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Seasonal infestation of mango leaf cutting weevil and its response to some weed extracts

Md. Masum Al Helal, Md. Adnan Al Bachchu*, Hasan Fuad El Taj, Most. Zannatul Ferdushe Shilpi
Md. Harun-Ur-Rashid

Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh

Corresponding email: adnan@hstu.ac.bd

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Abstract

The seasonal abundance of mango leaf cutting weevil (*Deporaus marginatus* Pascoe) was studied on nine varieties of mango viz. Amropali, Harivanga, Mallika, Surjapuri, Gopalvog, Langra, Fazli, Ashwina and Guti during October 2016 to September 2017 in the orchard of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. In this study toxicity of some weed extracts namely black nightshade, wild tobacco, leucas, lantana, goatweed and raan tulas were evaluated on the weevil. Results showed that the highest percentage of infestation was found in Surjapuri (average 52.6%), and the lowest in Ashwina (average 33.4%). In regards to month, maximum infestation was found in August (77.5%) at surjapuri and minimum was in February (7.9%) at Mallika. No infestation was observed on the mango leaves during December and January. The highest toxicity effect (average mortality 78.3 %) was found in rann tulas at 5.0 % concentration, whereas black nightshade showed the lowest toxicity effect (average mortality 10.8 %) at 1.25 % concentration. On the basis of mortality, the order of toxicity of the plant extracts were found rann tulas > wild tobacco > lantana > goat weed > leucas > black nightshade. Adult's mortality were directly proportional to different concentration levels and hours after treatments (HAT). The lowest LD₅₀ values (3.3, 2.3 and 1.8 mg/ml at 24, 48 and 72 HAT) of rann tulas indicated its highest toxicity effects against *D. marginatus*. The present study revealed that synthetic pesticides can be replaced with botanicals for the management of *D. marginatus* in order to save the environment.

Keywords: *Deporaus marginatus*, damage incidence, weed extracts, toxicity, LD₅₀

Introduction

Mango is widely cultivated in the tropical and subtropical countries like India, Pakistan, Mexico, Brazil, China, Haiti, Philippines and Bangladesh (Alexander 1989). A large number of superior varieties of mangos are grown in Bangladesh and are wide demand in the market which is commercially important. Presently, mango cultivable land has increased of the country about an area of 306274.32 acres with a production of 1482937.04 m. tons and is now an increasing trend in area (BBS 2023). But the production of mango is hindered by various abiotic and biotic factors like insect pests, mites, diseases etc.

Mango leaf cutting weevil is considered as a important pest (Hill 1983) which cause extensive damage to the foliage (Amin 2020). Once upon a time it was treated as a minor pest but recently it turned into major pest. Mostly young trees (2 to 5 years old) suffer more than the older one. The female makes small cavities on either side of the midribs on upper surface of tender pinkish leaves which

are then cut by the weevils near the base. The damage to some mangoes by leaf cutting weevil was reported 23.9% to 57.4% defoliation (Rafiquzzaman *et al.* 1999) and cause damage as much as 53% on grafted plants (Uddin *et al.* 2003). By the attack of mango leaf cutting weevils, ultimate result of delay growth of root stock and poor success of new grafts as well as failure of fruit setting and therefore on the yield (Singh 2014).

However, to develop an integrated pest management program of *D. marginatus*, in-depth understanding and knowledge of the infestation rate and incidence caused by the pest is a prerequisite. Despite many extensive studies on the seasonal infestation and incidence of different mango variety in regards to Bangladesh are reported but detail information on temperature dependent development and infestation caused by *D. marginatus* is surprisingly limited and maximum data were not in a useful for the modelling of management purposes. On the other hand, it is vital to understand the seasonal infestation and incidence in respect of time on various mango varieties despite its

economic importance and worldwide distribution an eco-friendly and suitable management is utmost necessary.

Pesticide application is a recommended control practice of mango leaf cutting weevil when young leaves become 3 cm wide (Singh 2014). However, the use of synthetic insecticide is not environmentally safe for animal and beneficial insects. When it is used in heavy amount accumulation of residues in the harvested produce becomes hazardous (Prakash *et al.* 2008). Botanical pesticides have long been practiced as effective alternatives to synthetic insecticides as green pesticide for mango leaf cutting weevil, because it have low toxicity and low persistence in environment, biodegradable, nontoxic to animals and humans but have moderate effect on insect due to multiple modes of action (Koul *et al.* 2008, Gurjar *et al.* 2012). In the context of biochemical studies of Black nightshade (*Solanum elaeagnifolium*) it was found a secondary metabolite which has insecticidal activity and toxic alkaloids (Mkula 2006). Various types of compounds including alkaloids, coumarins, flavonoids, chromenes, benzofurans, sterols and terpenoids etc. are found in Goat weed (*Ageratum conyzoides*) which have pharmacological and insecticidal activities (Kamboj and Saluja 2008). *Solanum nigrum* contain flavonoids which is used in commercial crops to manage many agricultural pests like thrips (*Frankliniella occidentalis*) mite (*T. urticae*), aphid (*Shizaphis graminum*) etc. (Muthuvel *et al.* 2014). Therefore, the present study was designed primarily to find out the leaf infestation and seasonal incidence of *D. marginatus* on different mango varieties different month of the year. As a part of management program, attempt was also made to find out the toxicity effect of six weed extracts based on adult mortality of *D. marginatus*.

Materials and methods

Variety selection and experimental design: Nine mango varieties viz. Amrapali, Harivanga, Mallika, Surjapuri, Gopalvog, Langra, Fazli, Ashwina and Guti were selected to estimate the seasonal infestation and damage incidence by mango leaf cutting weevil. The experiment was designed in randomly completely block design (RCBD) with three replications. Therefore, the total number of plants was 27. For taking data, five new twigs were tagged randomly from each mango plant.

Rearing of of the weevil: Freshly infested fallen leaves of mango were collected under the mango trees of HSTU campus. The infested leaves were then placed on Petri dish (150 ml) containing moist soil and kept them in the laboratory (25 - 32°C and 85 - 90 % RH). After emerging the adults, they were released in big plastic pot / chamber (40 cm) and newly flushed twigs of mango were supplied as food for *D. marginatus* during that period. This process was continued until the experimental requirements.

Collection and preparation of weed extracts: The leaves of tested weeds namely, Black nightshade (Tit begun)–*Solanum nigrum*, Wild tobacco (Bon tamak)–*Nicotiana plumbaginifolia*, Leucas (Shethdru)–*Leucus aspera*, Lantana–(*Lantana camara*), Goat weed (Saglagacha)–*Ageratum conyzoides* and Raan tulas (Ban marich)–*Croton sparsiflorus* were collected from campus and the surrounding area of HSTU, Dinajpur. After collection, they were kept in laboratory for air-drying and after dried they were made powder separately by electric grinder and passed through the sieve (60 mm meshes) to get fine powder. For extracts preparation, 100 g of each category of powder was separately mixed with 300 ml of solvents (methanol). The mixture stirred for 30 minutes and left stand for next 72 hours with shaking several intervals in mechanical shakers. After that, the mixture was filtered through Whatman no.1 filter paper. The filtrates were taken into round bottom 100 mm flasks and condensed by evaporator at 70°C temperature to make it crude extract. Then the extracts were preserved in refrigerator for further experimental use.

Experimental protocol and bioassay of test insect: Newly flushed 5 twigs of each mango variety were selected and tagged for observing the seasonal infestation and damage incidence of mango leaf cutting weevil. The injured with cut leaves were counted from each selected twigs. The infestation was observed on only newly flushed twigs emerged in every month of study period. Before bioassay test, 3 concentrations (1.25, 2.5 and 5.0%) along with control were prepared from the crude extracts with methanol solvent. Pilot experiment was done to obtain the appropriate dose prior to conducting study. Newly flushed leaf twigs of Amrapali mango variety were collected and the base of the leaf twigs was kept in the water containing bottle to retain it fresh. The bottles with leaf twigs were

kept in different plastic containers (30 cm × 26 cm). Each weed extract was diluted with respective solvent to make the desired doses. The leaf twigs were sprayed with the weed extracts using hand sprayers. After spraying, the leaf twigs were dried by electric fan or air at shading condition for 20 minutes to avoid wet condition. Spray with only solvent was maintained for the control treatment. Each weed extract with each concentration was considered as one treatment and three replications were maintained for each treatment. Three days old, 10 adult weevils were randomly selected from the mass culture and released inside the plastic container for each replication.

Data collection: The number of cut leaves and uncut leaves were counted in each month. The percent infestation was calculated with the following formula:

% Leaf infestation = Number of cut leaf / Total number of leaf (number of cut leaf + number of uncut leaf) × 100.

Adult mortality was recorded at 24, 48, and 72 and 96 hours after treatments (HAT) and mortality percent was calculated by Abbott's formula (Abbott 1987).

$$P = \frac{p' - C}{100 - C} \times 100$$

Where,

P = Percentage of corrected mortality

P' = Observed mortality (%)

C = Mortality (%) at control.

Statistical analysis: The collected data for insect mortality rates were statistically analyzed by analysis of variance followed by Duncan's New Multiple Range Test (DMRT). The observed mortality data were also subjected to probit analysis.

Results and discussion

The monthly infestation of leaf caused by *D. marginatus* in tested mango varieties is shown in figure 1. The percentage of leaf infestation differed significantly from variety to variety. It was observed that all the varieties were infested by mango leaf cutting weevil (figure 1). Our results are in general agreement with reported by Rafiquzzaman *et al.* 1999 and Uddin *et al.* 2003. Rafiquzzaman *et al.* (1999) carried out an experiment with 10 mango varieties and reported that all of them are susceptible to mango leaf cutting weevil, with Amropali

as the most prone variety having 53.9% leaf infestation. Uddin *et al.* (2003) also conducted an experiment with 12 mango cultivars and observed that all cultivars are susceptible to *D. marginatus*. This infestation difference could be related to cultivar specific traits.

Significant difference were observed among different mango varieties from month to month ($df = 9$, $F = 291.8$, $P < 0.01$). The highest infestation of leaf was found in the month of August (63.9%) and the lowest was observed in February (11.1%) in Amropali. The infestation caused by *D. marginatus* in the variety of Harivanga were 38.48%, 27.85%, 9.2%, 45.4%, 54.3%, 56.4%, 62.3%, 72.3%, 72.8%, 57.0% for the month of October, November, February, March, April, May, June, July, August, September, respectively. Maximum infestation of leaf of Mallika variety was recorded in the month of August (75.6 %) and minimum was in February (7.9 %). In Surjapuri variety, the percentage of leaf infestation in the months of March, April, May, June, July, September and October were 45.8%, 58.9%, 65.5%, 66.9%, 72.2%, 51.4%, 41.7%, respectively and the highest was recorded in August (77.4%) as well as the lowest in February (28.2%). The Gopalvog variety showed the highest leaf infestation in the month of July (62.8%) and the lowest in the month of February (22.3 %). The mango leaf cutting weevil infested the highest percentage of leaf in July (59.4%) and the lowest in the month of February (15.3%) in Langra variety. Maximum percentage of leaf infested by *D. marginatus* was recorded in the month of August (54.3 and 49.8%) whereas minimum was perceived in February (12.5 and 9.7%) in Fazli and Ashwina variety, respectively. In Gutti variety, the highest infestation was observed in the month of June (53.6%) and the lowest was in February (18.8%).

From the results of current study, it is clear that the leaves of all tested mango varieties were infested by mango leaf-cutting weevil. The weevil attacked newly flushed of pink leaves of mango from the month of February to November. The data also indicated that there were variations of leaf damage in different months. The infestation gradually increased from the initial attack in February and reached peak in August, which was statistically identical to June and July. It indicate that from April to August month mango leaf cutting weevil was more active and maximum infestation to mango plants ranging from

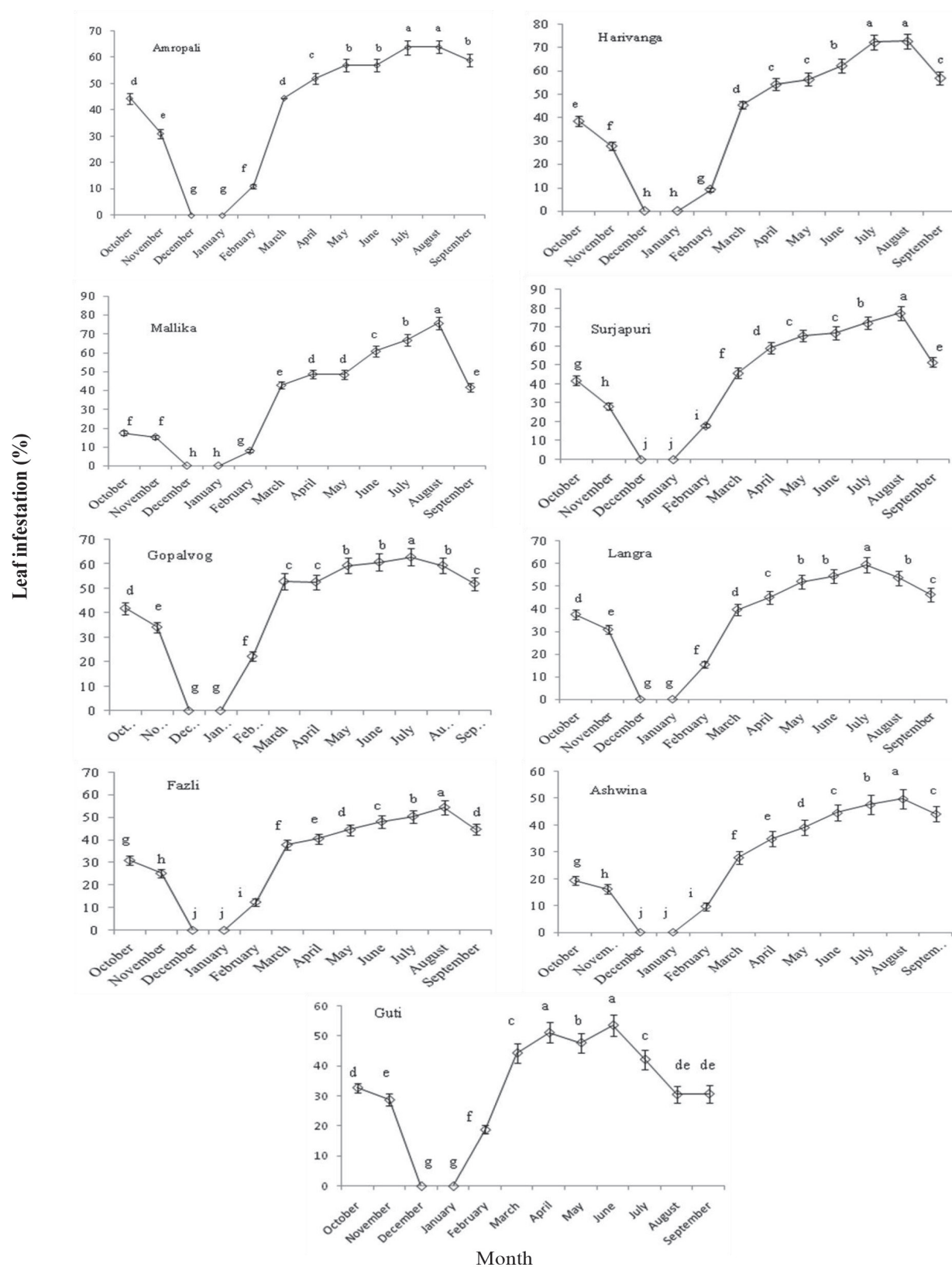


Figure 1. Monthly infestation of leaf (%) by *D. marginatus* in different mango varieties.

34.9 to 77.5 percent. It was gradually decrease from the month of September to November and no infestation was observed on the leaves of all tested mango varieties during December and January. Uddin *et al.* (2012) reported that there was no leaf damage occurred by *D. marginatus* in the months of December, January and February. The persistence of incidence of the pest species reported by Bhole *et al.* (1987) under field condition was up to October and peak incidence in July to October. Rafiquzzaman and Maiti (1999) reported that the leaf damage on mangoes was peak during July-August and least during the second fortnight of November followed by no activity during winter period of December –January. If the new flush is not available then there is no chance to damage in these months because *D. marginatus* only damage to new young leaves. The infestation percentage was extreme during the months of July and August in all tested mango varieties. It was observed that new leaves of mango trees gradually started to flush from February and it was excessive in the months of July and August. The weather data also showed the maximum temperature and rainfall occurred in this two months. So, there was a relationship in between the new leaves and rainfall with temperature. Probably this is the important reason to infest heavily by mango leaf cutting weevil during the month of July and August. The

incidence of the insect might be related to the prevailing temperature, relative humidity and rainfall, which was recorded lowest in the winter month as recorded 4.4-36.6°C; 58-99%; 0-647 mm, respectively.

Toxicity effects of six weed extracts and their doses at different time intervals against the adult of *D. marginatus* are presented in Table 1. The mortality of the adult insects were not differed significantly among all the weed extracts applied but differed significantly ($df=5$, $F=20.2$, $P<0.05$) from the control treatment at 24 hours after treatments (HAT). However, adult mortality was dissimilar among the treatment at 48, 72 and 96 HAT and percentage of mortality was increased with the increased of time. The mortality percentage of *D. marginatus* at different HAT revealed that Rann tulas weed extract showed the highest (average mortality, 39.2%) and Black nightshade weed extract indicated the lowest (average mortality, 30.6%) toxic effect (Table 1). It was also found that mortality percentages were increased proportionally with the time intervals. On the basis of insect mortality, the order of the toxic effect of six weed extracts against mango leaf cutting weevil were Rann tulas > Wild tobacco > Lantana > Goat weed > Leucas > Black nightshade. Mortality of mango leaf cutting weevil was differed significantly ($P<0.05$)

Table 1. Toxicity effect of different indigenous weed extracts and doses against the adults of mango leaf cutting weevil at different hours after treatment

Weed extracts used	Insect mortality (%) in different time interval				Average mortality (%)
	24 HAT	48 HAT	72 HAT	96 HAT	
Wild tobacco	20.0 a	30.8 b	45.8 ab	53.3 a	37.5 ab
Rann tulas	20.8 a	39.2 a	6.7 a	50.0 ab	39.2 a
Black nightshade	19.2 a	30.8 b	35.0 c	37.5 c	30.6 c
Leucas	19.2 a	28.3 b	37.5 bc	47.5 b	33.1 bc
Goat weed	19.2 a	31.7 b	40.0 abc	46.7 b	34.4 abc
Lantana	21.7 a	33.3 ab	35.8 c	48.3 ab	34.8 abc
Control	0.0 b	0.0 c	0.0 d	0.0 d	0.0 d
LSD	4.8	6.5	8.4	5.3	4.8
CV %	34.3	28.9	29.7	15.9	19.8
Doses used (%)					
5.00	39.5 a	54.8 a	66.2 a	78.6 a	59.8 a
2.50	22.4 b	43.3 b	52.4 b	58.6 b	44.2 b
1.25	6.7 c	12.9 c	19.1 c	24.8 c	15.8 c
Control	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d
LSD	3.6	4.9	6.3	3.9	3.6
CV %	34.3	28.9	29.7	15.9	19.7

Within column, values followed by different letter(s) are significantly different at 5% level probability by DMRT.

among all the concentration levels at different time interval of different weed extracts. The highest mortality (59.8%) was found at the maximum concentration (5.0mg/L) of weed extract. On the other hand, the lowest mortality (15.8%) was found at the minimum concentration (1.25mg/L) of weed extract. No mortality was observed in control treatment up to 96 HAT. The combined effect of weed extracts, their doses and different time intervals are shown in Table 2. The average percentage of adult mortality at 24, 48, 72 and 96 HAT indicated that the highest toxic effect observed on the extract of Rann tulas (78.3%) followed by Goat weed (74.2%), Wild tobacco (72.5%) and Lantana (69.2 %) at highest dose (5 mg/l) which was statistically identical whereas Black nightshade possessed the lowest toxic effect (10.8 %) at the minimum dose (1.25 mg/L) followed by Leucas (15.0%) whose are statistically identical.

From the above findings it was observed that all weed extract showed toxic effect against the adult mango leaf cutting weevil but Rann tulas was the most toxic. Ramar

et al. (2015) reported that Rann tulas with hexane extract caused 100 and 89 % mortality of larvae and pupae of *Culex quinquefasciatus* respectively, after 24 hours exposure under laboratory conditions.

The probit analysis was performed for the estimation of LD_{50} values, chi-square values and their 95% fiducially limits at 24, 48, 72 and 96 HAT using six weed with methanol solvent for the mortality of mango leaf cutting weevil are presented in Table 3. The LD_{50} values of wild tobacco (5.9 mg/ml), rann tulas (3.3 mg/ml), black nightshade (6.7 mg/ml), leucas (4.9 mg/ml), goat weed (5.4 mg/ml) and lantana (4.8 mg/ml) at 24 HAT revealed that rann tulas extract showed the highest toxic effect followed by the lantana weed extract. On the other hand, the highest LD_{50} values of black nightshade indicated the lowest toxic effect among all the weed extracts applied. The LD_{50} values of wild tobacco, rann tulas, black nightshade, leucas, goat weed and lantana weed extracts were 3.4, 2.3, 3.3, 3.6, 3.0 and 3.1 mg / ml, respectively at 48 HAT also indicated that rann tulas showed the highest

Table 2. Interaction effect of different indigenous weed extracts and doses against the adults of mango leaf cutting weevil at different hours after treatment

Weed extracts used	Doses used (%)	Insect mortality (%) in different time interval				Average mortality (%)
		24 HAT	48 HAT	72 HAT	96 HAT	
Wild tobacco	5.00	43.3 a	56.7 bc	90.0 a	100.0 a	72.5 a
	2.50	26.7 b	50.0 c	70.0 bcd	80.0 bc	56.7 b
	1.25	10.0 c	16.7 de	23.3 ef	33.3 f	20.8 cd
Rann tulas	5.00	46.7 a	73.3 a	93.3 a	100.0 a	78.3 a
	2.50	30.0 b	56.7 bc	66.7 cd	73.3 cd	56.7 b
	1.25	10.0 c	23.3 d	33.3 e	36.7 f	25.8 c
Black nightshade	5.00	43.3 a	53.3 bc	60.0 cd	66.7 de	55.8 b
	2.50	23.3 b	53.3 bc	56.7 d	56.7 e	47.5 b
	1.25	6.7 c	6.6 ef	10.0 fg	20.0 g	10.8 d
Leucas	5.00	46.7 a	56.7 bc	76.7 abc	93.3 a	68.3 a
	2.50	30.0 b	46.7 c	53.3 d	66.7 de	49.2 b
	1.25	0.0 c	10.0 def	20.0 ef	30.0 fg	15.0 d
Goat weed	5.00	43.3a	76.7 a	86.7 ab	90.0 ab	74.2 a
	2.50	23.3 b	46.7 c	56.7 d	66.7 de	48.3 b
	1.25	10.0 c	16.7 de	23.3 ef	26.7 fg	19.2 cd
Lantana	5.00	53.3 a	66.7 ab	56.7 d	100.0 a	69.2 a
	2.50	23.3 b	50.0 c	63.3 cd	66.7 de	50.8 b
	1.25	10.0 c	16.7 de	23.3 ef	26.7 fg	19.2 cd
Control		0.0 c	0.0 f	0.0 g	0.0 h	0.0 e
LSD		9.6	13.1	16.7	10.6	9.7
CV %		34.3	28.9	29.7	15.9	19.7

Within column, values followed by different letter(s) are significantly different at 5% level of probability by DMRT.

Table 3. Relative toxicity (Probit analysis) of different weed extracts treated against the adult of mango leaf cutting weevil after 24, 48, 72 and 96 hours after treatment

Weed extracts used	No. of insect used	LD ₅₀ (mg/ml)	95% fiducial limits		values with 1 df
			Lower	Upper	
24HAT					
Wild tobacco	30	5.9	3.2	11.0	0.1
Rann Tulas	30	3.3	2.2	4.8	1.1
Black Nightshade	30	6.7	3.0	14.8	0.1
Leucas	30	4.9	3.4	7.0	1.7
Goat weed	30	5.4	3.4	8.5	1.1
Lantana	30	4.8	3.2	7.2	0.2
48HAT					
Wild tobacco	30	3.4	2.3	5.1	1.8
Rann Tulas	30	2.3	1.8	3.0	0.4
Black Nightshade	30	3.3	2.3	4.9	2.6
Leucas	30	3.6	2.6	5.1	2.6
Goat weed	30	3.0	2.4	3.7	1.3
Lantana	30	3.1	2.3	3.9	1.4
72HAT					
Wild tobacco	30	1.9	1.6	2.4	0.6
Rann Tulas	30	1.8	1.4	2.4	0.1
Black Nightshade	30	2.8	1.9	4.2	2.4
Leucas	30	2.5	1.9	3.2	0.2
Goat weed	30	2.3	1.9	2.7	0.0
Lantana	30	2.1	1.6	2.7	0.4
96HAT					
Wild tobacco	30	1.6	1.3	1.9	0.1
Rann Tulas	30	-	-	-	-
Black Nightshade	30	2.4	1.7	3.5	1.5
Leucas	30	1.8	1.4	2.3	0.0
Goat weed	30	-	-	-	-
Lantana	30	1.8	1.4	2.2	0.5

Values were based on three concentrations, three replications of 10 insects each. χ^2 = Goodness of fit. The tabulated value of χ^2 is 3.84 (d.f = 1 at 5% level).

and wild tobacco exhibited the lowest toxic effect against mango leaf cutting weevil. Among the six weed extracts applied rann tulas also performed the highest toxicity as compared the LD₅₀ values at 72 and 96 HAT. The chi-square values were insignificant at 5 % level of probability of different weed extracts at different HAT and mortality data did not show any heterogeneity.

From the above probit results, it was observed that all the tested weed extracts would more or less effective for controlling mango leaf cutting weevil but rann tulas leaves extract had the most effective.

Conclusion

The present study indicates the year round infestation and damage incidence of mango leaf-cutting weevil in field conditions. Surjapuri (leaf infestation 52.6%) mango variety showed the highest susceptibility to mango leaf-cutting weevil but Ashwina (leaf infestation 33.4%) showed the lowest susceptibility. Mango leaf cutting weevil damaged the new pinkish flushes of mango leaves almost round the year except the month of December and January. The percentage of leaf infestation was higher during the month of July and August. Applied all weed

extracts showed different efficacies against the adult of mango leaf cutting weevil but extract of rann tulas was the most promising to control this pest.

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Value chain and consumer acceptance analysis of different types of cooking oil in Bangladesh

Mohammad Moziball Hoque¹, Rinki Akter¹ and Md. Abdul Karim^{*2}

¹Solidaridad Network Asia, House # 32, Road 10A, Dhanmondi, Dhaka 1209, Bangladesh; ²College of Agricultural Sciences, International University of Business Agriculture and Technology, Uttara Model Town, Dhaka, Bangladesh

Corresponding email: akarim1506@gmail.com

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Abstract

The present study explored the potential of regional linkage among oil seed producers, retailers, wholesalers, crushers and consumers, with a particular focus on the production, processing and market systems in the major oilseeds production regions, like Thakurgaon, Dinajpur and Tangail districts of Bangladesh. The key stakeholders of soybean include producers (farmers), input suppliers (such as agro-dealers and corporation), assemblers, collectors, wholesalers, processors and exporters. Farmers typically get inputs, like seeds, pesticides and fertilizers from agro-dealers, corporation or fellow farmers. The oil quality is the most important factor for the majority respondents (60), while 58 consumers expressed the brand name as the key indicator of preference. Some consumers opined that both quality and brand are important in selecting cooking oil. Nearly all consumers used a combination of soybean oil and mustard oil, with a few incorporating olive oil and sunflower oil into their diets. The majority oil users consumed approximately one liter per month, followed by those used half a liter. A significant portion of the households consume up to 2 liters per month. In contrast, soybean oil consumption was significantly higher, with many households use more than 5 liters per month. About 61% of the respondents revealed the health benefits as the main reason for choosing mustard oil. Additionally, 20% of the consumers mentioned the organic nature of mustard oil as the key factor of their selection, while many noted that it enhanced the taste of food. The majority of the respondents prioritized the quality of the product above all other factors, including brand preference. While 50% of the respondents preferred to stick to a single brand, relying on the established credibility and quality of the product, the other 50% frequently switched to different brands. Price plays a significant role, as many consumers select a brand on affordability. When selecting of an oil brand, consumers prioritize company reputation. The mustard oil market varied from 270 BDT/liter to 400 BDT/liter with an average price of 285- 290 BDT/ liter during the study period in 2024. Half of the consumers thought that the mustard oil price is exorbitant to afford for the commoners.

Keywords: Value chain, retailer, consumer, wholesaler

Introduction

Edible oil is an indispensable component of balanced diet of human being. It is considered as a vital source of energy (Chowdhury *et al.* 2007). The daily recommended oil intake per person is 6 gm for a diet 2700 kcal (Islam *et al.* 2021). Oilseeds are also widely used by people for health benefits, generating income and employment opportunities. The commonly grown oilseeds in Bangladesh are rapeseed mustard, soybean, sesame, sunflower and peanut (Miah and Mondal 2017, USDA 2023). The rapeseed and mustard, collectively known as mustard, account for more than 60% of the nation's total oilseed production (Sarkar *et al.* 2020). The second main crop used to make oil in Bangladesh is soybean. It is an outstanding source of protein, isoflavones, lecithin,

and polysaccharides, as well as oil, protein, vitamins, and minerals that are necessary for human function (Islam 2019).

Mustard producers connect to value chains by gaining access to both short and long term credit, which enables them to improve production efficiency and reduce the risks associated with asset loss and financial insecurity. This financial strength made the producers competitive in the market (Shah and Devkota 2024). Dalipagic *et al.* (2014) defined value chain as the complete set of activities necessary to bring a product or service from its origin to the end customers. Though mustard and soybean are important oilseeds in Bangladesh and the cooking oil market is enormously big, study related with value chain analysis is limited. Solidaridad Network Asia

(SNA), an international development organization has been working with oilseed crops, especially soybean since 2017. SNA undertook a comprehensive study in Bangladesh to understand further the value chain mechanisms of mustard and soybean cooking oils. It is envisaged that the information will help to strengthen inter-linkages among different stakeholders of mustard oil and soybean oil.

Methodology

Study area selection and sampling technique: The study areas were selected three important oilseeds growing areas like Dinajpur (Birgonj upazilla), Tangail (Sadar upazilla), and Thakurgaon (Baliadanga upazilla; and Sadar upazilla) districts.

The study on oil seeds collection was carried out using multiple techniques including collecting primary data through survey questionnaires and conducting Key Informant Interview (KII) and Focus Group Discussions (FGD) with farmers along with a wide range of other relevant stakeholders.

Field test of the primary survey: On the first day of the field visit there was a field test conducted to assess the feasibility and accuracy of the research tools towards collecting relevant and required data. Following the tools testing necessary changes were made in the survey questionnaire.

Desk research: Desk research was carried out on a regular basis following a list of relevant documents. The policy anatomy was considered with a view to exploring the policy support provisions and challenges/policy barriers in relation to oil seeds cultivation and throughout the complete value chain. The primary aim was to explore the supportive and challenging aspects as well as scope and opportunities in relation to oilseeds production to marketing.

To address different aspects and acquire relevant knowledge and information, the participants were selected from a wide range of stakeholders' groups. For conducting K-II, a semi-structured questionnaire as a tool was used. The semi-structured format was considered keeping provision of flexibility to ask probes and more

relevant questions as when required to serve the specific purpose of conducting that particular K-II. Altogether 24 K-II and 100 FGDs were conducted.

Data collection methods: The study followed a mixed approach including both quantitative and qualitative methods. Desk research was carried out on a regular basis following a list of relevant documents. The policy anatomy was considered with a view to exploring the policy support provisions and challenges/policy barriers in relation to oilseeds cultivation to end uses.

The Research Assistants who got engaged in collecting data from the fields were trained on the tools after finalizing the survey.

Results and discussion

Mustard value chain description: Figure 1 describes that farmers in Thakurgaon and Dinajpur use mustard seeds from different companies, including some local companies like Salam Seed and Malik Seed. Most of them mentioned that they use BARI sorisha-14 variety for mustard oilseeds production. They purchase seeds from company, and seeds of Ispahani Seed Company are popular among the farmers. In Tangail Sadar the farmers collect mustard seeds from Bangladesh Agricultural Development Corporation (BADC).

