, Abu Leila B, El-Zeiny HA and Khalil S. 2007. Estimating the performance of salt-stressed sesame plant treated with anti-transpirant. Journal of Applied Sciences Research*, 9*: 811-817.

Ghadiri H, Dordipour I, Bybordi M and Malakouti MJ. 2006. Potential use of Caspian Sea water for supplementary irrigation in Northern Iran. Agricultural water management, *79*: 209-224.

Gharsallah C, Fakhfakh H, Grubb D and Gorsane F. 2016. Effect of salt stress on ion concentration, proline content, antioxidant enzyme activities and gene expression in tomato cultivars, Ao. B. PLANTS, Volume 8.

Giuffrida F, Scuderi D, Giurato R and Leonardi C. 2013. Physiological response of broccoli and cauliflower as affected by NaCl salinity. Acta Horticulture, *1005*: 435-441.

Gomez KA and Gomez AA. 1984. Statistical procedures for agricultural research. John Wiley & Sons, 1984.

Hasanuzzaman M, Hossain MA, da Silva JAT and Fujita M. 2012. Plant response and tolerance to abiotic oxidative stress: antioxidant defense is a key factor. Crop Stress and Its Management: Perspectives and Strategies, 261-315.

Hasanuzzaman M, Raihan MRH, Masud AAC, Rahman K, Nowroz F, Rahman M, and Fujita M. 2021. Regulation of reactive oxygen species and antioxidant defense in plants under salinity. International Journal of Molecular Sciences, *22*: 9326.

Islam MT, Rahman T, Rahmatullah SM, Sarker J, Khandum R and Mahmaud MSA. 2019. Biosecurity status in some commercial aquafarms of Kishoreganj and Mymensingh districts. Bangladesh Journal of Fisheries, *31*: 229-242.

JanivanS , Fernandes P, Brito M, Arriel N, de Melo A and Fernandes J. 2017. Tolerance to Salinity of Sesame Genotypes in Different Phenological Stages. American Journal of Plant Sciences, *8*: 1904-1920. doi: 10.4236/ ajps.2017.88129.

Jiang X, Qi W, Xu X, Li Y, Liao Y and Wang B. 2014. Higher soil salinity causes more physiological stress in female of Populuscathayana cuttings. ActaEcol Sin. *34*: 225-231.

Koca H, Bor M, Özdemir F and Türkan İ. 2007. The effect of salt stress on lipid peroxidation, antioxidative enzymes and proline content of sesame cultivars. Environmental and Experimental Botany, *60*: 344-351.

Kumari A and Parida AK. 2018. Metabolomics and network analysis reveal the potential metabolites and biological pathways involved in salinity tolerance of the halophyte Salvadorapersica. Environmental and Experimental Botany, *148:* 85-99.

Langham DR, Riney J, Smith G and Wiemers T. 2008. Sesame grower guide. Sesaco Sesame Coordinators, Lubbock, USA.

Mannan MA, Karim MA, Haque MM, Khaliq QA, Higuchi H and Nawata E. 2012. Response of Soybean to Salinity: I. Genotypic Variations in Salt Tolerance at the Vegetative Stage. J. of Tropical Agriculture and Development, *56*: 117-122.

Rahneshan Z, Nasibi F and Moghadam AA. 2018. Effects of salinity stress on some growth, physiological, biochemical parameters and nutrients in two pistachio (*Pistaciavera* L.) rootstocks. Journal of Plant Interaction *13*: 73-82.

Romeroaranda R, Soria T and Cuartero J. 2001. Tomato Plant Water Uptake and Plant-Water Relationships under Saline Growth Conditions. Plant Science Journal, *160*: 265-272.

Sánchez-Blanco MJ, Rodríguez P, Olmos E, Morales MA and Torrecillas A. 2004. Differences in the effects of simulated sea aerosol on water relations, salt content, and leaf ultra structure of rock-rose plants. Journal of Environmental Sciences. *33*: 1369-1375.

Sangakkara UR, Hartwig UA and Nosberger J. 1996. Responses of root branching and shoot water potentials of French bean (Phaseolus vulgaris L.) of soil moisture and fertilizer potassium. Journal of Agronomy and Crop Science *177*: 165-173.

Shani U and Dudley LM. 2001. Field studies of crop response to water and salt stress. Soil Science Society of America Journal, *65*: 1522-1528.

Stepien P and Johnson GN. 2009. Contrasting responses of photosynthesis to salt stress in the glycophyte arabidopsis and the halophyte thelluniella: role of the plastid terminal oxidase as an alternative electron sink. Plant Physiology. *149*: 1154-1165.

Tunçtürk M, Tunçtürk R, Yildirim B and Çiftçi V. 2011. Effect of salinity stress on plant fresh weight and nutrient composition of some Canola (*Brassica napus* L.) cultivars. African Journal of Biotechnology, *10*: 1827-32.

Wahome PK, Jesch HH and Grittner I. 2001. Mechanisms of salt stress tolerance in two rose rootstocks: *Rosa chinensis* Scientia Horticulturae, *87*: 207-216.

Witham H, Blades DF and Devin RH. 1986. Exercise in Plant Physiology (2nd Edition). PWS Publishers, Boston, USA, Pp. 128-131.

Yang F, Xiao X, Zhang S, Korpelainen H and Li C. 2009. Salt stress responses in *Populus cathayana* Rehder. Plant Science, *176*: 669-677.

Zhang H, Miao H, Wei L, Li C, Zhao R and Wang C. 2013. Genetic analysis and QTL mapping of seed coat color in sesame (*Sesamumindicum* L.). PLOS ONE, *8*: e63898.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 207-212

KNOWLEDGE, ATTITUDE AND PRACTICES ON REPRODUCTIVE HEALTH CARE AMONG RURAL ADOLESCENT FEMALES: A CROSS SECTIONAL STUDY ON CHINGUSPUR VILLAGE, BOGURA SADAR, UPAZILLA OF BANGLADESH

Senera Ferdous[1], ATM Rezaul Hoque [2], Md. Matiur Rahman[3], Ahmed Sharif [3] and Md Ruhul Amin [5]

[1]TMSS Nursing College, Bogura, Bangladesh. [2]Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. [3]Master of Public Health Program, TMIRT-TMSS, Bogura, Bangladesh. [4]Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.

***Corresponding e-mail:** luizareza@yahoo.com

Received: 02 December 2023, revised: 12 December 2023, accepted: 18 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.14

ABSTRACT

Adolescent's reproductive health is a serious concern in Bangladesh. The present study was based on primary data of 150 rural adolescent females of Chinguspur village, Bogura Sadar, Upazilla of Bangladesh. Objectives of the study was to assess the socio-demographic features of sample rural adolescent females and to explore the level of knowledge and awareness to demonstrate the role of the information and education (media, counseling, services facilities) in the management of reproductive health issues. The mean age of the respondents was 16.2 years. The religion of the surveyed population were found 92% Muslim while 8% Hindu. A large number of rural adolescent females have been found to discontinue education after a few years of schooling. Only 14% girls are currently enrolling and reading in class nine or more. Most of the girls (36.33%) in the study population used pieces of old cloths/rags (nekra) as pads during menstruation, while some did not use anything. 39% of the rural adolescent females used rags that were wet or had not been dried in a hygienic fashion. Among all most of them were not known or received any information about the management of menstruation before their first menstruation. The study revealed that 72.41% of adolescents were suffering at least one complication or problems of menstruation, were not visited or seeking any consultation or treatment from any service providers available. Only 27.59% taken consultation from the service providers. While 41.66% go to traditional or herbal practitioners (locally called Kobiraj) but 33.33% visited to qualified doctors. The study indicated that the rural adolescent females of the study area poorly informed about most of the reproductive health issues. They have misconceptions regarding healthy management of menstruation and a big gap between their knowledge, attitude and practice.

Keywords: Knowledge, attitude, reproductive healthcare, adolescent, puberty

Introduction

Adolescents constitute one-fourth of the population of Bangladesh (Bhuiya *et al.* 2004). The term "Adolescent" is derived from the Latin word "ADOLESCERE" meaning to grow, to mature. Adolescent can be defined as the development period between childhood & adulthood-beginning with the changes associated with puberty & culminating in the acquisition of adult roles and responsibilities. An important implication for reproductive health programs is to ensure that the quality of services is improved, particularly from the user perspectives. The focus of the program is based on women since they are the primary users of these programs. Equal importance should be given to promote male responsibility and enhance their involvement.

Target groups for the reproductive healthcare services are women and men of different stages of life. Reproductive events in women's life can be divided in many parts such as: preconception, conception, childbirth, post-natal, interconnection, and premenopausal and infertility. In the ICPD (International on Population and Development) Conference in 1994 (held in Cairo) it was decided that for ensuring the reproductive health services, the service should include reproductive healthcare through Primary Healthcare System, family planning services, information education and counseling; management of side-effects of family planning methods; information services for pre and post-natal, safe delivery, breast feeding and women's healthcare; treatment of infertility and reproductive tract infections and prevention and management of unsafe abortion; diagnosis and treatment of sexually transmitted

diseases and information, education and counseling, as appropriate on human sexuality, reproductive health and responsible parenthood; diagnosis and treatment of breast cancer and cancer of the reproductive tract; prevention and increasing awareness about consequences of HIV.

The main purpose of the program is the reduction of maternal and child mortality, contaminated diseases, unwanted fertility and total fertility rate, enhancing of life expectancy, age of women at birth of first child and nutritional status and healthy life style and ensuring of health and family planning services to the underserved rural population of Bangladesh. The main strategy of the programs is to introduce sector-wide management approach, essential service package, building of union health and family welfare center, establishing of community clinics, and support services. Under HPSP there will be 13,500 set-up and 775 UHFWCs will be constructed in spite of existing 3,175 UHFWCs in the country. There will be one clinic for 6000 population. To foster better understanding and bring attitudinal changes, Behavior Change Communication activities will also be strengthened.

Thus successful implementation of HPSP will be an important element of Bangladesh's poverty reduction in three ways: *firstly* improvements in the health/family welfare status of the population are important indicators of poverty alleviation. They will increase the labor productivity and, thus, support the economic growth component of the poverty reduction strategy; *secondly* positive impact of HPSP will be through targeting the underserved population; and *thirdly* improvements in health/ family welfare status will be achieved more easily with respect to the legal status of women.

The government of Bangladesh has thus identified adolescent health and education both as a priority and a challenge and to face the challenge, has incorporated this issue in the current Health and Population Sector Program (HPSP, 1998–2003). There are expectations that with the introduction of the Essential Services Package (ESP) across Bangladesh through the HPSP, there will be an overall increase in the quantity and quality of information and services available for adolescents through a network of clinics at various levels: community, upazila, and district. However, studies conducted by the different agencies for improvements directly associated with HPSP service delivery are unlikely to make significant contributions to achieving ARH results during the HPSP period (1998- 2003) without additional efforts from other agencies. Keeping these in view the study was under taken to assess the socio demographic features, explore the level of knowledge of awareness and the role of information and amp; education (media, counseling services facilities) for the management of reproductive health issues of the adolescent female in rural area.

Methodology

Study design: This is the descriptive cross sectional study designed to collect quantitative information to assess the knowledge, attitude and practices on reproductive health issues among rural adolescent females on Chinguspur village, Bogura Sadar, Bogura. Quantitative data was collected through structured questionnaire.

Target site and population: It is known that more than 23 percent of the total populations of Bangladesh are adolescents. Nearly half of the m are girls aged between 10-19 years. For this study, girls aged between 14-19 years were included; as it seems that the girls aged less than 14 years are too young to responds the pre-selected question.

Study area and period: It was detected that Chinguspur village of Bogura district under Rajshahi division taken as the study area or study site. Data was collected during the period January 2021 to June 2021

Sampling size: Through multistage randomization sampling technique 150 adolescent female were interviewed and data were collected from them.

Inclusion criteria

1. Unmarried female adolescent who age 14-19 years was included in the study.
2. At least six month living in the village.
3. Study objects was free from mental and chronic diseases.

Sampling technique: Rural adolescent females were selected purposively. Multi stage randomization sampling

technique was followed for the identification of sample population in Chinguspur village, Bogura Sadar, Bogura. Finally, 150 rural adolescent females of age between 14-19 years were interviewed for data collection.

Data collection: A questionnaire were developed for collection of data from the adolescent female. The interviewer's and supervisors were trained on the data collection as per questionnaire. After incorporating the pretest findings and finalizing the questionnaire, the interviewers and supervisors were trained. In each selected ward of the union first the interviewers were identified randomly ten adolescent females of 12 - 19 years from one village. Asked them and obtained consent for the interview. When they agreed then again asked her guardians for their consent of this interview. If any one refused to give consent for interviewed, the interviewers find another adolescent from the same or from the other villages within the same ward of the union. The interviewers was collected information as need based.

Statistical analysis: All interview questionnaires were checked for their internal consistency, to exclude missing or inconsistent data. Data was entered into the data file using statistical software called W Stata. The analytical plan of the study includes description of the study population by their socio-demographic characteristics. For this, some descriptive statistics was used like mean, median, mode and percentages in order to find out the association between the dependent and independent variables. Chi-square tests was performed to find out the bivariate relationship and their level of significance. To adjust confounding effect multiple linear regression was done.

Results and Discussion

The mean age was 16.2 years of the surveyed adolescent. It was observed that the highest concentration of the surveyed population was in age group of 16-17 years which reflected 50% but the second highest group 18-19 years of 30%. It was interesting to note that the population composition in lower age group was 14-15 years.

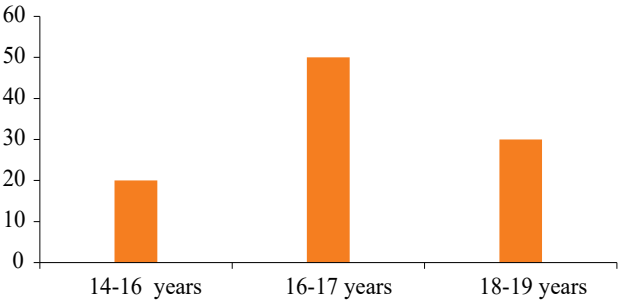


Figure 1. Distribution of surveys population by age group (n-150).

The religion of the surveyed population showed 92% of Muslim while Hindu 8%. No other adolescent were interviewed by the interviewer from any other religions. It is not exactly same distribution of national average of religions. Though there is population of other religion in the study area the interviewer may find it easy to contact with them to interview. Also may be they were not willing to talk about the issues.

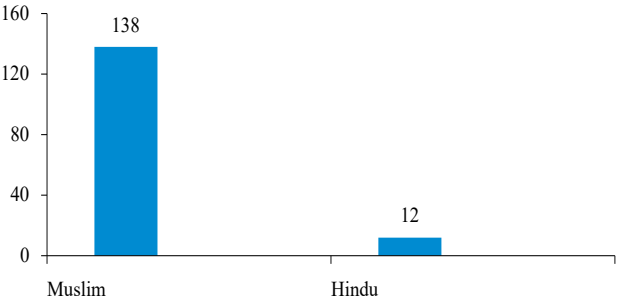


Figure 2. Distribution of religion of the surveyed population.

Education is expected to enhance the management of reproductive health, to restrain fertility, increase contraceptives use, reduce maternal and infant mortality etc. Also the increased education and employment opportunities for women will lead to more congenial gender roles and reduce the incidence of complications. Primary level of education is considered as compulsory for all in Bangladesh but shows depressing picture of education (Table 1). Only 46% of adolescent has completing the level 5 and rest 54% were failed to obtain the level 5. The table also showed 8% of adolescent never attended any school where 46% attended level 1-4, 32% attended level 6-8 but only 14% were now completing level 8 and currently studying level 9 and above.

Reproductive Health Knowledge and Practice

Knowledge on first menstruation: This study asked the respondents whether they know generally when and at what age a girl have started first menstruation. A significant high proportion 84% thinks a girl staring her first menstruation at the age between 10 to 15 years of which 70% starting at 10-12 years of age and 14% are at age group of 13-15 years. While 6% of respondents opinioned that first menstruation started at 7-9 years age group and no one thinks that the first menstruation started at 15+ years of age. Among all 10% of girls were not aware about the first menstruation of a girl's life.

Knowledge about healthy measures during menstruation: The knowledge about healthy measures should be taken during menstruation shows that 36.33% respondent opinioned in favor of use of old cloths and 15.66 % used clean and dry cloths but 13.33 % adolescent female garment workers use of Panty during menstruation. Besides 9.37% sued savlone/Dettol/soap. The researcher further asked to identify the sources of information they have taught which should be followed during menstruation. The results showing that, most of the information were obtained from the own family. 76.66 % of the information on the issue received from the closed family members especially mother (32.33%) and sisters (30.33%) also from other sources. Nair *et al.* (2013) reported that Majority of community stakeholders expressed that adolescents get knowledge regarding personal hygiene from their family itself and that they have poor knowledge about genital hygiene. Present results are comparable with that of (Alam *et al*. 2022). Sixty-five percent girls disagreed/strongly disagreed about feeling distracted or trouble concentrating in class at endline, compared to 41% at baseline during menstruation.