After harvesting the crop, small traders known as Faria/Chatia collect the seeds from the farmers and sell it to the larger traders, referred to as Bepari/Arotiders. Occasionally, some farmers directly sell their produced crops to larger traders, though this practice is less common due to transportation issues. The regional processors, such as mustard crushing mill owners, then procure mustard from the large traders for further processing. Not only regional processors, but national level processors like Radhuni and Pran also collect mustard seeds from the Arotiders (large traders). After processing, the regional and national level traders market their packaged products to retailers under various brandings. These products then make their way to the end consumers through the retail distribution channels. Some well-known seed companies such as ACI Seeds Bangladesh, Lal Teer Seed Limited, BRAC Seed and Agro Enterprise, Supreme Seed Company Limited, Krishibid Seed Limited and Pioneer Seed Company Ltd, etc. closely involved in mustard and soybean oil market.

Major importers of mustard oil: The major mustard oil companies involved in oil production and sell are Partex Star Group, Bangladesh Edible Oil Ltd., Pran Foods Ltd., Wilmar International and City Group.

Soybean value chain description: From Figure 2 it is found that there are different actors in the soybean oil value chain, such as producers, input suppliers, assemblers, collectors, wholesalers, processors, retailers, exporters or large corporations and NGOs. The farmers produce oil seeds through purchasing inputs like seed, pesticides,

and fertilizers from agro-dealers as well as from large corporations. Sometimes smallholder farmers also take inputs from the fellow farmers. Five groups basically buy seeds from the farmers and they are enterprises, medium-scale traders, village level assemblers, large wholesalers and big companies. Big companies basically buy from farmers through contract farming with a buyback guarantee system. Small scale or village level assemblers sell the collected seeds to the large wholesalers, who sell it to the animal feed or oil processing companies. Finally the

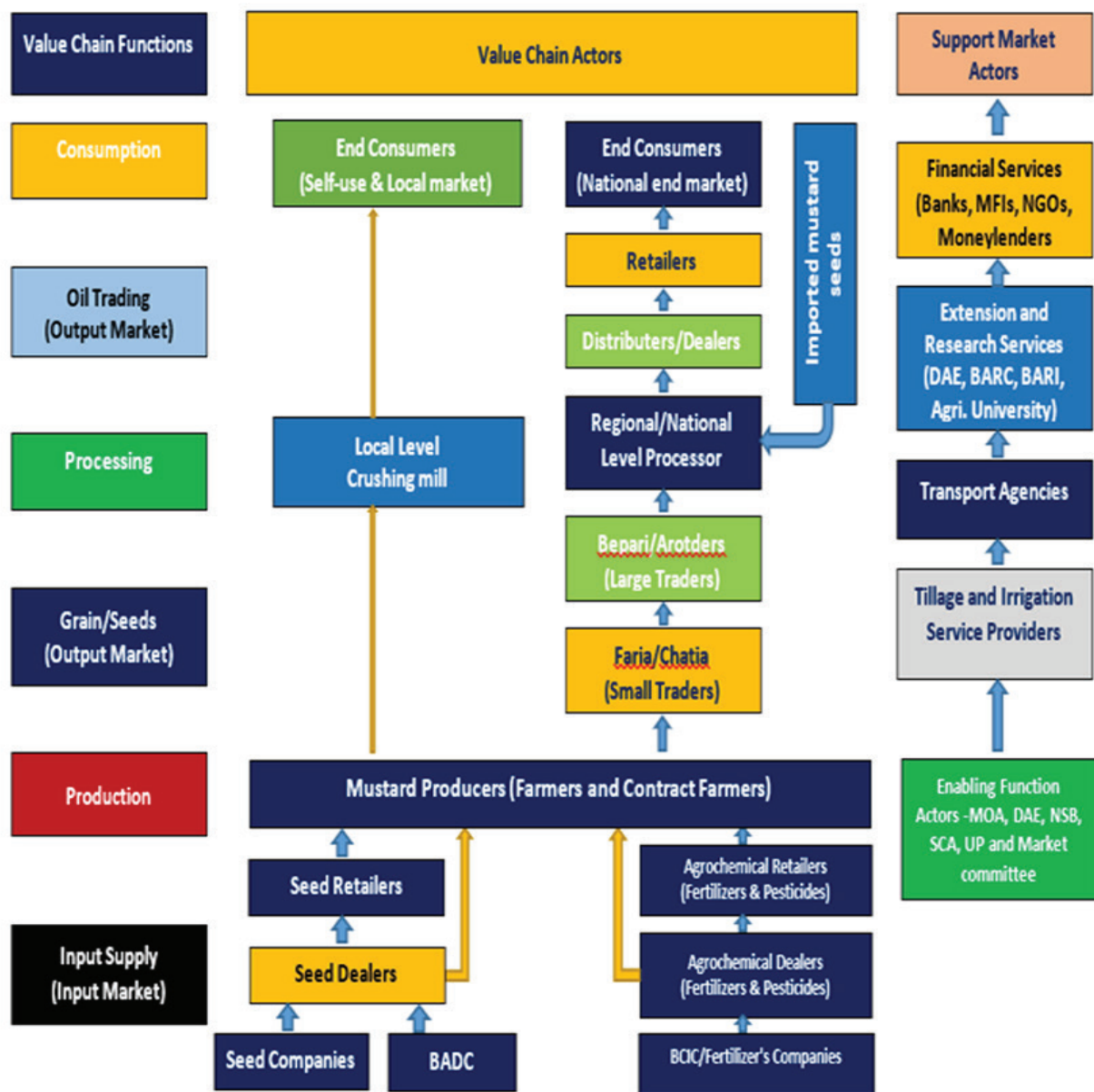


Figure 1. Schematic diagram of value chain of mustard seed in Bangladesh.

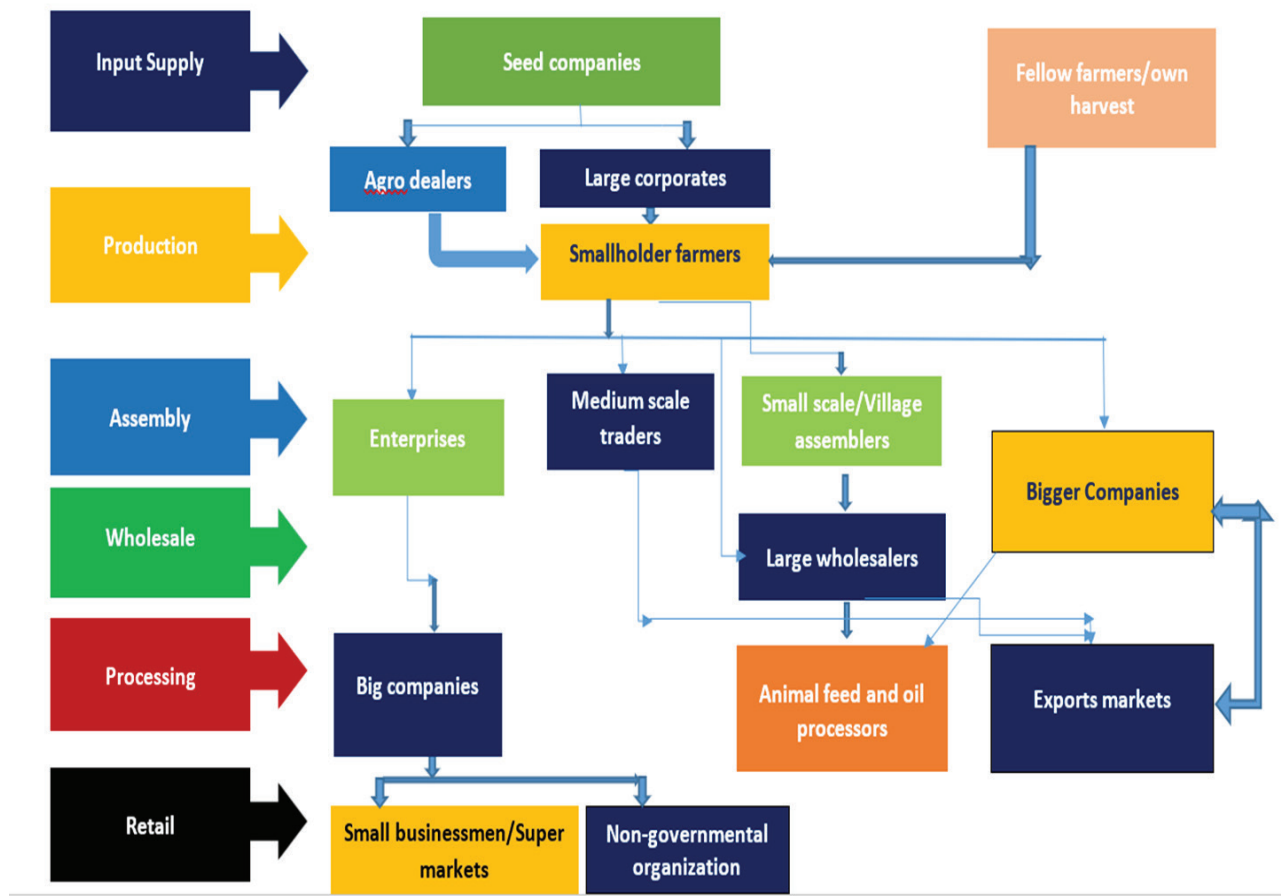


Figure 2. Schematic diagram of value chain of soybean seed in Bangladesh.

large companies go for exporting as well as supply the oils to the super markets or small business enterprises.

Consideration while buying edible oil: The participants were asked the question about their preferred indicators while buying edible oil from the market. Figure 3 indicates

that out of 100 consumers, 60 respondents considered the quality of the oil, while 58 respondents preferred the brand name. Many respondents consider both quality and brand for their choice of cooking oil. Thus, the total count is more than hundred here. However, the understanding to

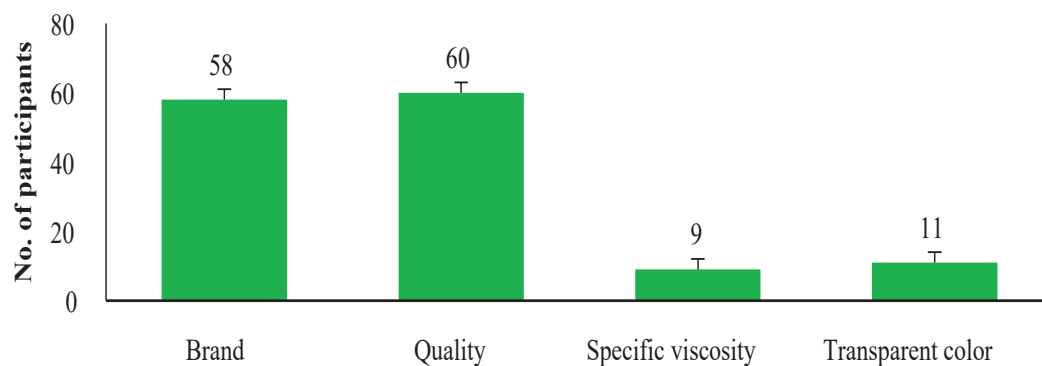


Figure 3. Customers' consideration while buying edible oil.

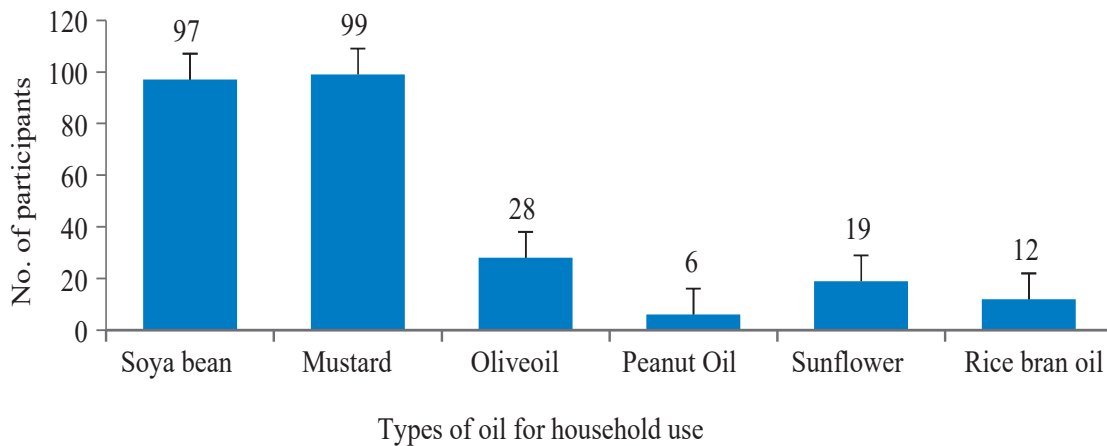


Figure 4. Types of edible oil used by the consumers.

the consumers for both quality and brand is almost equally important, while 11 consumers also added that color is an issue to them.

Types of oil used by the consumers: Figure 4 reflects about the types of edible oil that the households prefer to use. It was found that almost all consumers use both soybean and mustard oil in their kitchens. There are also a considerable percentage of consumers who use olive oil and sunflower oil. Rice bran oil is also used by a few numbers of consumers, such as 12 households out of 100 families. Thus, it is well understood that the market demand is mostly for mustard oil and soybean oil, though some consumers started to using sunflower oil.

Purpose of using mustard oil: Since the study was focused on the use of mustard and soybean oil, it was learned that soybean oil is used only for cooking purpose,

while mustard oil has multiple uses. The uses of mustard oil as the respondents reply is shown in Figure 5.

Amount of mustard and soybean oils use monthly/ household: The data reveals that the majority of mustard oil users (in 100 households) consume one liter per month, followed by those who use half a liter per month. A significant number of households consume 2 liters per month. On the other hand, most households consume more than 5 liters soybean oil per month. The difference in boiling point between mustard and soybean oils can be one of the significant factors for comparative higher volume requirement of soybean oil. According to Hasan *et al.* (2016), the best edible oils have a relatively high boiling point and a low peroxide value, and low quantities of free fatty acids.

The Figure 6 represents the monthly usage of mustard and soybean oil among the 100 surveyed households,

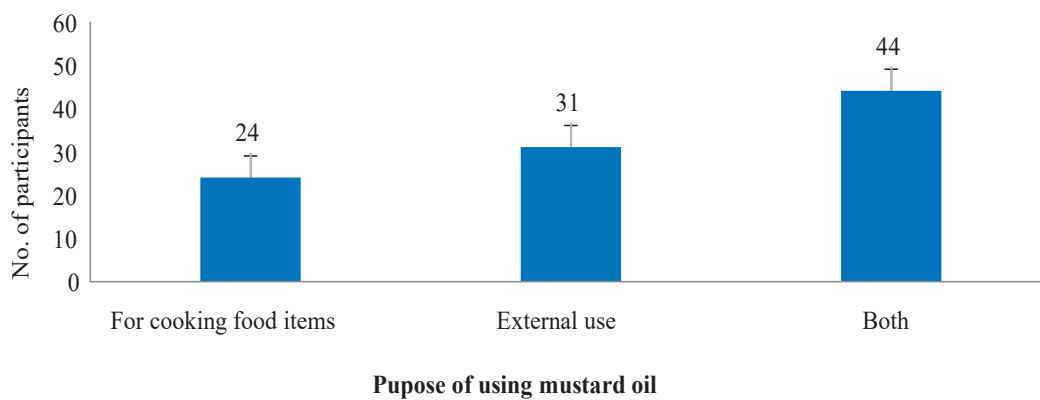


Figure 5. Uses of mustard oil.

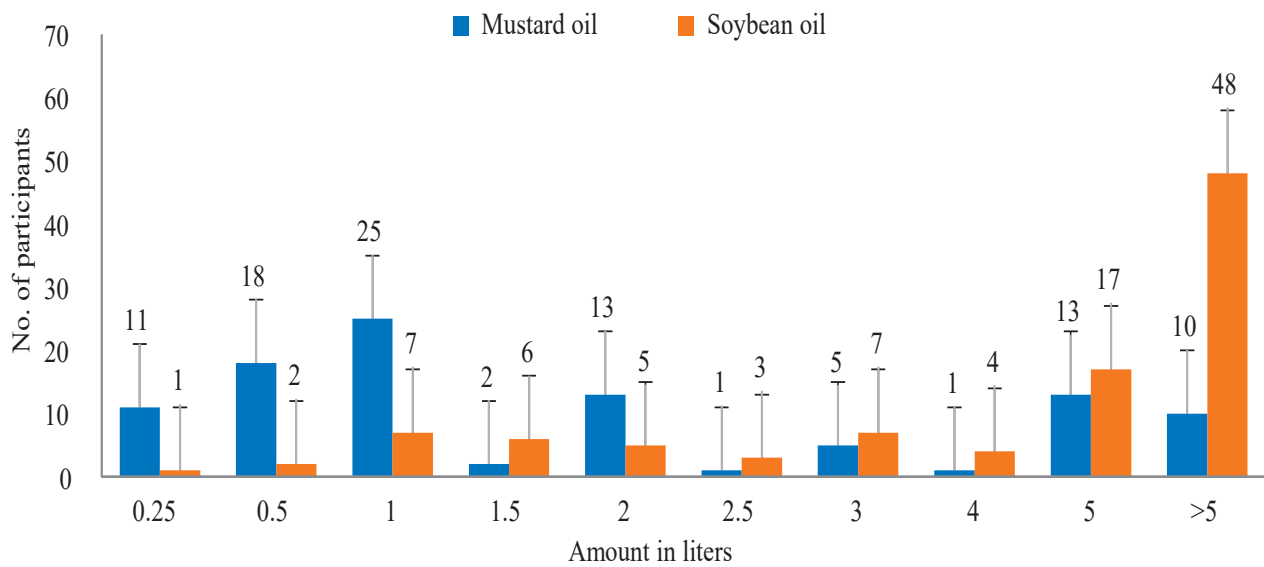


Figure 6. Amount of mustard and soybean oil monthly used by the consumers.

with one respondent not using mustard oil. This data provides valuable insights into the oil consumption habits of the surveyed households and highlights the prevailing trends in oil usage within the community. Further, the consumers were asked to learn whether their use of mustard oil was increasing or not. In response, 70 % of households shared that it was almost the same amount that they were using monthly for at least last year, while 30 % of the respondents shared that their use is increasing.

Motivation or reasons for using mustard oil: In response to the question about the reasons for using mustard oil, 61% respondents opined the health benefit was their consideration, while 20% opined the organic nature of mustard oil. The rest respondents replied that the good taste was their preference of using mustard oil (Figure 7).

In response to the question about whether any health problem facing for using mustard oil or soybean oil,

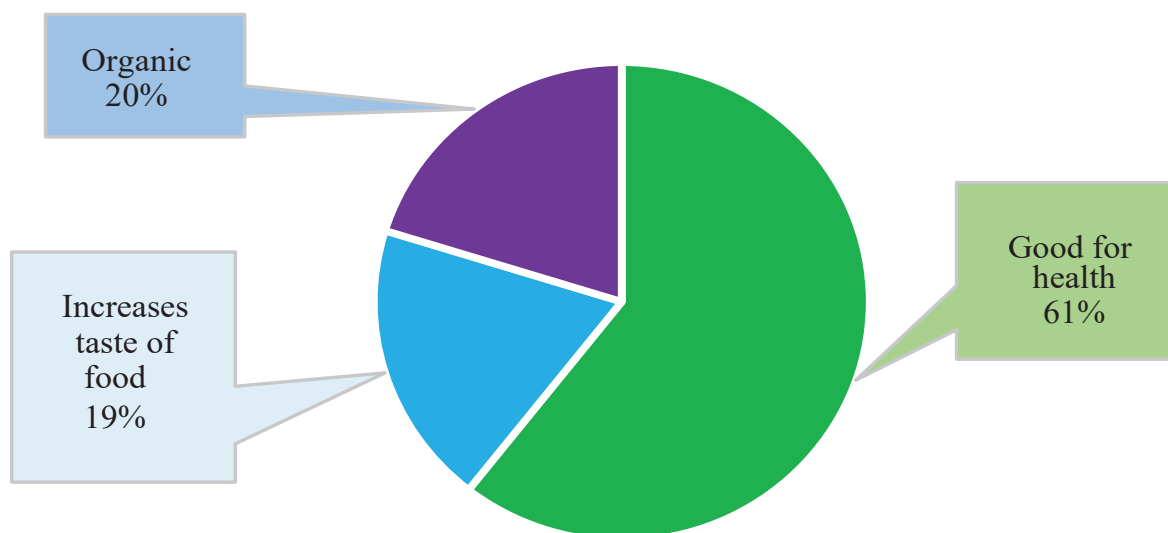


Figure 7. Reasons of using mustard oil by the consumers.



Figure 8. Respondents on facing problems for using mustard or soybean oil.

most of the participants (94%) opined that they did not face any problem with using mustard oil or soybean oil, though 4% said they had a problem and 2% had no idea (Figure 8).

Factors that influence brand preference: Figure 9 reflects the opinion of the respondents on the considerations for selecting the brand of the mustard and soybean oils. Most of them (69%) opined that quality is the preference for

selecting the brand. However, few of them also said that they also consider the trust and confidence in the brand value of the company.

Choices for a single company or multiple companies:

Figure 10 shows the ratio of single or multiple brands for using cooking oils by the respondents. It was found that 50:50 ratio of using single and multiple brands of cooking oil.

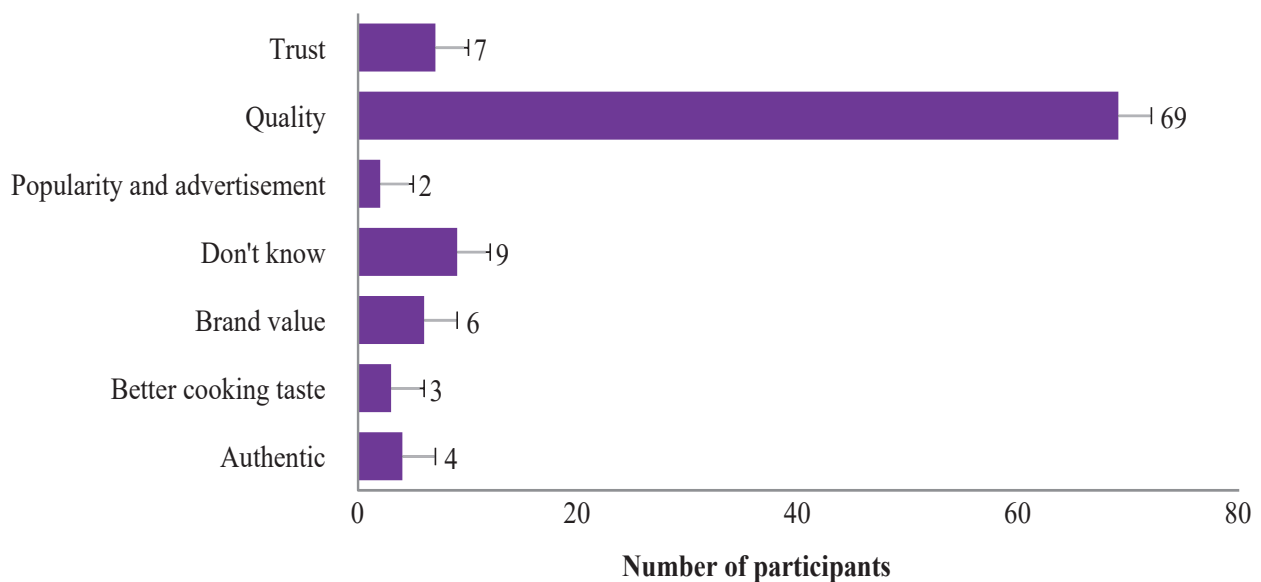


Figure 9. Factors those consumers consider for brand preference.

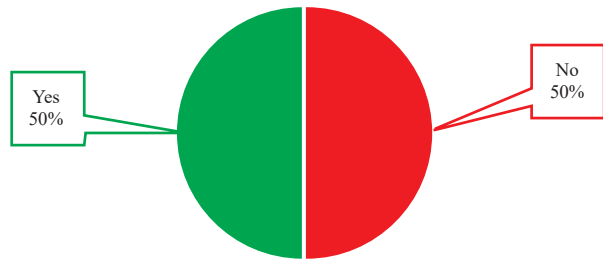


Figure 10. Choice the product of a single or multiple company.

However, Figure 11 revealed that the consumers have considered quality as an influencing factor to decide the product. However, the consumers also considered price of the product to select the brand of oil. Among the 50% participants who had the preference of a single brand opined that the less price is one of the fundamental

considerations of choosing any company product. Not only the price, consumers also considered regular supply of the product, good color and odor in selecting oil.

The consumers also added less price, trust about quality, availability of the product, color and odor are the considerable factors to choose the oil brand shown in figure 12.

It was learned that most of the consumers buy oil from the shop (Figure 13), while there is a new trend that many of the consumers also buying oil either directly from the mills or from the small entrepreneurs. Some of them also directly go to the small mill and buy the oil directly. The Figure 13 reveals the number of consumers based on the source of purchasing their cooking oil.

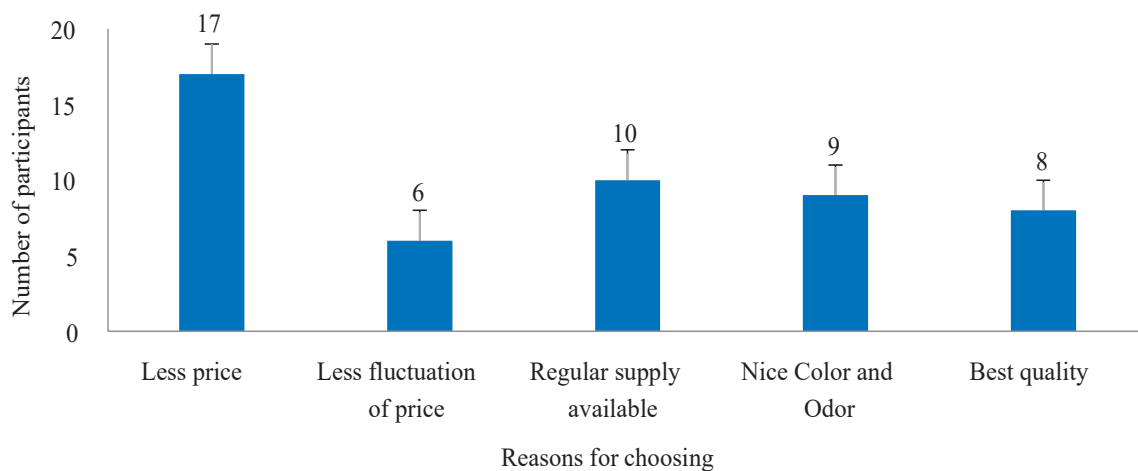


Figure 11. Reasons the consumers' preference a particular company's product.



Figure 12. Factors those consumers consider for selecting oil brand.

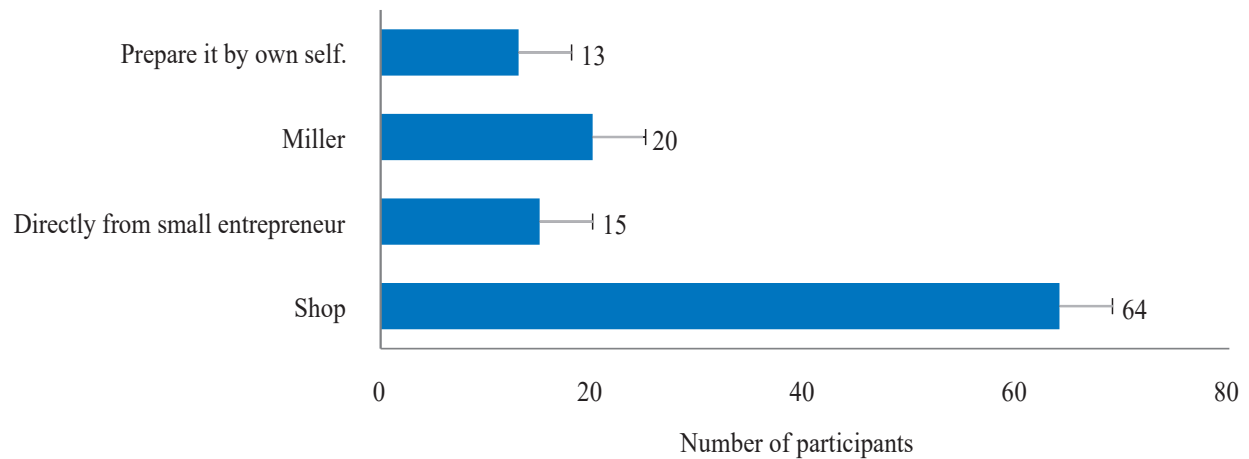


Figure 13. Source from where consumers buy oil.

Different brands and pricing of mustard oil: There are more than hundred branded mustard oils in the market and accordingly the price range also varied, ranging from 270 BDT/liter to 400 BDT/liter. However, the average price of per liter mustard oil in the market was 285 -290 BDT/liter. The most sold mustard oil brands are: Radhuni, Suresh, Telghor, Grammen Jibon, Desh, Khaas food, Fresh, Acme, Rokomari food, Panash, Ifad, Nababi, Pran, Soul and Rochon. Out of all these brands, the price of Nababi's per liter mustard oil is 400 BDT/liter. In relation to price reasoning, almost 50% consumers opined that the price per liter of mustard oil was very high and they did not think that the price was reasonable. The consumers also shared the opinion that the price of mustard oil was

almost double than that of soybeans oil which was also a reason for not using mustard solely for cooking. They further opined that the price should be less than that of the soybean oil as mustard seed is produced in the country. The consumers opined that the price of mustard oil should be within 230 BDT/liter.

Brand preference for soybean oil in Bangladesh: Many companies in Bangladesh have established their own distinct soybean oil brands, such as Teer (City Group), Fresh (Meghna Group), Muskan (SA Group), Pusti (TK Group), and Rupchanda (Bangladesh Edible Oil Limited). Figure 15 revealed the participants preferences regarding the branded soybean oil.

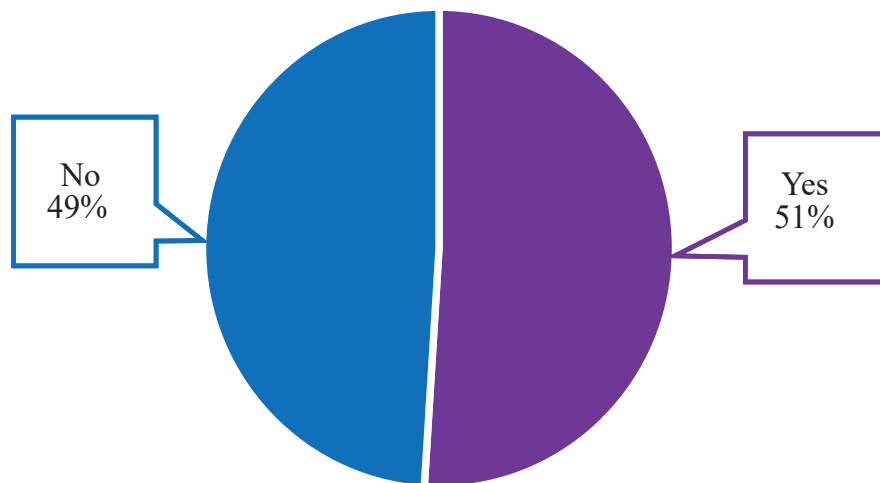


Figure 14. Consumers perception about price of mustard oil.

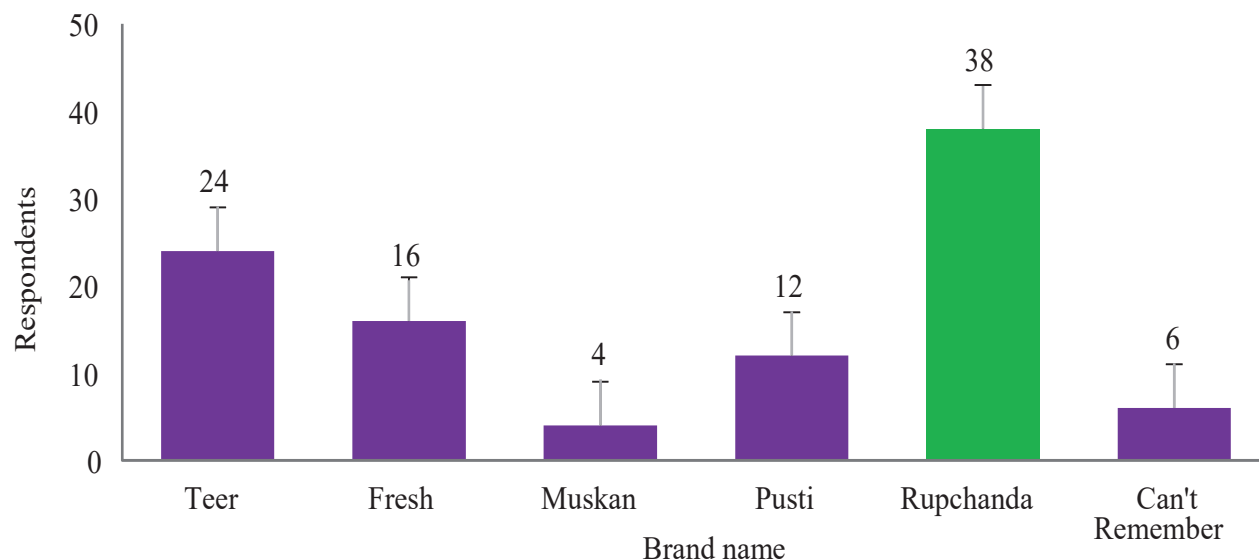


Figure 15. Brand preferences for soybean oil in Bangladesh.

Rupchanda was the most widely used soybean oil brand in the market, exhibiting unmatched popularity. About 38 respondents chose Rupchanda among 100 participants, 24 people chose Teer, 16 people Fresh, and 12 people Pusti brand soybean oil. Six individuals were unable to recall the brand they currently use and 4 chose Muskan. According to the respondents, many new brands are entering in the market. This influx occasionally leaves consumers struggling to find their preferred brands. Considering these findings, it was evident that effective advertising like Rupchanda holds immense potential to capture a larger share of the soybean oil market. The data underscored the importance of brand awareness and visibility in influencing consumer choices and gaining a competitive edge in this thriving market.

Conclusion

The study was conducted to find out the value chain mechanisms of mustard and soybean cooking oils through undertaking FGDs and KII involving consumers and related stakeholders including farmers, processors, retailers and general consumers. The findings revealed that oil quality and brand reputation are the primary factors that influence the consumer choices of the cooking oil. In addition affordable price and health consciousness also play a role on selecting the oils. Reputed brands like Rupchanda, Teer, Fresh and Pusti are dominating the

markets. About 70% of households shared that it was almost the same amount that they were using monthly for at least last year, while 30 % of the respondents shared that their use is increasing. The majority respondents opined that mustard oil price is exorbitant for the general consumers.

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Responses of linseed genotypes to salinity stress during early seedling growth

Hosna Kohinoor^{1*}, M. Shalim Uddin¹, N. A. Sultana¹, Debi Rani Dutta¹ and Abul Kashem Chowdhury²

¹Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh; ²Department of Genetics and Plant Breeding, Patuakhali Science and Technology University, Dumki, Patuakhali, Bangladesh

*Corresponding email: hosnaprc@gmail.com

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Abstract

Salinity is an important abiotic stress causing severe reduction in early seedling growth, plant stand and crop yield. Linseed (*Linum usitatissimum* L.) is known to be one of the oldest versatile crops having medium salt tolerant characteristics. The study aimed to evaluate the effects of salinity stress induced by NaCl on the early seedling growth of 29 linseed genotypes under 5 salinity levels (0, 4, 8, 12 and 16 dS m⁻¹) during the winter season of 2019-2020. The results showed that early seedling growth related parameters such as fresh and dry weights, and root length and shoot length of seedling, root to shoot ratio, seedling vigor index and salt tolerant index were decreased gradually with the increasing salinity level. The reduction in these traits was positively and significantly correlated with salinity levels. Compared to control, NaCl treatments of 4, 8, 12 and 16 dS m⁻¹ caused reduction in seedling dry weight, fresh weight, shoot length by (33.82, 46.08, 54.14 and 77.34%), (11.69, 25.35, 38.31 and 51.97%), (36.36, 50.00, 54.55 and 77.27%), and (15.30, 24.76, 39.69 and 50.77%), respectively. Root to shoot ratio was more or less similar in 7 genotypes, while it was significantly increased in 6 genotypes at all salinity levels. The ratio was increased significantly over control at 16 dS m⁻¹ in other 7 genotypes, and at 12 and 16 dS m⁻¹ in 9 genotypes. In 29 genotypes, the average reduction in seedling vigor index was 37.27, 52.21, 64.28 and 84.57% respectively at 4, 8, 12 and 16 dS m⁻¹. The highest mean seedling vigor index (SVI) was recorded from Neela followed by Lin-W-17, Lin-503, Lin-1403 and Lin-2403, while the lowest was found in BD-7143 (6.06) followed by Chilmari (6.46) and BD-7142. The average salt tolerant index of dry weight of whole seedling varied from 52.28 to 54.84% among 29 genotypes. Ten genotypes showed more than 60% tolerant level. Considering high level of early seedling growth and salt tolerance genotypes Neela, Lin-W-17, B-10708, BD-10710, Lin-1303, Lin-2403, BD-10698, Lin-S-19, BD-7143 and Lin-503 were noted as prospective materials for the development of salt tolerant linseed varieties.

Keywords: Linseed, flax, salinity tolerance, early seedling growth, genotype evaluation

Introduction

Linseed (*Linum usitatissimum*), a member of the family Linaceae is an economically potential versatile crop throughout the world (Berti *et al.* 2010). It is grown for oil seed as well as fiber or both. Its seeds contain 40-45% oil (EL-Nagdy *et al.* 2010). Linseed oil is used to manufacture paints, varnishes, clothes, patent leathers, printer inks, enamels, soaps, linen fabrics, linen threads, canvas bags, quality papers, etc. Linseed oilcake is a good manure and nutritious livestock feed. Its seeds are rich in protein, and essential fatty omega-3 fatty acids, including alpha-linolenic acid. Seed may be used for treatment of constipation, diabetes, high cholesterol, obesity, and swelling of the kidneys in people (Vittal *et al.* 2005).

Linseed can grow in a wide range of climatic conditions because it is comparatively less affected by stressful

environments. In spite of glycophytic crop plant, linseed is moderately tolerant to salinity (Day *et al.* 2018, Dubey *et al.* 2020). There is a prospect to grow the linseed in the Southern Coastal Zones of Bangladesh, where salinity is a problem (Ahsan 2010). To promote its cultivation, it is crucial to develop high-yielding linseed varieties with enhanced salt tolerance, which are currently lacking.

Salinity is a major abiotic stress which reduces crop yield through negative impacts on seed germination, seedling establishment, and plant growth (Munns and Tester 2008, Nasri *et al.* 2017). This stress alters different metabolic processes of plants, particularly photosynthesis and reduces the chance of survival. While some plants are sensitive to saline conditions, some survive by genetically controlled tolerance mechanisms induced by various

physiological, biochemical and molecular responses (Culha and Cakırlar 2011).

Seed germination and early seedling growth stages are the beginning of plant life cycle, which are the most vulnerable stages to salinity (Yasar and Yetissin 2023). The salinity causes osmotic stress by lowering the water potential of the germination medium in comparison to the seed interior and reduces or prevents the uptake of water (imbibition process) required for germination and seedling growth (Kaya *et al.* 2012, Moghaddam *et al.* 2018, Kocak *et al.* 2022, Mohammadi *et al.* 2023). In many cases, high salt stress causes absorption of too much Na^+ and Cl^- ions by seeds resulting in ionic stress and ion toxicity to the embryo (Mwando *et al.* 2020) and salinity causes imbalance of hormones especially GA and ABA, and seed nutrients like Na^+ and K^+ (Zaghdoudi *et al.* 2015). High salt concentration in the soil inhibits seed germination or induces dormancy (Farooq *et al.* 2015). Survival of plant under salinity stress is governed by the salt tolerance mechanisms of respective plants to salinity as physiological and biochemical responses (Culha and Cakırlar 2011). Plants can combat salinity stress through enzymatic (such as catalase, ascorbate peroxidase, and superoxide dismutase) and non-enzymatic (such as carotenoids, proline, α -tocopherol, and ascorbic acid) antioxidants (Sharma *et al.* 2012, Singh and Tiwari 2021).

Decrease in fresh and dry weights and biomass of seedling with the increase in the salinity level have been reported

by Nasri *et al.* (2017). General approaches of identifying salinity tolerance sources of crop plants are growing available germplasm in the salt affected soils and selection of desirable plants. However, selection of a salt tolerant genotype based on germination and seedling growth under controlled conditions is simple, quick, precise and very less time consuming (Kaya *et al.* 2012).

Considering these facts, the present study was conducted to evaluate the effects of salinity on the early seedling growth of linseed genotypes under different NaCl levels, with to the aim of identifying potential salt-tolerant genotypes for a varietal improvement program.

Materials and methods

A total of 29 linseed genotypes were tested in the present experiment. Name and sources of the genotypes are shown in Table 1. The genotype, Neela is a linseed variety, which is recommended for cultivation in Bangladesh and it was included in the experiment as a check material. The experiment was conducted in the Laboratory of Oilseed Research Center (ORC) of Bangladesh Agricultural Research Institute (BRAI), Gazipur, Bangladesh during *Rabi* (winter) season of 2019-2020. For germination test, the guidelines recommended by the International Seed Testing Association (ISTA 2003) were followed with minor adjustment according to available of laboratory facilities. Germination and early seedling growth of the genotypes were studied using distilled water (control)

Table 1. Name and source of linseed genotypes studied in the experiment

Name of genotype	Source
Neela (check variety)	Oilseed Research Center (ORC), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
BD-7141, BD-7142, BD-7143, BD-7146, BD-10703, BD-10704, BD-10706, BD-10707, BD-10708, BD-10709, BD-10710, BD-10698 and BD-10696	Plant Genetic Resource Center (PGRC), BARI, Gazipur, Bangladesh
Lin-303, Lin-503, Lin-703, Lin-803, Lin-1203, Lin-1303, Lin-1403, Lin-1903, Lin-2403 Lin-1503/2 and Lin-1507/2	Oilseed Research Center, BARI, Gazipur, Bangladesh
Chilmari	Farmer of Chilmari upazila under Kurigram district
Lin-S-19	Farmer of Fatkhira upazila under Shatkhira district
Lin-C-16	China
Lin-V-18	Vietnam
Lin-W-17	Thailand

and under NaCl concentrations of 4, 8, 12, and 16 dS m⁻¹. To prepare salt solutions, a stock solution of NaCl was prepared by dissolving 58.44 gram (1 gram mole) of NaCl in one liter of distilled water. The concentration was measured in an Electrical Conductivity (EC) meter (HANNA) and adjusted to required concentrations of 4, 8, 12 and 16 dS m⁻¹ (1 dS m⁻¹=10 mM) by adding required quantity of distilled water using a pipette under constant stirring.

Before sowing, seeds were surface sterilized with 0.5% sodium hypochlorite solution for 5 minutes followed by rinsing thrice with sterilized distilled water. Surface sterilized seeds were placed on 90 mm diameter filter paper discs in 90 mm Petri dishes. Each Petri dish received 25 seeds and 4 dishes were used for each treatment. The filter paper in a Petri dish was soaked with 10 ml NaCl solutions with desired concentrations and sealed with parafilm to prevent evaporation. Petri dishes containing seeds were incubated in the laboratory at 25-28°C.

The experiment was checked every day at the same time and data were taken on the following parameters:

Germination percentage: Seeds with a radicle of 2 mm were considered as germinated. Five days after seeds were plated into the Petri dishes, germinated seeds were counted and the germination percentage was calculated based on total number of seeds plated.

Five days after germination, 10 seedlings were removed from each Petri dish and data were recorded on the following early seedling growth parameters:

Shoot length and Root length: To determine shoot and root length the distances from crown to leaf tip and root tip were measured as shoot length and root length, respectively.

Seedling fresh weight - After measurement of shoots and root length, the seedlings were soaked with tissue paper and fresh weight of whole seedling was recorded.

Seedling dry weight: After recording the fresh weight, seedlings were dried in an oven at 70°C for constant weight and dry weight was recorded.

Root length to shoot length ratio: The root to shoot ratio was computed by dividing the root length by the shoot length.

Seedling vigor index: Seedling vigor index was calculated using the following equation (Zahedi *et al.* 2011)-

$$SVI = (\text{Germination \%}) \times \text{Mean seedling dry weight in gram}.$$

Salinity tolerance index: The parameter was calculated using the formula suggested by Kokten *et al.* (20210) as:

$$SVI = \frac{\text{Total seedling dry weight at St}}{\text{Total dry weight of seedling at Sc}} \times 100$$

where St is the total seedling dry weight at a salinity level and Sc is the total dry weight of seedling under control.

A 29×5 factorial experiment in completely randomized design with 4 replications was followed, where the first factor was linseed genotypes with 29 levels and the second factor was salinity with 5 levels. The collected data were subjected to statistical analysis for analysis of variance and the treatment means were compared using least significant difference (LSD) test at 5% probability level. For statistical analyses Statistix-10 computer software was used.

Results and discussion

Fresh weight of seedling: Among the 29 genotypes, the fresh weight (FW) was ranged (0.522-0.895 g), (0.476-0.788 g), (0.343-0.673 g), (0.251-0.575) and (0.177-0.472 g) with a mean of 0.710, 0.627, 0.530, 0.438 and 0.341 g at 0, 4, 8, 12 and 16 dS m⁻¹, respectively. The percentage of reduction over control in FW of whole seedlings was 11.69, 25.35, 38.31 and 51.97% at 4, 8, 12 and 16 dS m⁻¹, respectively. The relationship between percent reduction in FW and salinity level was positive, linear and highly significant ($r=0.999^{**}$). In case of genotypes, the heaviest seedling (highest pooled mean of fresh weight) was found in Lin-803 (0.6879 g), which was followed by Lin-W-17 (0.676 g), Lin-2403 (0.672 g), Neela (0.662 g) and Lin-1303 (0.585 g). The lowest fresh weight was recorded from Lin-S-19 (0.353 g) followed by Lin-V-18 (0.385 g), BD-10704 and Lin-1507/2 (Table 2). Results of the present investigation

clearly revealed that salinity stress reduced fresh weight of linseed seedlings. Higher reduction was corroborated with higher levels of salinity. These observations are in

accordance with the findings of Patil *et al.* (2015), Pervez *et al.* (2021), and Kocak *et al.* 2022 for linseed, and Nasri *et al.* 2017 for lettuce, where increase of salinity levels induced seedling fresh weight.

Table 2. Effect of salinity (NaCl) stress on early seedling growth parameters of 29 linseed genotypes under control conditions

Genotype	Seedling fresh weight (g) under different salinity levels (dS m ⁻¹)						Seedling dry weight (g) under different salinity levels (dS m ⁻¹)					
	0	4	8	12	16	Mean	0	4	8	12	16	Mean
Neela	0.864	0.788	0.646	0.552	0.462	0.662	0.294	0.195	0.167	0.108	0.168	0.294
BD-7143	0.574	0.537	0.482	0.376	0.288	0.451	0.129	0.108	0.085	0.054	0.079	0.129
BD-10710	0.722	0.650	0.542	0.473	0.341	0.545	0.182	0.121	0.112	0.104	0.116	0.182
BD-7146	0.758	0.653	0.550	0.480	0.380	0.564	0.211	0.136	0.118	0.106	0.127	0.211
BD-10708	0.780	0.686	0.577	0.486	0.380	0.581	0.170	0.121	0.103	0.085	0.105	0.170
Lin-1303	0.793	0.682	0.577	0.488	0.386	0.585	0.228	0.183	0.115	0.102	0.137	0.228
Lin-703	0.718	0.672	0.547	0.443	0.373	0.550	0.247	0.132	0.116	0.108	0.133	0.247
Lin-303	0.748	0.671	0.552	0.447	0.372	0.558	0.257	0.139	0.117	0.105	0.135	0.257
Lin-1403	0.791	0.640	0.523	0.461	0.379	0.559	0.260	0.177	0.116	0.105	0.144	0.260
Lin-C-17	0.678	0.554	0.462	0.405	0.294	0.479	0.226	0.151	0.115	0.102	0.129	0.226
Lin-1203	0.695	0.644	0.517	0.438	0.323	0.523	0.253	0.145	0.113	0.103	0.135	0.253
Lin-W-17	0.891	0.779	0.668	0.573	0.470	0.676	0.276	0.188	0.146	0.106	0.156	0.276
BD-10698	0.644	0.610	0.494	0.396	0.296	0.488	0.228	0.134	0.111	0.101	0.126	0.228
Lin-503	0.695	0.638	0.549	0.446	0.335	0.533	0.273	0.217	0.116	0.106	0.156	0.273
Lin-C-16	0.736	0.679	0.576	0.452	0.355	0.559	0.250	0.156	0.112	0.106	0.136	0.250
BD-10707	0.705	0.626	0.559	0.431	0.334	0.531	0.224	0.130	0.116	0.102	0.123	0.224
BD-10706	0.668	0.590	0.475	0.361	0.263	0.471	0.209	0.120	0.112	0.101	0.115	0.209
BD-10704	0.582	0.507	0.384	0.291	0.219	0.396	0.215	0.122	0.115	0.106	0.121	0.215
BD-10703	0.694	0.602	0.521	0.425	0.330	0.514	0.232	0.123	0.115	0.105	0.125	0.232
Lin-1507/2	0.564	0.495	0.428	0.310	0.255	0.410	0.222	0.124	0.113	0.104	0.121	0.222
Lin-V-18	0.558	0.486	0.351	0.304	0.228	0.385	0.242	0.121	0.116	0.104	0.126	0.242
Lin-S-19	0.522	0.476	0.343	0.251	0.177	0.353	0.148	0.113	0.100	0.075	0.092	0.148
Lin-2403	0.884	0.775	0.670	0.567	0.465	0.672	0.263	0.173	0.123	0.102	0.142	0.263
Lin-803	0.895	0.781	0.673	0.575	0.472	0.679	0.280	0.186	0.111	0.102	0.149	0.280
Lin-1503/2	0.786	0.632	0.572	0.466	0.368	0.564	0.185	0.140	0.110	0.101	0.114	0.185
Chimari	0.755	0.625	0.558	0.500	0.373	0.562	0.155	0.120	0.110	0.087	0.100	0.155
BD-7141	0.693	0.604	0.540	0.448	0.360	0.529	0.164	0.125	0.106	0.082	0.101	0.164
BD-7142	0.561	0.506	0.483	0.391	0.286	0.445	0.146	0.117	0.102	0.074	0.092	0.146
Lin-1903	0.658	0.608	0.561	0.485	0.337	0.529	0.173	0.126	0.111	0.101	0.112	0.173
Mean	0.710	0.627	0.530	0.438	0.341	0.529	0.218	0.142	0.114	0.098	0.125	0.218
SD	0.103	0.088	0.084	0.082	0.074	0.084	0.045	0.029	0.014	0.013	0.021	0.045
Minimum	0.522	0.476	0.343	0.251	0.177	0.353	0.129	0.108	0.085	0.054	0.079	0.129
Maximum	0.895	0.788	0.673	0.575	0.472	0.679	0.294	0.217	0.167	0.108	0.168	0.294
LSD (P=0.01): Genotype=0.0206, Salinity =0.0008565, Salinity*Salinity = 0.0461							LSD (P=0.01): Genotype=0.0005811, Salinity =0.002413, Salinity*Salinity =0.0130					

Dry weight of seedling: The highest dry weight (DW) of linseed seedlings was recorded under control in all 29 genotypes. Due to salinity stress, the trait was decreased significantly over control. Among the genotypes, the average DW ranged (0.129-0.294 g), (0.108-0.217 g), (0.085-0.167 g) and (0.054-0.108 g) (0.079-0.168 g) with a mean of 0.218, 0.142, 0.114 and 0.098 g seedling⁻¹ under 0, 4, 8 and 12 dS m⁻¹, respectively. As the concentration of NaCl increased, the dry weight of whole seedlings was reduced significantly over control up to 12 dS m⁻¹ showing 36.36, 50.00 and 54.55% reduction at 4, 8 and 12 dS m⁻¹, respectively. In every genotype, the trait was found to be increased significantly at 16 dS m⁻¹ compared 12 dS m⁻¹ showing the average dry weight of 0.125 g seedling⁻¹.

Significantly the highest average DW was found in Neela (0.168 g) followed by Lin-W-17 (0.156 g), Lin-503 (0.156 g), Lin-803 (0.149 g) and Lin-1303 (0.144 g); while the lowest in BD-7143 (0.079 g) followed by BD-7142 (0.092 g), Lin-S-19 (0.092 g), BD-7142 and BD-7143 (Table 2). In the present investigation, it was found that salinity stress reduced dry weight of linseed seedlings and the trait varied with genotypes. Higher reduction was corroborated with higher levels of salinity up to the salinity level of 12 dS m⁻¹. These observations are in accordance with the findings of Kaya *et al.* (2012), Patil *et al.* (2015), Pervez *et al.* (2021) and Yasar and Yetissin (2023) in linseed, and Nasri *et al.* (2017) in lettuce.

Table 3. Effect of salinity (NaCl) stress on seedling root and shoot lengths (cm) of 29 linseed genotypes under control condition

Genotype	Seedling root length (cm) under different levels of salinity (dS m ⁻¹)						Seedling shoot length (cm) under different levels of salinity (dS m ⁻¹)					
	0	4	8	12	16	Mean	0	4	8	12	16	Mean
Neela	4.25	4.90	3.08	2.11	1.30	3.12	7.20	6.70	4.40	3.33	1.53	4.63
BD-7143	3.88	3.43	4.48	3.95	3.18	3.78	5.73	4.90	5.50	4.83	3.68	4.93
BD-10710	4.40	3.78	3.38	3.10	2.40	3.41	5.70	5.38	4.48	3.73	3.28	4.51
BD-7146	5.13	4.08	3.83	3.30	2.88	3.84	5.68	5.18	4.88	4.10	3.48	4.66
BD-10708	5.18	3.90	3.75	3.00	2.70	3.66	5.45	4.80	4.08	3.68	3.13	4.23
Lin-1303	4.93	4.18	3.58	2.45	2.18	3.51	6.43	5.05	3.38	1.45	1.03	3.47
Lin-703	3.68	3.88	3.40	2.43	1.93	3.06	5.78	4.50	4.23	3.03	1.20	3.75
Lin-303	3.75	3.33	3.35	2.20	1.78	2.88	4.70	4.53	4.00	1.50	0.93	3.13
Lin-1403	4.48	3.78	3.28	2.43	1.78	3.15	5.33	5.38	2.50	1.23	0.98	3.08
Lin-C-17	4.13	2.93	2.24	1.83	1.84	2.59	4.93	3.53	2.85	1.73	0.96	2.80
Lin-1203	2.80	2.29	2.25	1.80	1.25	2.08	4.48	3.11	1.35	0.91	0.76	2.12
Lin-W-17	4.26	2.84	2.51	2.81	1.30	2.74	6.08	4.48	3.13	1.75	0.99	3.28
BD-10698	2.05	1.49	1.21	1.00	1.38	1.43	3.84	2.62	1.71	1.15	0.89	2.04
Lin-503	2.42	2.28	2.36	1.69	1.20	1.99	3.81	2.83	1.45	1.04	0.66	1.96
Lin-C-16	3.33	2.19	1.98	1.56	1.13	2.04	3.54	2.48	1.21	1.06	0.60	1.78
BD-10707	2.52	2.12	1.25	0.98	1.10	1.59	4.35	3.86	1.96	0.94	0.67	2.35
BD-10706	2.88	2.06	1.67	1.13	0.82	1.71	4.13	3.11	1.87	0.98	0.72	2.16
BD-10704	2.59	1.95	1.62	1.02	0.74	1.58	4.28	2.93	1.43	0.93	0.67	2.05
BD-10703	2.31	2.52	2.33	1.80	1.26	2.04	3.19	2.85	1.93	0.95	0.63	1.91
Lin-1507/2	2.86	2.50	1.95	1.40	1.10	1.96	3.75	2.96	1.73	0.92	0.58	1.99
Lin-V-18	3.20	2.36	1.90	1.43	0.98	1.97	3.90	3.30	1.88	1.05	0.73	2.17
Lin-S-19	3.00	2.30	1.90	1.40	1.01	1.92	3.48	2.55	1.70	1.05	0.78	1.91
Lin-2403	3.83	2.93	2.42	1.54	2.14	2.57	6.45	4.40	2.55	1.42	1.00	3.16
Lin-803	2.65	2.18	2.21	1.93	2.10	2.21	5.25	3.95	2.78	2.11	2.12	3.24
Lin-1503/2	3.57	2.99	2.64	2.56	2.34	2.82	4.68	4.28	2.99	2.93	2.06	3.39
Chimari	3.67	3.87	4.03	3.21	2.60	3.47	5.34	4.58	3.83	3.65	1.70	3.82
BD-7141	4.06	3.52	3.53	2.88	1.83	3.16	5.83	5.33	4.93	4.28	2.90	4.65
BD-7142	4.10	4.24	3.05	3.05	2.55	3.40	5.80	5.38	3.83	3.63	2.97	4.32
Lin-1903	4.43	3.68	3.43	3.03	2.65	3.44	5.83	5.25	4.43	3.65	2.15	4.26
Mean	3.60	3.05	2.71	2.17	1.77	2.66	5.00	4.14	3.00	2.17	1.51	3.16
SD	0.87	0.87	0.87	0.81	0.69	0.75	1.04	1.11	1.28	1.30	1.01	1.04
Minimum	2.05	1.49	1.21	0.98	0.74	1.43	3.19	2.48	1.21	0.91	.058	1.78
Maximum	5.18	4.90	4.48	3.95	3.18	3.84	7.20	6.70	5.50	4.83	3.68	4.93
LSD (P=0.01):Genotype=0.2603, Salinity =0.1081, Salinity *Salinity = 0.5822							LSD (P=0.01):Genotype=0.2902, Salinity =0.1205, Salinity *Salinity = 0.6489					

Root length of seedling: The root length (RL) of seedling was found to be increased in 4 genotypes (Neela, Lin-703, BD-10703 and Chilmari) at 4 dS m⁻¹ compared to control but it was begun to decrease from immediate higher level (8 dS m⁻¹). In other 25 genotypes, the RL was begun to decrease from the lowest salinity level (4 dS m⁻¹) and continued up to the highest level (16 dS m⁻¹). In these 25 genotypes the longest root was recorded under control and use of NaCl solution for soaking germination paper caused gradual reduction in the trait over control in every genotype. The average RL among these 25 genotypes ranged (2.05-4.24 cm), (1.49-4.24 cm), (1.21-4.48 cm), (0.98-3.95 cm) and (0.74-3.18 cm) with a mean of 3.61, 2.93, 2.563, 2.14 and 1.77 cm at 0, 4, 8, 12 and 16 dS m⁻¹, respectively. The reduction of the trait was significant at all salinity levels in 16 genotypes and at 8, 12 and 16 dS m⁻¹ in the rest 13 genotypes. The reduction in pooled mean of RL over control was 15.30, 24.76, 39.69 and 50.77% at 4, 8, 12 and 16 dS m⁻¹, respectively. The relationship between percentage of reduction and level of salinity was linear, positive and highly significant ($r=0.996^{**}$). In case of genotypes, the longest root was found in BD-10708 (5.18 cm) followed by BD-7146 (5.13 cm), Lin-1303 (4.93 cm), Lin-1403 (4.48 cm), Lin-1903 (4.43 cm) and BD-10710 (4.40 cm). The shortest root was found in BD-10698 (2.05 cm) followed by BD-10703 (2.31 cm), Lin-503 (2.42 cm) and BD-10707 (2.52 cm) under control (Table 3). Roots are the first organs to be exposed to salinity and this organ of plant is in direct contact with the soil. They absorb water and nutrient from the soil and transfer it to shoots. Salinity prevents the maintenance of nutrient levels necessary for plant growth and limits root development and seedling growth (Abari *et al.* 2011, Bilgili *et al.* 2011). It was also reported that increasing salt doses decreased root lengths (Moghaddam *et al.* 2018, Kocak *et al.* 2022).

Shoot length of seedling: In all genotypes, the maximum shoot length (SL) was found under control and salinity stress caused reduction in the trait in parallel with increasing salinity levels. At the salinity levels of 0, 4, 8, 12 and 16 dS m⁻¹, the SL was varied (3.19-7.20 cm), (2.48-6.70 cm), (1.21-5.50 cm), (0.91-4.83 cm) and (0.58-3.68 cm) with a mean of 5.00, 4.14, 3.00, 2.17 and 1.51 cm, at 4, 8, 12 and 16 dS m⁻¹, respectively. The reduction in the trait was begun at 4 dS m⁻¹ in 17 genotypes, and at 8 dS

m⁻¹ in other 12 genotypes, and in both cases the reduction was continued up to 16 dS m⁻¹. In every genotype, the pooled mean of shoot length was corroborated with the level of salinity showing the shortest shoot at the highest level. Percentage of reduction in shoot length over control was 17.20, 40.00, 56.60 and 69.80% at 4, 8, 12 and 15 dS m⁻¹, respectively. The relationship ($r=0.992^{**}$) between reduction percentage in the trait and level of salinity was linear, positive and significant. Withstanding the salinity stress, genotype BD-7143 showed the longest shoot (4.93 cm) followed by BD-7146 (4.66 cm), BD-7141 (4.65 cm), Neela (4.63 cm) and BD-10710 (4.51 cm); while the lowest was recorded from Lin-C-16 (1.78 cm), which was statistically similar to BD-10703 (1.91 cm), Lin-S-19 (1.91 cm), Lin-503 (1.96 cm), Lin-1507/2, BD-10698 and BD-10704 (Table 3). Results of the present investigation showed that salinity stress reduced shoot lengths of linseed seedlings. Higher reduction was corroborated with higher levels of salinity. When a plant is grown under saline environment, reduction in shoot length is common in various crop species (Amin *et al.*, 1996). The findings supported the findings of many other researchers (Nasri *et al.* 2017, Pervez *et al.* 2021, Kocak *et al.* 2022, Yasar and Yetissin 2023). They also found significant reduction in fresh and dry weights of seedlings and whole seedling biomass due to salinity stress.

Root to shoot ratio of seedling: Seven genotypes (Neela, BD-7143, BD-10710, BD-7146, BD-10708, BD-7141 and BD-714) showed statistically similar root to shoot ratio (RL:SL) values up to the highest level, while in other 7 genotype (Lin-1403, Lin-1203, Lin-503, Lin-C-16, BD-10703, Lin-1507/2, Lin-S-19), the trait was significantly increased at all salinity levels compared to control. The RL:SL was statistically similar up to 12 dS m⁻¹ and significantly increased over control at 16 dS m⁻¹ in other 6 genotypes (Lin-703, BD-10698, Lin-803, Lin-1503/2, Chilmari, Lin-1903). In 9 genotypes (Lin-1303, Lin-303, Lin-C-17, Lin-W-17, BD-10707, BD-10706, BD-10704, Lin-V-18, Lin-2403), the RL: SL was statistically similar up to 8 dS m⁻¹ but increased significantly over control at 12 and 16 dS m⁻¹ indicating increase in root length under salinity stress at two higher levels in these 9 genotypes. Higher RL:SL indicated higher growth of root length compared to shoot length under salinity stress condition. The pooled mean of RL: SL under control (0.73) and at 4

dS m⁻¹ (0.75) was almost identical but significantly lower compared to 3 higher levels of salinity. Significantly the highest RL:SL was found at 16 dS m⁻¹ (1.47) followed by 12 dS m⁻¹ (1.20) and 8 dS m⁻¹ (1.00). Due to salinity stress, the trait was increased by 2.74, 36.99, 64.38 and 101.37% at 4, 8, 12 and 16 dS m⁻¹. Regarding response of RL:SL of 29 genotypes, the pooled mean in 14 genotypes (BD-10703, Lin-C-16, Lin-503, Lin-1403, Lin-1303, Lin-1203, Lin-1507/2, Lin-303, Lin-S-19, Lin-C-17, Lin-2403, Lin-V-18, Lin-W-17, Chimera) was more than 1.00 (1.02-1.55) and the rest 15 genotypes showed less than 1.00 (0.70-0.97) RL:SL values. Well defined variations were observed in linseed genotypes in terms of root to shoot ratio (Table 4).

In general, both root and shoot lengths of seedlings were found to be diminished due to salinity stress in all genotypes in the present study. However, the length of root was higher compared to shoot in 14 genotypes under higher salinity levels where the RL:SL was more than 1.00. Similar findings have been reported by Pervez *et al.* (2021), Kocak *et al.* (2022) and Yasar and Yetissin (2023). Keaya *et al.* (2012) tested 10 linseed genotypes for their response to salinity stress and found that most genotypes showed increase in root length. According to Pervez *et al.* (2021) common response of linseed genotypes are to enhance root to shoot to ratio depending of variations in genotypes.