Sources of information on healthy measures during menstruations

First menstruations and problems faced: The respondents were asked that when their menstruation have started and what was their age at the time of their first menstruation. All of them answered that the first menstruation aged between 10 to 15 years (Table 3). Among them 65.34% respondents answered 13 to 15 years while rest 34.66% were at the age 10 to 12 years. Results revealed that all the respondents were faced and suffering from different types of problems. Lower abdominal pain is the common complaint and highest 46.6% of the populations. 23.96% respondents were suffering from Hip Joint Pain. Other common complain were excessive blood loss 8.5%, loss of appetite, Vertigo, Headache 6.64%, irregular menstruation 3.6%, and scanty blood loss 6.64%. Present results are parallel with Alam *et al.* (2022). They found that most girls received information from the closed family members.

Seeking treatments for problems of menstruations: The table 4 shows the types of service provides and available places of reproductive health services/treatments that seeking treatments from different type of service providers. Among them the highest 41.66% population were taking consultation/ treatment from the traditional Kobiraj while 33.33% taken treatment from qualified doctors. The place of availability of reproductive health services and treatment, the respondents has scattered idea. The table below brings to us that 30.66 % of the populations have no idea about it. Highest 60 % has told about the Upazilla

Table 1. Distribution of population by Schooling status, level of education and menstruation

Level of education				First menstruation	
Indicator	Percent	Class	Percent	Age (years)	Percent
Never attend school	8.0	0	8.0	7-9	6.0
Currently in school	40.0	1-4	46.0	10-12	70.0
Drop out	52.0	5-8	32.0	13-15	14.0
				15 +	0.0
Total	100	9-10+	14.0	Unknown	10.0

Table 2. Knowledge about healthy measures and sources should take during first menstruation*

Awareness about healthy measures during menstruation		Sources of information	
Measures Taken	Percent	Measures taken	Percent
Use old cloths	36.33	Friends	2.0
Sanitary/cotton pad	13.33	Mother	32.33
Soap/ savlone/Dettol	9.37	Grand mother	2
Clean dry cloths	15.66	Sister	30.33
Not eating fish-meat	0	Cousin sister	12.0
Not going out of house	5.66	Aunties	4.0
Not taking pin religious activity	10.0	Neighbors	11.33
Eat good & nutritious food	0	Health workers	4.0
Use hot water	6.66	Teachers	0
No measures should taking	0	Radio/TV	2.0
Use Pantry/ underwear	2.99	Doctors	0
Don't Know	0	Newspapers	0
Total	100.0		100.0

*Multiple Responses exist

Table 3. Distribution of study population by age of having first menstruations in life

Age	Percent	Problems	Percent
7-9 years	0.0	Lower abdomen pain	46.6
10-12 years	34.66	Hip joint pain	23.96
13-15 years	65.34	Irregular menstruation	3.6
15 + years	0.0	Excess blood loss	8.5
Don't Known	0.0	Less blood loss	6.64
Total	100	Loss of appetite, Vertigo, Headache	10.7

health complex is the place for treatment of reproductive health problem. 31.33 % identified private clinic/ qualified doctor, 20.66 % told for FWC, 8.66% for district hospital and4.66 % told for permanent clinic. On the other hand 6.66 % has told Air Fakir Hujur and 3.33 % for village/ traditional doctor and 3.33 % for pharmacy. Other 2 % claimed MCWC and 2.66% for HA/FWA.

Attitude and practice of service providers: Only 18 respondents were visited the health care center to obtain services. This research further investigated about the attitude and practice of the service providers while they have providing services. Table 2.8 describes the service provider's attitude. Behavior and practice towards clients. 61.11 % were welcomed, 66.66% said that they have showing interest on them and 55.66 % replied no one were in the same room where they received treatment. Besides, 88.89 % said the service providers were not examining the client, 94.45% claimed for not maintaining privacy during giving services and not taking consent for examination. 100 % of them were claim against not using separate room for examination, not explaining any things, not using pictorials for making understanding, not share follow up time and places and also do not refer any client. In Bangladesh, Marlow *et al*. (2016) cited that women were strongly influenced by health providers when deciding which method to use.

Satisfaction on health care service: Figure 3. showed the status of satisfaction of the client after receiving the health care services. Most of the respondents (83.33%) were not satisfied while only 16.67% express their satisfaction on the health care services.

Table 4. Response of the population by attitude and practices of service providers on reproductive health during first menstruation

Service providers	Percent	Types of facilities	Percent	Types of facilities	Percent
Qualified doctor (MBBS)	33.33	District Hospital	6.33	Private clinic	20.33
Nurse/FWV/FWA/HA	8.33	FWC	10.33	Pharmacy	2.33
Home / Ayurvedic	0	Upazila Health Complex	30.33	Village doctor	3.33
Village doctor	16.66	HA/FWA/MCWC	2.67	Pir/ Fakir/Hujur	3.33
Others (specify) Kobiraj	41.66	Permanent clinic	3.67	Don't Know	17.33

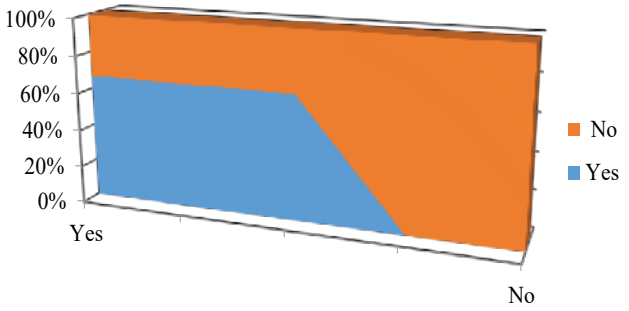


Figure 3. Distribution of population by level of Satisfaction on health care service received

Conclusion: The study indicates that the adolescent females are poorly informed about most of the reproductive health issues. There also exist important misconceptions regarding healthy management of menstruation. Besides, there is big gap between their knowledge, attitude and practice. A mechanism needs to be devised for improving adolescent's knowledge and imparting that knowledge in practice. Parents, guardians, teachers, religious leaders and immunity leaders (they are main gatekeeper) concerns regarding management reproductive health issues of adolescent females often acted as a great barriers to reaching them. It will be extremely difficult to work with adolescent females without their whole hearted participation and support. Strategies need to be taken for creating positive change in the behavior and attitude.

Besides appropriate information, the other most critical need is that of easily accessible reproductive health services for the adolescent. While married adolescents still have some access, but the unmarried ones with reproductive health problems have almost no option for accessing services. Utilizations of services both information and treatments, through adolescent friends centers would depend to a large extent upon the adolescent's and their guardians knowledge about the existence of such centers and also their opinions/ views about these centers. Strategies need to be taken to reach them both gatekeepers and adolescent females to make them understandable that this for their wellbeing and ensure their participation.

References

Alam MF, Sultana EC, Hunter PJ, Winch Unicomb L, Sarker S, Mahfuz MT, Masud A, Rahman M and Luby SP. 2022. Evaluation of a menstrual hygiene intervention in urban and rural schools in Bangladesh: a pilot study. BMC Public Health, *22*: 2-16.

Bhuiya U, Rob AH, Chowdhury L, Rahman N, Haque S, Adamchk, Homan R. and Khan ME. 2004. Improving adolescent reproductive health in Bangladesh, Frontiers Final Report. Washington, DC: Population Council.

Malitha JM, Islam MA, Islam S, Mamun ASMA, Chakrabarty S. and Hossain MG. 2020. Early age at menarche and its associated factors in school girls (age, 10 to 12 years) in Bangladesh: a cross-section survey in Rajshahi District, Bangladesh. Journal of Physiological Anthropology, *39*: 1-9.

Marlow HM, Biswas K, Griffin R and Menzel J. 2016. Women's experiences with medication for menstrual regulation in Bangladesh. Culture, Health and Sexuality, *8*: 349-360.

Nair MKC, Leena ML, George B, Thankachi Y, Swamidhas P and Russell S. 2013. Reproductive health needs assessment of adolescents and young people a qualitative study on 'perceptions of community stakeholders. DOI: 10.1007/s12098-013-1141-5.

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 213-218

NOISE IMPACT TO STUDENTS OF ROADSIDE PRIMARY SCHOOLS AT RAJSHAHI CITY IN BANGLADESH

Md. Alamgir Hasan[1], Md Abul Kalam Azad[1*], Md. Moniruzzaman[2] and Md. Kamruzzaman[3]

[1]Institute of Environmental Science, University of Rajshahi, Rajshahi-6205, Bangladesh. [2]Department of Geography and Environmental Studies, University of Rajshahi, Rajshahi-6205, Bangladesh. [3]Department of Civil Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6205, Bangladesh

***Corresponding e-mail:** akazad-ies@ru.ac.bd.com

Received: 06 December 2023, revised: 15 December 2023, accepted: 25 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.15

ABSTRACT

A high level of noise in classroom impairs verbal communication of students, which have negative effects on the cognitive performance. The high noise can also limit episodic memory of students. In this context, this study was conducted to measure the noise levels and its impact to students in selected roadside government primary schools in Rajshahi City, Bangladesh during May to November, 2022. The noise level was measured with the help of a digital sound level meter and a questionnaire survey was conducted among the students to evaluate the perception of noise. The results show that the average noise levels (Leq) in the roadside primary schools varied between the 74.1 and 80.1 dBA, with maximum noise 108 dBA and minimum 57.2 dBA. These noise levels are higher than the permissible range of 35 dBA recommended by the World Health Organization (WHO). The high level of noise was found to school adjacent busy road. During noise impact study, the majority of students (70%) expressed that their school are noisy "very much". They indicated that outside factors are responsible for excess noise in school premises. About half (51.7%) of the students responded that noise distracted their attention from the lesson and only 1% of students suffered from moderate headaches due to noise pollution. In terms of immediate reaction to excess noise, the majority of students (62.5%) had to cover their ears with hands to prevent noise hearing.

Keywords: Noise level, dBA, primary school, noise impact

Introduction

Nowadays, noise pollution is one of the major problems facing urban people, which has many adverse effects on the urban environment and may cause a great deal of cost to society (Martin *et al.* 2006). Moreover, noise can cause physical and mental health problems as well as disturbance of everyday life activities (Picoolo *et al*. 2005). Exposure to noise has various acute and chronic effects (Koh *et al*. 1998), which may have negative physiological and psychological effects such as sleeplessness, irritation, hearing loss, and mental disorders (Ingle *et al.* 2005).

These days, a significant portion of a child's youth is spent at school, which also serves as one of their primary social settings and activities (Alsubaie 2014). Learning in the classroom is usually conducted through verbal and auditory communication between teachers and students (Flexer and Long 2003). A calm and quiet environment is necessary for achieving the learning outcomes of the pupils.

The high noise levels in the classroom impair verbal communication, causing students to get tired very often, and this premature fatigue might have a negative effect on their cognitive effectiveness (Hagen *et al*. 2002). Effects of noise can result in limiting the episodic memory of teachers (Enmarker 2004). Students might not be an exception either if they are regularly exposed to loudness. Therefore, there is no substitute for improved learning in a healthy school. A health-promoting school frequently enhances its capacity as a health setting for living, learning, and working (WHO 2014). This is something we must make sure of for our children; however, the noise level around schools has raised some issues. There is a need to control the noise exposure levels in sensitive areas like hospitals, schools, and kindergartens (Amin *et al*. 2014). Thus, it is necessary to ascertain the volume of noise and how it affects students in classrooms. Noise pollution may be considered a serious environmental issue due to the rapid growth of industrialization and urbanization.

Though many research works have been conducted on the same topic in different parts of the world, there has been

no work done on this topic in Rajshahi city. For this, this research was undertaken to fill up the gap to assess the noise pollution levels and its impacts to students in some roadside primary school in Rajshahi City.

Materials and Methods

Description of survey site: The study was carried out in Rajshahi City, which is a divisional headquarters and widely known as an educational city since the establishment of educational institutions like Rajshahi College, Rajshahi University, etc. Rajshahi City, located on the bank of the Padma River, is the fourth-largest city in Bangladesh. According to the Thana Education Office, there are 61 government primary schools and 80 non-government primary schools in the city, where 16,471 students are at primary education.

Noise level data measurement: Eight government primary schools with similar socioeconomic backgrounds were selected for this study. The sample schools were chosen from sites within 10 meters of major arterial roadways. The chosen schools may be referred to as "busy roadside schools" in this study, as the sites were located close to Rajshahi City's major arterial roads and are subject to numerous environmental noises. The list of schools is shown in Table 1.

The noise level was measured using with an IEC-compliant sound level meter (SL-4023SD) during May to November, 2022. The steps were taken to prevent sound reflection during noise measurement. An equivalent continuous noise (Leq) descriptor was used to determine the average noise level during a given period. The study also considered the maximum (Lmax) and lowest (Lmin) noise characteristics of time periods. Measurements of noise levels in the schoolyard, corridor, and classroom were done while classes were in session. The noise levels were recorded for two consecutive working days to calculate the average noise levels.

Noise impact survey: A questionnaire survey was conducted among the students to evaluate the views about noise pollution, sources of noise, effects on learning activities, and controlling measures. A five-point Likert scale and multiple-choice questions were used in the questionnaire. An observational check list was used to assess the factors responsible for noise pollution inside and outside the school premises, which include tree coverage, boundary walls, building type, doors and windows, and furniture arrangements. Due to time constraints, the survey was conducted during leisure period, therefore 15 students from third, fourth, and fifth grade students were interviewed from each school and the sample size was 120 students (male 61 and female 59) ages between 8 to 12 years. For data analysis, descriptive statistics were used to analyze questionnaire findings.

Results and Discussions

The noise data shows that the noise levels (Leq) in the roadside primary schools fall between the 80.1 and 74.1 dBA range (Table 2). The S-1 school was observed to have the highest Lmax of 108 dBA as it located adjacent to the inter-district national highway (Natore Road), where the flow of heavy vehicles such as buses and trucks occurred. On the other hand, the lowest Lmax of 93.4 dBA was recorded at S-3. The S-4 had the highest Leq of 80.1 dBA, while S-5 recorded 79 dBA. S-6 was close to

Table 1. General information of primary schools

SL	Name of school	Symbol used	Students Number	Teaching staff	Non-teaching staff
1	Mirjapur Government Primary	S-1	193	7	0
2	Khademul Government Primary	S-2	123	6	1
3	Krishokanto Government Primary	S-3	118	7	1
4	Kadirgonj Government Primary	S-4	180	9	1
5	Gourhanga Government Primary	S-5	129	6	1
6	Railway Government Primary	S-6	109	7	1
7	Helenabad1 Government Primary	S-7	298	8	1
8	Raninogor Government Primary	S-8	309	10	1

Table 2. Noise level in roadside primary schools

SL	School	Noise level in dBA								
		School yard			Corridor			Classroom		
		Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin
1	S-1	76.3	108.0	63.1	78.2	105.2	64.1	80.1	107.2	64.0
2	S-2	77.2	102.5	65.1	75.0	98.0	63.0	76.1	95.3	63.2
3	S-3	75.4	98.5	63.0	75.1	93.8	63.0	76.0	93.4	63.1
4	S-4	77.3	104.2	62.2	78.1	98.4	62.2	80.0	97.2	62.2
5	S-5	76.5	105.3	63.4	78.0	98.2	65.3	79.0	98.3	64.1
6	S-6	77.1	106.0	65.5	78.0	102.3	65.3	78.5	102.0	65.1
7	S-7	74.4	103.4	57.4	74.1	97.6	57.1	74.2	97.3	57.2
8	S-8	75.2	102.6	59.2	75.5	104.3	60.2	78.2	104.2	60.0
	Average	76.1	103.8	62.3	76.5	99.7	62.5	77.7	99.3	62.3

Dhaka bus stand and Rajshahi railway station, but it did not have the most noise because it was encircled by some bushy trees. The lowest equivalent noise level (Leq) of 74.1 dBA was measured at S-7, where vehicle movements were comparatively low. The range of minimum noise level (Lmin) was 57–65 dBA. The average noise of the schools at the schoolyard was 76.1 dBA, the corridor was 76.5 dBA, and the classroom was 77.7 dBA.

The noise level in the highway region school of Kargil, India, was around 57.4 dBA indoors and 63.0 dBA outdoors (Fatima *et al*. 2023), which were lower than the current findings, but the noise levels of classrooms (78–92 dBA) and playgrounds (61–97 dBA) in the schools in Anambra State, Nigeria, seemed to be similar (Ochiabuto *et al*. 2020). On the other hand, noise levels (75.7-98.5 dBA) in schools in Zaria, Nigeria, were a bit higher (Owojori *et al*., 2017). In Turkey, the noise level was found to be 82.18 dBA in public schools during break time (Bulunuz *et al*. 2017).

However, the World Health Organization (WHO) standard background noise level for classrooms of 35 dBA was exceeded at least by 39.4 dBA in each of the 8 surveyed roadside schools (WHO 1999). This might be due to how close they are to the road and how many residential buildings, stores, and other workshops surround them. In addition to this, two schools (S-5 and S-6) were located near the railway. Most of the schools were found to have little or no trees around them, and no school had suspended ceilings, which could have acted as a soundproofing measure.

So, it was evident that average classroom noise in the surveyed schools remained higher than that in the corridor and schoolyard. It was due to the students' usual chanting and physical movements. Additionally, the noise level went up during loud reading. Sometimes dragging the steel-frame benches created extra noise along with the vibrating sound of the students jumping. The corridor was noisy during the intermission period, and the schoolyard was noisy during assembly and closing. Concrete buildings with two doors and four windows, with an average rectangular classroom size of 35 square meters, are used for classes. These buildings had limited sound absorption capabilities. In most cases, roadside windows remained close to prevent outside noise. There was no false ceiling in any of the schools.

From noise survey it was found that 70% of students expressed that their school premises was "very much" noisy, 19.20% said it was "moderately," 6.7% said "slightly," and 4.2% said "extremely" noisy (Table 3). A half of students (50%, mean 2.28) expressed that an inside element was "slightly" responsible for the noise, while 41.7% (mean 4.18) opined that an external factor was to blame for the increased noise volume at their schools. It is clear from this that outside factors (mean 4.18 > 2.8) contributed to school noise more than inside factors.

There are different types of noise at school that could annoy, bother, or disturb. Here, the sources were divided into two sections: inside factors and outside factors. The inside factors include noise derived from students'

Table 3. Noisiness in the school premises

Variables		Not at all	Slightly	Moderately	Very much	Extremely	Mean
How noisy is your school? (Noisiness)	N	0	8	23	84	5	3.72
	%	0	6.7	19.2	70.0	4.2	
Which factor is responsible for noisy? Inside factor	N	14	60	36	10	0	2.28
	%	12	50.0	30.0	8.0	0	
Which factor is responsible for noisy? Outside factor	N	00	4	20	46	50	4.18
	%	0.0	3.3	16.7	38.3	41.7	

voices, like hue and cry, screaming, and shouting; noise derived from the physical movements of students, like running, jumping, and pulling the benches; noise derived from devices like ringing; and announcements from school authorities through amplified sound. The outside factors include road traffic noise, noise from construction sites, workshops, and industries, and noise derived from communities like public meetings, miking, religious activities, and entertainment. The students traced the outside factor as the culprit for the noise in the schools. Similarly, in Surat, India, there was comparatively more noise outside the campus than inside the schoolyard when it came to areas with urban traffic streams (Ranpise and Tandel 2021).

Different types of disturbance, attentiveness, warning by teacher, hearing impact and headache are shown in Table 4. A half (51.7%) of students stated that noise during the lecture "very much" distracted them from paying attention. Interestingly, about 48.3% had been warned "sometimes", and 41.7% "fairly often" by the teacher for making noise in the school. So, it meant (mean 3.59) that they fairly often made noise and got warning. In terms of

Table 4. Effects of noise at schools

Items	Response type	Respondents	%	Mean (SD)
Does noise affect attentiveness during lessons? (Distract attentiveness)	Not at all	1	0.8%	3.58 (.806)
	Slightly	11	9.2%	
	Moderately	36	30%	
	Very much	62	51.7%	
	Extremely	10	8.3%	
Do you get warning from teacher for making noise in the school? (Warned by teacher)	Never	00	00%	3.59 (0.667)
	Almost never	01	0.8%	
	Sometimes	58	48.3%	
	Fairly often	50	41.7%	
	Very often	11	9.2%	
How well you can hear your teacher during lessons in general? (Affect hearing)	Not at all	0	0%	3.25 (0.538)
	With difficulty	6	5.0%	
	Normally	78	65.0%	
	Well	36	30.0%	
	Very well	00	00%	
Does noise in the school causes headache? (Cause headache)	Not at all	72	60.0%	1.41 (0.51)
	Slightly	47	39.0%	
	Moderately	01	0.8%	
	Very much	00	00%	
	Extremely	00	00%	

Table 5. Immediate reaction of the students

Variables / In response to excess noise what you do?	Respondent	Never	Almost never	Sometimes	Fairly often	Very often	Mean
1. Wait for it to go away	N	00	00	38	82	10	3.68
	%	0.0	0.0	31.7	68.3	8.3	
2. Cover ears with hands	N	00	31	75	14	00	3.20
	%	0.0	25.8	62.5	11.7	0.0	
3. Request noise doers	N	114	5	1	00	00	1.06
	%	95.0	4.2	0.8	0.0	0.0	

hearing from the teacher during class, most of the students (65%, mean 3.25) heard "normally" and no one used to hear "very well". But alarmingly, 5% heard their teacher with difficulty.

Due to their proximity to roads and busy places, students faced that kind of difficulty during the lesson. The horns of the vehicles on the nearby roads and other sources made it difficult for the students to hear from the teacher. Noise worked as a barrier to their academic achievement, particularly in subjects like mathematics and foreign languages like English. Because learning outcomes depend on the smooth flow of classroom activities, noise interrupted the process. The students who heard their teacher with difficulty were usually the back benchers.

In Taranto and Naples, Italy, the mean noise annoyance was considerably higher in industrialized areas (Minichilli *et al.* 2018). Another study in India revealed that for every ten-percentage point increase in Noisy Days% (in the Jan-Mar Quarter of Calendar Year), there was a 6.1 percent rise in Class 12 Boys Fail% for every ten-percentage point increase in Noisy Days% (during the Jan-Mar Quarter of Calendar Year) (Sumit *et al*. 2023).

In response to unusual excess noise in the school, the immediate reaction of the students was evaluated (Table 5). Most of the students (68.3%) "fairly often" waited for the noise to go away; 31.7% did it "sometimes" and 8% waited "fairly often". This meant that students generally" fairly often" (mean 3.68) waited for the noise to go away, which indicated their endeavour to adapt to the noise. Sometimes (62.5%) they covered ears with hands, but generally they did not request the noise makers to turn off or reduce the sound. This is because they are too little to do so, and in most cases, the noise sources are automobiles.

Conclusion

This study found that noise levels (Leq) in the roadside primary schools varied between the 80.1 and 74.1 dBA ranges, higher than the permissible level of WHO. About 70% of students expressed that noise pollution was "high" in their school. Most of the students indicated that outside factors like traffic movement, construction works, amplified sound are responsible for excess noise in the school premises. A half (51.7%) of the students replied that noise distracted their attention from lesson, however less than 1% students suffered from moderate headache due to noise pollution in roadside primary school of Rajshahi City.

References

Alsubaie ASR. 2014. Indoor noise pollution in elementary schools of eastern province, Saudi Arabia. Journal of Research in Environment Science and Toxicology, *3*: 25-9.

Amin N, Sikder I, Zafor MA and Chowdhury MAI. 2014. Assessment of noise pollution of two vulnerable sites of Sylhet city, Bangladesh. International Journal of Water Resources and Environmental Engineering, *6*: 112-120. https://doi.org/10.5897/IJWREE2013.0464

Bulunuz N, Bulunuz M, Orbak AY, Mulu N and Tavşanlı, ÖF. 2017. An evaluation of primary school students' views about noise levels in school. International Electronic Journal of ElementaryEducation, *9*: 725-740. https://www.iejee.com/index.php/IEJEE/article/view/281

Enmarker I. 2004. The effects of meaningful irrelevant speech and road traffic noise on teachers' attention, episodic and semantic memory. Scandinavian Journal of Psychology, *45*: 393-405.

Fatima K, Rampal R, Muslim M, and Hussain K. 2023. Evaluating the noise exposure levels of different schools in noise-scapes of Kargil town: Ladakh, India. Noise & Vibration Worldwide, 09574565231161647. https://doi.org/10.1177/09574565231161647 .

Flexer C and Long S. 2003. Preliminary information regarding special education referrals. Communication Disorders Quarterly, *25*: 29-34.

Hagan M, Huber L and Kahlert J. 2002. Acoustic school design. Forum Acusticum Sevilla, Pp.1-7.

Ingle ST, Pachpande BG, Wagh ND, Attarde SB. 2005. Noise exposure and hearing loss among the traffic policemen working at busy streets of Jalgaon urban centre. Transportation Research Journal. *10*: 69-75.

Koh D and Jeyaratnam J. 1998. Occupational health in Singapore. International Archives of Occupational and Environmental Health, *71*: 295-301.

Martin MA, Tarrero A, González J and Machimbarrena M. 2006. Exposure–effect relationships between road traffic noise annoyance and noise cost valuations in Valladolid, Spain. Applied acoustics*, 67*: 945-958.

Minichilli F, Gorini F, Ascari E, Bianchi F, Coi A, Fredianelli L, Licitra G, Manzoli F, Mezzasalma L and Cori L. 2018. Annoyance judgment and measurements of environmental noise: A focus on Italian secondary schools. International Journal of Environmental Research and Public Health. https://doi.org/10.3390/ijerph15020208.

Ochiabuto OMTB, Abonyi IC, Ofili RN, Obiagwu OS, Ede AO, Okeke M and Eze PM. 2021. Assessment of noise levels in primary and secondary schools in Nnewi, Anambra state. European Journal of Environment and Public Health, *5*: 1-4. https://doi.org/10.29333/ejeph/8425

Owojori A A, Gadzama IMK and Sow GI. (2017). Characterization of the vulnerability of school children exposed to road traffic noise in some selected schools in Zaria, Kaduna state, Nigeria. FUW Trends in Science and Technology Journal, *2*: 188-194.

Piccolo A, Plutino D and Cannistraro G. 2005. Evaluation and analysis of the environmental noise of Messina, Italy. Applied acoustics, *66*: 447-465.

Ranpise RB and Tandel BN. 2021. Measurement of Noise Levels Inside and Outside Environment of Roadside Schools in Urban Area: A Case Study of Surat, India. In*:* International conference Sustainable Environmental Engineering and Science (Eds. Kumar S, Ghangrekar, MM, Kundu A). Singapore: Springer Nature Singapore. Doi: https://doi.org/10.1007/978-981-99-0823-3_11.

Sumit Agarwal, Arzi Adbi, Pulak G. 2023. Noise pollution and academic performance in India. https://doi.org/10.21203/rs.3.rs-2327906/v1.

World Health Organization. 2016. School and youth health. acessadoem06abril/2020.

World Health Organization. 1999. Guidelines for community noise. http://www.who.int/docstore/peh/noise/guidelines2.html

Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 219-227

SOYBEAN GERMPLASM SHOWS VARIATION IN FARMERS PARTICIPATORY TRIAL IN THE COASTAL REGION OF BANGLADESH

Md. Abdul Karim[1]*, Md. Abdul Mannan[1], Md. Abdullah Al Mamun[1], Mohammad Moziball Hoque[2] Md. Farhad Hossain[2], Mohammad Saifullah[2] and Uswatun Hasana Hashi[3]

[1]Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh; [2]Solidaridad Network Asia, House# 32, Road 10A, Dhanmondi, Dhaka-1209, Bangladesh; [3]Department of Agricultural Science, Daffodil University, Dhaka-2016, Bangladesh

***Correspondence e-mail:** akarim1506@gmail.com

Received: 08 December 2023, revised: 19 December 2023, accepted: 23 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.16

ABSTRACT

The cultivation of soybean is still concentrated in the coastal region of greater Noakhali District of Bangladesh, where salinity hinders crop production. There is no suitable salt tolerant variety so far. At Bangabandhu Sheikh Mujibur Rahman Agricultural University, 170 soybean genotypes were screened and finally three, namely AGS313 (BU soybean-3), G00028 (BU soybean-4), and BD2330 were found fairly salt tolerant at 5 and 10 dSm^{-1} salinity. In Rabi 2022-23 season the selected three genotypes, G00056 as a high yielding promising genotype, and three varieties namely BU soybean-2, BARI soybean-6 and Binasoybean-2, i.e. altogether seven genotypes were grown in 700 decimals land, both saline and non-saline soils, of 12 farmers in different upazillas of Noakhali, Laksmipur and Bhola districts. The seeds were sown by the last week of January' 23. Salinity of the fields at harvest was found 5- 13 dSm^{-1}, though initially varied from 0 – 4 dSm^{-1}. Yield contributing characters were measured appropriately. Standard error was used for showing the mean differences. Farmers' discussion on the performance of the genotypes were held from time to time. Salinity decreased plant height, maturity duration, number of pods $plant^{-1}$, 1000-seed weight and grain yield ha^{-1}. However, AGS313 and G00028 were affected less than other genotypes. Under non-saline and low saline conditions relatively higher yield was found in BU soybean2 (2657 kg ha^{-1} in Bhola, 3397 $kgha^{-1}$ in Subornachar), G00056 (2341 in Laksmipur sadar, 3390 kg ha^{-1} in Subornachar), AGS313 (2612 in Ramgoti, 3266 kg ha^{-1} in Subornachar) and G00028 (2464 in Bhola sadar, 3374 kg ha^{-1} in Subornachar) compared to other genotypes. The lowest yield was found in BARI soybean6 (1715 kg ha^{-1} in Ramgoti) followed by Binaoybean-2 (1868 kg ha^{-1} in Laksmipur sadar). However, under saline field conditions (5- 8 dSm^{-1}) G00028 (866 kg ha^{-1} in Komolnagar, 1374 kg/ha in Subornachar) and AGS313 (860 kg ha^{-1}in Ramgoti, 1333 kg ha^{-1} in Subornachar) produced substantially higher yield than other genotypes/ varieties. The lowest yield was obtained from G00056 (170 kg ha^{-1}) from Komolnagar. Based on the results of multi-location trials, and discussions with the farmers the genotypes AGS313 and G00028 were registered as BU soybean-3 and BU soybean-4, respectively as relatively salt tolerant varieties from the National Seed Board.

Keywords: *Glycine max,* salinity, variety, yield

Introduction

Among all the cultivated crops soybean (*Glycine max.* L) seeds contain the highest amount of nutrients, especially protein. The dry seeds of soybean contain high amount of protein (30- 50%), vegetable edible oil (18-22%), calcium (277 $mg100g^{-1}$), iron (15.7 $mg100g^{-1}$), magnesium (280 $mg100g^{-1}$), phosphorus (704 $mg100g^{-1}$), potassium (1797 $mg100g^{-1}$), folic acid (375 $\mu 100g^{-1}$), as well as several vitamins including different B vitamins, and minerals, such as molybdenum, copper, manganese etc. (Banaszkiewicz 2011, García-Rebollar *et al.* 2016, USDA 2018). That is why it is called "golden bean" or "miracle bean" in many places. In Bangladesh soybean is mostly used as animal feed. Recently consciousness on its high nutrition as food items is developing among the people in Bangladesh (Mannan *et al*. 2012, Khan *et al.* 2014, Mia 2020, Chowdhury *et al.* 2013, Sultana 2020a, Sultana 2020b).

However, since 2017 the soybean cultivation area and total production in Bangladesh remained more or less unchanged, though the national average yield increased from 1360 kg ha^{-1} in 2010 to 1773 kg ha^{-1}in 2018-19 (BBS

2020). The reasons for not increasing the cultivation of soybean are mainly due to high competition with different winter season crops in the northern Bangladesh, and particularly with maize, sunflower, watermelon, etc. cultivation in the southern part.

Bangladesh produced around 162,000 MT soybean only from 82,000 ha of land in 2021-22, while imported 2.8 million MT (USDA 2022). The huge demand has been created due to high demand for animal feed production, though soybean is used for both oil extraction and different forms of food consumption worldwide. The cultivation of this crop is still concentrated mostly in the southern coastal part of the country, more specifically in Noakhali and Laksmipur districts where salinity prevails at different degrees. The salinity area is increasing in Bangladesh due to intrusion of seawater to the fresh river water during dry seaon, seepage of salty water due to dryness of the soil, rising of salt through capilary movement and inundation of land due to cyclones (Karim 2015, Mannan *et al*. 2013a, Khan *et al*. 2014, Mondal *et al.* 2013). Many crop fieds in the coastal region remain fallow during Rabi season, after aman rice harvest, just because of rising salinity during Kharif I season. Moreover, many new charlands have been developed which remain fallow for lacking of due attention for bringing under crop cultivation during Rabi and Kharif II seasons.

Soybean is considered as a moderately salt tolerant crop (Maas 1985). Salinity tolerance is linked to maintennance of better water relations, efficient compartmentation of Na^+ into plant organs and balanced nutrition. By selecting tolerant soybean genotypes the yield of the crop can be improved to a great extent in the saline field conditions (Ghassemi-Golezani *et al*. 2009, Mannan *et al*. 2013b, Khan *et al*. 2014, Fujii and Higuchi 2019). Though soybean cultivation in the Bhola district has been increased to some extent, it is still very minimum in the northern part of the country, because of high crop competion in Rabi season and rather long duration requirement due to cooler winter compared to the south. Contrary, in the coastal region the aman rice is harvested in December when it is already late to grow Rabi crops. Moreover, due to delay in drying the land (lacking of ju condition) it is often becomes difficult to sow seeds of Rabi crops timely. However, soybean can be sown untill late January without much affecting the yiled. Unfortunately, there is no salt tolerant soybean variety that can endure rising salinity effect at the reproductive stage in the coastal region. Thus, attempt should be strenthened to increase soybean productivity in the coastal region of Bangladesh by developing high yielding salt tolerant varieties.

The Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has a collection of more than 280 soybean gnotypes from home and abroad, especially from AVRDC, Kyoto University, BARI and farmers fields of greater Noakhali district. Studies on the response of the soybean genotypes to different environmental stresses are going on for more than 17 years. Mannan *et al.* (2012), and Khan *et al.* (2013) selected 13 and 7 salt tolerant genotypes by screening 171 and 41 soybean genotypes, respectively at the Department of Agronomy, BSMRAU. In a study Jinzenji (2020) also reconfirmed the salt tolerance of three genotypes, AGS313, BD2330 and G00028, which are common with the earlier selection of Mannan *et al.* (2012) and Khan *et al.* (2013). Later on, those selected salt tolerant genotypes were again screened in 2019-2020 against 5 and 10 dSm^{-1} salinity in pot culture under vinylhouse conditions (Tareq *et al.* 2022). From that experiment three genotypes namely AGS313, BD2330 and G00028 were extricated as the high salt tolerant ones. Another genotype, G00056 was found as the best yielder compared to the available varieties in pot experiment. In Rabi season of 2022-23, both saline and non-saline fields of 700 decimals of 12 farmers were selected for growing the selected 4 soybean genotypes in the coastal region of different upazillas of Noakhali, Laksmipur and Bhola districts. The objective of growing the selected four soybean genotypes was to get a comprehensive understanding on their performance in the coastal saline soils of Bangladesh in comparison to existing popular varieties. It was hoped that salt tolerant high yielding variety can be developed from the four promising soybean genotypes at the end of the study.

Materials and Methods

Before going for the main study in Rabi season 2022-23, the seeds were multiplied in the coastal region in the farmers' field. In Kharif 2 of 2022, a total 450 decimals of land involving 11 farmers in Ramgoti and Komolnagar Upazillas of Laksmipur district were cultivated for seeds production of four soybean advanced lines/ genotypes

namely AGS313 (BU soybean-3), G00028 (BU soybean-4), BD2330, and G00056. The farmers were selected with the support of the Solidaridad Asia Network with whom BSMRAU has formal LoA and Department of Agricultural Extension. The farmers were given training on Good Agricultural Practices (GAP) for soybean cultivation. The land size ranges from 20 decimal to 80 decimal. However, due to cyclone "Sitrang" during 22-25 October 2022 crops in many fields were damaged, though in some fields the crop survived to some extent. Seeds in some fields were re-sown. Crops in about 150 decimals of land were grown satisfactorily. By the 2nd week of January' 23 all the crops were harvested. A total of 750 kg seeds of the 4 genotypes were obtained.

Soybean fields of 700 decimal of 12 farmers, both saline and non-saline, were selected for growing the selected 4 soybean genotypes during Rabi 2022-23 season in the coastal region, covering 150 decimals in Subarnachar upazilla of Noakhali district, 150 decimals in Komolnagar, 100 decimals in Laksmipur sadar, 100 decimals in Raipur, 100 decimals in Ramgoti upazillas of Laksmipur district, 100 decimals in Bhola sadar upazilla of Bhola district (Table 1). Each field was 50 decimals in area. The seeds were sown by the last week of January' 23. Salinity was measured before sowing the seeds and at harvest. The salinity level was less than 3 dSm^{-1}, except a few having 4 dSm^{-1}, though increased to 5- 13 dSm^{-1} at the pod development stage. At and over 10 dSm^{-1} none of the genotypes produced seeds. Farmers' discussion on the performance were held time to time. Finally KGF monitoring team led by the Executive Director visited and discussed with farmers on selection of the best and relatively salt tolerant soybean genotypes.

At harvest each field of each genotype was divided into three sub-plots and yield of 2m X 3m was measured. Each field of each upazilla was considered as a replication under randomized complete block design, though each field was sub-divided into two repetitions for each crop for better data collection. Data on yield and yield contributing characters were recorded. Mean values was calculated and the standard error was used to show the mean differences.

Results and Discussion

Selected four soybean genotypes namely AGS313 (BU Soybean-3), G00028 (BU soybean-4), BD2330 and G00056 along with three popular varieties such as BU soybean-2, BARI soybean6 and Binasoybean-2 were grown in 700 decimals land in the coastal region in Rabi 2022-23 season in both saline and non-saline soils. The salinity level was less than 3 dSm^{-1}, except a few having 4 dSm^{-1} during sowing, though increased to 5- 13 dS m^{-1} at harvest. At and over 10 dSm^{-1} none of the genotypes produced seeds.

Table 1. List of farmers selected for growing soybean in different upazillas of the coastal region in rabi 2022-23 season

Sl. no.	Name of PG Member	Father/Husband Name	Soybean Land (dec.)	Cluster/Union	Upazila	District
1	Md.Dilder Hossain	Md.Sekandor Hossain	100	Char Amanullah	Subarnachar	Noakhali
2	Sohodeb Chandra Das	Nitis Chandra Das	50	Char Bata	Subarnachar	Noakhali
3	Mohon Lal Roy	Late Mahendra Kumar Roy	50	Char Gazi	Ramgati	Laxmipur
4	Md Dildar Hossain	Late Md Jahangir Alam	50	Char Algi	Ramgati	Laxmipur
5	Abul Kalam	Amin Ullah	50	Char Lawrence	Kamalnagar	Laxmipur
6	Nuruddin	Sayed Hawladar	100	patarir Hat	Kamalnagar	Laxmipur
7	Md Soykhot Hossin	Hossin Miya	50	Char kadira	Kamalnagar	Laxmipur
8	Md Abdur Rahman	Md Ibrahim kholil	50	kushakhali	Sadar Laxmipur	Laxmipur
9	Md Riad Hossin	Md Abdul hilim	50	kushakhali	Sadar Laxmipur	Laxmipur
10	Jamal Bapary	Billal bapary	50	Charkachia	Raipur	Laxmipur
11	Md. Anwar	Md. Alauddin	50	Sibpur, Bhola Sadar	Bhola sadar	Bhola
12	Md. Hasnain	Jakir Hossain	50	Char Shyamiya	Bhola sadar	Bhola
	Total land area (decimal)= 700					

Salinity decreased plant height, maturity duration, number of pods plant^{-1}, 1000-seed weight, and grain yield ha dSm^{-1}. Under both saline and non-saline conditions, the plant height was the highest in AGS313, while the lowest was in Binasoybean2 in all the study sites (Table 2). The reduction in plant height was minimum in AGS313 in all the upazillas compared to other genotypes. Salinity affected little the days to flowering of the genotypes though days to maturity enhanced in all the genotypes in all upazillas (Table 3 and 4). Under non-saline conditions AGS313 matured earlier (±90 days) than other genotypes. Under saline conditions the variation in maturity time was very high due to differences in salinity level (72 – 86 days across the genotypes). Salinity decreased seriously the number of pods plant^{-1} in all the genotypes and in all the locations (Table 5). In the saline field the highest number of pods were produced by G00028 (29 – 36 plant^{-1}) followed by AGS313 (31 – 34 plant^{-1}). The number of pods plant^{-1}varied noticeably in all the genotypes under saline field conditions as because of high variation in salinity levels (5-8 dSm^{-1}) from field to field. Salinity did not affect number of seeds per pod irrespective of locations and genotypes. The number of seeds were almost 3/pod irrespective of locations except in G00056 in some locations (Table 6). Salinity lowered the 1000-seed weight (Table 7). Under both non-saline and saline conditions G00056, AGS313, G00028 and BU soybean2 had the larger seeds (>200 g/1000-seeds under non-saline and > 1600 g/1000-seed under 5-8 dSm^{-1} saline conditions) irrespective of locations than other tested genotypes. Grain yield was decreased remarkably by the salinity and the salinity effects varied with the intensity of salinity in the field of different upazillas (Table 8). Under non-saline conditions the higher grain yield was found in G00056 (2342 – 3391 kg/ha), AGS313 (2612 – 3267 kg ha^{-1}), G00028 (2582 – 3374 kg ha^{-1}) and BU soybean2 (2333 – 3397 kg ha^{-1}). However, under saline conditions the substantially higher grain yield was produced by G00028 (866 – 1375 kg ha^{-1}) followed by AGS313 (860 – 3267 kg ha^{-1}) irrespective of locations. Other genotypes including the popular varieties produced very low yield compared to G00028 and AGS313. Even the same genotypes showed much variation in grain yield across the locations, especially under saline conditions. The variation was due to differences in salinity levels even in the same field.

Table 2. Plant height of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	76.3±6.4	31.3±1.2	67.5±5.5	30.3±1.2			55.7±2.3	39.0±2.1	66.5±3.9	35.7±3.2	
G00028 (BU soybean-4)	45.9±2.2	15.0±0.6	48.7±0.9	20.0±3.1	50.7±2.7	25.7±5.6	45.7±2.2	21.0±3.0	44.2±1.9	27.7±1.8	48.7±0.9
G00056	46.0±4.6	29.8±2.9	51.0±0.0	17.3±2.3	49.3±4.5	28.7±5.2	49.0±3.5	19.3±3.8	51.0±4.4	28.3±5.2	46.0±4.6
BD2330	40.3±1.5	19.7±3.3	54.3±4.5	18.0±6.1					42.5±5.4	23.7±2.3	
BU soybean2	45.2±4.9	23.0±3.6	52.0±1.5	17.7±2.9	48.7±3.2	30.0±6.0	51.0±3.6	24.0±4.6	49.7±1.2	23.6±3.9	52.0±1.5
BARI soybean6	49.7±3.2	25.5±6.7	49.7±4.3	20.3±4.4	55.3±3.2	19.7±5.8	51.7±6.0	28.7±3.5	50.0±3.6	27.9±5.7	51.7±6.0
Binasoybean-2	31.7±4.4	22.7±4.8	38.7±3.0	16.3±3.3	40.3±2.2	22.3±2.0	43.3±2.6	17.3±4.1	43.0±2.9	17.8±4.2	43.3±2.6

±: standard error

Table 3. Days to flowering of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soy-bean-3)	40.0±1.2	40.0±0.6	45.7±1.8	42.2±0.4			42.7±1.5	42.0±0.6	41.3±0.9	40.3±1.2	
G00028 (BU soybean-4)	42.2±0.2	41.0±0.6	51.0±1.2	46.7±0.9	41.7±0.3	41.7±0.3	47.3±1.2	43.0±0.6	40.7±0.6	42.0±0.6	42.0±0.6
G00056	40.0±1.2	40.7±0.9	49.3±0.3	44.0±1.0	42.3±0.3	42.3±0.3	42.7±2.2	42.7±0.9	41.2±0.4	41.0±0.6	41.7±0.9
BD2330	41.8±0.6	41.0±0.6							41.0±0.6	38.3±1.8	
BU soy-bean2	42.3±0.7	41.0±0.6	51.3±0.9	41.0±0.6		42.3±0.7	47.3±2.7	42.0±0.6	42.0±0.6	41.3±0.3	
BARI soy-bean6	42.0±0.6	41.3±0.9	42.0±0.6	48.5±2.3	41.3±0.3	41.3±0.9	42.3±0.7	47.0±3.0	42.3±1.5	42.2±0.4	41.0±0.6
Binasoy-bean-2	42.0±0.6	40.7±0.9	41.7±0.3	41.3±0.7	41.7±0.9	42.3±1.5	43.0±0.6	44.3±0.7	41.0±0.6	40.7±0.7	40.3±0.9

±: standard error

Table 4. Days to maturity of soybean genotypes grown in different upazillas of the coastal region

Name of geno-types	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	90.7±0.9	79.0±1.5	90.3±2.4	83.7±1.8			92.7±1.5	84.0±2.6	90.0±1.5	81.3±1.5	
G00028 (BU soybean-4)	96.7±0.9	85.3±1.2	95.7±0.9	82.0±3.8			95.7±0.9	84.0±2.1	92.2±2.4	83.3±1.8	104.7±2.3
G00056	95.7±1.2	73.3±2.7	95.0±1.5	78.7±1.5	96.3±0.3	85.0±2.1	96.0±0.6	83.3±2.3	98.5±0.3	85.3±2.2	104.3±0.7
BD2330	96.5±1.5	80.3±3.2	97.3±0.3	81.0±2.9					98.0±1.0	85.7±2.4	
BU soybean2	99.0±2.1	82.0±3.5	97.7±1.8	86.3±1.8	99.3±1.8	86.7±3.2	97.7±0.3	85.7±1.8	98.0±1.5	85.3±2.0	107.7±2.3
BARI soybean6	95.7±2.6	72.3±1.9	99.0±2.6	86.0±2.5	98.7±2.4	86.0±1.5	94.7±2.4	86.0±1.0	98.7±1.3	84.7±0.9	106.0±1.0
Binasoybean-2	91.0±2.6	75.0±5.0	92.7±1.8	82.7±2.2	94.0±1.2	82.0±1.5	95.0±1.0	83.0±3.1	98.0±1.0	83.7±1.8	92.0±2.0

±: standard error

Table 5. Number of pods/ plant of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	58.3±4.4	34.3±4.8	64.3±2.3	31.7±1.8			61.3±2.7	31.7±2.0	58.7±2.7	31.3±1.5	
G00028 (BU soybean-4)	54.3±6.7	36.7±3.9	50.0±5.9	28.3±6.9	48.7±4.5	27.3±2.7	54.0±4.5	29.3±2.4	46.2±3.9	30.7±2.4	
G00056	48.0±3.0	27.0±3.1	59.3±0.9	27.7±2.4	48.7±1.5	19.0±1.0	51.0±3.1	13.7±2.0	49.7±2.6	23.3±1.5	72.3±4.3
BD2330	54.3±1.8	17.3±3.5							53.7±1.9	23.3±1.3	
BU soybean2	58.7±5.4	26.8±4.3	67.3±1.2	23.3±3.9	53.7±7.3	24.7±3.0	50.7±7.2	29.0±3.0	58.3±3.4	27.0±1.0	75.0±2.8
BARI soybean6	53.5±6.0	23.3±1.5	53.7±6.7	26.0±2.5	43.7±2.3	24.7±2.0	64.3±1.8	26.0±2.5	66.0±5.1	27.5±5.5	81.0±12.7
Binasoybean-2	47.7±1.8	24.0±2.1	47.7±2.4	26.7±3.2	52.0±2.3	25.3±3.4	41.3±2.2	22.7±0.9	41.0±2.1	22.2±0.6	63.5±2.3

±: standard error

Table 6. Number of seeds/pod of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0			3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	
G00028 (BU soybean-4)	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0
G00056	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	2.7±0.3	2.7±0.3	2.7±0.3	3.0±0.0	3.0±0.0	3.0±0.0
BD2330	3.0±0.0	3.0±0.0							3.0±0.0	3.0±0.0	
BU soybean2	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	2.7±0.3	2.7±0.3	2.7±0.3	3.0±0.0	3.0±0.0	3.0±0.0
BARI soybean6	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	2.7±0.3	2.7±0.3	2.7±0.3	3.0±0.0	3.0±0.0	3.0±0.0
Binasoybean-2	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0	3.0±0.0

±: standard error

Table 7. 1000-seed weight of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	220±0.6	160±1.2	180±0.6	161±0.6			210±1.5	151±1.2	201±1.7	180±0.3	
G00028 (BU soybean-4)	191±1.4	160±0.9	200±0.3	160±1.9	210±0.6	150±0.3	230±0.6	160±0.9	220±1.8	171±0.3	230±0.5
G00056	231±0.7	160±1.7	250±0.2	150±1.2	230±1.7	151±0.7	270±0.7	170±0.6	170±4.1	161±1.3	270±0.6
BD2330	170±0.6	150±1.5	140±0.9	140±0.9					151±0.5	130±0.6	
BU soybean2	211±0.4	170±0.6	240±0.3	180±0.6	230±0.6		221±0.9	151±0.9	220±1.5	180±0.6	240±0.4
BARI soybean6	150±0.4	131± 0.9	150±0.6	121±0.5	160±0.6	130±0.6	141±0.7	111±0.3	150±2.1	120±0.6	141±0.3
Binasoyean-2	140±0.9	120±0.6	141±0.9	120±0.6	141±0.9	111±0.3	140±0.3	110±0.3	121±1.8	110±0.6	150±0.6

±: standard error

Table 8. Yield (kg/ha) of soybean genotypes grown in different upazillas of the coastal region

Name of genotypes	Suborna char, Noakhali		Komolnagar, Laksmipur		Raipur, Laksmipur		Laksmipur Sadar upazilla		Ramgoti, Laksmipur		Bhola Sadar upazilla
	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline	Saline (5-8 dSm^{-1})	Non-saline
AGS313 (BU soybean-3)	3266.6±91.1	1333.3± 88.2	3091.7± 213.9	998.0± 260.7			2921.3±61.6	1190.7±171.0	2612.0±311.3	860.0±70.2	
G00028 (BU soybean-4)	3374.1±144.4	1374.5± 138.1	3169.8± 41.2	866.3± 77.2	3266.7± 176.4	1309.7± 217.5	2582.0±360.1	1133.3±176.4	2832.3±119.9	1077.3±282.3	2464.3±117.8
G00056	3390.8±95.7	217.7± 31.5	3087.5± 0.0	172.9± 26.5	2692.0± 368.3	206.7± 52.1	2341.6±280	193.3±28.5	2786.0±221.7	405.7±198.7	2703.3±60.1
BD2330	2266.7±88.2	567.8± 222.2	2266.7± 88.2	391.8± 36.4					1746.2±305.1	319.2 ±61.9	
BU soybean2	3397.8±97.8	388.0± 107.0	3005.2± 41.2	301.9± 128.9	2866.7± 88.2	183.3± 60.1	2333.4±284.7	180.0±25.2	3001.2±115.5	259.4±39.7	2656.7±97.7
BARI soybean6	2603.6±112.4	231.2± 33.8	2533.3± 88.2	343.5± 94.9	2094.0± 351.6	176.0± 14.5	2474.3±125.7	196.7±43.3	1715.8±159.7	265.4±52.7	2414.5±93.8
Binasoybean-2	2796.9±26.2	181.8± 10.0	2726.7± 63.6	457.6± 71.6	2433.3± 120.2	966.7± 145.3	1868.7±67.2	426.7±93.3	2363.2±148.5	420.0±111.3	2414.5±93.8

±: standard error

Based on the yield ha^{-1} and yield contributing characters under saline conditions in different upazillas G00028 and AGS313 were found relatively salt tolerant genotypes.