Seedling vigor index of seedling: In every genotype, the highest seedling vigor index (SV) was found under control (0 dS m⁻¹), which was reduced over control due to salinity stress. Higher reduction was corroborated with higher dose of NaCl. The SVI values among the genotypes ranged (1.78 - 28.86), (8.37 - 19.58), (6.06 - 14.16), (3.13 - 8.96) and (0.92-5.11) with a mean of 19.92, 11.98, 8.91, 6.58 and 2.54 at 0, 4, 8, 12 and 16 dS m⁻¹, respectively. The reduction in SVI was increased significantly in parallel with increasing salinity levels. The average SVI in 29 genotypes was reduced by 37.27, 52.21, 64.28 and 84.57% respectively at 4, 8, 12 and 16 dS m⁻¹. Withstanding the salinity stress, the highest average mean of SVI was recorded from Neela followed by Lin-W-17, Lin-503, Lin-1403 and Lin-2403, while the lowest was found in BD-7143 (6.06) followed by Chilmari (6.46)

and BD-7142. Genotypes Neela, Lin-W-17, Lin-503, Lin-1403 and Lin-2403 were noted as better performers showing vigorous seedlings (Table 4). These findings of the present investigations are in agreement with the reports of many other researchers (Patil *et al.* 2015, Pervez *et al.* 2021, Yasar and Yetissin 2023), who reported that the SVI and RL:SL ratio of linseed decreased as salinity stress increased. They also reported that vigor index is a useful trait to identify salt resistant genotypes.

Salt tolerant index of seedling dry weight: In all genotypes, the salt tolerance index (STI) was significantly decreased over control starting from the lowest level (4 dS m⁻¹) and continued up to the highest level (16 dS m⁻¹). The reduction was gradual with increasing NaCl concentrations. The mean STI was reduced by 33.82, 46.08, 54.14 and 77.34% over control at 4, 8, 12 and 16 dS m⁻¹, respectively. The results of ANOVA indicated existence of variations among the genotypes in terms of SVI, which were influenced by salinity stress. Among 29 genotypes, the average STI was varied from 52.28 to 54.84% with a grand mean of 57.72%. Ten genotypes showed more than 60% STI and the best performing genotype was Lin-1903 followed by Chilmari, BD-10710, BD-7142 and Lin-S-19 (Table 5). The results of the present investigation showed that the STI was reduced significantly in parallel with increasing salinity levels. The findings are in agreement with the reports of Pervez *et al.* (2021) and Yasar and Yetissin (2023) who also identified adverse effect of salinity on salt tolerance indices of linseed.

In the present investigation, gradual decrease in fresh and dry weights and lengths of root and shoot of seedlings with increasing salinity levels was observed. Wide ranges of variations were found in the responses of early seedling growth related traits of linseed genotypes to salinity stress. Similar findings have also been reported by Pervez *et al.* (2021) and Yasar and Yetissin (2023). Variation in varietal responses to salinity stress in linseed has been reported by Pervez *et al.* (2021), Kocak *et al.* (2022) and Yasar and Yetissin (2023). Salt tolerant and survival of plant genotypes under salt stress might be attributed to their various salt resistance mechanisms such as prevention of the entry of salts into the plant, tissue tolerance, compartmentalization of toxic salt in

Table 4. Effect of salinity (NaCl) stress on root length:shoot length ratio and seedling vigor index of 29 linseed genotypes under control conditions

Genotype	Root length to shoot length ratio (RL:SL) under different salinity levels (dS m ⁻¹)						Seedling vigor index (SVI) under different salinity levels (dS m ⁻¹)					
	0	4	8	12	16	Mean	0	4 dS	8 dS	12	16	Mean
Neela	0.59	0.73	0.71	0.64	0.84	0.70	28.86	16.86	14.16	8.96	5.11	14.79
BD-7143	0.67	0.73	0.83	0.82	0.86	0.78	11.78	8.42	6.06	3.13	0.92	6.06
BD-10710	0.78	0.70	0.76	0.83	0.73	0.76	16.64	10.04	7.44	5.52	1.33	8.19
BD-7146	0.91	0.79	0.79	0.81	0.83	0.83	19.30	11.52	9.40	5.45	2.48	9.63
BD-10708	0.90	0.81	0.92	0.82	0.86	0.87	16.10	10.85	8.72	7.25	3.72	9.33
Lin-1303	0.81	0.83	1.06	1.84	2.19	1.35	21.99	16.12	8.97	5.11	2.73	10.99
Lin-703	0.64	0.86	0.80	0.82	1.62	0.95	22.60	10.74	8.66	5.56	3.00	10.11
Lin-303	0.80	0.74	0.84	1.50	1.97	1.17	23.51	11.79	9.13	5.61	2.78	10.56
Lin-1403	0.85	0.71	1.36	2.02	1.81	1.35	25.16	16.25	9.88	8.71	5.06	13.01
Lin-C-17	0.85	0.84	0.78	1.15	1.97	1.12	17.37	10.80	7.44	5.46	2.41	8.70
Lin-1203	0.63	0.74	1.67	1.99	1.65	1.33	24.48	13.02	9.58	8.41	3.52	11.80
Lin-W-17	0.71	0.64	0.81	1.68	1.34	1.03	25.71	16.56	11.88	8.61	4.10	13.37
BD-10698	0.53	0.58	0.73	0.92	1.50	0.85	22.42	12.24	9.78	8.44	3.43	11.26
Lin-503	0.68	0.81	1.67	1.63	1.98	1.36	25.84	19.58	9.65	8.46	3.14	13.33
Lin-C-16	0.95	0.88	1.75	1.55	2.05	1.44	20.38	12.03	8.23	5.48	2.41	9.71
BD-10707	0.58	0.55	0.64	1.07	1.46	0.86	21.30	11.49	9.84	8.29	2.02	10.59
BD-10706	0.71	0.67	0.92	1.16	2.78	0.95	18.50	10.00	8.80	7.22	2.09	9.32
BD-10704	0.60	0.68	1.16	1.18	1.26	0.97	19.66	10.35	9.40	7.98	2.20	9.92
BD-10703	0.77	0.91	1.41	1.89	1.21	1.55	19.73	9.60	8.65	6.98	2.86	9.56
Lin-1507/2	0.78	0.85	1.15	1.53	1.93	1.25	20.38	10.75	9.23	7.98	2.43	10.16
Lin-V-18	0.83	0.72	1.07	1.39	1.40	1.08	22.94	10.44	9.31	5.70	1.66	10.01
Lin-S-19	0.87	0.92	1.16	1.34	1.35	1.13	13.28	9.56	8.12	5.96	1.28	7.64
Lin-2403	0.59	0.67	0.97	1.21	2.14	1.12	24.96	15.24	10.41	8.29	2.63	12.30
Lin-803	0.50	0.56	0.80	0.95	1.17	0.80	23.30	13.92	6.82	5.46	2.55	10.41
Lin-1503/2	0.76	0.71	0.87	0.87	1.15	0.88	17.23	11.40	9.16	8.04	1.81	9.53
Chimari	0.70	0.85	1.08	0.92	1.54	1.02	11.85	8.37	6.57	4.18	1.32	6.46
BD-7141	0.70	0.66	0.75	0.71	0.76	0.71	14.72	10.17	7.91	4.92	1.63	7.87
BD-7142	0.71	0.79	0.81	0.88	0.87	0.81	13.57	9.71	7.78	4.53	1.23	7.36
Lin-1903	0.76	0.70	0.77	0.83	1.26	0.86	14.09	9.62	7.37	5.19	1.94	7.64
Mean	0.73	0.75	1.00	1.20	1.47	1.03	19.92	11.98	8.91	6.58	2.54	9.99
SD	0.12	0.10	0.31	0.42	0.52	0.22	4.61	2.83	1.60	1.64	1.06	4.42
Minimum	0.50	0.55	0.64	0.64	0.73	0.70	11.78	8.37	6.06	3.13	0.92	6.06
Maximum	0.95	0.92	1.75	2.02	2.78	1.44	28.86	19.58	14.16	8.96	5.11	14.79

LSD(P≤0.05): Genotype=0.1808, Salinity =0.0751, Salinity*Salinity =0.4043

LSD(P≤0.05): Genotype=0.6592, Salinity =0.2737, Salinity*Salinity =1.4741

the vacuoles without any physiological impairment, ion discrimination (K^+ , Na^+ , Cl^- and SO_4^{2-}) during uptake by roots and translocation to shoot. Various biochemical processes such as production of some enzymes, hormones, antioxidants, osmoprotectants (malate, proline) are also involved in salt mechanisms of crop plants (Almansouri *et al.* 2001; Parida and Das 2005).

Conclusion

The results of the present investigation revealed that salinity (NaCl) stress at 4, 8, 12 and 16 dS m⁻¹ caused significant reduction over control in early seedling growth related parameters such as fresh and dry weights, and root length and shoot length of seedling, root to shoot ratio,

Table 5. Effect of salinity (NaCl) stress on salt tolerance indices of seedling dry weight of 29 linseed genotypes under control condition

	Salt tolerance index (%) under different levels of salinity (dS m ⁻¹)					Mean
	0	4	8	12	16	
Neela	100.00	66.27	56.73	36.63	26.06	57.14
BD-7143	100.00	83.66	65.76	41.63	15.17	61.24
BD-10710	100.00	66.39	61.43	57.02	33.88	63.74
BD-7146	100.00	64.37	55.82	50.12	30.64	60.19
BD-10708	100.00	71.09	60.47	50.29	27.43	61.86
Lin-1303	100.00	80.22	50.33	44.83	26.59	60.39
Lin-703	100.00	53.35	46.85	43.61	26.16	53.99
Lin-303	100.00	54.09	45.42	40.93	22.42	52.57
Lin-1403	100.00	68.11	44.67	40.15	24.30	55.45
Lin-C-17	100.00	66.86	50.98	45.52	21.66	57.00
Lin-1203	100.00	57.71	45.03	41.06	23.96	53.55
Lin-W-17	100.00	68.06	52.81	38.29	23.41	56.51
BD-10698	100.00	58.84	49.02	44.78	24.22	55.37
Lin-503	100.00	78.03	43.00	39.27	24.58	56.98
Lin-C-16	100.00	60.97	45.24	42.79	22.29	54.26
BD-10707	100.00	58.05	51.69	45.27	18.46	54.69
BD-10706	100.00	57.39	53.65	48.19	15.86	55.02
BD-10704	100.00	56.78	53.61	49.41	21.24	56.21
BD-10703	100.00	52.93	49.81	45.28	21.82	53.97
Lin-1507/2	100.00	55.88	50.90	46.87	19.65	54.66
Lin-V-18	100.00	49.90	48.13	42.86	20.50	52.28
Lin-S-19	100.00	76.27	67.46	50.51	17.96	62.44
Lin-2403	100.00	65.65	46.62	38.63	54.18	61.02
Lin-803	100.00	66.37	39.53	36.49	53.45	59.17
Lin-1503/2	100.00	75.61	59.62	54.47	62.00	70.34
Chimari	100.00	77.35	70.87	55.98	64.79	73.80
BD-7141	100.00	76.15	64.52	50.15	62.02	70.57
BD-7142	100.00	80.07	69.76	50.51	63.16	72.70
Lin-1903	100.00	72.75	64.06	58.26	64.87	71.99
Mean	100.00	66.18	53.92	45.86	57.72	59.62
SD	100.00	83.66	70.87	58.26	64.87	6.48
Minimum	0.00	9.58	8.61	6.05	4.03	52.28
Maximum	100.00	49.90	39.53	36.49	52.28	73.80
LSD (P=0.05): Genotypes = 1.3913, Salinity = 0.5777, Genotypes*Salinity = 0.4043						

seedling vigor index and salt tolerant index. The reduction was gradual in parallel with increased level of salinity. A wide range of variations were observed in the genotypes of linseed in terms of responses of early seedling growth related parameters to salinity stress. The genotypes Neela, Lin-W-17, B-10708, BD-10710, Lin-1303, Lin-2403, BD-10698, Lin-S-19, BD-7143 and Lin-503 demonstrated considerably early seedling growth and salt tolerance, withstanding salinity stress effectively. These genotypes were noted as prospective materials for the development of salt tolerant linseed varieties.

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Taxonomic notes on some newly recorded species of orb-weaving spiders of Bangladesh

Vivekanand Biswas

Department of Zoology, Khulna government Womens' College, Khulna-9000, Bangladesh

Corresponding email : vivekarach@gmail.com

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Abstract

Taxonomic studies on some orb-weaving spiders of the genus *Singa* C.L. Koch, 1836 was made in the coastal areas of district Khulna, Bangladesh. Two species were newly recorded from this study, namely - *S. chota* Tikader and *S. haddoensis* Tikader. Generic diagnosis, illustrated description, distribution and key to the species were included herewith.

Keywords: Taxonomy, Orb-weaving spider, Araneae, Araneidae, Araneinae, Bangladesh

Introduction

Orb-weaving spiders (family Araneidae) are one of the important predatory members in the crop-fields and gardens of Bangladesh. These are very attractive due to their beautiful colour and ornamented body appearances. They play a great role in the insect pest management systems in the crop-fields and gardens by making typical webs within plan leaves and stay there for the preys.

Members of the family Araneidae are small to medium in size. At present, the the family contains a total of 3,129 species belonging to 191 genera in the world fauna (World Spider Catalog, 2024). Species of genus *Singa* C.L. Koch are small and colourful spiders. The genus also called striped orb-weavers, first erected by C. L. Koch in 1836 with the type-species *S. hamata* (Clerck, 1757). At present the genus contains a total of 28 species world wide (World Spider Catalog, 2024) of which there is no previous record in the fauna of Bangladesh (Chowdhury & Nagari 1981 ; Chowdhuri & Pal 1984 ; Okuma *et al.* 1993 ; Begum & Biswas 1997 ; Biswas *et al.* 1995). But there are satisfactory records available in different countries of the world like – India (Tikader 1970 , '77 ; Tikader & Biswas 1981), China (Song & Zhu 1992 ; Yin *et al.* 1997), The Philippines (Barrion & Lisinger 1995), Korea (Kim & Lee 2012), Israel (Levy 1984), USA (Levi 1972, '2002), USSR (Marusik 2009) and so on.

The present paper contains illustrated description of 2 (two) newly recorded species namely – *S. chota* Tikader

and *S. haddoensis* Tikader with their distribution and key to the species.

Materials and methods

Collection and preservation: Specimens of the genus *Singa* C.L. Koch were collected from the crop-fields and gardens of different areas of districts Jashore, Khulna, Bagerhat, Barisal and Faridpur of Bangladesh. Collections were made by hand with vials from the webs and by jarking the branches of plants on an inverted umbrella placed underneath the plants (Tikader 1987). Collected specimens were then placed to a large glass vial containing chloroform with cotton for paralyzing the specimens. These were then transferred to a petri-dish filled with 70% ethyl alcohol for sorting the specimens. After sorting, the specimens were separated each other and preserved separately in glass vials with 70% alcohol for identification and future study.

Identification and study: The preserved specimens were identified following various famous books and journals of home and abroad. These are – Tikader (1982, '87), Barrion and Litsinger (1995), Biswas (1995), Yin *et al.* (1997), Song *et al.* (1999), Dondale *et al.* (2003), Levy 1984), Kim and Lee (2012) and Jhao (1993).

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

In the taxonomic study, necessary important body-parts of the identified specimens were dissected out under the Stereozoom Binocular Microscope on a petridish filled with 70% alcohol and few sand grains. Male palps after dissection were boiled in 10% KOH for 3-5 minutes and female epigynum after dissection stay in clove oil for 12-18 hours (Levi 1965 ; Tikader 1987). After study, both male palp and female epigynum were placed in separate microvial and put it in a large vial (containing Audmans' Preservatives) along with parent spider.

Illustration and photographs : Adult body and different body-parts of identified spiders were illustrated by Camera lucida fitted with Stereozoom Binocular microscope. Legs were measured in the following sequences : femur, patella, tibia, metatarsus, tarsus and total length, under the same condition and all measurements were taken in millimeters (mm). Photographs were taken in the laboratory by Camera-fitted microscope , model SV8, Zeiss.

Type-deposition : After study and illustrations, the preserved specimens are placed 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 : ARANEIDAE

Subfamily : Araneinae

Genus : *Singa* C.L. Koch, 1836

Type-species : *Aranea hamatus* Clerck, 1757

1836. *Singa* : Koch, *Die Arachniden*, III : 42.
 1940. *Singa* : Comstock, *The Spider Book* : 475.
 1970. *Singa* : Tikader, *Rec. zool. Surv. India*, **64**(1-4) : 35.
 1977. *Singa* : Tikader, *Rec. zool. Surv. India*, **72** (1-4) : 183.
 1981. *Singa* : Tikader & Biswas, *Rec. zool. Surv. India*, **30** : 43.
 2015. *Singa* : Platnick, *World Spider Catalog*, Version 15.5, <http://www.research.amnh.org/iz/spider/catalog/intro.html>
 2024. *Singa* : *World Spider Catalog*, Version 24.5, Nat. Hist. Mus. Bern, <http://www.wsc.nmbe.ch> (accessed on 07th Nov., 2024)

Diagnosis : Spiders of the genus *Singa* C. L. Koch are small to medium in size. Cephalothorax broad, sparsely

covered with short hairs. Eyes usually in 2 rows, posteromedian eyes closer than the anterolaterals. Legs relatively short, without ventral femoral spines. Males have protuberances on coxae I and II. The male palpal organs are rather similar.

Abdomen oval or nearly so, covered with sparsely distributed short hairs, medially broad and little depressed.

Biological note : Species of the genus *Singa* are usually called striped orb-weaving spiders. They make typical orb-webs in the crop-fields and gardens in the afternoon during sunset and stay near the middle of the webs for the prey. They are predatory in habit and consume small pest insects by their webs. Thus, they help in the biological control of crop pests and so that they are considered as one of the important biological control agent in the crop-fields and gardens.

Distribution : ASIA ; AMERICA ; AFRICA.

Key to the species of genus *Singa* C. L. Koch

1. Abdomen elongately oval, faintly constricted anteriorly ; sternum medially broad and posteriorly produced ; cheliceral tooth absent ; maxillae oval and labium urchin-like anteriorly truncate, epigyne as in fig. 2e
 *haddoensis*
- Abdomen typically oval, without any such constriction; sternum typically heart-shaped ; chelicerae toothed; maxillae flat, elongate, anteriorly broad and labium anteriorly bluntly pointed ; epigyne as in fig. 1e
 *chota*

Description of the species

1. *Singa chota* Tikader, 1970 (Figures 1a – 1e ; Plate - 1a)

1970. *Singa chota* Tikader, *Rec. zool. Surv. India*, **64**(1-4) : 35.
 1981. *Singa chota* : Tikader & Biswas, *Rec. zool. Surv. India*, **30** : 43.
 2015. *Singa chota* : Platnick, *World Spider Catalog*, version 15.0, <http://www.research.amnh.org/iz/spider/catalog/intro.html>
 2024. *Singa chota* : *World Spider Catalog*, version 24.5, Nat. Hist. Mus. Bern, <http://www.wsc.nmbe.ch> (accessed on 7th Nov. 2024)

Materia examined : 1 female, ADI Faridpur, 09. VI. 1995, Coll. V. Biswas ; 2 female, Jashore, 12 . II. 1998, Coll. V. Biswas ; 1 female, Dumuria, Khulna, 08. VII. 2001 , Coll. V. Biswas ; 2 females, Bagerhat, 24. VII 2002 , Coll. V. Biswas.

General : Body small, longer than wide, light yellow in colour. Cephalothorax and legs brown ; abdomen brown with white scally reticulations. Total body length 4.10 mm. Carapace 1.50 mm long, 1.25 mm wide ; abdomen 2.60 mm long and 1.45 mm wide.

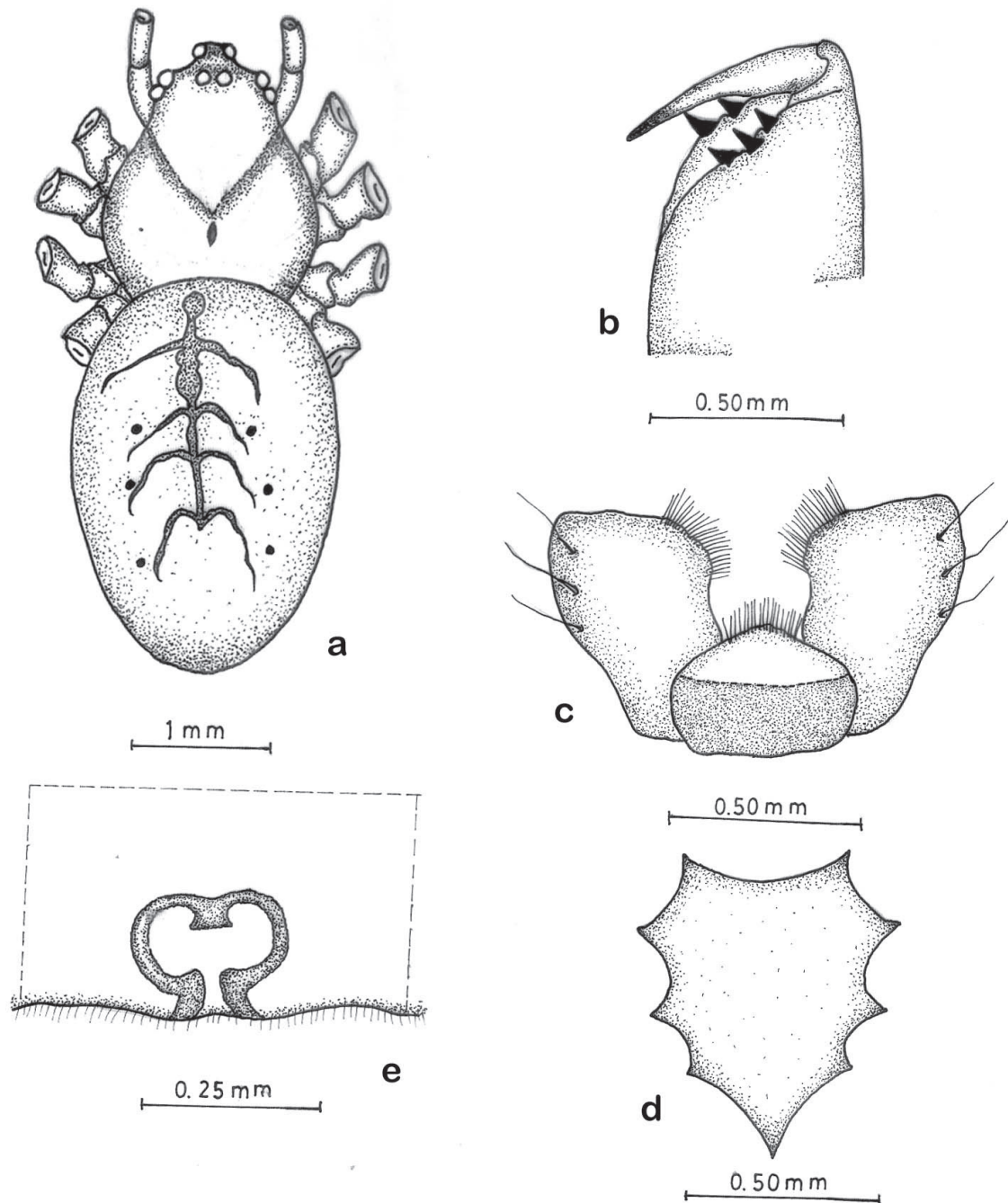


Figure 1 (a-e). *Singa chota* Tikader a. Whole body (dorsal view); b. Chelicerae; c. Maxillae and Labium; d. Sternum; e. Female epigynum.

Cephalothorax : Longer than wide, posteriorly broad, anteriorly narrowed, clothed with fine hairs ; cephalic region dark brown, raised, narrowing anteriorly, weakly constricted, with distinct cervical furrows ; thoracic region with central longitudinal fovea; radii distinct. Eyes pearly white, with black basal band, anterior row strongly recurved and posterior row faintly so ; lateral eyes close, placed marginally, anteromedians larger, situated on the lateral concavity of protuberance ; ocular quad wider than long, anteriorly broad, posteriorly narrowed. Chelicerae

brown, strong, each of inner and outer margins with 3 and 2 teeth, fang broad basally (Fig. 1b). Maxillae brown, longer than wide, anteriorly broad and scopulate (Fig. 1c). Labium brown, broad medially and scopulate anteriorly (Fig.1c). Sternum yellow brown, heart-shaped, narrowing posteriorly (Fig. 1d). Legs long and strong, clothed with few spines and hairs ; leg formula 1243 and the measurements (in mm) of leg segments are shown in Table -1.

Table 1. Measurements (mm) of leg segments of *S. chota* Tikader

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	2.00/2.00	0.90/0.90	2.00/2.00	2.00/2.00	0.80/0.80	7.70/7.70
II	2.00/2.00	0.50/0.50	1.50/1.50	1.20/1.20	0.60/0.60	5.80/5.80
III	1.50/1.50	0.30/0.30	1.00/1.00	0.70/0.70	0.40/0.40	3.90/3.90
IV	1.50/1.50	0.50/0.50	1.50/1.50	1.10/1.10	0.50/0.50	5.10/5.10

Abdomen : Oval, longer than wide, narrowing posteriorly, dorsum whitish, reticulate, provided with longitudinal and transverse brown stripes and 3 pairs of sigillae, clothed with fine hairs ; epigyne as in fig. 1e.

Male unknown and will be described when available.

Distribution : BANGLADESH : Faridpur, Jashore, Khulna, Bagerhat ; INDIA (Tikader, 1970; Tikader & Biswas, 1981).

2. *Singa haddoensis* Tikader, 1977 (Figures 2a - 2f ; Plate – Ib)

1977. *Singa haddoensis* Tikader, *Rec. zool. Surv. India*, **72**(1-4) : 183.

2015. *Singa haddoensis* : Platnick, *World Spider Catalog*, version 15.0, <http://www.research.amnh.org/iz/spider/catalog/intro.html>

2024. *Singa haddoensis* : *World Spider Catalog*, version 24.5, Nat. Hist. Mus. Bern., [http:// www.wsc.nmbe.ch](http://www.wsc.nmbe.ch) (accessed on 7th Nov. 2024).

Material examined : 1 female, Barisal, 08.II.1995, Coll. V. Biswas ; 2 female, Comilla, 18. V. 1995, Coll. V. Biswas ; 1 female, Bhawal park, Gazipur, 12. IV. 1996, Coll. V. Biswas ; 1 female, S. Park, Dhaka, 14.III. 1997, Coll. V. Biswas ; 2 females, Terosree, Manikganj, 08. VII. 1998, Coll. V. Biswas.

General : Body small, yellowish brown in colour. Cephalothorax and legs red brown ; abdomen chalk-white, with brown streaks. Total body length 4.50 mm. Carapace 2.00 mm long, 1.65 mm wide ; abdomen 2.60 mm long and 1.00 mm wide.

Cephalothorax : Longer than wide, posteromedially broad, narrowing anteriorly, with a weak constriction, clothed with hairs ; cephalic region faintly raised ; thoracic

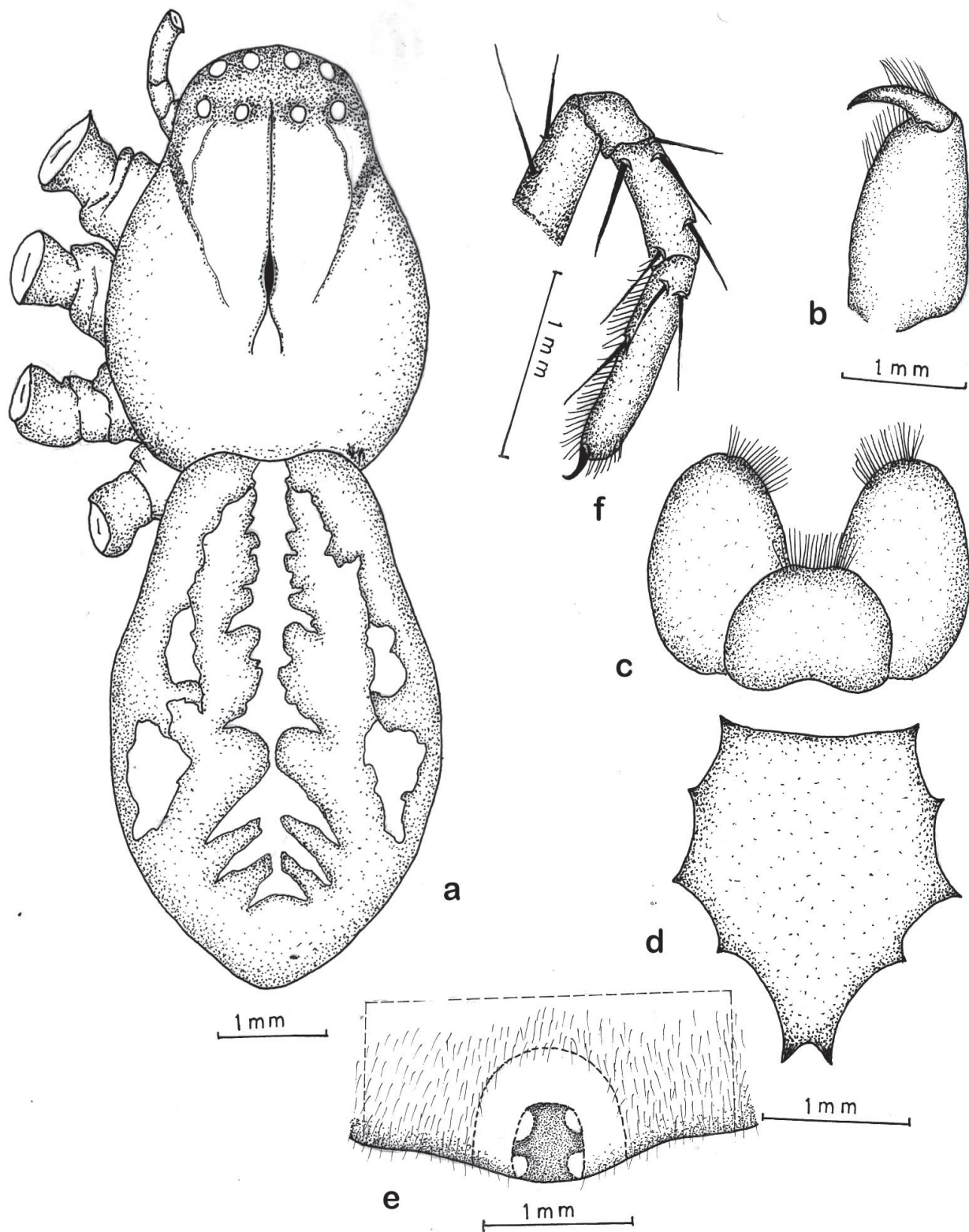


Figure 2 (a-f). *Singa haddoensis* Tikader a. Whole body (dorsal view); b. Chelicerae; c. Maxillae and Labium; d. Sternum; e. Female epigynum; f. Tarsal segment of leg-I.

region with a deep longitudinal fovea. Eyes pearly white, with black basal patch ; anterior row recurved and posterior row faintly procurved ; anteromedians largest ; ocular quad longer than wide, anteriorly narrowed. Chelicerae brown, strong, longer than wide, without any tooth (Fig. 2b). Maxillae pale brown, nearly oval, scopulate anteriorly (Fig. 2c). Labium brown, typically urchin-

like, anteriorly scopulate (Fig. 2c). Sternum yellow, broad medially, posteriorly narrowed and produced, with long fine hairs (Fig. 2d). Legs long and slender, clothed with hairs ; metatarsi and tarsi of leg I and II with brown, strong spines (Fig. 2f) ; leg formula 2143 and the measurements (in mm) of leg segments are shown in Table – 2.

Table-2. Measurements (mm) of leg segments of *S. haddoensis* Tikader

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	5.00/5.00	2.00/2.00	4.50/4.50	4.50/4.50	1.50/1.50	17.50/17.50
II	6.00/6.00	2.00/2.00	6.00/6.00	6.00/6.00	2.00/2.00	22.00/22.00
III	4.00/4.00	3.00/3.00	3.00/3.00	3.00/3.00	1.50/1.50	13.50/13.50
IV	5.00/5.00	1.30/1.30	3.50/3.50	4.00/4.00	1.20/1.20	15.00/15.00

Abdomen : Elongately oval, posteromedially wide, posteriorly narrowed ; dorsum decorated with white bands, clothed with hairs and dense pubescences ; ventrally pale with deep brown longitudinal bnds, clothed with dense pubescence and hairs ; epigyne as in fig. 2e.



Plate-1a. *Singa chota* Tikader.



Plate-1b. *Singa haddoensis* Tikader.

Figure 3. Orb-weaving spiders.

Conclusion

Members of the genus *Singa* C.L. Koch are one of the important predatory spiders in the crop-fields and gardens. But the taxonomic history of these spiders in Bangladesh reveals that there is no previous record of study took place in this country. In the present study, it was observed that there are some variations observed with the previously described Indian fauna in different characters like - colour, shape, size etc.

In behaviour, both the species are natural predators of insect pests in the crop-fields and gardens. They consume a good number of preys regularly by their webs and thus, play a vital role in the biological pest management system as predator of insect pests. Therefore, a detailed taxonomic and ecological study on these spiders may be undertaken and thus, in future, may be observed their actual ecological position in crop pest management system in agriculture.

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Farmers preference and challenges of producing oilseed crops in Bangladesh

Mohammad Moziball Hoque¹ Rinki Akter¹ and Md. Abdul Karim^{2*}

¹Solidaridad Network Asia, House# 32, Road 10A, Dhanmondi, Dhaka 1209, Bangladesh; ²College of Agricultural Sciences, International University of Business Agriculture and Technology, Uttara Model Town, Dhaka, Bangladesh

Corresponding email: akarim1506@gmail.com

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Abstract

Despite substantial agricultural and economic growth, the country is still 90% dependent on importing edible oil. Considering the importance of promoting oilseeds cultivation, Solidaridad Network Asia (SNA) in Bangladesh conducted a market assessment and feasibility study on challenges and opportunity of expanding edible oilseeds production in the country. The present paper presents the comprehensive report of the study which was carried out for 6 months from January 2024 to June 2024 using multiple techniques including literature reviews, survey questionnaires, conducting Key Informants Interviews (K-II) with a wide range of other relevant stakeholders and Focus Group Discussions (FGD) with farmers in five Districts namely Dinajpur, Thakurgaon, Tangail, Lakshmipur and Noakhali. The findings indicated that in Lakshmipur and Noakhali districts, farmers cultivate only soybeans as oilseed crop, while in Dinajpur, Thakurgaon and Tangail the farmers cultivate mostly mustard. It was observed that farmers are cultivating some new varieties which are of high yielding, climate resilient and short duration resulted in making more profit than that of earlier time. Farmers of Dinajpur, Thakurgaon and Tangail are now getting more yields through cultivating BARI sarisha-14 mustard variety, while they used to cultivate Tori-7 earlier. BU soybean 2 is better option for soybean production. Most of the farmers opined that cultivating oilseeds was more profitable as they can cultivate three crops in a calendar year. Factor analysis indicated that making decision to cultivate oilseeds was not an issue of single factor, instead temperature, rainfall, cash, irrigation equipment, input availability, comparison of profitability to other crops, quality of seeds, high yielding and short duration varieties were also determining factors. Farmers are fond of cultivating mustard over other oilseeds like soybeans, sunflower or groundnut in the northern part of Bangladesh, while farmers of Noakhali and Lakshmipur preferred soybean. According to FGDs and K-II mustard suffers from thirteen diseases, while soybean from sixteen fungal, two bacterial and virus diseases, of which yellow mosaic virus and anthracnose are the major problems. Based on the findings it was recommended to ensure availability of high yielding climate resilient seeds, timely supply of fertilizer at a subsidized price, access to credit or financial support, area specific measures to solve the agricultural problems, forming effective farmers cooperatives, partnership between public-private research and extension organizations, involvement of next generations in farming, and introducing Rotating Savings and Credit Association (ROSCA) for sustainable and maximizing oilseeds production in Bangladesh.

Keywords: Oil seeds, challenges, respondent, constraints

Introduction

Agriculture is the most vital sector in Bangladesh economy, contributing around 12% of GDP and employing over a third of the population. However, the country relies heavily on imports of oil and fats, meeting only 12% of the demand from local production of oilseed crops like mustard (*Brassica* spp.), soybean (*Glycine max*), sesame (*Sesamum indicum*), and sunflower (*Helianthus annuus*). In Bangladesh, total amount of oilseed production in the year 2022-23 was 1171340.46 M tons from an area of 551299.98 hectares (BBS 2023). According to the National Board of Revenue (NBR) the country imported

0.74 M tons of soybean and 1.06 M tons of palm oil in crude and refined forms in Fiscal Year 2020-21. However, CEIC (2024) database indicated that edible oil imports dropped to 15,723.52 million BDT in July 2024 from 36,702.00 million BDT in June 2023. The big pressure of import on national economy necessitates dedicated, collective and incentive oriented initiatives and effort to inspire the farmers for cultivating more oilseeds crops in Bangladesh. According to Miah *et al.* (2015) by using improved varieties of mustard, groundnut, soybean and sesame the job opportunities may be increased to 12.7, 11.6, 15.4 and 6.1 % man days/ha.

The agricultural sector of Bangladesh faces challenges due to climate change, poor market integration, and limited farmer organizations, which heighten vulnerability to market fluctuations. According to Miah and Mondal (2017) there are challenges like climate variability, competition with other crops for scarce resources, and high infestation of insects and diseases for increasing oilseed crops production. In response, Solidaridad Network Asia (SNA) - an international development organization, in collaboration with the Department of Agricultural Extension (DAE) and private sector partners, is promoting sustainable soybean and mustard cultivation through an integrated approach to mitigate the climate and market risks. Considering the importance of promoting oil seed cultivation, SNA conducted a survey on edible oil seeds production in Bangladesh to identify the constraints that are facing by the farmers, and suggest measures for overcoming the problems. The specific objectives of the study were to identify viable interventions and working model for the small-holder oilseed farmers, take initiatives that need to be in place to encourage the smallholders to take up oilseed farming to reduce import outflows and to analyze the elasticity, prospects and challenges of oil seeds cultivation in Bangladesh. The outcome of the study is envisaged to support the planners to take appropriate actions for mitigating the gap between oilseeds production and demand.

Methodology

Study area selection and sampling techniques: The study focused on the locations where farmers grow mustard and soybeans, and to identify potential of new areas. Five districts were selected, covering six sub-districts (upazillas) and ten unions. Unions with ongoing oilseeds cultivation were prioritized, with two unions chosen from each upazilla, except Baliadanga and Tangail Sadar, which had one union each. The five districts were Dinajpur, Tangail, Thakurgaon, Laksmipur and Noakhali (Fig. 1). The six upazillas were Birganj (Dinajpur), Tangail sadar, Baliadanga (Thakurgaon), Thakurgaon sadar, Kamalnagar (Laksmipur) and Subarnachar (Noakhali). The study was carried out using multiple techniques including collecting

primary data through survey questionnaire, conducting Focus Group Discussions (FGD) with farmers and Key Informant Interviews (KII) with a wide range of other relevant stakeholders.

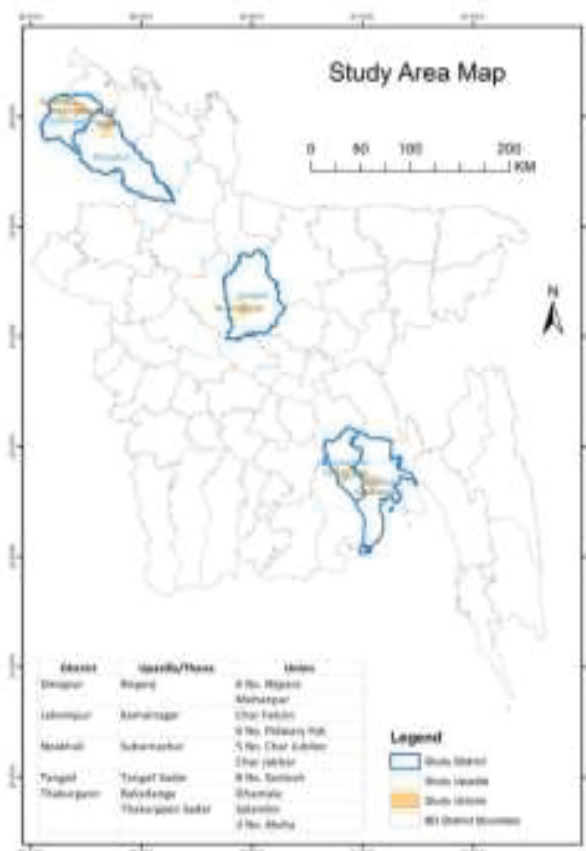


Figure 1. Map of the study areas.

Data collection methods: The study followed a mixed approach including both quantitative and qualitative methods. Desk research was carried out on a regular basis following a list of relevant documents. The policy anatomy was considered with a view to exploring the policy support provisions and challenges/policy barriers in relation to oil seeds cultivation.

The primary survey was conducted with 100 farmers under five districts. A structured questionnaire was used for conducting the survey with farmers. In addition, 30 KII was also conducted with the relevant personnel of the five districts. The sample size of the primary survey with farmers was 100, while 20 farmers were interviewed from each field of the five fields.

Two Research Assistants who got engaged in collecting data from the fields were trained on the tools after finalizing the survey, K-II and FGDs tools incorporating feedback from SNA personnel.

The selection of K-II participants was objective driven to cover the total scope of the study. To address different aspects and acquire relevant knowledge and information, the participants were selected from a wide range of stakeholders' group. For conducting K-II, semi-structured questionnaire as a tool was used. The semi-structured format was considered keeping provision of flexibility to ask probe and more relevant questions as and when required to serve the specific purpose of conducting that particular K-II. Altogether 24 K-IIs were conducted. The FGDs were conducted with farmers only. A total of 10 FGDs were conducted where 2 FGDs from each of the five districts.

Results and Discussion: In relation to oilseeds cultivation, there is a signature finding that in Dinajpur, Thakurgaon and Tangail the mustard cultivation is very common, while soybean cultivation is not commonly

available. On the other hand, in Noakhali and Laksmipur the farmers cultivate soybeans while they do not prefer to cultivate mustard. A very few farmers cultivate sunflower and groundnut.

Figure 2 reflects that out of 100 farmers, who got interviewed, cultivate mustard or soybeans, while only a very few responded cultivate sunflower and groundnut. Farmers of Birganj of Dinajpur district, Baliadanga and Thakurgaon Sadar of Thakurgaon district, and Tangail Sadar of Tangail district cultivate mustard only, while in Kamalnagar of Laksmipur district and Subarnachar of Noakhali district the farmers do not cultivate mustard usually, instead cultivate soybeans only.

Figure 3 indicates the experience of average, maximum, and minimum years of oilseed cultivation by the farmers across six Upazillas. Farmers of Baliadanga have the shortest cultivation history, with an average of 5 years, a maximum of 6 years, and a minimum of 2 years. This indicates that farmers here are relatively new to oilseed farming. Farmers of Birganj have more experience, with a maximum of 35 years, a minimum of 1 year, and an

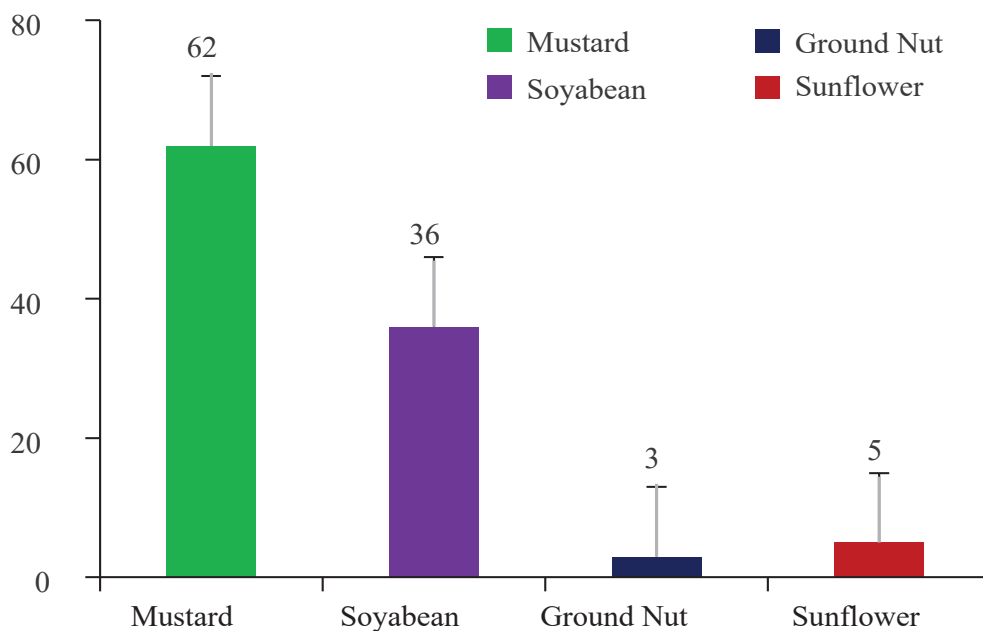


Figure 2. Respondent farmers on cultivation of different types of oil seed crops in five districts of Bangladesh.

average of 14 years. Kamalnagar and Subarnachar have identical maximum values (40 years) but differ in their averages (22 years and 25 years, respectively), showing a longer history of cultivation of soybean. Tangail Sadar stands out with the longest cultivation history of mustard, with a maximum of 50 years, an average of 29 years, and a minimum of 8 years. Farmers of Thakurgaon Sadar

have a maximum of 35 years and an average of 9 years, but with a lower minimum of 2 years. This data confirms that while most areas have a long history of oilseed farming, Baliadanga presents an opportunity for further development and awareness efforts, as it is comparatively new to this agricultural practice.

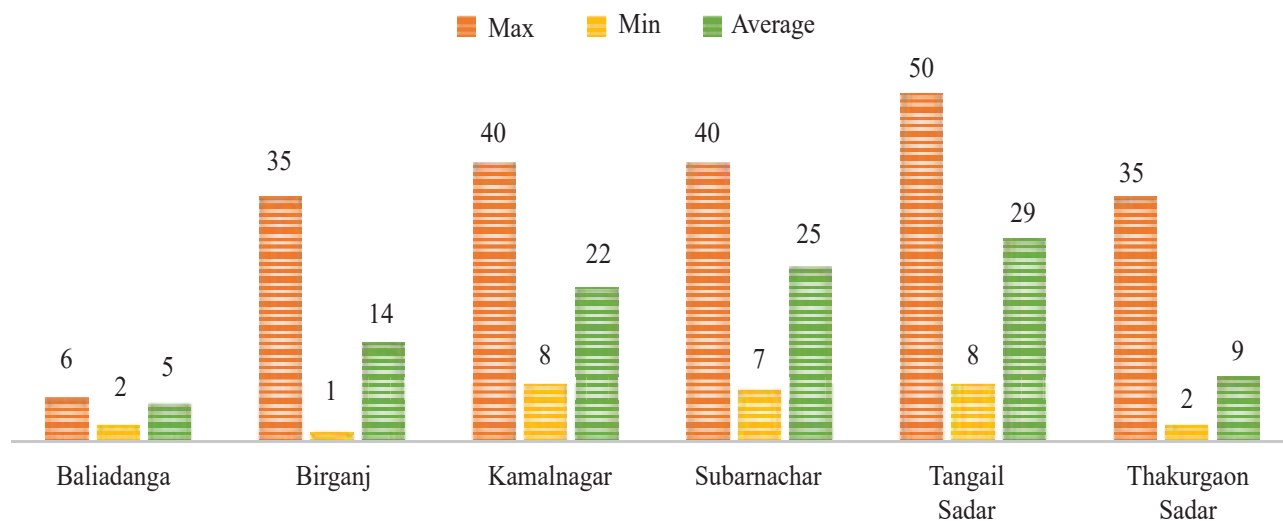


Figure 3. Average years of farmer experience of oil seed cultivation in six upazillas.

There is an important finding that 43% farmers cultivate oilseed on the total amount of land (Figure 4) that they have, or even they borrow from others which has a signature that they are convinced with cultivating oil seed.

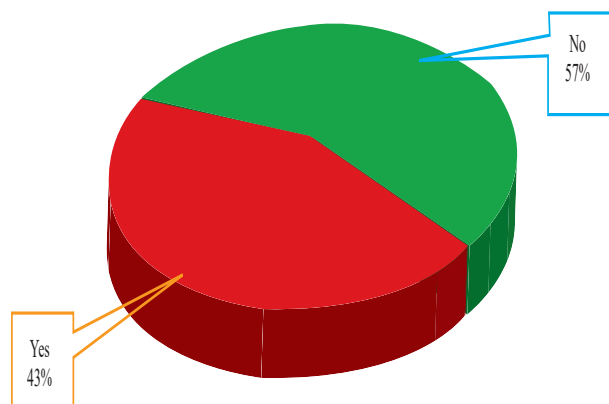


Figure 4. Percentage of respondents cultivate oilseed on the total land that they have or they borrow.

Motivation of farmers behind oilseed cultivation: In response to the question regarding reasons/motivation of cultivating oil seeds, almost all the farmers opined that oil seed cultivation was profitable. The Figure 4 depicts the response status and most of the farmers considered economic aspects while they choose for oil seed cultivation.

The Figure 5 illustrates various motivations behind oilseed cultivation across different regions. More profit was the top motivation for farmers in all regions, with Baliadanga 9 respondents, while Thakurgaon Sadar 10, Birganj 20, Kamalnagar 20, Subarnachar 20, and Tangail Sadar 19 respondents. Cultivating in between other crops is another significant factor, especially in Kamalnagar (2 respondents), Tangail Sadar (1 response), and Birganj (2 responses). Buy-back guarantee and training were noted by some farmers in Thakurgaon Sadar (2 respondents each). Regular advice from BADC/DAE was more prominent in

Baliadanga (3 respondents), but it was a minor factor for others (2 respondents in Birganj, and 1 in Tangail Sadar). Other factors had minimal impact overall, with only 1-2

respondents across the regions. Therefore, profitability is the primary motivation for oilseed cultivation, followed by the flexibility to cultivate between other crops.

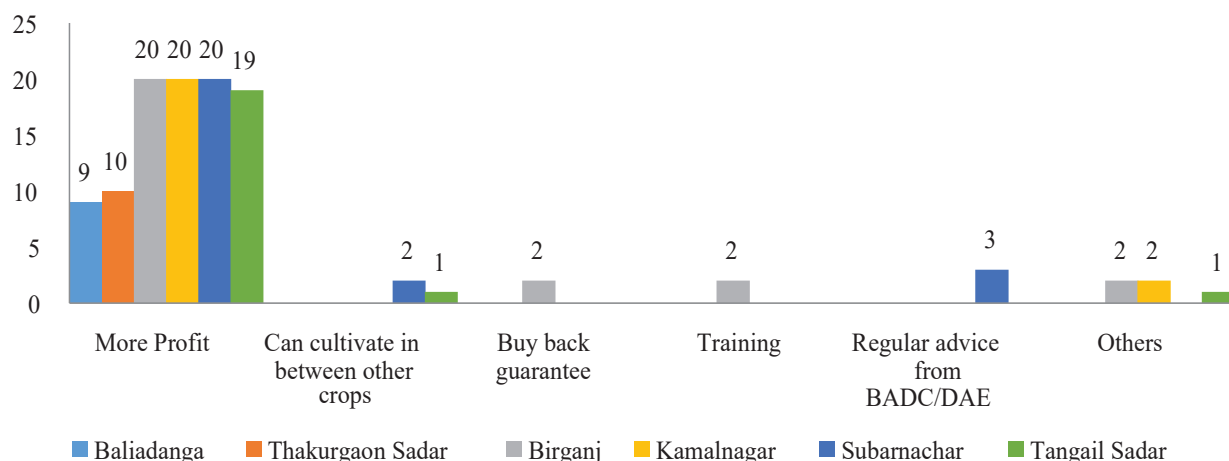


Figure 5. Types of motivation works behind to cultivate oilseed.

Profitability of cultivating oil seeds: While cultivating oilseeds is comparatively profitable but in reality, the economic analysis of production of this crop remains unnoticed to most of the farmers who are not cultivating oil seeds.

In response to the question to know about comparison of income with other crops, Figure 6 indicates that 98% of the farmers opined that cultivation of oilseed is more profitable than other crops, while 2% are unsure. No one believes that it was less profitable than other field crops.

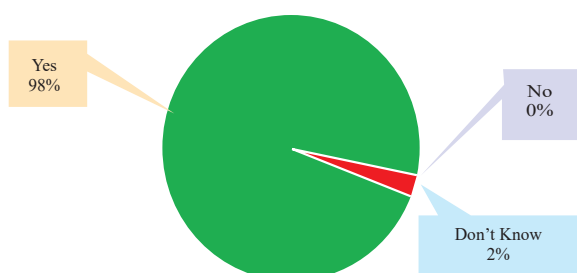


Figure 6. Response in relation to comparative profitability of oilseeds with other field crops.

Figure 7 indicates the response of farmers on the average income from oilseed cultivation from 6 regions. In Thakurgaon, specifically in the Baliadanga and Thakurgaon Sadar upazilas, farmers earn the highest income (30,000 Tk/ bigha) from mustard seeds compared to other upazilas like

Birganj (28,320 Tk/bigha) and Tangail Sadar (16,579 Tk/bigha) and average income from soybean seeds in Kamalnagar (28,080 Tk/bigha) and Subarnachar (28,600 Tk/bigha). This is because

oilseed cultivation is relatively new in Thakurgaon, leading to fewer farmers growing it and causing higher demand with limited supply, which results in better prices for the farmers there.

Figure 8 presents the average income per bigha (0.133 ha) of mustard seed cultivation against cost invested. Cultivating oilseed is profitable which has been further validated from the income and cost calculation. It was observed that in Baliadanga and Thakurgaon the cultivation of mustard was higher profitable, which was about 30,000 BDT, than that of Tangail Sadar (15,750 BDT). The income in Tangail was relatively less and the reasons behind were the lack

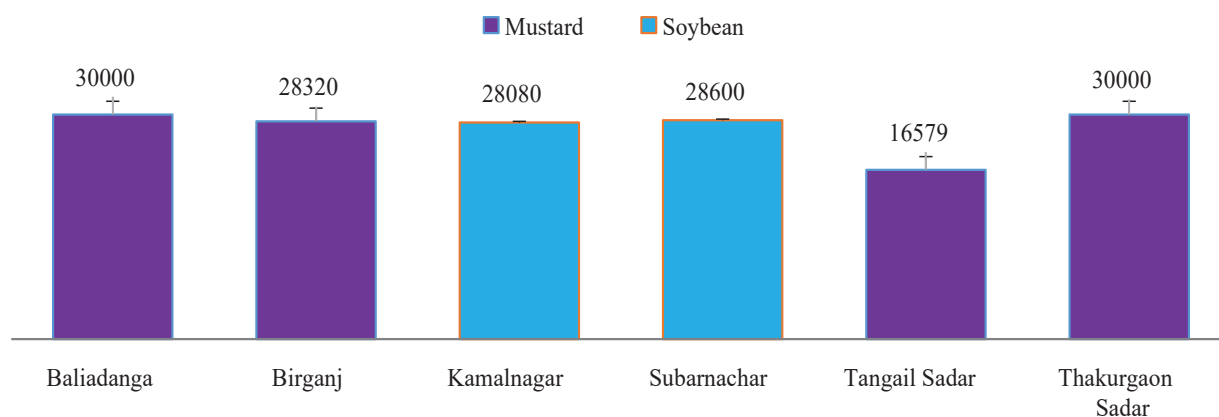


Figure 7. Average income (Tk.) from oilseed cultivation per bigha.

of ensuring good management. Farmers there cultivate mustard without taking much care of land preparation, giving sufficient fertilizers and using the old varieties. In Tangail Sadar, the area where the study was conducted, farmers were cultivating mostly Binasorisa-9, Tori-7 and Maghi which are low yielding varieties. According to DAE, altogether 41,700 hectares of land in the district was cultivating mustard. While BARI sharisha 14 is the good variety, still the farmers of Tangail cultivate other varieties. Moreover, compared to other districts, farmers of Tangail give main effort for rice cultivation, and often neglect to take proper care for their oilseed cultivation, especially after sowing seeds, leading to lower yields.

This negligence further contributes to their reduced income levels. However, farmers opined that mustard cultivation requires less efforts, less labor and less cost. Farmers in Kamalnagar upazilla of Lakhmipur district claimed that average price of soybean was 58.5 Taka/ kg while farmers of Subarnachar Upazilla of Noakhali district recorded a slightly higher rate of 59.63 Taka/ kg. The farmers in Kamalnagar got higher yields (3361.5 kg/ ha) on an average than the farmers in Subarnachar who harvested on an average 3025.3 kg/ha. As a result, farmers in Kamalnagar got more profit as the production cost per Bigha was almost same.

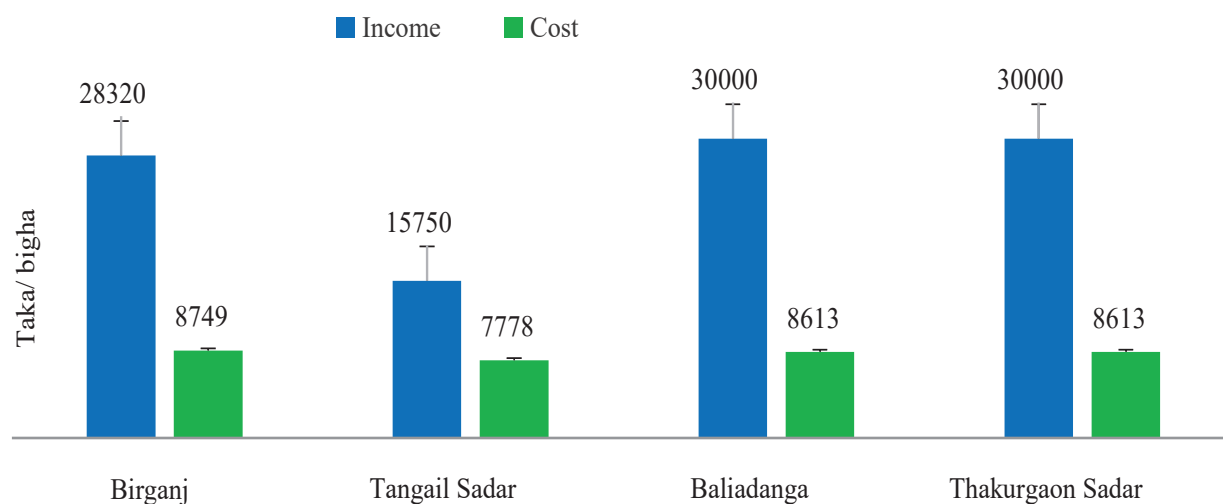


Figure 8. Average income of mustard seed cultivation.

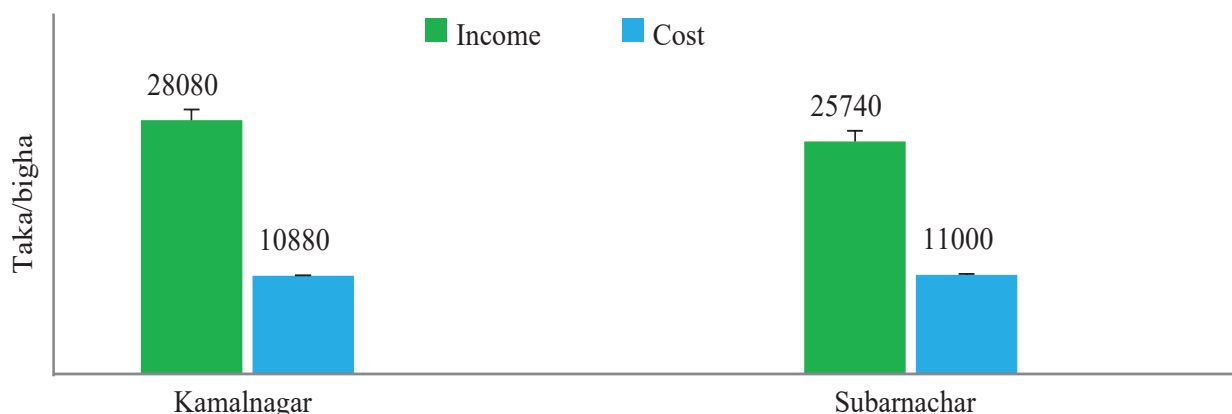


Figure 9. Income and cost of soybean production in Kamalnagar and Subarnachar.

The Figure 9 shows that the average income (per bigha) was 28,080 BDT when cost was 10,880 BDT of soybean production in Kamalnagar, while the average income was 25,740 BDT when the cost was 11,000 BDT of soybean production in Subarnachar. The profitability of oilseed cultivation was substantiated with the logic that farmers can cultivate three crops in one land per year.

Use of the produced seed: Dunford (2016) reported oilseeds need to be cleaned by removing plant stems, sticks, leaves and foreign material before storing in order to keep the seed quality in good shape. Managing oil seeds in storage conditions are more difficult than storing cereal grains as they are more susceptible to quality deterioration and have limited insect control options. Yaseen *et al.* (2019) found that the quality degradation of stored food items including cereals, pulses and oilseeds is largely caused by insect and pest infestation.

In response to the question about the use of seed by the farmers, they responded that most of the amount of seed they usually sell immediately while they keep a portion for their own use. After interviewing 60 farmers, it was found that 53 farmers sold immediately their seeds after harvesting. However, most of the farmers shared that usually they don't store oil seeds because they need money immediately for which they sell it soon after the harvest.

In order to check the reality, the study team explored the information about market directly from the farmers. In response to the question relating to the selling of their oil seeds, maximum farmers shared that they sell their oilseed to the wholesalers. The Figure 11 presents the status of the farmers' responses.

Figure 12 shows that the farmers sell their oilseeds mostly in the local markets where a certain percentage of farmers

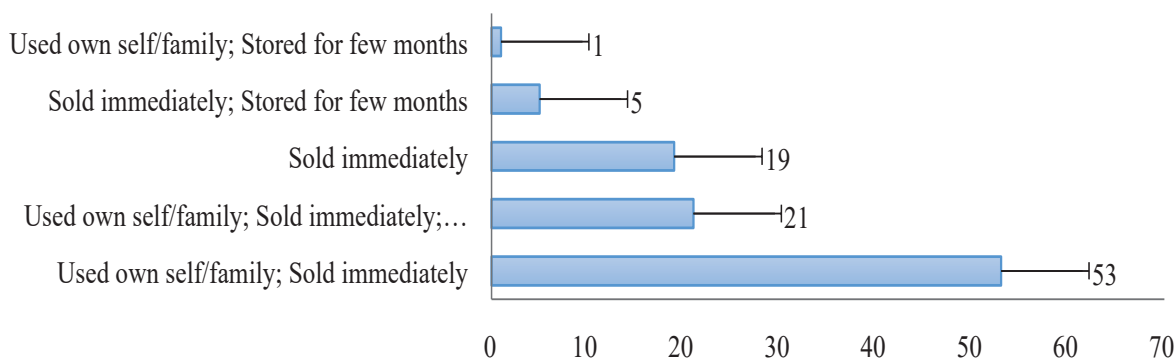


Figure 10. Use of oil seed after harvesting.

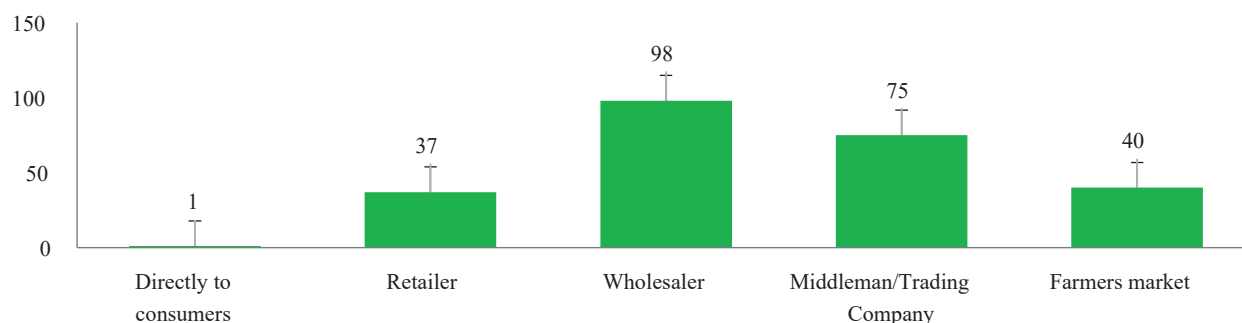


Figure 11. Types of customers to whom farmers sell their produced oilseeds.

sell the seeds to the next level market like regional markets. In relation to the satisfaction of getting fair price, most of them responded that they get the fair price of oil seed due to high demand in the market. About 80 % of the farmers said that they have the contracts (buyback guarantee) with the buyers and that is the reason of the ready market of their products.