It was estimated that about 1.056 million ha out of a total 2.86 M ha in the coastal and offshore area of Bangladesh are affected by varying degrees of salinity, where the cropping intensity is much lower than the average of the country (SRDI 2010; Karim *et al.* 2017). In the present study the genotypes AGS313 and G00028, which are already registered as BU soybean-3 and BU soybean-4 respectively, produced substantially higher grain yield than the popular varieties under saline conditions. Since the demand of soybean is significantly higher than that is produced in Bangladesh (USDA, 2022; DAE, 2022) the new varieties will presumably be supportive for increasing the soybean production in the coastal saline soils.

Conclusion

Three genotypes, AGS313, G00028 and BD2330, along with another high yielding genotype G00056 and three popular varieties namely BARI soybean6, BU soybean-2 and BINAsoybean-2 were grown in different upazillas of coastal districts, namely Noakhali, Laksmipur and Bhola under both saline and non-saline conditions. Farmers were given training on Good Agricultural Practices for soybean cultivation, quality seeds were supplied to them and time to time visited the fields. Based on the field performance, farmers' perception and on-station trial the genotypes AGS313 and G00028 were selected as the bold seeded, high yielding and fairly salt tolerant genotypes. Finally, AGS313 and G00028 have been registered as BU soybean-3 and BU soybean-4 from the National Seed Board, Ministry of Agriculture.

Acknowledgement:

We gratefully acknowledge the financial support of Research Management Committee (RMC) of BSMRAU and Ministry of Science and Technology, GoB for conducting the experiments under vinylhouse semi-controlled conditions in BSMRAU, and Krishigobeshona Foundation (KGF) for field study at the farmers' field in the coastal region. We are also thankful to the Department of Agricultural Extension (DAE) and Solidaridad personnel for helping in selection the farmers and participating in selection of promising soybean genotypes for developing suitable varieties for the coastal region of Bangladesh.

References

Banaszkiewicz T. 2011. Nutritional Value of Soybean. *In:* Soybean and Nutrition, Hany A. El-Shemy (ed). Published by In: Tech Janeza Trdine 9, 51000 Rijeka, Croatia ISBN 978-953-307-536-5 free online editions of In: Tech Books and Journals, www.intechopen.com

BBS (Bangladesh Bureau of Statistics) 2020. Yearbook of Agricultural Statistics-2019. Ministry of Planning, Government of the People's Republic of Bangladesh. www.bbs.gov.bd.

Chowdhury MMU, Sarker MJU, Choudhury AK, Farhad ISM, Bhowal SK and Hossain KMF. 2013. Soybean cultivation in coastal area of Noakhali. On-Farm Research Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Department of Agricultural Extension (DAE). 2022. Crop Statistics of DAE (unpublished data, personal communication), Dhaka.

Fujii K and Higuchi H. 2019. The saline-tolerant mechanism of the Bangladesh soybean variety AGS313. Tropical Agriculture and Development, *63*: 186-191.

García-Rebollar P, Cámara L, Lázaro RP. Dapoza C, Pérez-Maldonado R and Mateos GG. 2016. Influence of the origin of the beans on the chemical composition and nutritive value of commercial soybean meals. Animal Feed Science and Technology, *221*: 245-261

Ghassemi-Golezani K, Taifeh-Noori M, Oustan S and Moghaddam M. 2009. Response of soybean cultivars to salinity stress. Journal of Food Agriculture and Environment, *7:* 401-404.

Jinzenji Y. 2020. Differences for salt stress between soybean varieties which are cultivated in the coastal area in Bangladesh. MS dissertation, Faculty of Agriculture, Kyoto University.

Karim MA. 2015. The Challenge of Increasing Climatic Variability to Climate Smart Agriculture in Bangladesh. Proceedings of the Annual Conference of the Bangladesh Society of Agronomy, BARC, Dhaka.

Karim MA, Quayuum MA, Samsuzzaman S, Higuchi H and Nawata E. 2017. Challenges and opportunities in crop production in different types of char lands of Bangladesh: Diversity in crops and cropping. Tropical Agriculture and Development, *61*: 77-93.

Khan MSA, Karim MA, Haque MM, Karim AJMS and Mian MAK. 2013. Screening of soybean genotypes for salt tolerance in hydroponics. Bangladesh Agronomy Journal, *16*: 95-104

Khan MSA, Karim MA, Haque MM, Karim AJMS and Mian MAK. 2014. Variations in agronomic traits of soybean genotypes. SAARC Journal of Agriculture, *12:* 90-100.

Maas EV. 1985. Crop tolerance to saline sprinkling water. Plant and Soil, *89:* 273-284.

Mannan MA, Karim MA, Haque MM, Khaliq QA, Higuchi H and Nawata E. 2012. Response of soybean to salinity: I. Genotypic variations in salt tolernce at the vegetative stage. Tropical Agrculture and Developoment, *56*: 117-122

Mannan MA, Karim MA, Haque MM, Khaliq Q.A, Higuchi H and Nawata E. 2013a. Response of soybean to salinity: ii. Growth and yield of some selected genotypes. Tropical Agriculture and Development, *57*: 31-40.

Mannan MA, Karim MA, Haque MM, Khaliq Q.A, Higuchi H and Nawata E. 2013b. Response of soybean to salinity: III. Water Status and Accumulation of Mineral Ions. Tropical Agriculture and Development, *57*:41-48.

Miah AA, Karim MA, Mamun MAA, Khan MAR, Akter N and Haque MM. 2020. Planting time effects on phenology and yield of early maturing dwarf soybean genotypes, Bangladesh Journal of Ecology, *2:* 19-24.

Mondal MS, Jalal MR, Khan MSA, Kumar U, Rahman R and Huq H. 2013. Hydro-Meteorological Trends in Southwest Coastal Bangladesh: Perspectives of Climate Change and Human Interventions. American Journal of Climate Change, *2*: 62-70. http://dx.doi.org/10.4236/ajcc.2013.21007

SRDI. 2010. Saline Soils of Bangladesh. Soil Resource Development Institute (SRDI). SRMAF project, Ministry of Agriculture, Govt. Peoples Republic of Bangladesh.

Sultana D, Bari MN, Mamun MAA, Higuchi H and Karim MA. 2020a. Grain growth and seed quality of some soybean genotypes, Bangladesh Journal of Ecology, *2*: 47-52.

Sultana D, Bari MN, Mamun MAA, Higuchi H and Karim MA. 2020b. Genotypic difference in phenology and dry matter distribution pattern in soybean, Bangladesh Journal of Ecology, *2*: 13-18.

Tareq MS, Mannan MA, Rahman MM, Mamun MAA and Karim MA. 2022. Salinity-induced changes in growth, physiology and yield of soybean genotypes. Annals of Bangladesh Agriculture, *26* (press).

The United States Department of Agriculture (USDA). 2018. USDA-ARS Nutrient Data Laboratory, USDA Nutrient Lists from Standard Reference Legacy.

The United States Department of Agriculture (USDA). 2022. Global Agricultural Information Network. Report Number: BG2021-0011. Date: April 04, 2021. *https:// www.newagebd.net*

Review article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 229-235

A REVIEW ON COMPREHENSIVE MANAGEMENT STRATEGIES OF BRINJAL SHOOT AND FRUIT BORER

Farha Tamanna Ila Haque, Rinki Akter, Md. Shamim Hossain, Md. Mamunur Rahman and Md Ruhul Amin*

Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

***Correspondence e-mail:** mramin@bsmrau.edu.bd**

Received: 18 November 2023, revised: 19 December 2023, Accepted: 21 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.17

ABSTRACT

Cultivation of brinjal (*Solanum melongena* L.) is of significant global importance, especially in Bangladesh, where it ranks second after potato. The production of brinjal in Bangladesh was 619000 Mt in 2021-22. However, the annual brinjal production in Bangladesh lags behind to leading brinjal-producing countries like India, China, and Japan due to various challenges encompassing environmental factors, soil conditions, insect pests, and diseases. One of the most formidable challenges is the infestation of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* (Lepidoptera: Pyralidae), which inflicts substantial yield losses and threatens food security. This review synthesizes existing knowledge and innovations to provide a comprehensive understanding of management strategies to combat this notorious pest. This article states the effectiveness of various approaches, and their ecological and economic impacts, and offers insights and recommendations for sustainable management strategies of BSFB. Integrated pest management (IPM) packages have demonstrated significant success in reducing the infestation of brinjal shoot and fruit borer. Among the tactics of IPM, cultural practices such as mulching and clipping prove to be highly effective in reducing infestation levels. Neem oil and leaf extract have shown to be effective in controlling this pest.

Keywords: *Leucinodes orbonalis*, infestation, damage, management

Introduction

Brinjal (*Solanum melongena* L.) belongs to the family Solanaceae and is one of the important vegetable crops ranked second after potato in Bangladesh. The annual production of brinjal in Bangladesh is 619000 metric tons (BBS 2022). Approximately 15 percent of the nation's vegetable farming space is under brinjal cultivation. Brinjal has therapeutic value and is also abundant in minerals like calcium, magnesium, sodium, potassium, iron, etc. (Alam *et al*. 2022).

The most significant and highly destructive pest of brinjal in Bangladesh and across Asia is the brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* (Lepidoptera: Pyralidae). The insect has been responsible for a staggering role in annual yield losses in Bangladesh. BSFB pose a significant threat to brinjal crops in Bangladesh, leading up to 90% yield losses (Alam *et al*. 2022). According to another research finding, BSFB cause a big chunk of our crops to be lost per year around 67 to 80 percent (Majumdar and Powell 2011). Prevalence and infestation of this insect pest become a concern and need effective management strategies to safeguard brinjal yields in this region. Its capacity to damage both the shoots and fruits of the plant makes it a formidable adversary to growers. To combat this pest effectively, a comprehensive set of management strategies is essential. Farmers are presently using countless insecticides nearly 140 times or more in a cropping duration of 6-7 months and 32% of the total cost is contributed to crop production (Alam *et al*. 2006). According to a report from an insecticide survey, 180 times insecticides were used within a year to protect the brinjal against BSFB in Bangladesh (Islam *et al*. 2019). However, non-toxic microbial insecticides might be a potent alternative to chemical insecticides (Mollah *et al.* 2022a). Some microbial insecticides were found effective against BSFB in Bangladesh (Mollah *et al.* 2022b, Mollah *et al.* 2023). The economic threshold level of brinjal for shoot and fruit borer is 0.5% of shoot, 5% of fruit damage. By synthesizing existing knowledge and innovations, this review aims to provide a holistic understanding of how

farmers, researchers, and policymakers can collectively tackle the persistent challenge posed by the BSFB while maintaining the sustainability of brinjal cultivation. The objective of this review is to figure out the effectiveness of various management strategies employed to combat brinjal shoot and fruit borer infestation.

Production of brinjal in Bangladesh

The soil and climatic conditions of Bangladesh are favorable for brinjal production in Bangladesh. There are adequate varieties for cultivation throughout the year. According to the report of BBS 2022, brinjal production has increased 103 metric tons (from 516000 to 619000 Mt) in the last five years (Figure 1). Area of brinjal cultivation in the summer and winter seasons of the fiscal year 2021-22 in Bangladesh were 19995 ha and 34211 ha, respectively (BBS 2022). Amounts of brinjal production in the summer and winter seasons of the year were 145207 Mt and 409002 Mt, respectively. However, brinjal is native to our region and there have been domesticated large number of fruiting cultivars but the yield is still low because of the infestation of different insect and mite species. Brinjal faces challenges from various insect pests. Seventeen species of insects and six types of diseases in Bangladesh are found in brinjal plants (Roy 2014). Some common insect pests of brinjal are listed in Table 1. Amin *et al.* (2018) reported nine species of insects belonging to seven families under four orders as the pest of brinjal in Bangladesh. In our country, infestation of brinjal shoot and fruit borer is the key factor causing a decline in brinjal production.

Diagnostic characteristics and life cycle of brinjal shoot and fruit borer

The adult brinjal shoot and fruit borer, with a wingspan of 18-24 mm, features white wings with a distinctive brown patch and black spots. Females are larger, characterized by a swollen, ovate abdomen, while males have a slimmer, cylindrical abdomen with a blunt tip and white hairy structures. Reproductively, elongated, creamy white eggs hatch into larvae that can grow up to 155 mm in length, displaying a reddish color through five larval instars. The fifth instar larvae leave the fruit, cease feeding, and enter a pupation phase, secreting a silk cocoon (Wankhede *et al*. 2009, Maravi *et al*. 2013, Bindu *et al*. 2015). Mating occurs at night or in the early morning, lasting about 43 minutes. (Sharma *et al.* 2017).

Brinjal shoot and fruit borer is a holometabolous insect having four distinct life stages namely egg, larva, pupa, and adult (Figure 1). The larval stage is the longest, followed by the pupa, and the incubation period. The larval stage in the life cycle of this insect is the lengthiest in terms of growth duration, followed by the pupal stage, and finally, the incubation period (Neetam *et al*. 2018). Oviposition or egg-laying occurs over 2-3 days, and the incubation period ranges from 3-8 days depending on temperature. According to Table 2, larvae undergo 5-6 molts, lasting 16.8 ± 4.54 days. The pupal stage usually lasts 12.3±1.76 days. Adult moths have varying lifespans, with males surviving 2.95 ± 0.98 days and females 5.4±1.5 days. The

Table 1. Common insect and mite pests of brinjal plants

Common name	Scientific name	Family	Order
Thrips	*Hercothrips indicus*	Thripidae	Thysanoptera
Aphid	*Aphis gossypii*	Aphididae	Hemiptera
Jassid	*Amrasca biguttula*	Cicadellidae	Hemiptera
Whitefly	*Bemisia tabaci*	Aleyrodidae	Hemiptera
Leaf hopper	*Amrasca devastans*	Cicadellidae	Hemiptera
Epilachna beetle	*Epilachna punctata*	Coccinellidae	Coleoptera
Fruit and shoot borer	*Leucinodes orbonalis*	Crambidae	Lepidoptera
Stem borer	*Euzophera perticella*	Phycitidae	Lepidoptera
Leaf roller	*Eublemma olivacea*	Noctuoidea	Lepidoptera
Mite	*Tetranychus urticae*	Tetranychidae	Acari

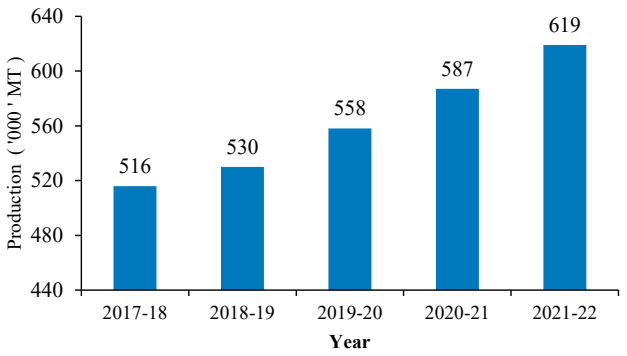


Figure 1. Production of brinjal in Bangladesh during the 2017-18 to 2021-22.

Figure 2. Life cycle of brinjal shoot and fruit borer.

larval stage of *L. orbonalis* lasts for approximately 12-15 days during the summer and extends to 14-22 days during the winter season (Rahman, 2006).