Challenges of oilseeds cultivation facing by the farmers : Farmers who are cultivating oilseeds have been encountering multiple challenges. Through FGDs, the study team explored the following problems with the oilseeds cultivation:

Mustard diseases : Thirteen diseases affect mustard, with four of economic significance, such as *Alternaria* blight, white rust, downy mildew complex, *Sclerotinia* stem rot, and powdery mildew. According to Shrestha *et al.* (2005) average yield loss ranged from 32 to 57 % due to humidity, temperature and frequent rainfall, with higher seed infection in non- sprayed treatments and 4.2

to 4.5% decrease in oil content due to the *Alternaria* leaf blight disease caused by *Alternaria brassicae* in mustard (*Brassica juncea* (L).

Soybean diseases: Sixteen fungal, two bacterial, six viral, and three nematode related diseases affect soybean. Bacterial blight, common in soybeans, is exacerbated by cool, rainy weather but is less damaging in hot, dry conditions. Islam *et al.* (2021) observed that soybean production faces challenges such as lack of suitable varieties, pest issues, climate changes, lack of promotion, industrial reluctance, inadequate oil extraction facilities, disease attacks, unstable market prices and limited funding and technical knowledge. Begum (1995) reported thirty-nine insect pest species in oilseed crops in Bangladesh, with seven classified as major pests and the rest as occasional or potential pests.

Crop duration of modern varieties: Farmers need short-duration varieties of mustard, groundnut, and soybean to fit in the 80-90 days gap between aman and boro rice as reported by Miah and Mondal (2017). Long duration

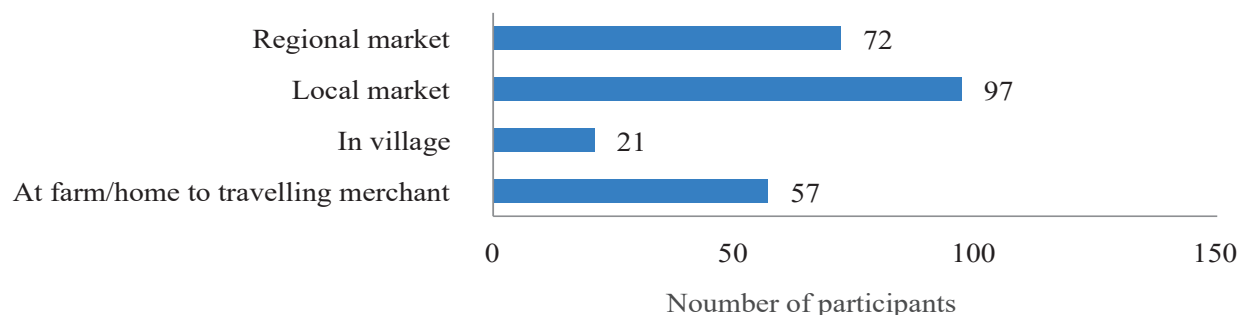


Figure 12. Different selling points of oilseeds.

varieties are usually high yielder but affect the next season crops. BARI sarisha14, BU soybean1 and BU soybean5 are short duration varieties.

Climate variability: Climate change has led to unpredictable weather, necessitating the introduction of crop varieties suitable for diverse climate conditions. Yu *et al.* (2010) reported that even with substantial investments, floods, droughts, cyclones over the past twenty years have still resulted in considerable economic losses and negatively impacted peoples' livelihoods. Oilseeds crops suffer from sudden temperature rise, early flash flood, salinity (in the coastal belt) and drought mostly.

Financial constraints: Hossain *et al.* (2022) concluded that small farmers are facing many risks for unavailability of viable land holdings, poverty and financial inability for investment in the farming sector. Farmers face high interest rates, buy expensive fertilizers, and lack of access to government financial support leading to inferior input purchases. As consequence the farmers can not apply sufficient inputs for their standing crop in time and get reduced production.

Transport issues: Limited transport options lead farmers to sell in local markets, reducing their potential earnings. Improved transportation could increase their profits.

Other constraints : The FGDs with the farmers indicated many other constraints in oilseeds cultivation (Figure 13). The top five challenges that the farmers mentioned are high price of fertilizer, lack of high-quality seeds, high price of pesticides, high price of insecticides and excessive rain.

The relevance of climate change to the production of oil seeds in Bangladesh is significant due to its potential effects on agricultural productivity and the livelihoods of farmers. Rising temperatures, changing rainfall patterns, sea-level rise and salinity intrusion, increased frequency of extreme weather events, water availability and irrigation challenges have become pressing global issues with significant implications for various sectors, including agriculture. Rao (2014) found some challenges in oilseeds production include inadequate quality seeds, insufficient input subsidies, poor extension services, lack of procurement facilities, insufficient storage and processing infrastructure and low, fluctuating yields due to rain-fed and poor soils. The combination of the climate change-related factors poses a significant challenge to oilseeds production in Bangladesh. Weather variability in different parts of Bangladesh, especially the very irregular pattern of temperature and rainfall is harming mustard and soybean production, and also expanding saline situation that is hindering the expansion of oilseed areas (Miah and Mondal 2017).

Soybean can be cultivated in two seasons each year, Rabi (15 December to 15 April) and Kharif-2 (15 July to 15 November). Soybean production occurs predominantly

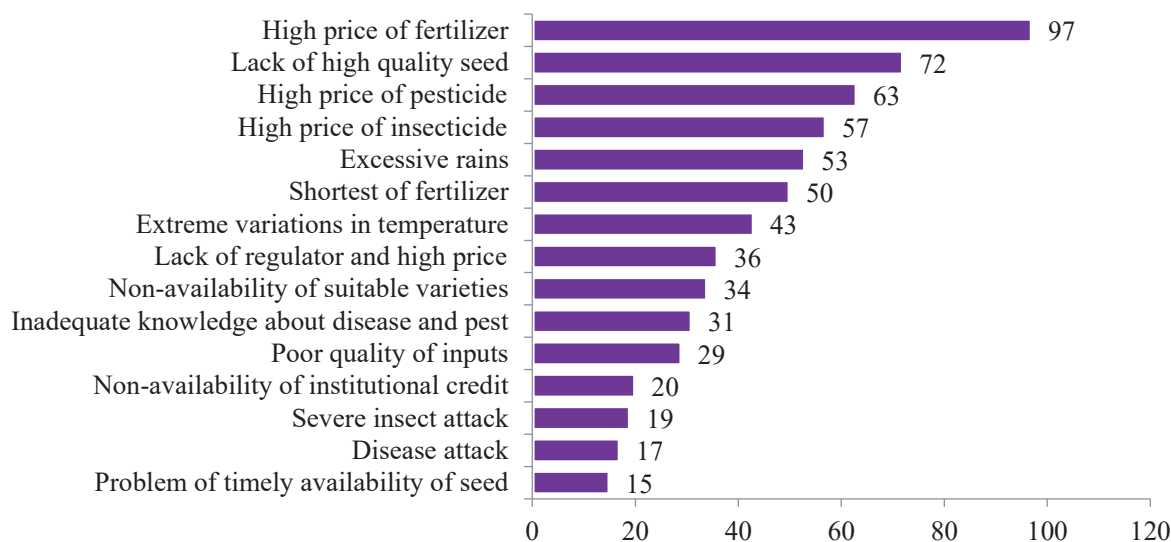


Figure 13. Constraints or difficulties in oilseed production faced by the farmers.

during the Rabi season, and production of soybean seeds takes place mostly during the Kharif-2 season.

According to the FGDs dry weather in some areas, downpour in others prevents soybean sowing. Farmers cannot start soybean sowing due to lack of monsoon rainfall, and now that monsoon has arrived about a week ago, it has been consistently down pouring. Because of this, some farmlands are submerged in water, and some are in a condition that they cannot prepare the seedbed.

Out of 100 farmers almost 50% opined that their oil seed cultivation gets affected due to climatic events, which have been shown in the following figure 14.

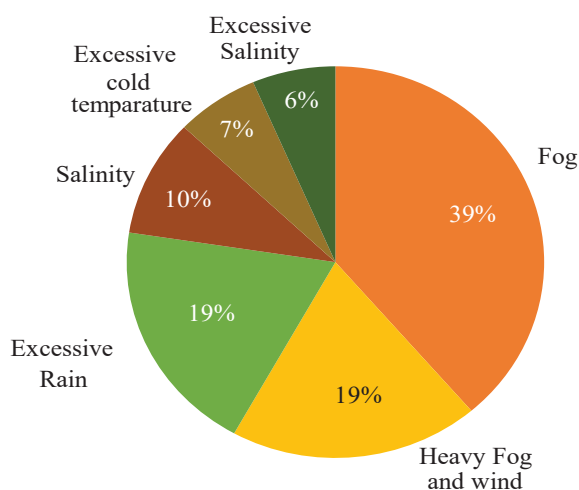


Figure 14. Farmers' opinion about climatic events that affect oilseed production.

Support required for the farmers : The Figure 15 presents the number of participants' opinion about their requirements for oilseed cultivation.

Measures that needed to take for increasing oilseeds production: Gupta and Gupta (2016) suggested that new approaches are needed to address the challenges to increase oil crops productivity in a sustainable manner. Karim *et al* (2023) elaborated the potentiality of stress tolerant genotypes to address the problems of soybean cultivation in the coastal area. Through FGDs the following suggestions have been made to ensure sustainable oilseeds production in Bangladesh:

- Farmers should have easy access to high yielding and locally adapted seeds.
- Ensuring timely supply of quality fertilizer at a subsidized rate.
- Support access to credit or financial support and area specific measures should be taken.
- Formation, activation and strengthening farmers' cooperatives and facilitate their actions in seed breeding, production, collection, distribution, crushing, refining and marketing as needed. Support should be provided to institutionalize the networks of all actors with the farmers' cooperatives.
- It is important to facilitate the partnership building between Research Institutions and farmers' cooperative to have access to information about new, high yielding and climate resilient varieties.

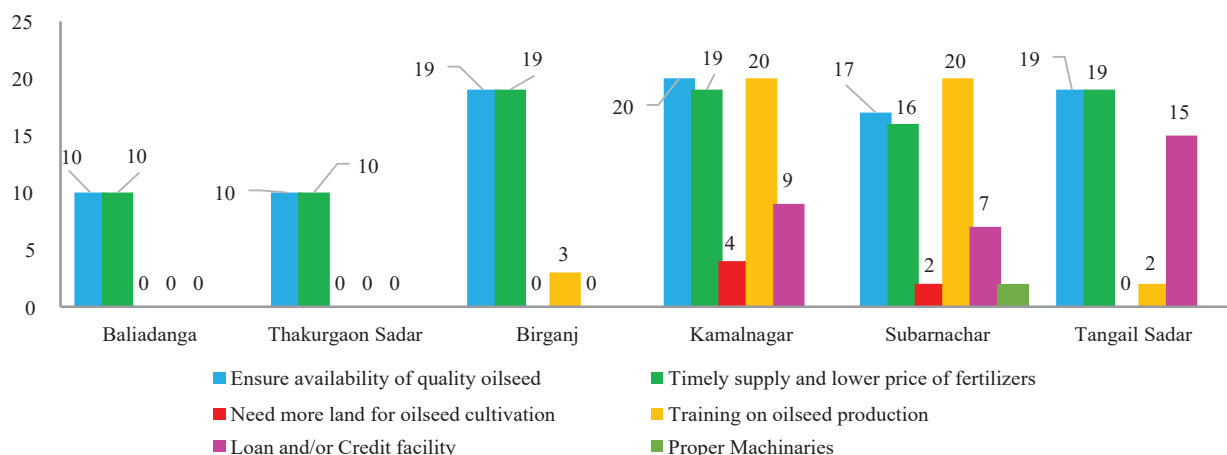


Figure 15. Facilities and supports that required for increasing oilseed cultivation.

Conclusion

Although Bangladesh is almost self-sufficient in cereal production, the country is dependent on 90% import of oilseed. Mustard is the predominant oilseed crop in almost all over the country, though soybean remains concentrated in the southern coastal region. Climatic variability, insufficient availability of short duration varieties, lack of quality inputs including seeds, access to financial institutions, attack of pest and diseases, lack of easy access to market, and high input costs are the major challenges of oilseeds production in the country. However, concerted effort of public and private organizations, pragmatic and realistic research on technology development and formation of farmers' cooperative for combating problems and challenges may lessen the constraints of increasing oilseed crop production in the country.

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Spatiotemporal variability of sea surface temperature and its relationship with salinity, chlorophyll-a concentration and bathymetry in Bangladesh

Asib Ahmed^{1*}, Bandhan Dhar¹, Md. Mahmudul Hasan² and Maisha Mahboob¹

¹Department of Geography and Environment, University of Dhaka, Bangladesh. ²Department of Environmental Science, Bangladesh University of Professionals, Bangladesh

Corresponding email: asib01geo@du.ac.bd

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Abstract

The present research aimed to examine the long-term connections (i.e. from 2010 to 2021) between monthly chlorophyll-a, sea surface temperature, and sea surface salinity. The long-term variability of SST in the Bay of Bengal (BoB) was analyzed using open access data sets of monthly SST, Chlorophyll-a and Sea Surface Salinity to understand trends, relationships, and bathymetric influences on these oceanographic parameters. The SST records for the Bay of Bengal indicates a gradual increasing trend over the period studied. The Sea Surface Salinity (SSS) follows a seasonal trend and plays an essential effect in the distribution of SST in the BoB. The SST for the corresponding time range has been compared, and a strong correlation ($R^2=0.81$) between SST and SSS has been found. The salinity value for the near-coastal zone is less than the away from the coast. The monsoon season lowers the value of SSS, which might be related to monsoonal rainfall and fresh water influx in the Bay of Bengal. Moreover, the Chlorophyll-a concentration, which is a direct indicator of the phytoplankton productivity, has been analyzed for this study. The chlorophyll-a concentration follows a locational and seasonal trend. The correlation between sea surface temperature (SST) and chlorophyll-a concentration was determined to be quite weak, primarily due to the minimal fluctuations in chlorophyll-a levels. For all of the data (i.e. SST, SSS, chlorophyll-a concentration and bathymetry), seasonal and locational variability have been observed. A strong positive correlation was observed between the variability in sea surface temperature (SST) and sea surface salinity (SSS). The value of SST varies with increasing depth; with increasing depth the mean value for SST value decreases and the dispersion of values increases from the mean. This study would help ocean scientists and policy makers in understanding the interaction between physical parameters with the biological parameters and benefit them in further study as well as in maritime planning.

Keywords: Bay of Bengal, chlorophyll-a, correlation, sea temperature, salinity

Introduction

The Bay of Bengal (BoB), the largest bay in the world situated in the Indian Ocean, is a home to a wide range of marine species. Due to the convergence of multiple ocean currents in the Bay, tropical cyclones are common and require monitoring using sea surface temperature (SST) data. Since the oceans have a great capacity for heat storage, which impacts the atmosphere via energy exchange at the ocean's surface, SST plays a crucial role in controlling the climate and its variability. Slow changes in SST serves as a valuable indicator for forecasting seasonal and longer-term climatic changes (Deser et al., 2010). The Earth's climate and weather are greatly influenced by SST, especially as it relates to the development of tropical cyclones. SST changes continuously but more slowly than air temperature, and scientists are investigating how the ocean and atmosphere interact as well as how climate

change may be influencing SST (Kotal et al., 2009; Yu and McPhaden, 2011; Sebastian and Behera, 2015). The SST in the Bay of Bengal's northern zone is crucial for understanding climate change in Bangladesh, forming sea fog and sea breezes. The fluctuation in water quality in the BoB is largely impacted by some factors such as seasonal SW and NE monsoons, pollution discharge from rivers and numerous industries on the coast, and regular tropical cyclone (TC) episodes (Miranda et al., 2021). A rise in SST leads to increased river flow, more rapid channel shifts, and intense cyclones and rainstorms. Temperatures in Bangladesh have risen by 0.5°C in the last century and is expected to rise by 1.5-2.0°C by 2050. This will lead to more intense hydrologic cycles, increased evaporation, and a rise in global precipitation, resulting in an increase in rainfall in Bangladesh.

In continental regions, sea surface temperature (SST) can affect water and climatic conditions. SST is a

crucial parameter that defines some areas because of the interaction between oceans and the atmosphere. Weather, currents, and seasonal fluctuations are some variables that affect SST. Two important climate change factors that significantly influence the hydrological cycle are SSS and SST. Anthropogenic climate change often interacts with hydrological processes (Belward et al., 2016). Hydrodynamic processes have shown a strong link between SSS and SST in the tropical Pacific. Freshwater inflow impacts SSS, density, and marine stratification, which in turn impacts SST. Precipitation and river runoff dilute the oceanic surface layers, causing high stratification of surface-level salinity (Girishkumar et al., 2011; Rao and Sivakumar, 2003; Thadathil et al., 2007). The significant stratification of surface-level salinity strengthens the longitudinal consistency of the uppermost ocean layer and contributes to the maintenance of a thin mixed layer (Maes and O’Kane, 2014; Mignot et al., 2007; Thadathil et al., 2007; Girishkumar et al., 2013). A stabilization layer forms as a result of salinity stratification, located beneath the mixed layer. In the BoB, these barrier layers start developing in fall (October–November) and are at their highest in winter (December–March). (de Boyer Montegut et al., 2007; Rao and Sivakumar, 2003). Since density is the driving force behind the global thermohaline circulation, it’s important to investigate the connection between SSS, SST, and chlorophyll-a (Chl-a). The concentration of chlorophyll-a is a biological measure that shows the number of phytoplankton. Monitoring it can aid in the detection of circumstances that could lead to marine biological disasters such as red tide and cyanobacteria. (Tomlinson et al., 2004; Steidinger and Haddad, 1981). Numerous factors can influence the Chlorophyll-a concentration, as previously reported (Thomas et al., 2001; Gong et al., 1996). Cyclonic rings connect to regions with a large field of view for sea-viewing Chlorophyll-a. The anticyclonic rings correspond to regions with a low concentration of Chlorophyll-a (Chu and Kuo, 2009).

The Bay of Bengal (BoB) holds immense ecological, economic, and climatic significance, particularly for Bangladesh, a nation intrinsically linked to its coastal and marine ecosystems. Studying the relationships between

SST, SSS, and Chlorophyll-a (Chl-a) concentration is important because these factors affect marine life, fish availability, and the health of the ocean. Changes in these conditions, driven by climate change, can impact the livelihoods of millions of people who depend on the sea. Understanding these patterns helps in protecting marine resources, planning for climate challenges, and ensuring sustainable use of the BoB’s rich natural resource.

There hasn’t been much research on the combined study of SST, salinity, and chl-a concentration in the BoB in Bangladesh. The goal of this work is to analyze the trends and patterns of SST anomalies across various regions of the Bay of Bengal. The study conducts an analysis of temporal data trends of SST, SSS, chlorophyll concentration, and SST anomalies. Their relationship with each other has been analyzed using statistical methods, as well as their variation over temporal and spatial differences has been mapped and graphed with statistical and geospatial tools to find out their independent variability within the temporal and spatial frame for different locations of the Bay of Bengal over the last 10 years. This study attempts to compare the SST and other parameters and investigate each parameter for different geolocations with temporal variability, which is unique for the Bay of Bengal.

Methodology

Study area: The Bay of Bengal, located between latitudes 5°N to 22°N and longitudes 80°E to 100°E, has been chosen for this study. It covers a surface area exceeding 2.2 million square kilometers, with an average depth of 2,600 meters and a maximum depth of 5,258 meters. Bangladesh is situated on the eastern coast of the Bay.

Data used in the study: Data were collected in NetCDF format and then exported to dataframes for easier manipulation. They were indexed in time-series. The depth dataset had been subset into the zones of depth mentioned further into the paper. As all the datasets came georeferenced, the datasets were easier for comparisons and associations to other datasets. The kinds of analyses are explained in the later parts.

Sea Surface Temperature (SST) data were acquired from GHRSSST. It is available as a retrospective dataset with

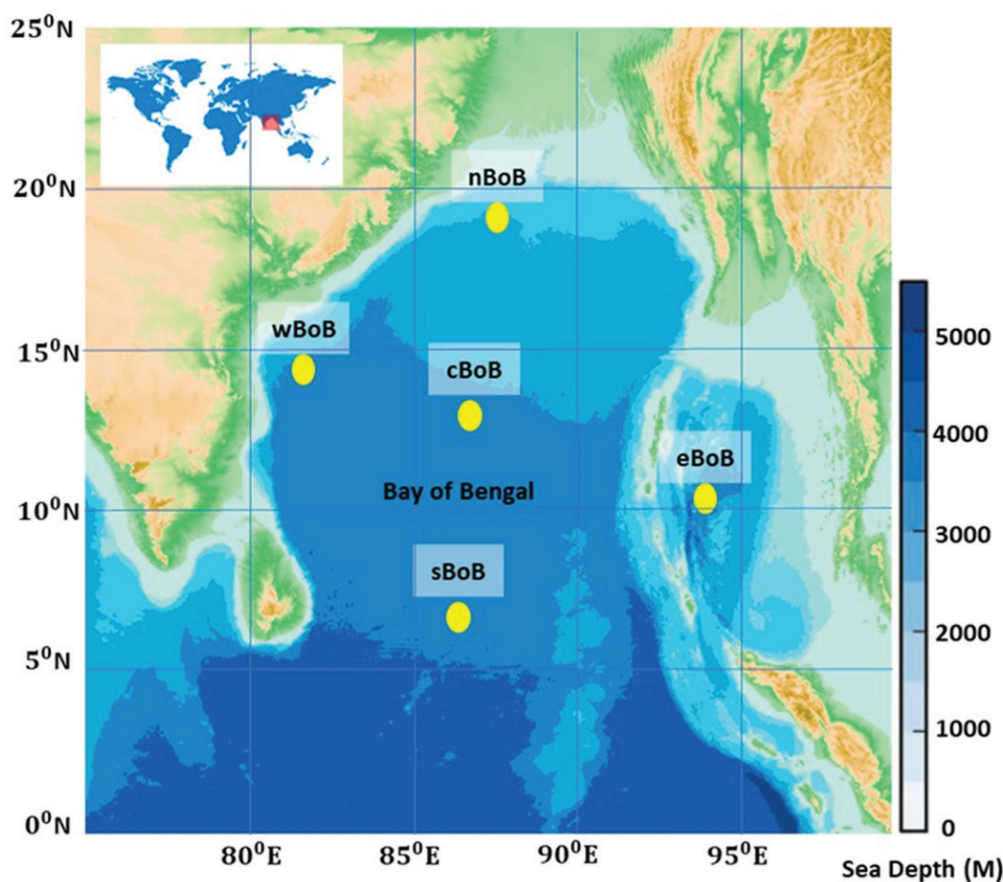


Figure 1. The Bay of Bengal and its adjacent regions used for assessing sea surface temperature. The yellow dots are the locations selected for addressing in-depth relationships among SST, SSS and chlorophyll-a concentration.

a four-day delay and a near-real-time dataset with a one-day delay. The data is produced using an optimal interpolation approach with wavelets as the basic functions on a global 0.01-degree grid. The spatial resolution for SST analysis data is 0.01 degrees for both latitude and longitude, and the temporal resolution is hourly to less than daily. The projection type for these datasets is cylindrical Lat-Lon projection, and each pixel includes geolocation information. The World Geodetic System (WGS 84) is used as the coordinate system. The data for Sea Surface Temperature and Chl-a concentration were obtained from MODIS Aqua measurements, which were obtained from the ocean color website. SST and Chlorophyll-a monthly data at level 3 (4 km) from January 2010 to December 2021.

All of the data were located at 80°-100°E and 5°–25°N. Sea surface salinity (SSS) data has been downloaded from NASA salinity website for the time frame of 2010 to 2021, and the 4-year interval has been used to condense the data to a level where it is sufficient to measure the correlation between SST and SSS and also the locational and seasonal variability measurement could easily be drawn from this time frame. The correlation between SST and SSS indicates variations in the atmospheric and oceanic systems and is crucial to the overall climate system

The pearson correlation coefficient: The Pearson correlation coefficient (Equation i) assesses the linear relationship between two variables (Pearson, 1985). It

also shows how closely related the two variables are.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2][n(\sum y^2) - (\sum y)^2]}} \quad \dots\dots\dots(i)$$

where, n denotes the sample size. A Pearson correlation coefficient of +1 represents an ideal positive linear relationship, meaning that an increase in one variable corresponds to a proportional increase in the other. In contrast, a coefficient of -1 indicates an ideal negative linear relationship, where an increase in one variable leads to a proportional decrease in the other. A coefficient of 0 suggests that there is no linear relationship between the two variables.

Mann–Kendall (MK) test

The MK (Mann 1945, Kendall 1957) trend analysis is a widely used statistical method for detecting increasing and decreasing trends in climatic time series data (Zarenistanak et al., 2014; Liang et al., 2010; Yue and Pilon, 2004). The MK analysis was conducted on the time series data to identify increasing and decreasing trends in SST, SSS, and Ch-a levels in the Bay of Bengal. To conduct the test, the below formula was used (Equation ii):

$$S = \sum_{i=2}^n \sum_{j=1}^{i-1} \text{sign}(x_i - x_j) \quad \dots\dots\dots(ii)$$

Where, x_i, x_j indicate data values and n indicates the extent of data collection.

Using the Z-values identified the statistically significant trends. The Z value that was positive indicates an increasing trend, while a negative Z value signifies a decreasing trend.

Results

Variability of sea surface temperature: A time series of seasonal variations of SST in the Bay of Bengal from 2010 to 2021. indicates that SST of the BoB varies within the range of approximately 24°C to 31°C (Fig. 2). The minimum surface temperature occurred in 2010 in this time series SST of 2010 to 2021, and the maximum occurred in 2010 and 2020.

Between 2010 and 2020, Bay of Bengal experienced an apparent seasonal variability in SST. Seasons are broadly classified in this part as pre-monsoon (February–May), monsoon (June–September), and post-monsoon (October–January). In the summer season the months of April and May typically have the highest ambient temperatures, while the winter season in the months of December and January have the lowest.

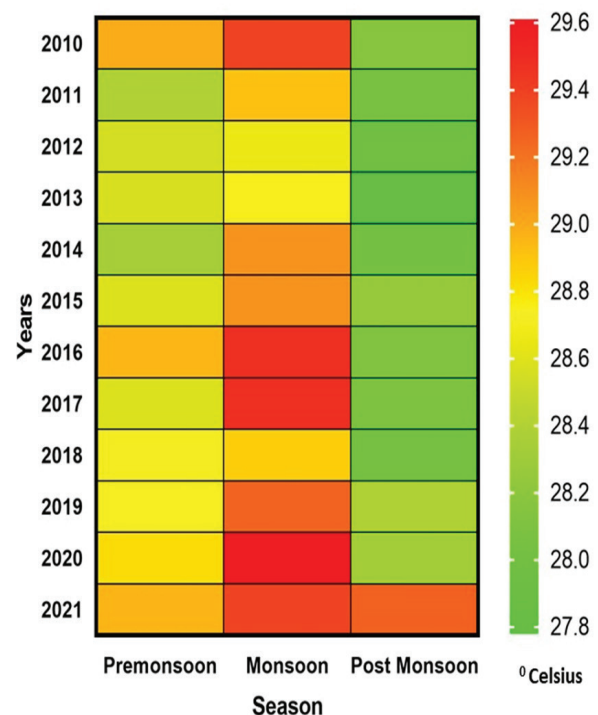


Figure 2. Yearly average seasonal changes in sea surface temperature (2010-2021).

At the start of the pre-monsoon, which is likely to be the month of February, the sea surface temperature stays as low as 26°C, whereas, in the following months, it increases gradually and reaches up to around 30 degrees Celsius. At the end of the pre-monsoon, the prominent monsoon season coincides with the summer season/ summer monsoon in this region. The monsoon season

retains the SST with an average temperature of 29.38°C, with a minimum SST value of 28°C and rises to the maximum of 31°C. In post-monsoon season during which

the sea surface temperature mostly gets to its low point less than 26 ° C and maintains the SST range of 27-28°C in its peak stage.

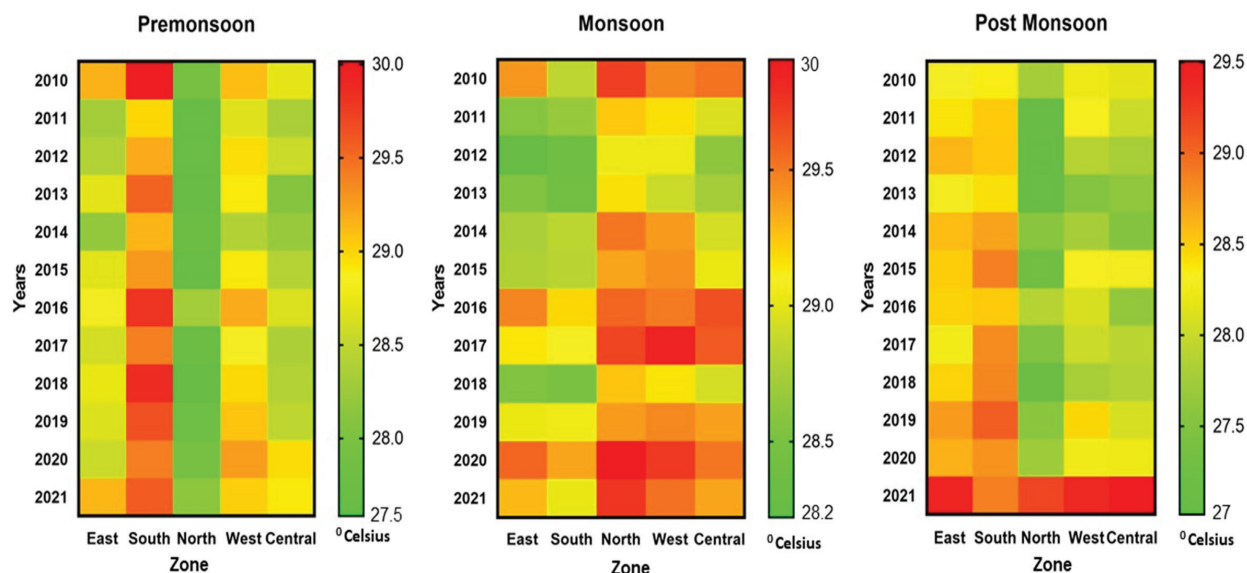


Figure 3. Time series analysis (2010-2021) for the average sea surface temperature in all zones of the Bay of Bengal.

The monthly average values for each year were plotted in a time series, revealing a seasonal and yearly variation in SSTs in different zones of the BoB. Figure 3 illustrates the seasonal and yearly variations in SST across different zones of the BoB from 2010 to 2021. In the north part of the BoB the SST values showed a yearly fluctuation, with the highest temperature reaching around 31 °C in 2020 and the lowest temperature recorded as around 24.5 °C in 2012. The SST values fall and rise within the range of 24 °C to 31° C in the northern part of the sample area, and the trend is increasing. The central and southern parts of the Bay of Bengal showed a consistently higher mean temperature than the northern region, with the central zone recording the highest monthly average of around 30.5 °C in 2010, 2020, and 2021. The eastern zone of the BoB had a slightly lower mean temperature than the western zone, with a maximum temperature of 31.31 °C and a minimum temperature of 26.43 °C. The findings suggest that SSTs in the BoB have been increasing over the last decade, with notable regional differences in temperature fluctuations. According to the Mann-Kendall test SST value, all the zones follow an increasing trend.

Yearly SST for Different Parts of the Bay of Bengal:

The SST values in the BoB from 2010 to 2021 have fluctuations, and there is a seasonal variation in the SST values in various parts of the Bay (Fig. 4). In 2010, the SST was lowest during January-February and peaked in May. In 2011, the SST distribution was even, and the western part of the Bay had the highest values. The lowest temperature was near most coastal areas, and the temperature variation was dependent on the seasonal variation. The SST values for 2012 followed a six-month rise and falls pattern. The highest SST was recorded in the BoB's south-eastern and south-western regions. The SST for 2014 was quite similar to that of 2010, where the south-eastern part retained the highest SST values. In 2015, the variability in the SST was the lowest, and the coastal region had the lower SST values. The temperature distribution for 2016 was a cluster with higher values in the central BoB. In 2018 and 2019, the highest temperature was recorded in the south-eastern part of the Bay of Bengal. The SST distribution in 2020 showed a seasonal variation in the temperature, with the seasonal increase in temperature during pre-monsoon season and monsoon season. The 2021 composite SST

map shows that the temperature retains its higher value in large portion of the BoB. SST reaches its low value near the coastal areas of the BoB and at the border of the southern part with the Indian ocean.