Nature of damage and infestation level of brinjal shoot and fruit borer

The Brinjal shoot and fruit borer primarily target eggplants but can infest other plants in the Solanaceae family, including tomatoes, sweet potatoes, *Solanum indicum*, and African eggplants. Shoot and fruit borer infestation is highly destructive, causing holes in shoots and fruits, reducing yields, and depleting vitamin C content by up to 80%. The larvae of this pest bore into tender shoots, buds, and flowers. Later, they make tunnel inside fruits, creating feeding tunnels and dead heart damage. The entry holes on fruits are often obscured by frass, and circular exit holes become visible. A single fruit can host up to 20 larvae, with each larva capable of damaging 4-7 healthy fruits. This voracious feeding behavior poses a significant threat, necessitating effective pest management strategies for eggplants and related crops (Baral *et al*. 2006, Plazas *et al*. 2014). Yasmin *et al*. (2021) studied the abundance and infestation of brinjal shoot and fruit borer on different germplasms of brinjal. They reported that the abundance of larvae in the tested germplasms ranged from 1.1±0.1 to 2.6±0.2 per fruit and infestation from 14.0±1.2 to 19.3±0.9%, and the results differed with the morphological and biochemical characteristics of the germplasms.

Table 2. Developmental time of brinjal shoot and fruit borer

Biological parameter	Duration(days)
1st instar	3.95±0.92
2nd instar	2.3±0.94
3rd instar	3.2±0.67
4th instar	3.55±0.98
5th instar	3.8±1.03
Pupal period	12.3±1.76
Male longevity	2.95±0.98
Female longevity	5.4±1.50

Management strategies of brinjal shoot and fruit borer

Cultural practices: An ecologically based approach to pest management is centered on population regulation through preventive strategies. Instead of relying on chemical control, this approach emphasizes the use of environmentally safe and practical alternatives to manage significant insect pests in fruit and vegetable crops, including brinjal. Various cultural practices are recommended for effectively managing BSFB. These practices offer environmentally friendly alternatives to mitigate pest damage. Some of these strategies include mulching, weed control, irrigation, pruning, stalking, mixed cropping, and removal of alternate hosts. Muhammad *et al*. (2021) reported that mulching, clipping, and mulching along with clipping reduced shoot infestation 39.2%, 47.1% and 61.6%, respectively (Figure 3). They reported that mulching, clipping, and mulching along with clipping reduced fruit infestation 34.8%, 52.8% and 67.9%, respectively (Figure 3).

Mechanical control: Mechanical control methods for managing brinjal shoot and fruit borer involve physical interventions to prevent or remove the pest. Mechanical methods include hand picking, traps, crop rotation,

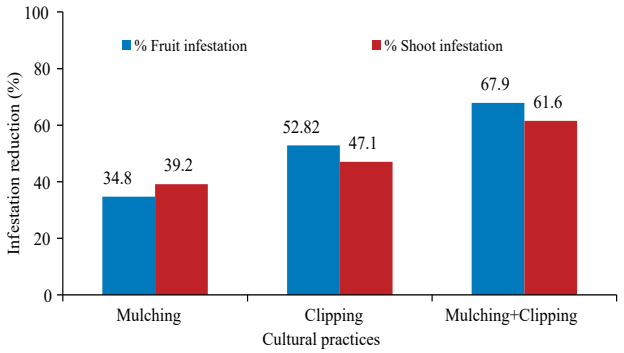


Figure 3. Reduction of brinjal shoot and fruit borer infestation (%) by different cultural practices.

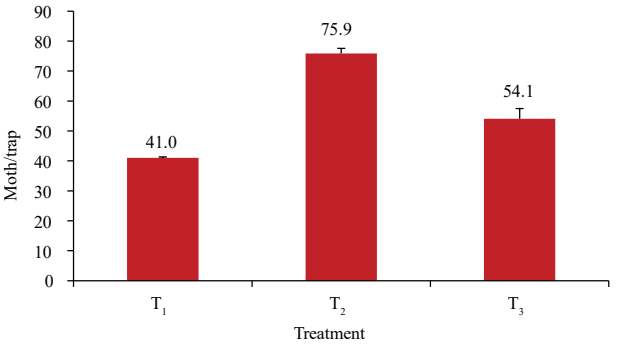


Figure 4. The mean number of adult moths captured in plots using pheromone and sticky traps over a 56-day period.

planting traps, physical barriers, pruning and sanitation, soil drenching etc. These methods help to reduce pest populations and infestations. Combining the use of barriers and prompt removal of damaged shoots, the pest has proven highly effective in reducing shoot damage by an average of 62.7% (Chaukikar *et al*. 2020). Erect barriers made of nylon net at suitable heights affect the flight capabilities of the adult moths. Under such conditions, moths can fly short distances. Net houses or poly-houses are effective protection measures for brinjal shoot and fruit borer (Kaur *et al*. 1998). Faruq *et al*. (2021) applied treatments such as treatment 1(T_1: Voliam flexi 300 SC at the @ 0.5 ml/L water at 10 days intervals + hand collection and destruction of infested fruits and larvae + pheromone trap+ nappy trap), treatment 2 (T_2: Spinosad 45SC @ 0.4 ml/L water at 10 days interval + nappy trap), and treatment 3 (T_3: Ripcord 10EC @ 1.0 ml/L water at 10 days interval + pheromone trap) to control the brinjal shoot and fruit borer, and found that the treatment 2 was best for capturing adult moth.

Table 3. List of brinjal varieties resistance to shoot and fruit borer

Country	Tolerant varieties
Bangladesh	BARI begun-6, BARI begun-4, Katabegun, Marich begun, EG075, Jumki-1, Jumki-2, Islampuri-3
India	Long Purple, Katrain-4, Doli-5, Pusa Purple Cluster, Junagarh Long
Pakistan	Shilpa, Nirala and Hybrid 3715

Cultivation of resistant varieties: Studies by Manna *et al*. (2003), Ahmed *et al*. (2008), and Abhishek *et al*. (2021) have documented the presence of brinjal varieties, cultivars, and hybrids that exhibit varying degrees of resistance to pests (Table 3). These resistant strains have shown promise in reducing pest damage and improving crop yields. Several scientific research efforts have developed into a range of host plant resistance mechanisms, including antixenosis, antibiosis, and tolerance (Abhishek *et al*. 2021).

Table 4. List of natural enemies (predators and parasitoids) of insect pests of brinjal

Predators			
Common name	Scientific name	Family	Order
Transverse ladybird	*Coccinella transversalis*	Coccinellidae	Coleoptera
Lady beetle	*Harmonia dimidiata*	Coccinellidae	Coleoptera
two-spotted lady beetle	*Adalia bipunctata*	Coccinellidae	Coleoptera
Striped Lady Beetle	*Cheilomenes propinquq*	Coccinellidae	Coleoptera
Marmalade Hoverfly	*Episyrphus balteatus*	Syrphidae	Diptera
Parasitoids			
Cameron	*Trathala flavoorbitalis*	Ichneumonidae	Hymenopteraa
Wasp	*Trichogramma spp.*	Trichogrammatidae	Hymenoptera
Wasp	*Bracon hebetor*	Braconidae	Hymenoptera

Biological control: Biological control of the brinjal shoot and fruit borer involves the use of natural enemies, such as predators, and parasitoids. Biological control promotes sustainable and environmentally friendly pest management practices, ensuring the quality and yield of agricultural produce. Borkakati *et al*. (2019), Chaukikar *et al*. (2020), Abhishek *et al*. (2021), Das *et al*. (2023), and Maqsood *et al*. (2023) reported different predator and parasitoid species as effective biological control agents of brinjal shoot and fruit borer (Table 4). Srinivasan (2012) reported that the gram-positive and spore-forming bacterium species *Bacillus thuringiensis* (Bt) had effective microbial activity against the larvae of different insects.

Botanical insecticides: Natural plant extracts or oils such as neem oil can be used as organic alternatives for controlling brinjal shoots and fruit borer. Plant oils and extracts are less harmful to beneficial insects, and have fewer residual effects on the environment. Findings of Manzoor *et al*. (2023) showed that the chili and neem leaf extracts reduced shoot infestation of 32.2% and 84.2%, respectively, and the reduction of fruit infestation by tobacco and neem leaf extracts was 10.1% and 18.2%, respectively (Figure 5).

Chemical control: Chemical control of brinjal shoot and fruit borer involves the use of insecticides to manage the pest infestation. Carbamates, pyrethroids, and neonicotinoids are some common chemical insecticides for controlling brinjal shoot and fruit borer. Reddy and Kumar (2022) studied the effect of different insecticides on the fruit infestation of brinjal shoot and fruit borer and

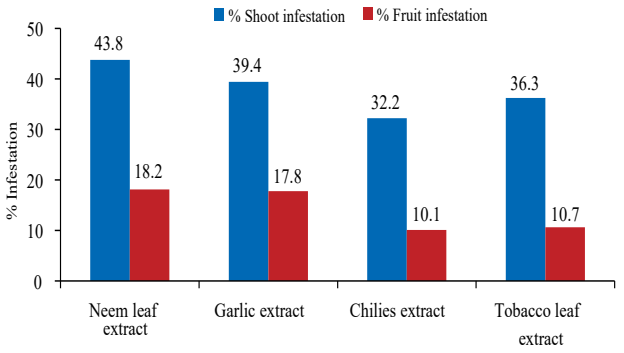


Figure 5. Effect of different botanical extracts on reduction of shoot and fruit infestation (%) of brinjal shoot and fruit borer after 1st spray

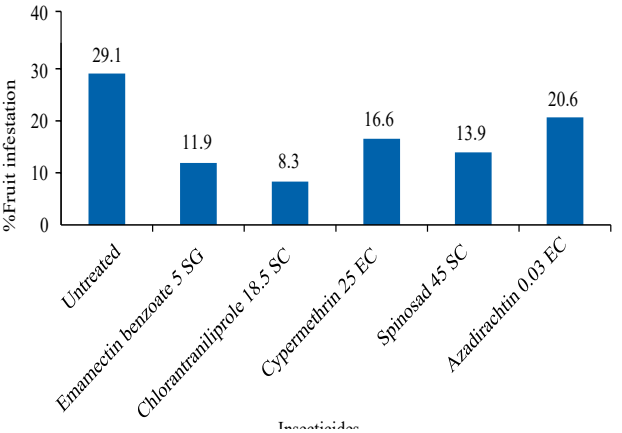


Figure 6. Effect of different insecticides on the fruit infestation rate (%) of brinjal shoot and fruit borer.

reported that the tested insecticides had significantly lower levels of fruit infestation compared to control (Figure 6). In their study, fruit infestation levels of the insecticides ranged from 8.3% to 29.1% and the results were obtained from Azadirachtin 0.03 EC and Chlorantaniliprole 18.5 EC treated plots, respectively.

IPM strategies

In Bangladesh, more than 75% of brinjal is contaminated with pesticides from the growing to marketing stage without consideration of residual toxicity (Islam and Haque, 2018). To overcome this problem, the Integrated Pest Management (IPM) program of brinjal shoot and fruit borer needs to be encouraged. IPM is widely regarded as the most effective approach to managing pests while safeguarding the environment and preserving biodiversity. This holistic strategy combines various management practices like cultural, mechanical, biological, and chemical methods to achieve the goals. However, farmers and researchers must work collaboratively in developing and implementing integrated and environment friendly approaches to manage brinjal shoot and fruit borer effectively. Such efforts will not only protect brinjal crops but also contribute to the overall sustainability of brinjal cultivation, ensuring food security and environmental health. Encouraging the conservation of natural predators, parasitoids, and adopting practices like crop rotation, sanitation, and the timely removal of infested plant material can significantly reduce the infestation of brinjal shoot and fruit borer.

Conclusion

In this article, different management practices of brinjal shoot and fruit borer has been reviewed to figure out their comparative efficacy. Through an in-depth exploration of various control methods, it becomes evident that an integrated approach is the most effective way to manage the infestation. The integration of chemical, biological, and cultural practices offers a multi-pronged strategy to combat the pest while minimizing environmental impacts. Pesticides, when used judiciously, can provide short-term relief, but long-term sustainability requires a shift towards biological control methods and cultural practices. Further research into new techniques and technologies should be encouraged to refine and enhance the effectiveness of brinjal shoot and fruit borer management strategies. Additionally, monitoring the crops regularly to detect early signs of infestation remains critical for prompt intervention.

References

Abhishek T and Dwivedi S. 2021. Review on integrated management of brinjal shoots and fruit borer, *Leucinodes orbonalis* Guenee. Journal of Entomology and Zoology Studies, *9*: 181-189.

Ahmad H, Rahman MH, Haque MA and Ahmed KS. 2008. Screening of brinjal varieties/lines resistance to brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. Journal of Agroforestry and Environment, *2*: 131-133.

Alam MJ, Siddika MI, Khan MAM, Kulsum U and Ahmed KS. 2022. Management Of brinjal shoot and fruit borer using exclusion nets. Tropical Agrobiodiversity, *3*: 60-64.

Alam SN, Hossain MI, Rouf FMA, Jhala RC, Patel MG, Rath LK and Talekar NS. 2006. Implementation and promotion of an IPM strategy for control of eggplant fruit and shoot borer in South Asia. AVRDC.

Amin MR, Mia MS, Rahman H, Nancy NP and Bhuiyan MKA. 2018. Functional and group abundance of insects on eggplant. Bangladesh Journal of Agricultural Research, *43*: 647-653.

Bangladesh Bureau of Statistics (BBS). 2022. Agricultural Statistical Year Book Bangladesh 2022, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Baral K, Roy BC, Rahim KMB, Chatterjee H, Mondal P, Mondal D and Talekar NS. 2006. Socio-economic Parameters of Pesticide Use and Assessment of Impact of an IPM Strategy for the Control of Eggplant Fruit and Shoot Borer in West Bengal, India. Tashkent, Uzbekistan: AVRDC.

Bindu SP, Pramanik A and Padhi GK. 2015. Studies on biology and physical measurements of shoot and fruit borer (*Leucinodes orbonalis* Guenee) of brinjal in West Bengal, India. Global Journal of Biology, Agriculture and Health Science, *4*: 215-219.

Borkakati RN, Venkatesh MR and Saikia DK. 2019. Insect pests of brinjal and their natural enemies. Journal of Entomology and Zoology Studies, *7*: 932-937.

Chaukikar K, Vaishampayan S and Marabi RS. 2020. The succession of insect pest complex on brinjal at central Narmada valley region (Madhya Pradesh). Journal of Entomology and Zoology Studies, *8*: 1757-1761.

Das B, Choudhury MAR, Dash CK and Al-Habib MJ. 2023. Abundance and fluctuation pattern of insect pests and natural enemies in winter brinjal plant in Sylhet. Bangladesh Journal of Entomology, *31*: 43-55.

Faruq MO, Latif MA, Khan MMH, Das GP and Uddin MR. 2021. Management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) using selected insecticides in farmer's fields at Bandarban hill tracts, Bangladesh. International Journal for Asian Contemporary Research, *1*: 106-112.

Islam MS, Choudhury MAR, Maleque MA, Mondal MF, Hassan K and Khan AU. 2019. Management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) using selected bio-rational insecticides. Fundamental and Applied Agriculture, *4*: 1025-1031.

Majumdar A, Powell M, 2011. Net house vegetable production: pest management successes and challenges. Journal of the NACCA, *4*: 450-454

Mannan MA, Begum A, Rahman MM and Hossain MM. 2003. Screening of local and exotic brinjal varieties/ cultivars for resistance to brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). Pakistan Journal of Biological Sciences, *6*: 488-492.

Manzoor M, Hamza A, Javaid A, Anees M, Tariq MR, Firdosi MFH and Haider MS. 2023. Bio-efficacy of some botanical extracts against brinjal fruit and shoot borer (*Leucinodes orbonalis* Guenee); Lepidoptera, Pyrallidae. Plant Protection, *7*: 263-272.

Maqsood S, Shafi MU, Javaid A, Khan IH, Ali M and Ferdosi MF. 2023. Control of insect pests and yield improvement in brinjal by plant extracts. International Journal of Biology and Biotechnology, *20*: 329-335.

Matsubara K, Kaneyuki T, Miyake T and Mori M. 2005. Antiangiogenic activity of nasunin, an antioxidant anthocyanin, in eggplant peels. *Journal of agricultural and food chemistry*, *53*: 6272-6275.

Mollah MMI, Hassan N, Khatun S, Rahman MM. 2023. *Bacillus thuringiensis* increases the efficacy of bio-pesticides against eggplant shoot and fruit borer, *Leucinodes orbonalis* Guenee. Journal of Natural Pesticide Research, *6*: 100055.

Mollah MMI, Hassan N, Khatun S, Rahman MM. 2022a. Sequential application of biopesticides suppress eggplant shoot and fruit borer, *Leucinodes orbonalis* G. infestation. Journal of Entomology and Zoology Studies *10*: 140-146.

Mollah MMI, Hassan N, Khatun S. 2022b. Evaluation of Microbial Insecticides for the Management of Eggplant Shoot and Fruit Borer, *Leucinodes orbonalis* Guenee. Entomology and Applied Science Letters, *9*: 9-18.

Muhammad W, Javed H, Ahmad M and Mukhtar T. 2021. Economic impact of some selected cultural practices on population build-up of *Leucinodes orbonalis* in brinjal crop. Fresenius Environ Bull, *30*: 7346-7354.