Relation between chlorophyll-a concentration and SST: The correlation coefficient between Chlorophyll-a and sea surface temperature (SST) was calculated using the monthly mean data sets for both Chlorophyll-a and SST. The Bay of Bengal's Chlorophyll-a and SST correlation coefficient distribution from 2010 to 2021 is shown in Fig. 5.

The correlation coefficient between chl-a and SST value in the Bay of Bengal is low ($R^2=0.115$), indicating a weak correlation. According to Kumar (2016), this may be since chlorophyll concentration varies little seasonally and has a weak annual cycle in the region, with high concentrations in winter (October-December) and low concentrations in summer (June). In contrast, SST is lower in the post-monsoon season and tends to increase in summer.

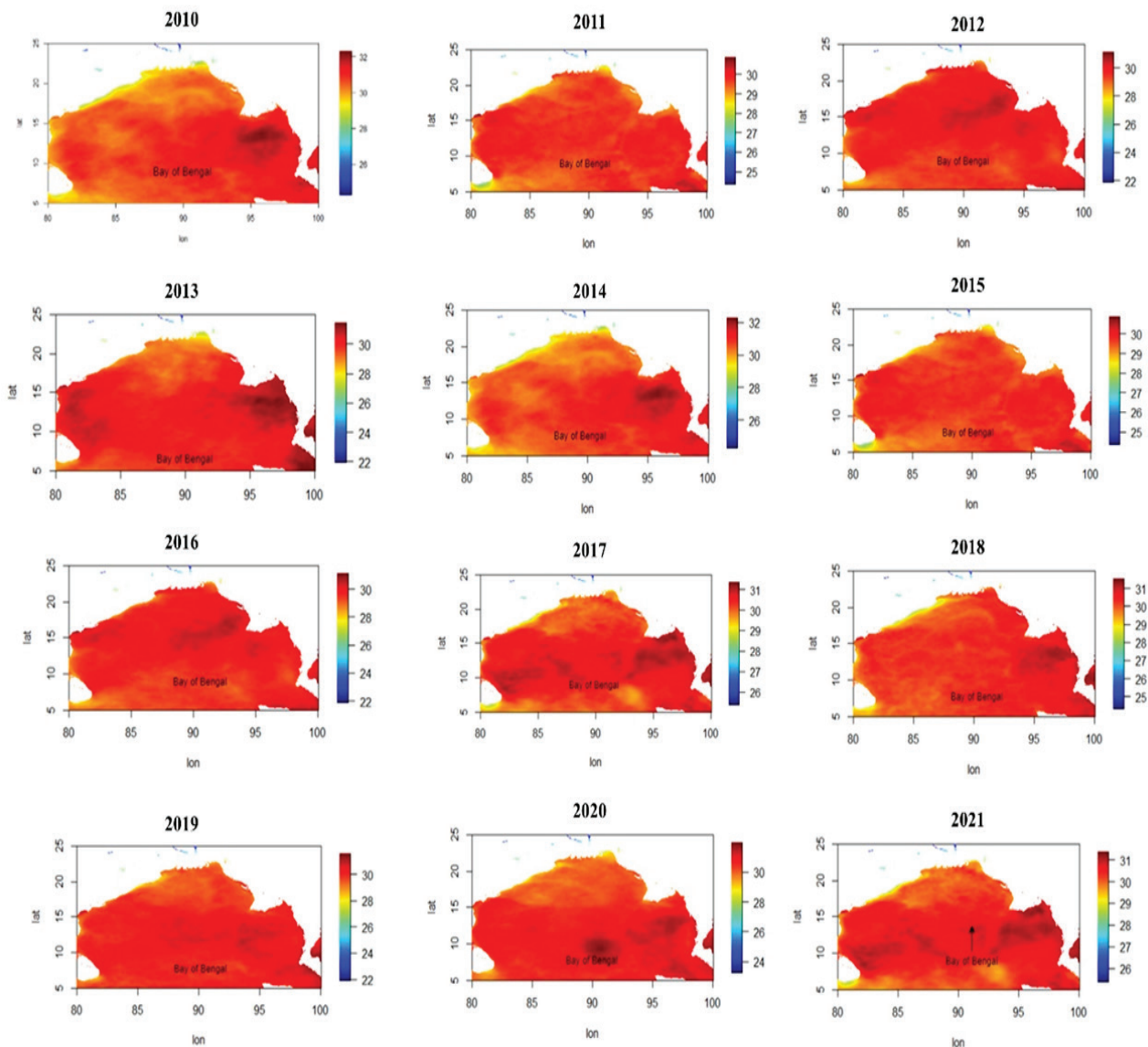


Figure 4. Sea surface temperature composite for each year from 2010-2021.

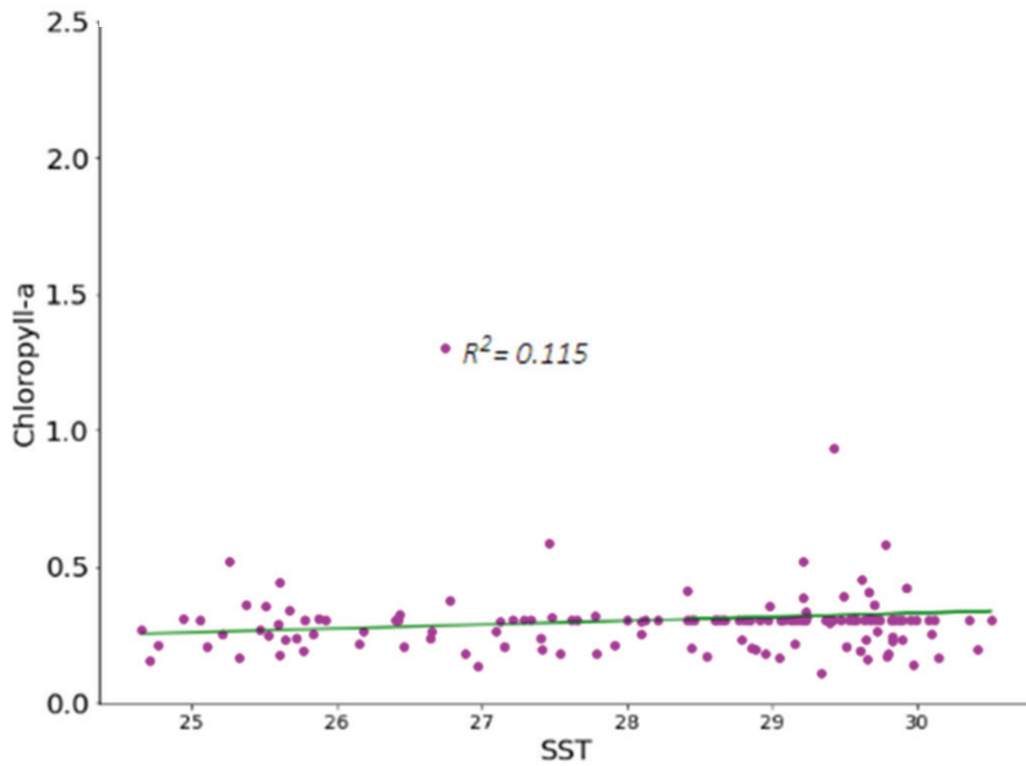


Figure 5. Correlation scatter plot for chlorophyll-a and sea surface temperature.

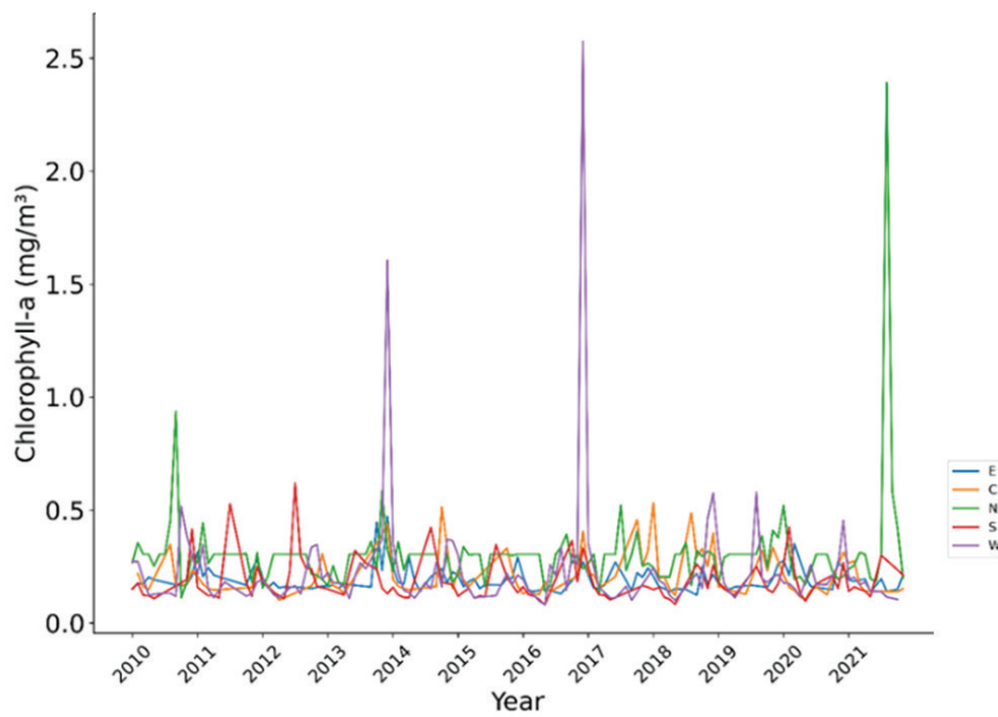


Figure 6. Chlorophyll-a trend for all zone (2010-2021).

In the years 2014, 2017 and 2021 there are some large increases in chlorophyll concentration. This rise in chlorophyll concentration has been observed in some specific part of Bay of Bengal. The northern part had an increase in concentration up to 2.4 mg per cubic meter, whereas the western part had an increase in the end of 2016 and 2013. The north-western BoB was distinguished by a seasonal increase in chlorophyll due to strong coastal upwelling caused by alongshore winds throughout the summer monsoon season. Furthermore, nutrients delivered by monsoonal river outflow support increased chlorophyll concentrations in near shore seas.

Relation between SSS and SST : The sea surface salinity has a temporal and spatial variation in the BoB, which is clear from the time series analysis of the SSS for the last ten-year period (2010-2021). The SST is supposed to correlate with the SSS directly, and the Pearson correlation has been calculated to find the correlation between these two-parameter. Using the SSS and SST monthly mean data sets, the correlation coefficient was calculated to assess the relationship between SSS and SST. Figure 7

shows the correlation coefficient distribution for Salinity and SST in the Bay of Bengal from 2010 to 2021. The significant correlation between the SSS and SST is indicated by the correlation coefficient, $R^2=0.81$.

Relationship of bathymetry with SST : The Bay of Bengal is divided into five zones based on its depths for this study. These zones are divided into very shallow zone (VS) (0-1000 meter), shallow zone (S) (1000 meter-2000 meter), Deep zone (D) (2000 meter-3000 meter), Very Deep zone (VD) (3000 meter-4000meter) and Extremely Deep zone (ED) (4000 meter – 5000 and above meter).

The very shallow zone has the mean SSTs value of 27.50°C, and the minimum and maximum values for this zone are 20.13°C and 30.91°C, respectively. The standard deviation is highest in the very shallow zone for the SST, which is 2.63°C, which signifies that the temperature is widely dispersed from the mean. The mean sea surface temperature for the shallow zone is 28.236 ° C with a standard deviation of 1.54°C. The maximum value for the shallow zone is 30.69 °C, and the minimum value is 24.53°C. The mean temperature for the deep zone is

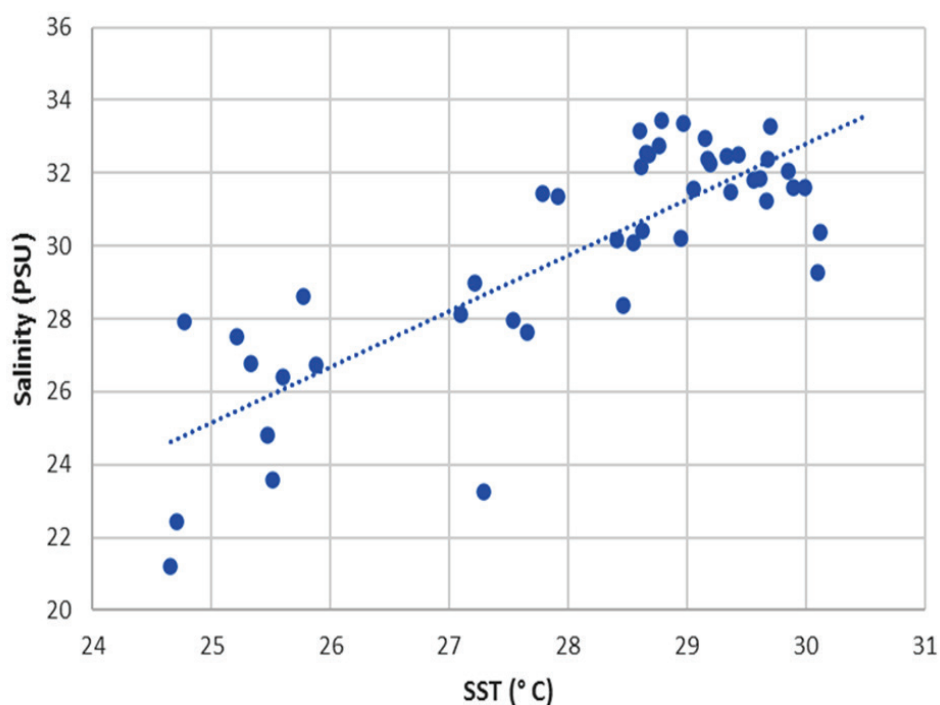


Figure 7. Correlation between salinity and sea surface temperature.

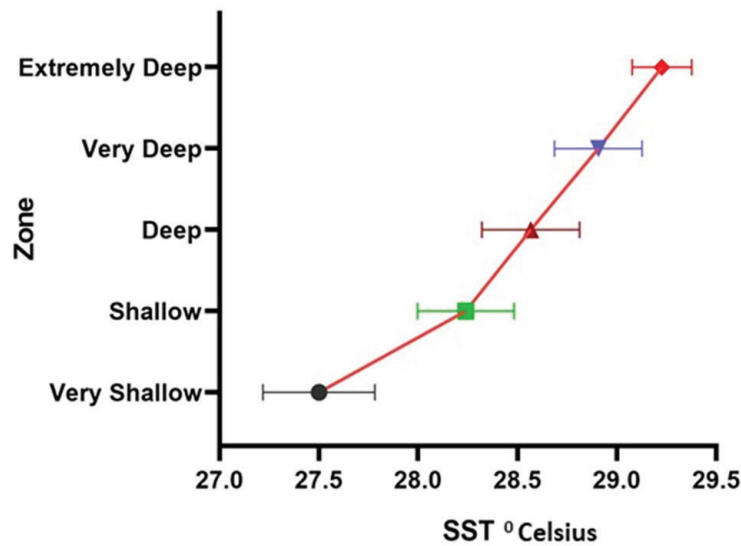


Figure 8. Mean sea surface temperature with varying depths.

28.56 ° C, whereas the standard deviation is 1.52°C with the maximum value of 30.83°C and minimum value of 25.62. On the other hand, the mean values for the very deep and extremely deep zones are 28.91 ° C and 29.23°C, respectively. The standard deviations are 0.91°C and 0.59°C for the very deep and extremely deep zone of the BoB.

The SST of the BoB exhibits a direct correlation with depth. Analysis of the mean SST values in the BoB reveals an increasing trend with depth, ranging from 27.50°C to 29.23°C. This trend can be attributed to the proximity of the extreme deep zone to the equator, where SSTs generally increase due to greater heating of the ocean surface caused by direct sunlight. However, this trend

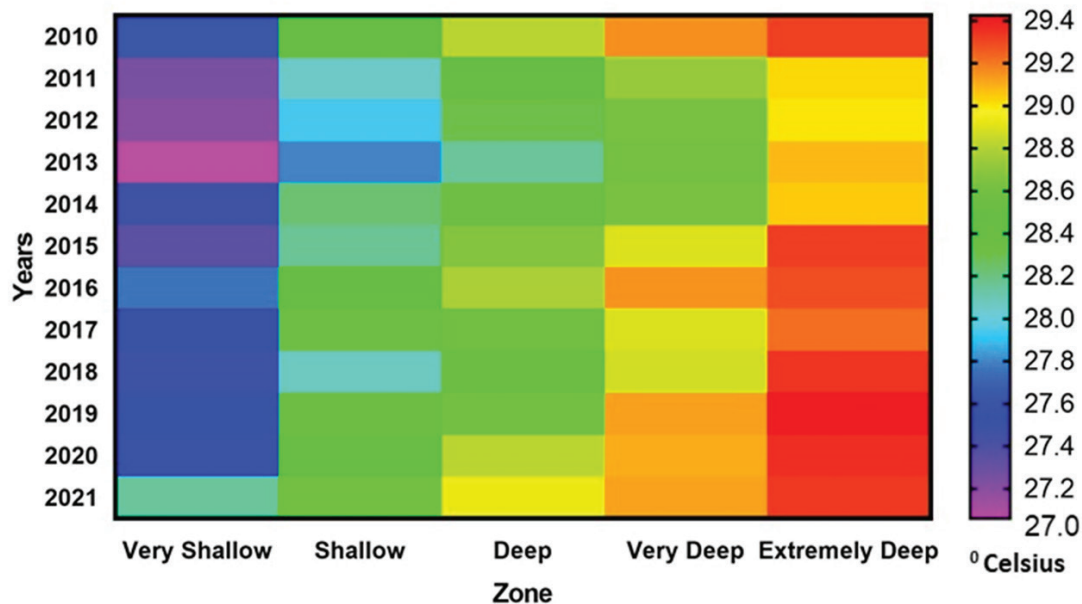


Figure 9. Depth wise sea surface temperature time series for all the depth class.

also implies a positive correlation between depth and the dispersion of SST values from the mean. The standard deviation is lower in the extreme deep zone, indicating that SST values are more closely distributed around the mean in the shallow areas of the BoB. These findings highlight the importance of considering depth when analyzing SST data, particularly in areas such as the BoB where the proximity to the equator can have a significant impact on SST values.

Discussion

The outcomes of this study demonstrate that the SST in the Bay of Bengal has been increasing over the past decade with regional differences in temperature fluctuations. The analysis reveals that the SST values in the BoB varied within the range of approximately 24°C to 31°C from 2010 to 2021. The peak SST values were observed in 2010 and 2020, while the lowest value was recorded in 2012. The study also found that the BoB experiences apparent seasonal variability in SST, with the pre-monsoon, monsoon, and post-monsoon seasons affecting the temperature range. The summer months of April and May typically have the highest ambient temperatures, while the winter months of December and January have the lowest. The monsoon season coincides with the summer season in the region, and it retains the SST with an average temperature of 29.38°C. Conversely, the post-monsoon season has a lower SST, with a range of 27–28°C in its peak stage. The outcomes of this study align with previous studies that have reported an increasing trend in SST in the Bay of Bengal. The study also revealed that the northern part of the BoB has a yearly fluctuation in SST, with the highest temperature recorded in 2020 and the lowest in 2012. Meanwhile, the central and southern parts of the Bay of Bengal consistently have higher mean temperatures than the northern part, with the central zone recording the highest monthly average in 2010, 2020, and 2021. The eastern region of the BoB had a slightly lower mean temperature than the western zone. The increasing trend in SST values observed in this study may have several implications for the region, including shifts in the marine ecosystem, sea level rise, and changes in weather patterns. Therefore, it is essential to continue monitoring and studying the SST in the BoB

to understand its implications and develop appropriate adaptation measures.

The study found a weak correlation between SST and Chl-a concentration in the BoB. This could be due to the weak annual cycle of Chl-a concentration, with increased concentrations in winter and lower concentrations in summer. In contrast, SST is low in the post-monsoon season and increases in summer. However, there were increases in Chl-a concentration in specific areas of the BoB in 2014, 2017, and 2021, particularly in the northwestern region where coastal upwelling and monsoonal river discharge support increased chlorophyll concentrations. These findings highlight the necessity for ongoing monitoring and additional research to gain a deeper understanding of the intricate interactions between sea surface temperature (SST), chlorophyll-a, and environmental factors in the Bay of Bengal.

From 2010 to 2021, a strong link was found between SST and SSS in the BoB. This implies that changes in one can affect the other. Similar connections have been reported in other ocean regions. Both factors are important when studying the Bay's physical and biogeochemical processes. More research is needed to understand the correlation and its impact on the Bay's oceanography and climate.

The findings show that in the BoB, as depth increases, SST decreases. This means that as the depth increases, the mean sea surface temperature decreases. Additionally, the standard deviation increases with an increment in depth, indicating a direct correlation between depth and SST dispersion from the mean. This implies that the SST varies significantly from the mean with the increasing depth.

Moving seawards from the shore towards lower latitudes, temperature increases towards the Equator. There has been studies regarding SST increasing from the mouth of estuary inflow seawards (Bashevkin and Mahardja, 2022). The fact that salinity also increases with depth might be related to increasing salinity with distance from the shore and rendering a positive correlation with SST, but previous studies show some extent of inverse relationship between distance from shore to increase in salinity mainly referring to estuarine inflow (Geawhari, 2014; Guillou, 2022).

Conclusions

In this study it was found that the SST trend was positive and varied with the location in the BoB, following a seasonal pattern. The SST starts to rise during the end of pre-monsoon and starts to fall during the monsoon season, which is related to monsoonal rainfall in the BoB region. The southern zone had the highest mean value of SST. The SST is closely linked to the SSS, and Pearson correlation was employed to determine the relationship between these two parameters. The correlation coefficient was calculated using monthly mean data sets. The correlation coefficient retains a higher value, which indicates a strong relationship between SSS and temperature. The mean chlorophyll concentration in the southern BoB is lower than in the other three zones, except for the eastern Bay. With the increase in depth, the mean value of sea surface temperature decreases. With increasing depth, the sea surface temperature deviates significantly from the mean. The standard deviation is lower in the very shallow zone of the Bay of Bengal, indicating that SSTs are more evenly distributed in the shallow areas of the Bay of Bengal. The findings of this study could be valuable for understanding the complex interactions between various oceanic parameters and their impact on the marine ecosystem and climate. The study may also yield valuable insights for managing fisheries, overseeing coastal zones, and planning for climate change adaptation in the Bay of Bengal adjacent area.

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Relative abundance of owl species in Bangladesh

MS Alam* and ATM Hasanuzzaman

Vertebrate Pest Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

Corresponding email: alamvpd@yahoo.com

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Abstract

An attempt was made to document the relative abundance of available owl species in Bangladesh. The study was conducted in Gazipur, Rajshahi and Barishal districts of Bangladesh during June, 2018 to July, 2020. Owls were counted once in a month using line transect, point counting as well as look and see methods. Other owl species all over Bangladesh were recorded with the help of some Facebook group such as Birds Bangladesh, Birds and Wildlife of Bangladesh, etc. A total of 14 species of owl were documented in which the species Barn owl, spotted owl, Brown Hawk owl, Brown fish owl, Collard scops owl, etc. were recorded as the most abundant in different regions of Bangladesh. All other owl species were also present in different regions but their density was lower than those of other owl species.

Keywords: Owl species, relative abundance, documentation

Introduction

Owls are mainly a group of nocturnal (active at night time) birds which belong to the order Strigiformes, a group which is most closely related to the nightjars (Caprimulgiformes). The order is divided into two families: Tytonidae or Barn Owls and related species, and Strigidae or Typical Owls. A large, round head and huge, forward-facing eyes are features that make an Owl instantly recognizable. They also have a sharp, downward-facing beak (or bill), and soft, cryptically colored plumage. Males and females are generally similar in appearance, although the female is often up to 25% larger (Lewis 2012)

Owls are Raptors, or Birds of Prey, which means they hunt other living things for their food, using their special adaptations and unique abilities that set them apart from any other creature. Exceptional vision, and acute hearing play a major part in an Owl's hunting technique. Couple these with powerful talons and beak, plus the ability to fly silently, and you have a formidable predator, using stealth to hunt down prey. After eating, Owls regurgitate pellets, which contain the indigestible bones, fur and feathers of their victims. These pellets can be collected by researchers to study Owls' eating habits. (Lewis 2012). Owls are found on all continents except Antarctica, and are absent from some oceanic islands and in a great variety of habitats, from thick forests to open prairies.

Biodiversity is not evenly distributed throughout the world. It may be influenced by geography (Karr 1976). Elevation gradient distributions across the globe are a powerful test system for understanding biodiversity (McCain 2009). From the last decades, relation between species community composition and elevation at global level is an important theme in ecology. Urbanization and human modification of the natural landscape has profound effects on existing ecological processes occurring at a variety of scales (Crooks *et al.* 2004, McDonnell 1997). Species richness and the presence of rare species are two of the most frequently used criteria for the selection of conservation areas (RodriguezFerraro and Blake 2008). In addition, community composition and relative abundance of target species are important in selecting areas for conservation (Wijesundara and Wijesundar 2014).

Owls are not particularly efficient nest builders. Usually, they appropriately use an abandoned woodpecker hole or natural tree cavity, or an abandoned crow or hawk nest. Owls are vocal during the nesting season, and may exchange courtship and territorial calls that both enhance the pair bond necessary to raise the young owls, and discourage other intruding owls (Rachel and Tompkins 1914). Owls play an important role in the maintenance of a natural balance since they are at the apex of trophic levels in terrestrial and aquatic ecosystems (Sergio *et al.*

2008). Understanding the diversity and structure of bird communities is essential to delineate the importance of regional or local landscapes for avian conservation. Determinations of bird population in different habitats are central to understanding the community structure and niche relationships, as well as for intelligent management of populations (Sethy *et al.* 2015). Moreover, seasonal monitoring is equally important to trace the dynamic movement of owls in such habitats. According to Banglapedia, Bangladesh has 15 species of owls (family Tytonidae: 1 species; family Strigidae: 14 species), of which 3 are endangered, 1 species is vulnerable and 7 could not be evaluated due to paucity of data. At present, there is no information on how many species of owls are available in Bangladesh. Therefore, the present study was undertaken to assess the available species of owls, their distribution and locality.

Materials and methods

The present study listed and documented the owl species that are usually found in Gazipur, Rajshahi and Barishal districts. It was carried out during June 2018 to July 2020, once in a month. Owls were counted by line transect, point counting and look and see methods by using cameras and were identified with the help of taxonomic books. Other owl species documentations were made by the help of some Facebook group such as Birds Bangladesh, Birds and Wildlife of Bangladesh etc. Line transect is a tape or string laid along the ground in a straight line between two poles as a guide to a sampling method used to measure the distribution of organisms. The essential feature of line transects is that one walks along a straight path and records the individuals seen and their perpendicular distance from the transect line. The simplest method of counting birds is called a “point count”, in which a trained observer records all the birds seen and heard from a point count station for a set period of time. A series of point counts completed over a fixed route can then be compared to the results of the same point counts in other seasons or years. Observations were made by standing and sitting from a hiding place and recorded along with their abundance. Surveys were conducted in the morning hours (from 6.30 am to 9.30

am) and evening hours (3.30 pm to 7.30 pm) by a single observer. Samplings were made in seasonal basis for the period of three years (2018 to 2020) using the same transect and time. Bird surveys were not performed during heavy rains, fog and during strong winds, since these conditions reduce bird activity and detectability (Sutherland 2004). No specimens were collected but photographs of most of the species was taken for reference.

The data collected during the whole study period were analyzed in IBM SPSS 26 statistical software. Analysis of variance (ANOVA) was used to test the hypotheses, and Tukey’s HSD post hoc analysis was carried to identify specific variables that differ significantly. Diversity and species richness was calculated by using the following formulae.

$$\text{Shannon-Wiener Index (H')} H' = -\sum \left[\left(\frac{m_i}{N} \right) \times \ln \left(\frac{m_i}{N} \right) \right]$$

Where m_i = number of individuals or amount (e.g., biomass) of each species (the i th species) and N = total number of individuals (or amount) for the site, and $\ln$ = the natural log of the number.

$$\text{Simpson's Index, } \lambda = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where n_i = number of individuals or amount of each species (i.e., the number of individuals of the i th species) and N = total number of individuals for the site.

$$\text{Simpson's Diversity Index, } D = 1 - \lambda$$

The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

Results and discussion

According to Banglapedia 15 species of owl have been recorded in Bangladesh, of them one species was under the Tytonidae and fourteen species were under the Strigidae family. The total number of bird species, mean number of species/transect, and their density recorded in various zones are shown in Fig. 1 and Fig. 2. Two species of owls were detected in three locations (Fig. 1). The most abundant species of owls were Spotted owlets (mean 2.6 birds/point count and total specie 13.33/location) followed by Barn owl in Gazipur whereas, Barn owl species was

recorded higher in Rajshahi (mean 51.6/point count and total species) compared to Spotted owl (Fig. 1 and Fig. 2). In Barishal more or less equal number of owl species (barn owl and spotted owl) were recorded.

Distribution of two owl species in three region, Gazipur region had recorded the highest number of Spotted owl followed by Rajshahi and Barishal regions (Fig. 3 and 4). In case of Barn owl distribution Rajshahi had supported the highest number compared with those of other two regions and followed by Barishal and Gazipur with the lowest number of Barn owl species (Fig. 3 and 4). Among different zones, Spotted owl was the most abundant in Gazipur and Barn owl in Rajshahi zone.

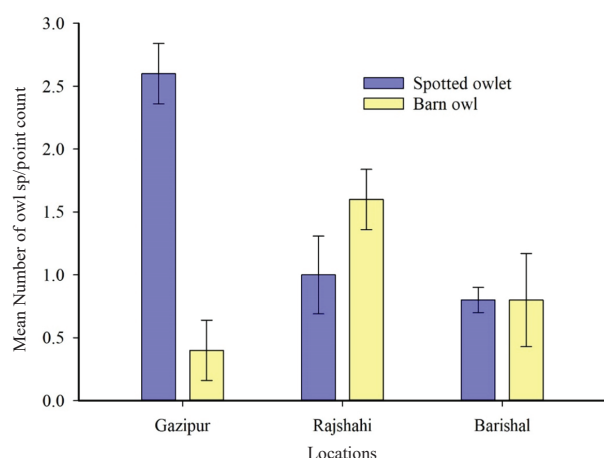


Figure 1. Mean number of owl species/count in three districts of the study areas.

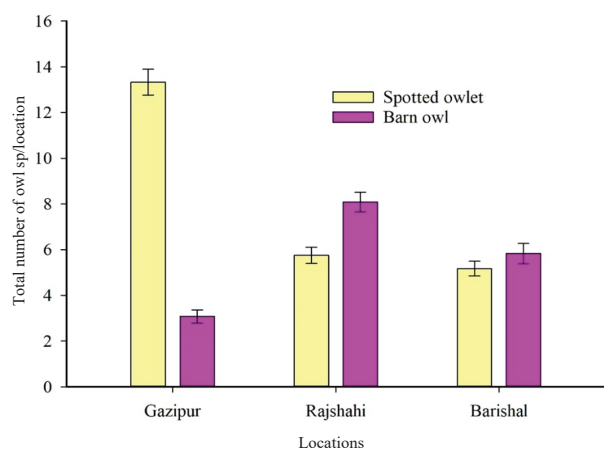


Figure 2. Total number of owl species recorded in three districts of the study area.

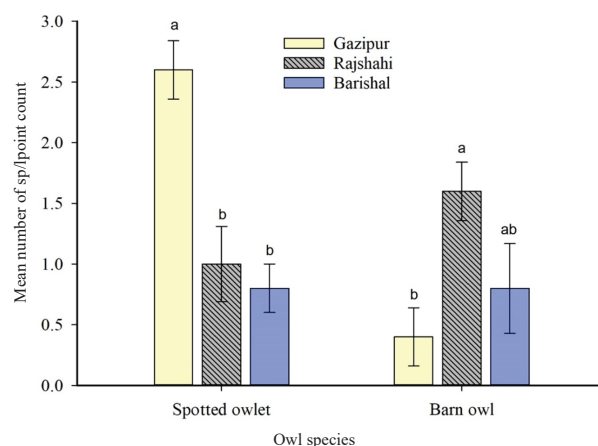


Figure 3. Abundance of owl species (Mean number/point count) in three districts of the study area.