Netam M, Lakra R, Koshta VK, Sharma D and Deole S. 2018. Screening of Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee), for Resistance in Brinjal *(Solanum melongena* L.) Germplasm Lines. International Journal of Current Microbiology and Applied Sciences, *7*: 3700-3706.

Plazas M, Prohens J, Cunat AN, Vilanova S, Gramazio P, Herraiz FJ and Andujar I. 2014. Reducing capacity, chlorogenic acid content and biological activity in a collection of scarlet (*Solanum aethiopicum*) and Gboma (*S. macrocarpon*) eggplants. International Journal of Molecular Sciences, *15*: 17221-17241.

Rahman MM. 2006. Vegetable IPM in Bangladesh. Radcliffe's IPM world textbook. University of Minnesota, St. Paul, MN. USA.

Sharma A, Rana RS, Sharma KC, Singh S and Kumar A. 2017. Studies on biological parameters of *Leucinodes orbonalis* Gunee on brinjal under laboratory conditions. Journal of Entomology and Zoology Studies, *5*: 415-419.

Reddy CSTS and Kumar A. 2022. Efficacy of selected insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee). The Pharma Innovation Journal, *11*: 1327-1330.

Roy UK. 2014. Farmers' attitude towards integrated pest management (IPM) practices in vegetable cultivation (Doctoral dissertation, Department of Agricultural Extension & Information system).

Yasmin F, Shipa AS, Amin MR, Swapon MAH and Hossain MM. 2021. Field screening of brinjal germplasm for resistance against shoot and fruit borer. Bangladesh Journal of Ecology, *3*: 11-16.

Review article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2023) 5 (2) : 237-246

DEGRADATION OF POLYMER MATERIALS IN ENVIRONMENT

Tazeen Fatima Khan[1*] and Md. Golam Faruque[2]

[1*]Department of Soil, Water and Environment, University of Dhaka, Dhaka 1000, Bangladesh. [2]Bangladesh Institute of Governance and Management, Agargaon, Dhaka 1207, Bangladesh.

***Corresponding email:** tazeenkhan18@du.ac.bd

Received: 24 November 2023, revised: 03 December 2023, accepted: 05 December 2023, DOI: https: //doi.org/10.59619/ej.5.2.18

Abstract

Environmental occurrence of the polymer-based materials (PBMs) and their associated chemical additives have been recognized as an emerging worldwide problem, and their impacts are now a subject of wider scientific and social interest. Production of PBMs have increased substantially over the last few years due to their flexible nature, making them compatible for use in domestic, industrial and developmental purposes. PBMs can be released into the environment form a variety of sources. The principal introduction routes being general littering, dumping of waste materials, migration from landfills, emission during refuse collection and air-blasting technologies. Once in the environment, PBMs can be broken down by thermal, biological and chemical processes. A number of literatures to date have addressed the impacts of PBMs in the environment and eventually on human health. Bulk PBMs are well documented as entanglement and ingestion hazards. Interaction of PBMs with persistent organic pollutants (POPs) have been shown to biomagnify in food webs causing traumatic injury and cardiovascular diseases in human body. This review summarizes up-to-date findings about the source and occurrence of PBMs in both aquatic and terrestrial environments, various degradation processes of PBMs and most important, the harmful effects of PBMs on environment and human.

Keywords: Aquatic, environment, food webs, organic pollutants, terrestrial.

Introduction

Polymer-based materials (PBMs) are a complex mixture of their respective polymer/s and their various additive compounds (Plastics Europe 2021). The first synthetic mass produced polymer was Bakelite, developed by the Belgian chemist Leo Baekeland in 1909. Later in the 1900s the modern form of PVC was created in 1926, followed by polyurethane (PUR) in 1937, a more processable polystyrene in 1938, and high-density polyethylene (HDPE) and polypropylene (PP) in 1951 (Hammer *et al*. 2012). More recently, technological advances have seen the development of polymers produced from the bacterial fermentation of sugars and lipids, and include polyhydroxyalkanoates (PHA), polylactides (PLA), aliphatic polyesters and polysaccharides (Martinho *et al*. 2022).

Different types of polymers have different properties due to their variations in molecular structure, size of the molecule, density of the polymer and functional groups. In general, polymers consist of a range of organic and inorganic molecules formed from elements, such as carbon, silicon, hydrogen, nitrogen, oxygen and chloride (Martinho *et al*. 2022). These elements are joined together in different bond combinations to achieve the differences in polymer properties. Polymers in their pure states are not generally usable as a commercially viable material. Therefore, polymers are processed with a range of compounds to adjust their characteristics which make them suitable for their intended purpose.

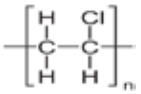
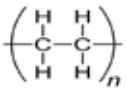
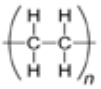
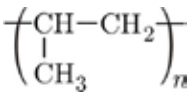
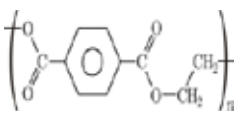
Increasing human population and associated economic growth has led to an increase in the demand for consumable goods such as those made from PBMs (i.e., plastics and elastomers). During their lifecycle PBMs can be released into the environment from a variety of sources. Once in the environment, PBMs are exposed to a variety of mechanical and chemical weathering processes. This causes a change to the PBM structure and facilitates the disintegration of the PBM into increasingly smaller fragments (Martinho *et al*. 2022). Furthermore, these materials are now thought to be contributing to the build-up of chemicals in the environment via the leaching of chemical additives that

are used in the manufacturing process (Erren *et al*. 2009). The majority of physical effects data regarding bulk PBM items identifies them as presenting a hazard to mammals and birds as they can become entangled and/or mistake PBMs as a food source (Mao *et al*. 2022). The majority of ecotoxicity data regarding PBM additives has focused on the effects of compounds that are generally referred to as having endocrine disruptive potential, such as the phthalates (Oehlmann *et al*. 2009). However, receiving environments are potentially exposed to a combination of both these physical and chemical components, as well as substances produced during degradation processes. Therefore, PBMs and their associated degradation products may compromise the viability of organisms at all trophic levels. At the base of the food chain primary producers may be more sensitive to substances that have a biological action. Non-selective and filter-feeding consumers could be susceptible to ingesting both bulk PBMs and fragmented particles, leading to the potential passage up the food chain to secondary and tertiary consumers (Mao *et al*. 2020, Oehlmann *et al*. 2009). The purpose of this review is to shed light on the release, occurrence and degradation of PBMs and their associated chemical additives in aquatic and terrestrial environments.

Types and production of PBMs

There are currently twenty different groups of PBMs, each with numerous grades and varieties. The PBMs used in society today are made from a broad class of materials that are both natural and synthetic in origin (Table 1). Production of polymers has increased substantially over the last sixty years from around 1.5 million metric tons in 1950 to approximately 367 million metric tons in 2020 (Dehaut *et al.* 2016). Plastics Europe (2021) have predicted that the net polymer production by 2050 will be around 34 billion tons.

Table 1. Characteristics and uses of major polymer types in Europe

Polymer type	Global polymer usage (%)	Characteristics
Polyvinylchloride 	10.3	Rigid; can be blended with other materials; readily available; good tensile strength.
Low density polyethylene 	17.2	High tensile strength; high impact and puncture resistant; good electrical properties.
High density polyethylene 	12.1	Large strength to density ratio; strong intermolecular force and tensile strength; can tolerate higher temperatures.
Polystyrene 	7.0	Thermoplastic; brittle; poor barrier to oxygen and water vapour; low melting point.
Polypropylene 	19.2	Low density; high stiffness; heat resistance; chemical inertness; steam barrier properties; good transparency; good hinge property.
Polyethylene terephthalate 	7.0	Absorbs little water; gas barrier properties; chemical resistant, transparency.

Releasing phenomena of PBMs to environment

Polymer-based materials (PBMs) may enter the environment from both ocean- and land-based sources. Ocean-based sources include items lost or discarded from commercial fishing vessels, offshore oil or gas platforms and waste dumped by recreational boat users. Losses of cargo can also occur from shipping during bad weather events or accidents and items lost from improper loading, unloading or on-board storage (Liang *et al*. 2021). In the past, pre-production polyethylene (PE) and polypropylene (PP) pellets have reportedly being used on the decks of ships to reduce friction when moving large objects; as such, many of these pellets are washed from the deck and are dispersed by winds and ocean currents (Borrelle *et al.* 2020).

On land, general and accidental littering are important routes of environmental entry of PBM debris. General littering is the direct dropping of litter and dumping of items; for example, illegal dumping of waste that can then be transported by wind or from drainage and storm water runoff to ocean sinks. Littering at festival sites is noted as an issue; especially from sites that have inadequate waste management systems. Accidental littering, results from windblown debris from bins, or from recycling and landfill facilities (Cierjacks *et al*. 2012). Landfills are a major end-of-life disposal route for PBMs (Schyns and Shaver 2021). In most developed regions of the world, waste is collected, transferred to landfills and is typically covered with soil daily (Liang *et al*. 2021). However, in many developing regions waste materials are often disposed of in areas lacking adequate infrastructure, and are rarely or inadequately covered with soil. This increases the likelihood of windblown debris migrating from landfill sites. PBMs associated with personal hygiene products and microscopic polyethylene beads found in some hand cleaners can constitute a portion of this waste stream. Larger items are generally removed by screening methods, but may enter the environment during sewage overflow events that occur during periods of heavy rainfall. The ability of sewage treatment works to process microscopic beads and fibres has now been questioned.

Industrial sources of PBM waste include air-blasting technologies that use microscopic beads to strip paint from metallic surfaces and for cleaning engine parts; when discarded, they enter the environment through foul-water, or via transfer through sewage treatment processes (Mao *et al*. 2020). Low density polyethylene (LDPE) films constitute a large-volume use of PBMs in agricultural crop production, and consequently they have become an important agricultural emission. Their application is thought to be one of the most important sources of PBM contamination of soils, because they become brittle and easily disintegrate rendering their recovery difficult. Agriculture films can also contain light-sensitive additives, such as ferric and nickel dibutyldithio-carbamates, the ratio of which can be adjusted so that the film is usable during a specific growing season, after which the product begins to photo-degrade. This ultimately results in disintegration of the materials (Lozano and Rillig 2020, Schyns and Shaver 2021).

Occurrence of PBMs in oceans

Large item of PBM debris, known as 'macro-plastics' (>5 mm in diameter,) provides an opportunity to assess markings to trace an object to its origin. PBMs are believed to contribute up to 80% of all anthropogenic debris in the oceans (Mao *et al*. 2020). A well-documented example are pre-production PE and PP (polypropylene) pellets that are transported from manufacturing plants to plastic injection factories, where they are melted and molded into consumer products. These pellets have been reported floating in coastal surface waters, and in the world's oceans (Lozano and Rillig 2020, Moore 2018). Lightweight items, such as PE bags, polystyrene (PS) foam items and polymer bottles, inappropriately disposed of on land, can be readily transported long distances via a windblown route or carried by freshwater to eventually accumulate in the oceans (Ryan *et al*. 2009).

Shorelines around the world have been found to accumulate debris, including island shorelines far from any centres of human activity. Ana *et al.* (2023) surveyed beach litter on Ducia Atoll in the south Pacific and found 953 items of debris over a 1.5 miles survey transect. Evidence of the increasing occurrence of PBMs is provided from Scotland, where Duis and Coors (2016) found 0.35 items of litter/m^2, with plastics accounting for 29% of items found. Ten years later the same area of beach was surveyed and the density of litter was found to have increased to 0.8 items of litter/m^2, with PBMs accounting for 37% of

items found (Ding *et al*. 2020). Particles <5 mm, known as microplastics, formed as a result of the breakdown of larger materials, are now found floating on the ocean surface, mixed into the water column, and embedded in bottom sediments and beach sands (Ding *et al*. 2020). In 2004, the CPR survey, the longest running plankton monitoring program in the North Sea and North Atlantic, added micro-plastic as their first non-biological marine entity to their recordings (Richardson *et al*. 2006). One area that has received particular attention is the subtropical accumulation zone in the North Pacific gyre. In this area, debris has accumulated at such high densities as a result of high atmospheric pressure and the clockwise rotation of ocean currents that forces debris into a central area where strong winds and currents diminish. Neuston sampling at 11 sites, using a mantra trawl, estimated a mean PBM abundance of 334,271 pieces km^2 (Moore 2018). Infra-red spectroscopy techniques have been utilized to identify fragment PBMs in the microscopic range by comparing spectra to those in a database of common polymers. This technique was principally pioneered by Thompson *et al*. (2004), whose research identified synthetic fibres (PE, PP, PS) in samples of beach sand and sub-tidal sediments from around the UK.

Nature of degradation of PBMs in environment

Once in the environment PBMs are degraded through abiotic or biotic factors working together or in sequence; these processes cause the polymer matrix to disintegrate, resulting in the formation of fragmented particles of various sizes and leached additives. There are now a number of studies whose authors have investigated the degradability of a range of PBMs under a range of exposure conditions (Table 2).

In the aquatic environment the disintegration of PBMs is facilitated by wave action and grinding with sediment particles, whereas changes in chemical functionality are driven by UV exposure. Floating debris has a greater exposure to sunlight and the oxidative properties of the atmosphere, which act alongside the hydrolytic properties of water to cause the material to become brittle and fragment. In the deep ocean environment where sunlight and oxidative processes are missing, the rate of degradation is extremely low (Mao *et al*., 2020). Degradation in these environments is considered minimal, due to the reduced diversity and density of microbial communities. Therefore, PBMs do not readily biodegrade but rather disintegrate, breaking into smaller and smaller pieces.

Soil burial studies have been used as a method to evaluate the degradation of PBMs in the terrestrial environment. Soil type is an important factor affecting degradation; under laboratory conditions, polycaprolactone (PCL) degraded to a greater extent in clay soils than in sandy soils, owing to the great density of microbial communities associated with the clay soils (Yu *et al.,* 2022). However, when compared to solar exposed samples, buried samples degraded at a much slower rate. The combined effect of multiple degradation processes has also been studied. For example, Oehlmann *et al*. (2009) used polyhydroxybutyrate (PHB) films with a 0.1 – 0.12 mm thickness and found samples exposed to 9 h UV radiation showed ~52% weight loss after 28 days soil burial, compared to ~32% weight loss for samples without pre-UV exposure. These studies suggest that abiotic pre-treatment acts as a first step in weakening the polymer structure. This initiates the formation of oxygenated compounds and low molecular weight hydrocarbons, which are recognized by microbial communities and can be utilized as a food source (Yu *et al*. 2022). Biodegradation studies have tended to deal with the use of concentrated microbial cultures, with the aim of assessing a particular strain's ability to degrade a particular PBM. Actinomycetes are reported to be the main group of NRL degrading microbes, with *Bacillus* sp. Erren *et al*. (2009) studied strains of *Nocardia* and observed that they only slightly degraded strips of tread cut from truck tires, when used as a sole carbon source. However, degradation of the tire was enhanced by the addition of more easily accessible carbon sources in the form of latex glove and unvulcanized rubber materials, which were readily utilized by the bacteria (Erren *et al*. 2009). Biological processes are affected by the amount and type of microorganisms present, their sensitivity to associated environmental parameters and the adaptability of the microbiota. Martinho *et al*. (2022) isolated bacterial strains from forest soils, most belonging to different genera of the proteobacteria group and three *Rhodcoccus* strains, and showed that commonly found bacteria were capable of adhering to and growing on the surface of oxidized LDPE film (Kapanen *et al*. 2008).

Table 2. Polymer degradation studies in various environmental matrices

Type of material	Length of study	Main findings
Aquatic		
HDPE, LDPE, PP (1.5 mm thick)	6 months	Samples were immersed in the seawater at a depth of 3 m. Weight loss was greatest in LDPE sheets (2.5%), followed by HDPE (0.75%) and then PP (0.5%).
PE glycols (PEGs) water soluble	135 days	Greater degradation was observed in freshwater media when compared to seawater media.
PHA	42 days	Speices of bacteria belonging to the phylogenetic groups of *Cytophaga-Flavobacterium-Bacteroides*, *g-Proteobacteria* and *b-Proteobacteria* were found to utilize PHA in a eutrophic reservoir.
PUR	12 months	The degree of cross-linking effects PUR degradability in sea water. PUR with a heavily cross-linked network was very resistant to degradation.
Soil		
PE	10 years	Photooxidation processes produced carbonyl groups which were utilised by microorganisms to degrade the shorter segments of the PE chain.
LDPE	12 months	After 12 months it was impossible to separate film residues from soil. No change in diversity of ammonia-oxidizing bacteria was detected.
PP	12 months	Thermally pre-treated PP showed greater weight loss, greater loss of tensile strength and greater changes in crystallinity than non pre-treated PP.

*HDPE=high density polyethylene, LDPE=low density polyethylene, PP=polypropylene, PHA=polyhydroxyalkanoates, PUR= polyurethane

Polymer-based materials (PBMs) with a starch component are effectively hollowed out when exposed to microbial communities; this increases the surface to volume ratio allowing for higher oxygen and moisture permeability, enhancing both oxidative and hydrolytic processes (Yu *et al*. 2022). In theory, the released polymer fragments will have a greater surface area than the original polymer, allowing them to be further degraded by the micro-biota. However, in the case of PE, microorganisms have been found to utilize the starch component, but are unable to utilize the remaining PE fragments, which remain non-degradable. The starch is utilized by microorganisms, leaving behind a lace-like structure with reduced physical integrity. However, the molecular weight of the remaining material was not reduced sufficiently for permanent assimilation into the microbial biomass (Rutkowska *et al*. 2002). Therefore, the remaining polymer matrix was no more biodegradable than the untreated polymer. This causes the disintegration of the polymer matrix, which generates many smaller particles and produces a wider distribution of polymer particles in the environment (Kurkcu *et al.* 2012).

Polymer characteristics play an important role in the degradation rate of PBMs. Those PBMs that contain ester linkages are reported to be readily biodegraded by the action of esterases (Arkatkar *et al*. 2009). The molecular composition of a PBM also affects the hydrophobicity of the polymer surface, which in turn affects how easily microorganisms can attach themselves. Complexity of a specific polymer structure and composition (co-polymers) can affect overall degradability by directly influencing the accessibility of enzymes (Orhan and Buyukgungor 2000). PBMs with short and regular repeating units that have high symmetries and strong inter-chain hydrogen bonding often limit accessibility and are less susceptible to enzyme attack. Under ambient conditions, photo-degradation is one of the primary means by which PBMs are damaged (Richardson *et al*. 2006). The main processes involved are chain scission and cross-linking reactions, when exposed

to ultra-violet (UV) radiation (290-400 nm) or visible radiation (400-700nm) (Al-Salem 2009). Most polymers tend to absorb high-energy radiation, which activates their electrons to higher reactivity and foments oxidation, cleavage, and other forms of degradation. The most damaging UV wavelength for a specific material depends on the bonds present; for PE this is 300 nm and for PP 370 nm (Singh and Sharma 2008). Thermal degradation is the molecular deterioration of a polymer as a result of over-heating, which causes bond scissions of the main polymer chain and results in a change in properties. This process affects the entire polymer and not just the polymer surface, and results in changes to molecular weight, loss of tensile strength, changes in crystallinity, reduced durability, embrittlement, changes in color and cracking (Arkatkar *et al*. 2009). Thermal degradation of polyolefins at temperatures of 673, 773, 873 and 973 K were found to form tar-containing paraffinic structures in PP and LDPE, while aromatic structures were produced by pyrolysis of polyethylene terephthalate (PET) (Zhou *et al*. 2020). Typically chemical degradation processes are oxidation and hydrolysis leading to a reduction in the molecular weight and degree of polymerization of the polymer (Lucas *et al*. 2008). Oxidation processes can be photo or thermally induced and are considered important, especially for non-hydrolyzable materials such as PE (Rutkowska *et al*. 2002). The introduction of O_2 into the polymer matrix leads to the formation of OH and CO functional groups, which aid subsequent breakdown by biotic processes. The presence of O_3 in the atmosphere, even in small concentrations, accelerates the ageing process of PBMs, because O_3 attacks covalent bonds to produce cross-linking reactions and/or chain scissions producing free radicals (Bernhard *et al*. 2008). The rate of hydrolysis is dependent on the presence of hydrolyzable covalent bonds in the polymer (Lucas *et al*. 2008). PBMs with these functionalities are able to absorb moisture which then promotes hydrolytic cleavage of the polymer chain. Hydrolytic degradation occurs when positively charged hydrogen ions in acidic or negatively charged hydrogen ions in alkaline media attack the ester linkage, thus breaking the polyester chain (Zhou *et al.* 2020). Biological processes involved in PBM disintegration start outside the microbial cell, with the secretion of extracellular enzymes (Singh and Sharma 2008). These enzymes are too large to penetrate deep into the polymer, so act on the surface by cleaving the polymer chain via hydrolytic mechanisms. Biological processes are further enhanced by the formation of the utilizable functional groups in the polymer chain (Zhou *et al*. 2020).

Impacts of PBMs pollution on environment and human

Once the PBMs enter the environment they have the potential to mimic natural food sources (Table 3). Researchers identified 135 species of marine vertebrates and 8 species of invertebrates that are susceptible to entanglement; and 111 species of seabirds that are known to ingest PBMs. Researchers also reported PBM packing loops as a threat to sea lions in California and fur seals in Australia. Petry *et al*. (2009) identified PBMs in 77% of the stomachs of Cory's Shearwater, *Calonectris diomedea*, a pelagic seabird that winters in the waters off the state of Rio Grande do Sul in Southern Brazil.

Entanglement and ingestion of PBMs in the terrestrial environment is not as well documented in the literature as it is in the marine environment; however, livestock are known to consume PBMs. In a recent study, PBMs were identified as the dominant foreign item consumed by livestock (Andrady and Neal 2009). The ingestion by a variety of organisms of micro size PBM particles has been reported (Table 3). Thompson *et al*. (2004) exposed amphipods (detritivores), lugworms (deposit feeders), and barnacles (filter feeders) to microscopic plastic particles and found all three species ingested them within a few days. Barnes *et al*. (2009) found microscopic polystyrene fragments (2 μm in diameter) were ingested by the mussel *Mytilus edulis* under laboratory conditions; these particles were then translocated from the gut to the circulatory system. Researchers have suggested that ingesting PBM particles could present a potential physical hazard leading to the following effects: intestinal blockage in fish, hindering formation of fat deposits, blocking gastric enzyme secretion, feeding stimulus diminution, lowering steroid hormone levels, and delaying ovulation that may cause reproductive failure (Ryan *et al*. 2009).

Table 3. Potential impacts produced during the degradation of PBMs

PBMs	Behavioral effects	Morphological effects	Reproductive effects
Macro Meso	Blockage of digestive tract and internal injury; diminish food consumption and loss of vigor; starvation	Intestinal blockage; hinders fat formation; blocks gastric enzyme secretion; lowers steroid hormone levels; diminishes feeding stimulus	Delayed ovulation
Micro Nano	Mobility effects; reduced vigor		
Sub-lethal Lethal		Increase/ decrease in heart rate; induced malformation; neurotoxicity; pericardial edema	Inhibition of growth; delay in maturity

The Ingestion of PBMs could provide a novel route of expose for chemicals that adsorb to the PBM surface. Persistent organic pollutants (POPs) have been shown to biomagnify in food webs, mimic natural hormones to cause reproductive disorders, and possibly increase the risk of disease. If the PBMs are taken up by organisms, the polymer-associated chemicals would also be transported into the organisms, possibly leaching into tissues and leading to long-term toxicity issues. Since then, polymer particles have increasingly been investigated as a vector for hydrophobic contaminants to enter the food-web (Abdullah *et al*. 2023). Mato *et al*. (2001) found that PE and PP pellets (1–5 mm diameter) accumulated polychlorinated biphenyls (PCBs) at concentrations up to 106 times that of the surrounding environment, while Liang *et al*. (2021) found a positive correlation between ingested PBMs and PCB concentration in seabirds, indicating transfer of these contaminants to the organisms. It has recently been suggested that sorption behaviour of POPs to polymer surfaces is driven by polymer characteristics such as polymer type and density (Abdullah *et al*. 2023). In their study, authors found LDPE had higher diffusion coefficients than did HDPE, meaning shorter equilibrium times for low density polymers. The knowledge that chemical contaminants adsorb to PBMs creates the potential for novel uptake exposure routes, with the potential for indirect effects on PBM debris consumption.

It has been emphasized that PBMs may provide a substrate for fouling organisms to be transported long distances, thereby contributing to species dispersal (Lozano and Rillig 2020). Barnes *et al*. (2009) reported sightings of an exotic species of barnacle, *Elminius modestus*, on debris in the northern Pacific. However, Majer *et al*. (2012) do highlight temperature as a limiting factor with the geographical range of this species, as low water temperatures would prevent their full development.

The PBMs can impact human health at every stage of the plastic lifecycle through exposure to PBMs themselves and/ or associated chemicals. Over 170 chemicals that are used to produce the main feedstocks for PBMs have known human health impacts, including cancer, neurological, reproductive, and developmental toxicity and impairment of the immune system. These toxins exert documented impacts on skin, eyes, nervous, liver and brain (Lee *et al.* 2023). Production of PBMs releases carcinogenic substances into the environment eventually entering human bodies through ingestion and/or inhalation. Effects of exposure to these substances include impairment of the nervous system, chronic inflammation, cancer, leukemia, endocrine-disrupting, reproductive and developmental problems (Zhao *et al.* 2021, Lee *et al.* 2023).

Conclusions

Polymer-based materials (PBMs) can be released into the environment form a variety of sources. The principal introduction routes being general littering, dumping of

waste materials, migration from landfills and emission during refuse collection. Once in the environment, PBMs are primarily broken down by photodegradation processes, but due to the complex chemical makeup of PBMs, receiving environments are potentially exposed to a mixture of different sized polymer fragments, leached additives and subsequent degradation products. The majority of literature to date that has addressed the environmental contamination of PBMs has focused on the marine environment. This is because the oceans are identified as the major sink for macro PBMs, where they are known to present a hazard to wildlife via entanglement and ingestion. The published literature establishes the occurrence of microplastics in marine environment and beach sediments, but is inadequate as regards contamination of soils and freshwater sediments. There is currently a need to establish appropriate degradation test strategies consistent with realistic environmental conditions to evaluate the impacts of PBMs in soil and freshwater environments.

References

Abdullah AM, Tofan AEP, Indiah RD and Monsur A. 2023. Microplastics in human food chains: Food becoming a threat to health safety. Science of The Total Environment, *858*: 15-26.

Al-Salem SM. 2009. Influence of natural and accelerated weathering on various formulations of linear low density polyethylene (LLDPE) films. Mater Design, *30*: 1729-1736.

Ana CR, Maria CM, Norma T, Monica A and Andres HA. 2023. Microplastic levels on sandy beaches: Are the effects of tourism and coastal recreation really important? Chemosphere, *316*: 10-16.

Andrady AL and Neal MA. 2009. Applications and societal benefits of plastics. Philosophical Transactions of the Royal Society: Biological Science, *364*: 1977-1984.

Arkatkar A, Arutchelvi J, Bhaduri S, Uppara PV and Doble M. 2009. Degradation of unpretreated and thermally pretreated polypropylene by soil consortia. International Biodeterioration and Biodegradation, *63*: 106-111.

Barnes DKA, Galgani F, Thompson RC and Barlaz M. 2009. Environmental accu philosophical transactions of the royal society: Biological Science*, 364*: 1985-1998.

Bernhard M, Eubeler JP, Zok S and Knepper TP. 2008. Aerobic biodegradation of polyethylene glycols of different molecular weights in wastewater and seawater. Water Research, *42*: 4791-4801.

Borrelle SB, Ringma J, Law KL, Monnahan CC, Lebreton L, Mcgivern A, Murphy, E, Jambeck J, Leonard GH, Hilleary MA, Eriksen M, Possingham HP, Frond HD, Gerber LR, Polidoro B, Tahir A, Bernard M, Mallos N, Barnes M and Rochman CM. 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science, *369*: 501-510.

Cierjacks A, Behr F and Kowarik. 2012. Operational performance indicators for litter management at festivals in semi-natural landscapes. Ecological Indicators, *13*: 328-337.

Dehaut A, Cassone, AL, Frere L, Hermabessiere L, Himber C and Paul-Pont I. 2016. Microplastics in seafood: benchmark protocol for their extraction and characterization. Environmental Pollution, *215*: 223-233.

Derraik JGB. 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, *44*: 842-852.

Ding L, Mao R, Ma S, Guo X and Zhu L. 2020. High temperature depended on the ageing mechanism of microplastics under different environmental conditions and its effect on the distribution of organic pollutants. Water Research, *174*: 191-196.

Duis K and Coors A. 2016. Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environmental *Sciences* Europe*, 28*: 12-30.

Erren T, Zeuss D, Steffany F and Meyer-Rochow B. 2009. Increase of wildlife cancer: an echo of plastic pollution? Nature Reviews Cancer, *9*: 842.

Gaurav M, Haripada B, Pramod KB and Veena C. 2014. Mechanical and morphological properties of high density polyethylene and polylactide blends. Journal of Polymer Engineering, *34*: 813-821.

Hammer J, Kraak MHS and Parsons JR. 2012. Plastics in the environment: the dark side of a modern gift. Reviews of Environmental Contamination and Toxicology, *220*: 1-44.

Kapanen A, Schettini E, Vox G and Itavaara M. 2008. Performance and environmental impact of biodegradable films in agriculture: a field study on protected cultivation. Journal of Polymers and the Environment, *16*: 109-122.

Kurkcu P, Andena L and Pavan A. 2012. An experimental investigation of the scratch behaviour of polymers: influence of rate dependent bulk mechanical properties. Wear, *290*: 86-93.

Lee Y, Jaelim C, Jungwoo S and Changsoo K. 2023. Health Effects of Microplastic Exposures: Current Issues and Perspectives in South Korea. Yonsei Medical Journal, *64*: 301-308.

Liang Y, Lehmann A, Yang G and Rillig MC. 2021. Effects of microplastic fibers on soil aggregation and enzyme activities are organic matter dependent. Frontiers in Environmental Science, *9*: 1-11.

Lozano YM and Rillig MC. 2020. Effects of microplastic fibers and drought on plant communities. Environmental Science and Technology, *54*: 6166-6173.

Lucas N, Bienaime C, Belloy C, Queneudec M, Silvestre F and Nava-Saucedo JE. 2008. Polymer biodegradation: mechanisms and estimation techniques. Chemosphere, *73*: 429-442.

Mao R, Lang M, Yu X, Wu R, Yang X and Guo X. 2020. Aging mechanism of microplastics with UV irradiation and its effects on the adsorption of heavy metals. Journal of Hazardous Materials. *393*: 501-515.

Martinho SD, Fernandes VC and Delerue-Matos C. 2022. Microplastic pollution focused on sources, distribution, contaminant interactions, analytical methods, and wastewater removal strategies: a review. International Journal of Environmental Research and Public Health, *19*: 1-24.

Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C and Kaminuma T. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environmental Science and Technology, *35*: 318-324.

Moore CJ. 2018. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. Environmental Research, *108*: 131-139.

Oehlmann J, Schulte-Oehlmann U, Kloas W, Jagnytsch O, Lutz I, Kusk KO, Wollenberger L, Santos EM, Paull GC, Van Look KJW and Tyler CR. 2009. A critical analysis of the biological impacts of plasticizers on wildlife. Philosophical Transactions of the Royal Society: Biological Science, *364*: 2047-2062.

Orhan Y and Buyukgungor H. 2000. Enhancement of biodegradability of disposable polyethylene in controlled biological soil. International Biodeterioration and Biodegradation, *45*: 49-55.

Petry MV, Kruger L, Fonseca VSD, Brummelhaus J and Piuco RD. 2009. Diet and ingestion of synthetics by Cory's Shearwater Calonectris diomedea off southern Brazil. Journal of Ornithology, *150*: 601-606.

Plastics Europe. 2021. Plastics – the facts 2021: an analysis of European plastics production, demand and waste data. Plastics Europe, Belgium.

Richardson AJ, Walne AW, John AWG, Jonas TD, Lindley JA, Sims DW, Stevens D and Witt M. 2006. Using continuous plankton recorder data. Progress in Oceanography, *68*: 27-74.

Rutkowska M, Heimowska A, Krasowska K and Janik H. 2002. Biodegradability of polyethylene starch blends in sea water. Polish Journal of Environmental Studies, *11*: 267-271.

Ryan PG, Moore CJ, van Franeker JA and Moloney CL. 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society: Biological Science, *364*: 1999-2012.

Singh B and Sharma N. 2008. Mechanistic implications of plastic degradation. Polymer Degradation and Stability, *93*: 561-584.

Sudhakar M, Trishul A, Doble M, Kumar KS, Jahan SS, Inbakandan D, Viduthalai RR, Umadevi VR, Murthy PS and Venkatesan R. 2007. Biofouling and biodegradation of polyolefins in ocean waters. Polymer Degradation and Stability, *92*: 1743-1752.

Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AWG, McGonigle D and Russell AE. 2004. Lost at sea: where is all the plastic? Science, *304*: 838.

Yu H, Ying Z, Tan W and Zhang Z. 2022. Microplastics as an emerging environmental pollutant in agricultural soils: effects on ecosystems and human health. Frontiers in Environmental Science, *6*: 1-18.

Zhao T, Lozano YM and Rillig MC. 2021. Microplastics increase soil pH and decrease microbial activities as a function of microplastic shape, polymer type, and exposure time. Frontiers *in* Environmental Science, *9*: 67-74.

Zhou Y, Yang Y, Liu G, He G and Liu W. 2020. Adsorption mechanism of cadmium on microplastics and their desorption behavior in sediment and gut environments: the roles of water pH lead ions, natural organic matter and phenanthrene. Water Research, *184*: 1-14.