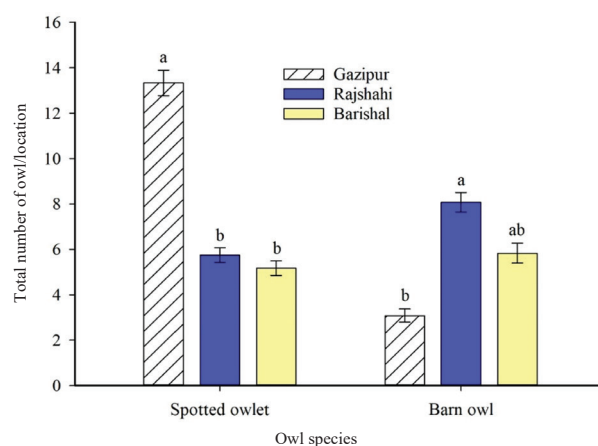


Figure 4. Abundant of owl species (total species/location) in three locations of the study area.

The species diversity index fluctuated from 0.69 (site-Barishal) to 0.5 (site- BARI Head Quarters, Gazipur) (Table 1). The highest diversity was found in coconut orchard, Barishal followed by Rajshahi (mango orchard) and the lowest diversity was recorded in Gazipur. Apart from the diversity, species evenness showed variation in the study sites with values of 0.53 (site-coconut orchard, Barishal), 0.523 (site-Mango orchard, Rajshahi), 0.038 (site-Gazipur). The variation in species diversity and species evenness at various sites may be due to the influx of visitors, vehicles and local people in and near the campus and the availability of food for the birds.

Shannon's diversity index indicated that Barishal and Rajshahi habitat had higher species diversity ($H = 0.69$ and 0.687) than Gazipur habitat ($H = 0.548$) (Table 1). The overall birds' diversity for Barishal, Rajshahi and Gazipur was ($H = 0.682$). On the other hand, the Simpson's diversity index for owl species were 0.533 , 0.523 and 0.38 , respectively. However, the overall Simpson's diversity index for the three habitats was 0.798 . This indicates greater variation in species diversity between the results obtained by using Shannon's and Simpson's diversity indices. This is because Simpson's diversity index takes into consideration relative abundance which is not the case for Shannon's diversity index. The higher diversity in the habitat may be due to high numbers of individuals in some of the bird species and diverse vegetation types as microhabitats which favored varieties of bird species. The anthropogenic disturbances by parking lots, housing developments and agricultural fields may have changed the diversity in the area which is well reflected by the species composition before human intervention (Sax and Steven 2003).

Table 1. Species richness and diversity index of owl species in three locations of the study area

Locations	Shannon-Wiener Diversity Index	Simpson's Diversity Index
Gazipur	0.548	0.380
Rajshahi	0.687	0.523
Barishal	0.690	0.533
Overall	0.682	0.498

During the study of the project, 14 species of owl were recorded and documented (Anon. 2007, 2013, 2016). The owl species recorded and documented during the study period are shown in Table 2.

Conclusion

Barn owl, spotted owlet, Brown hawk owl, Brown fish owl, Collared scops owl etc. were found as the most abundant species in different regions of Bangladesh. All other owl species were also present in different study areas but density was lower than those of other owl species.

Table 2. Different species of owl recorded in different areas of Bangladesh

English Name	Scientific name	Recorded place in Bangladesh
Barn owl	<i>Tyto alba</i>	Rajshahi, Mirpur, Dhaka, Bola, Dhaka, Gazipur, Barishal, Dinajpur,
Brown fish owl	<i>Bubo zeylonensis</i>	Dhaka, Bogra, Nilphamari, Meherpur, Faridpur, Shariatpur, sundarban, Khulna, Thakurgaon, Lakshmipur, Hobigonj
Brown hawk owl	<i>Ninox scutulata</i>	Comilla, Narayanganj, Munsigonj, Dhaka, Chattogram, Gazipur, Moulvibazar, Rajshahi, Magura
Buffy fish owl	<i>Ketupa ketupu</i>	Sundarban, Khulna
Collared scops owl	<i>Otus lettia</i>	Mymensingh, Brahmanbaria, Satkhira, Hobogonj, Pirojpur, savar, mirpur, Dhaka, Rajshahi, Narayanganj, Jashore, Jhenaidah
Indian scops owl	<i>Otus bakkamoena</i>	Thakurgaon, Rajshahi, Natore, Pabna
Oriental scops owl	<i>Otus sunia</i>	Rajshahi, Sylhet
Asian barred owl	<i>Glaucidium cuculoides</i>	Rangamati, Hobigonj,
Collared owlet	<i>Glaucidium brodiei</i>	Bandarban
Spotted owlet	<i>Athene brama</i>	Gazipur, Barishal, Rajshahi, Dhaka, Rangpur, Chandpur, Thakurgaon, Chattogram, Dinajpur
Short-eared owl	<i>Asio flammeus</i>	Rajshahi
Dusky eagle-owl	<i>Bubo coromandus</i>	Sundarban
Brown wood owl	<i>Strix leptogrammica</i>	Diginala, Khagrachari, Lawachara, Moulvibazar
Spot-bellied eagle-owl -	<i>Bubo nipalensis</i>	Khagrachari, Chattogram, Bandarban



Barn owl



Brown fish owl



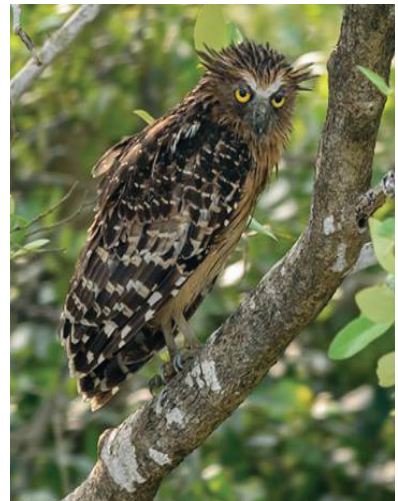
Brown hawk owl



Asian barred owl



Spotted owlet



Buffy fish owl



Dusky eagle owl



Spotted bellied eagle owl



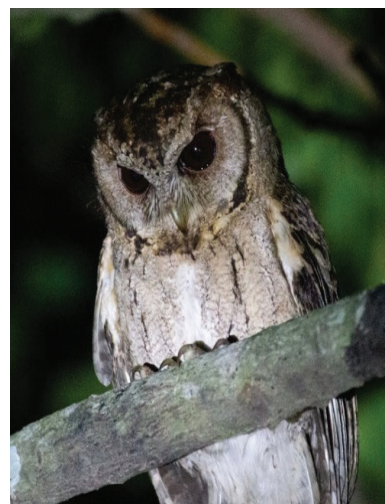
Short eared owl



Brown wood owl



Collared



Collared scops owl



Indian scops owl



Oriental scops owl

Figure 5. Pictorial views of different owl species.

Acknowledgement

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Zoonotic parasites in cats: regional prevalence and antiparasitic treatment outcomes

Md. Mahamudul Hasan¹, Md. Tasmir Rayan Labib¹, Amiya Bhushan Das¹, Robius Sani Sadi², Mousumi Saha¹, Md. Tuhinur Rahman¹, Sattwikesh Paul¹, Md. Taimur Islam² and Md. Ataur Rahman^{1*}

¹Department of Surgery and Radiology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh; ²Department of Pathobiology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.

Corresponding email: ataursra@bsmrau.edu.bd

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Abstract

Pet animals play a crucial role in the socio-economic aspect of society. With the increasing pet population, primarily cats and dogs, the risk of transmitting zoonotic diseases is on the rise. About 40 cats from the districts of Gazipur and Tangail were chosen for investigation of the prevalence of various ectoparasitic and endoparasitic zoonotic diseases in cats as well as the effectiveness of various antiparasitic medications against them. Results showed that Gazipur had a prevalence rate of 60% for both ecto- and endoparasites. On the other hand, Tangail had a prevalence of 100% and 80% for ecto- and endoparasites, respectively. Three types of zoonotic ectoparasites were identified: *Ctenocephalides felis* (flea), *Ixodes ricinus* (tick), and *Sarcoptes scabiei* (mite), which exhibited prevalences of 75%, 18.75%, and 6.25%, respectively. Two types of zoonotic endoparasite eggs (nematodes) were identified, with *Toxocara cati*, *Ancylostoma spp.*, and the mixed infection of these two exhibiting prevalences of 78.57%, 14.29%, and 7.14%, respectively, in fecal sample tests. Eprinomectin, Fipronil spray, and Ivermectin injection were used to treat the ectoparasites that resulted in 93.1%, 100%, 88% efficacy against ectoparasites, respectively. Pyrantel pamoate, a combination of Praziquantel, Pyrantel pamoate, and Febentel, and Ivermectin were used to treat endoparasites in three groups which showed the efficacy to be 80%, 100%, and 70%, respectively. To summarize, the most common area for both ecto- and endoparasites was the Tangail district. *Ctenocephalides felis* (75%) and *Toxocara cati* (78.57%) were the most prevalent ectoparasite and endoparasite, respectively. Fipronil spray emerged as the most effective treatment for ectoparasites, while the combination of Praziquantel, Pyrantel pamoate, and Febentel demonstrated the highest efficacy in controlling endoparasites. The prevalence of ectoparasite and endoparasite infestations found among cats in this study highlights a troubling potential for the transmission of zoonotic parasitic infections. Additionally, this study evaluated the relative effectiveness of various drugs in controlling these parasites.

Keywords: Zoonoses, ectoparasites, endoparasites, prevalence, treatment efficacy, cat

Introduction

Pet animals play a significant aspect of human-animal contact that offers an optimal context to explore how individuals perceive the similarities and distinctions between humans and non-humans in their daily experiences. They are viewed as an extended family and treated as a unit as a whole. Although raising pets has its benefits, there are some drawbacks as well. Inadequate housing, deworming, and vaccination practices for pets kept with humans are to blame for the spread of zoonotic diseases (Moskvina and Zheleznova 2015). Among the various diseases affecting felines, parasitic diseases are mostly prevalent, posing considerably significant health challenges to cats globally (Zajac and Conboy 2012). Studies in Bangladesh show a high prevalence of parasitic diseases such as feline ascariasis, demonstrating

their importance in feline health. Such diseases are an important part of veterinary care because they have a zoonotic potential that affects both animal welfare and public health (Alam and Rahman 2021).

Parasites are eukaryotic organisms that exist in nature as single-celled entities called protozoa, complex metazoans of various sizes known as helminths, or ectoparasites/arthropods (Christaki 2020). The cat flea, *Ctenocephalides felis*, is a widespread ectoparasite of cats and is the most prevalent external parasite of companion animals (Rust and Dryden 1997). Sarcoptic mange, *Sarcoptes scabiei*, poses a threat not only for causing cat mange but also for affecting humans (Bandi and Saikumar 2013). Ticks are widespread and significant ectoparasites that can easily feed on a variety of vertebrate hosts, including house cats (Claerebout *et al.* 2013). Tick-borne disease agent

such as *Ixodes ricinus* is the most common species of hard tick that feeds on a variety of hosts and acts as a reservoir and vector for numerous zoonotic infections, including viruses, bacteria, helminths, and protozoa (Rizzoli *et al.* 2014). Intestinal parasites *Toxocara spp.* are prevalent in felines. Humans may contract the disease by accidentally ingesting contaminated food (Overgaauw and van Knapen 2013). Visceral larva migrans (VLM), ocular larva migrans (OLM), neuro toxocariasis (NT) (e.g., eosinophilic meningoencephalitis), and common/covert toxocariasis (CT) are the four primary syndromes that arise from zoonotic *Toxocara* infection in humans (Rostami *et al.* 2020). As a result of their potential for zoonotic transmission *Ancylostoma tubaeforme* and *A. braziliense* are common feline endoparasites (Kalkofen 1987). Previous research found that cats were significantly infected with *A. tubaeforme*, resulting in dermatitis, anemia, lung lesions, and weight loss (Daba *et al.* 2021). The migration of *Ancylostoma spp.* larvae can cause dermatological problems such as cutaneous larva migrans, eosinophilic pneumonia, localized myositis, folliculitis, erythema multiforme, and ocular symptoms in humans (Paul *et al.* 2010).

In addition to jeopardizing the health and welfare of cats, these ectoparasitic and endoparasitic infestations also pose a zoonotic concern, particularly in the metropolitan and peri-urban areas of Bangladesh, where intimate human-animal interactions are common. Therefore, a prevalence study of various feline parasites is essential to prevent and control such zoonotic diseases.

A wide range of medications are available for the control of parasitic infestations in cats. For the control of endoparasites, certain medication such as praziquantel, pyrantel pamoate, febantel, ivermectin, milbemycin, etc. (Jacobs 1987, Pereira *et al.* 2016). For controlling ectoparasites ivermectin, fipronil, eprinomectin are widely used (Deger and Ural 2013, Shehzad *et al.* 2019, Tishyn *et al.* 2021). Furthermore, the resistance of cat parasites to commonly used antiparasitic medications underscores the urgent need to evaluate the efficacy of current therapeutic alternatives. In Bangladesh, veterinary facilities often lack modern methods tailored to regional parasite burdens and the increasing trends of treatment resistance. Comparative studies on the therapeutic

efficacy of antiparasitic medications are essential for optimizing treatment protocols, enhancing animal welfare and reducing concerns about zoonotic transmission.

Given this backdrop, a thorough study on the prevalence of zoonotic ectoparasites and endoparasites in cats across two districts (Gazipur and Tangail), along with a comparative analysis of the effectiveness of antiparasitic treatments, is necessary. This research will help to bridge knowledge gaps, contribute to evidence-based veterinary practices, and advance health initiatives in Bangladesh.

Materials and methods

Sample collection and experimental procedure: The study was conducted on 40 free ranging domestic cats (20 cats from Gazipur district and 20 cats from Tangail district) at different pet clinics and hospitals. Data were collected using a pre-designed questionnaire and direct observation of the cats. The questionnaire included inquiries about the cat's age, sex, breed, and any prior history of parasitic infestations. Direct observation revealed ectoparasites on the cat's skin and fur. The study was conducted in two separate experiments:

Experiment 1: Identification of zoonotic parasites and determination of prevalence: A total of 40 cats (20 cats from Gazipur district and 20 cats from Tangail district) were examined for the presence of zoonotic ectoparasites from skin samples, and hair samples (area 2×2 inches), and zoonotic endoparasites from fecal samples were collected from the cats to identify the type of parasites and determine their prevalence.

Experiment 2: Treatment and evaluation of therapeutic efficacy: From the total of 40 domestic cats, 20 cats were selected for the therapeutic efficacy of the treatment of ectoparasitic infestations. The following drugs were administered and divided the 20 cats into 4 groups.

Group 1: Five cats were selected as the control group & no treatment was given. The sample was collected on day 01 and after 15 days.

Group 2: Five cats were selected & Eprinomectin (brand name-Navaprin pour on®, Navana Pharmaceuticals Ltd., Bangladesh) was used at 16 drops/10kg on the skin, once

on day 01. After 15 days the sample was collected from the selected cats.

Group 3: Five cats were selected & Fipronil (brand name- Frontline Spray[®], Boehringer Ingelheim, Germany) was used at 6-12 pumps/kg on the skin once at day 01. Then after 15 days, the sample was collected from the cats.

Group 4: Five cats were selected & Ivermectin (brand name- Inj. Vermic[®], Techno Drugs Ltd., Bangladesh) was used at 0.2 mg/kg subcutaneous injection once at day 01. Then the samples were collected from these cats on day 15.

On the other hand, for the treatment of endoparasitic infestations, another 20 cats were selected to determine the therapeutic efficacy of the following drug and divided the cats into four groups as group 5, group 6, group 7 & group 8.

Group 5: Five cats were selected in group 5 as the control group & no treatment was given. The feces samples were collected from this group on days 01 & 15.

Group 6: This group had five cats and the combination of Praziquantel, Pyrantel pamoate, and Febentel (Brand name- Tab. Helminthicide-L[®], General Drugs House Co. Ltd., Thailand) was used at 1tab/10kg, oral administration at days 1. The feces samples were collected on day 01 & day 15.

Group 7: Another five cats were selected & Pyrantel Pamoate (Brand name -Sus. Delentin[®], Renata Limited. Bangladesh) was administrated orally at 10mg/kg, once on day 01. Then, feces samples were collected on day 01 & day 15.

Group 8: In this group, five more cats were selected and Ivermectin (Inj. Vermic[®], Techno Drugs Ltd., Bangladesh) was injected subcutaneously once at 0.2mg/kg on day 01. On days 01 & 15, samples were collected from this group.

Examination of ectoparasites: Potassium hydroxide (KOH) preparation was commonly used to detect ectoparasites in clinical specimens (Kaur and Kaur 2014). KOH is a strong alkali that dissolves, breaks down, and softens tissues in a skin sample, including keratin. This made it easier to see the parasite under a microscope

(Shavandi *et al.* 2017). The 10% KOH solution was first applied on a slide in two to three drops. The fur sample was then added in small amounts to the KOH solution and spread out as evenly as possible. The sample was then exposed to the Bunsen flame for three to four seconds while being shielded with a coverslip. For several minutes, the sample was held. Then, the slide was examined for ectoparasites using 4x and 10x magnifications under the microscope (Optima biological microscope G-206, Optima[®], Taiwan).

Examination of endoparasites: The isolation and identification of oocysts and cysts in canine and feline excrement can be accomplished using the centrifugal flotation method with zinc sulfate [specific gravity (S.G.) 1.18] (Cobban 2024). Initially, about 2 grams of excrement were put into a single-use plastic cup with a large opening. The feces and around 4 milliliters of flotation solution were thoroughly mixed. The container was filled with four milliliters of flotation solution and stirred again. A tea strainer was used to filter the fecal suspension before it was moved to a fresh container. A test tube with a volume of 10–15 ml and support on a stand received the contents. The sample was then centrifuged at 500 g for 10 minutes. Additional flotation solution was slowly added until a positive meniscus appeared at the top of the test tube. Then coverslip was placed on top and let to stand for another 5-10 minutes. The coverslip with the fluid drop attached to the bottom was meticulously removed and placed on a microscope slide. Before positioning the coverslip, a drop of Lugol's iodine was put on the slide. Subsequently, it was examined under a light microscope at 4x and 10x to detect the specific oocysts of endoparasite and count them also.

The prevalence of ecto- and endoparasite was calculated using the following formula:

$$\text{Prevalence (\%)} = \{(\text{Number of positive cases found in ecto- or endoparasite} / \text{total sample size in ecto- or endoparasite}) \times 100\}$$

The efficacy of the drugs was calculated using the following formula:

$$\text{Efficacy (\%)} = \{(\text{Average no. of ectoparasites or oocytes of endoparasites before treatment} - \text{Average no. of ectoparasites or oocytes of endoparasites after treatment}) /$$

Average no. of ectoparasites or oocytes of endoparasites before treatment} $\times 100$

Statistical analysis: The collected data were recorded and organized in a Microsoft Excel 365 worksheet. TTEST was carried out to evaluate the level of significance and $p < 0.05$ was considered as significant.

Results and discussion

Among the total 20 samples, 10 samples were taken from Gazipur and 10 samples were taken from Tangail district. From 20 samples, 16 samples were positive for ectoparasite infestations. The prevalence rate was 80% (Table 1). In Gazipur district the prevalence rate was 60%, where 6 cases were positive for ectoparasite infestation against 10 samples. On the other hand, 100% prevalence was observed in Tangail. There are no studies on prevalent ectoparasitic diseases in Gazipur and Tangail district. But in a study by Authoy *et al.* 2023, the prevalence of ectoparasites in cats in Dhaka was 76.92% (Authoy *et al.* 2023). In contrast only 27.4% prevalence was seen in Sylhet district (Nyema *et al.* 2024). In Mymensingh district the prevalence of ectoparasites in cats was 88.89% (Rahman *et al.* 2009). In Bangkok, Thailand, a similar study was conducted where the prevalence of ectoparasites in free roaming cats was 95.8% (Jittapalapong *et al.* 2008).

Three types of ectoparasites were found on the skin-scraping tests. The species of these parasites were identified based on their morphology. The flea species was *Ctenocephalides felis*. The tick and mite species were *Ixodes ricinus* and *Sarcoptes scabiei*, respectively (Figure 1). Among these fleas was most prevalent having 75% prevalence (Table 2). The prevalence of tick and mite was 18.75% and 6.25%, respectively. In contrast, the

prevalence of mites was 62.5%, fleas 8.92 and tick 3.57% in a study conducted in Dhaka (Authoy *et al.* 2023). Akucewich *et al.* 2002, showed that 92.5% of feral cats of USA had flea (*Ctenocephalides felis*) infestation whereas mites infestation was in 37% cases and the prevalence of ticks was 4.5% (Akucewich *et al.* 2002).

A total of 20 samples were collected, 10 samples were taken from Gazipur and 10 samples from Tangail district. Among these 20 samples, 14 samples were positive for endoparasite infestations where 70% of cases were prevalent (Table 1). 60% of cases in the Gazipur district tested positive for endoparasite infestations out of 10 samples. On the other side, Tangail showed an 80% prevalence. According to Mukutmoni *et al.* 2022, the prevalence of endoparasites in cats in Dhaka was 32.40% (Mukutmoni *et al.* 2022). But in another study by Mehedi *et al.*, 2020, the prevalence of endoparasitic infestation in cats of Mymensingh district was 62.9% (Mehedi *et al.* 2020). The prevalence of endoparasites household cats in Dhaka was 43.44% (Aurin *et al.* 2020) many of which have zoonotic potential. Because domestic owned cats (pet). According to Islam *et al.* 2018 the popularity of cats as a pet is increasing in Bangladesh specially in megacities where keeping large pets is difficult. However, this popular pet is being affected by various intestinal parasitism that may threaten public health by spreading zoonotic parasitic diseases. But surprisingly, no comprehensive study has been documented yet detailing the status of parasitic infections in Bangladeshi domestic cats and their public health importance. Therefore, the study was conducted to evaluate the prevalence of intestinal parasitism in household cats in Dhaka, Bangladesh to find out the associated risk factors and evaluate the perception of cat owners on the zoonotic potential of the associated diseases. Questionnaire based survey was conducted among the cat

Table 1. Prevalence of parasites in cats in Gazipur and Tangail district

Description	District	Sample size	Positive Cases	Prevalence (%)
Prevalence of ectoparasites	Gazipur	10	6	60
	Tangail	10	10	100
	Total	20	16	80
Prevalence of endoparasites	Gazipur	10	6	60
	Tangail	10	8	80
	Total	20	14	70

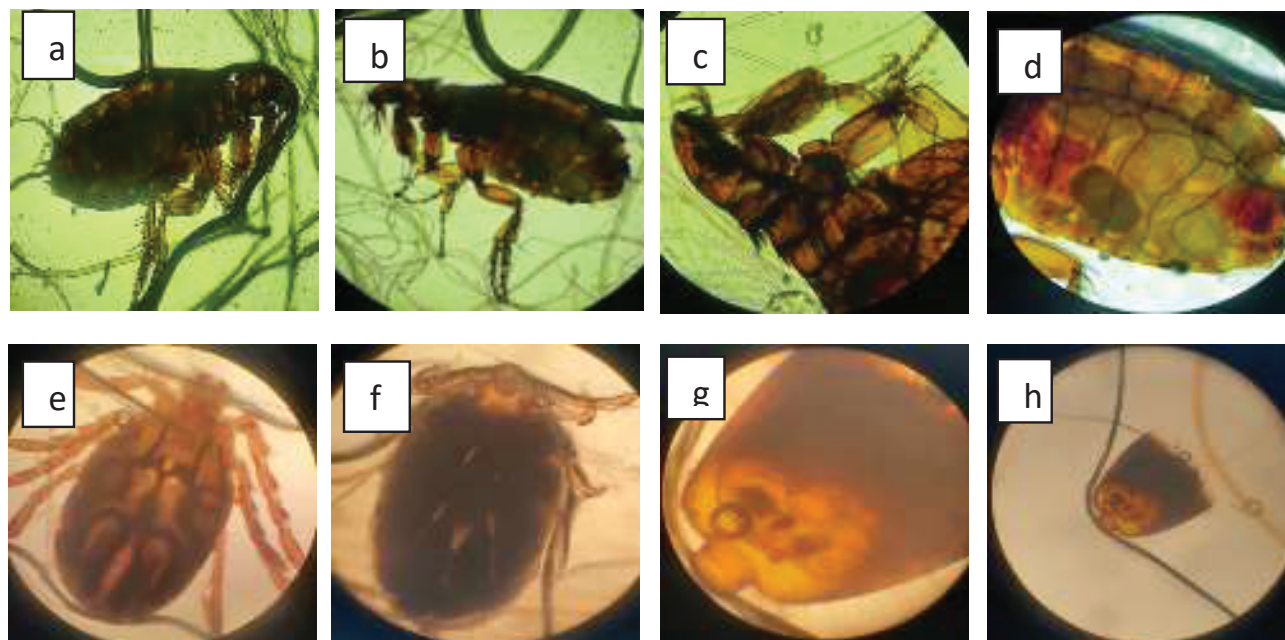


Figure 1. Different ectoparasites found in the body of the cats: (a) & (b) showed fleas (*Ctenocephalides felis*) (4x), (c) & (d) showed fleas (*Ctenocephalides felis*) (10x), (e) & (f) showed tick (*Ixodes ricinus*) (4x), (g) showed mite (*Sarcoptes scabiei*) (4x) and (h) showed mite (*Sarcoptes scabiei*) (10x).

owners to reveal their perception on parasitic diseases and potential health hazards. Besides, five hundred seventy nine (579, the prevalence rate of endoparasites in cats of Dhaka was 77.4% (Islam *et al.* 2018) the popularity of cats as a pet is increasing in Bangladesh specially in megacities where keeping large pets is difficult. However, this popular pet is being affected by various intestinal parasitism that may threaten public health by spreading zoonotic parasitic diseases. But surprisingly, no comprehensive study has been documented yet detailing the status of parasitic

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Table 2. Prevalence of different parasites in cats in Gazipur and Tangail district

Description	Types of parasites	No. of positive cases	Prevalence (%)
Prevalence of different ectoparasites	<i>Ctenocephalides felis</i>	12	75
	<i>Ixodes ricinus</i>	3	18.75
	<i>Sarcoptes scabiei</i>	1	6.25
	Total	16	
Prevalence of different endoparasites	<i>Toxocara cati</i>	11	78.57
	<i>Ancylostoma spp.</i>	2	14.29
	Mixed (<i>Toxocara cati</i> & <i>Ancylostoma spp.</i>)	1	7.14
	Total	14	

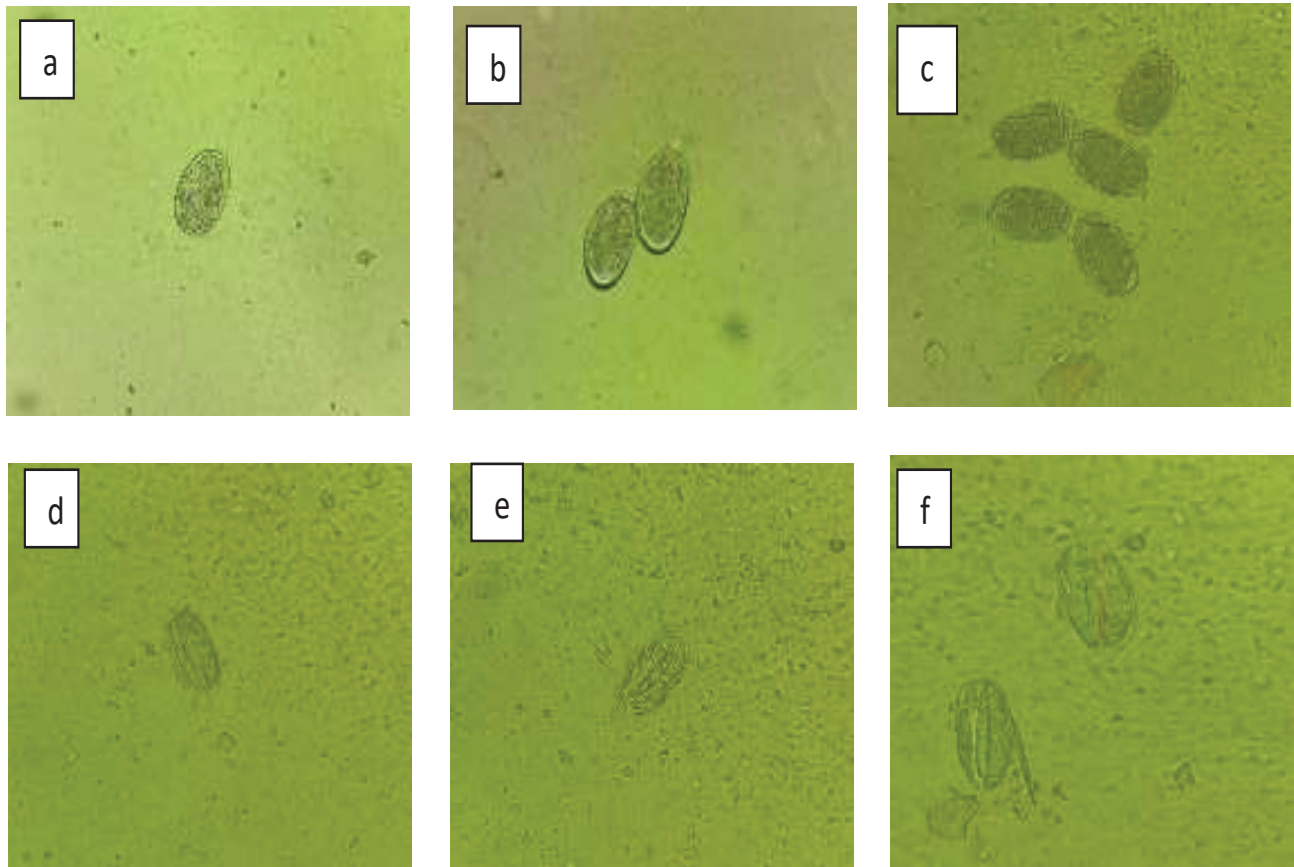


Figure 2. Different oocysts of endoparasites found in the feces of the cats: (a), (b) & (c) showed oocysts of *Toxocara cati* (10x) and (d), (e) & (f) showed oocysts of *Ancylostoma spp.* (10x).

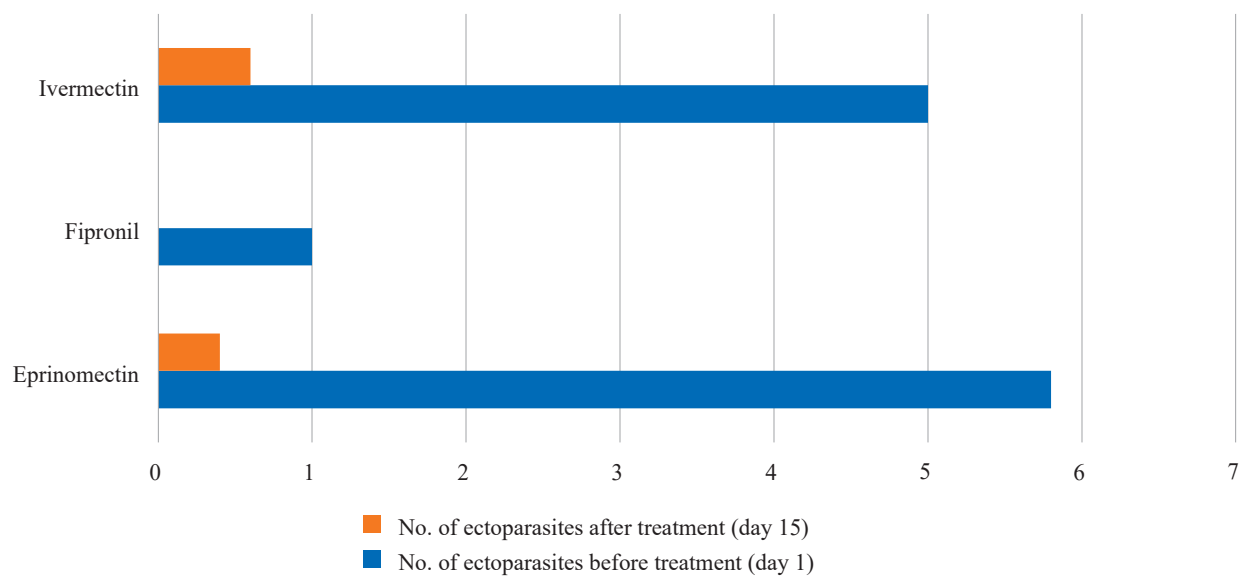


Figure 3. Therapeutic efficacy of eprinomectin, fipronil and ivermectin against ectoparasites.

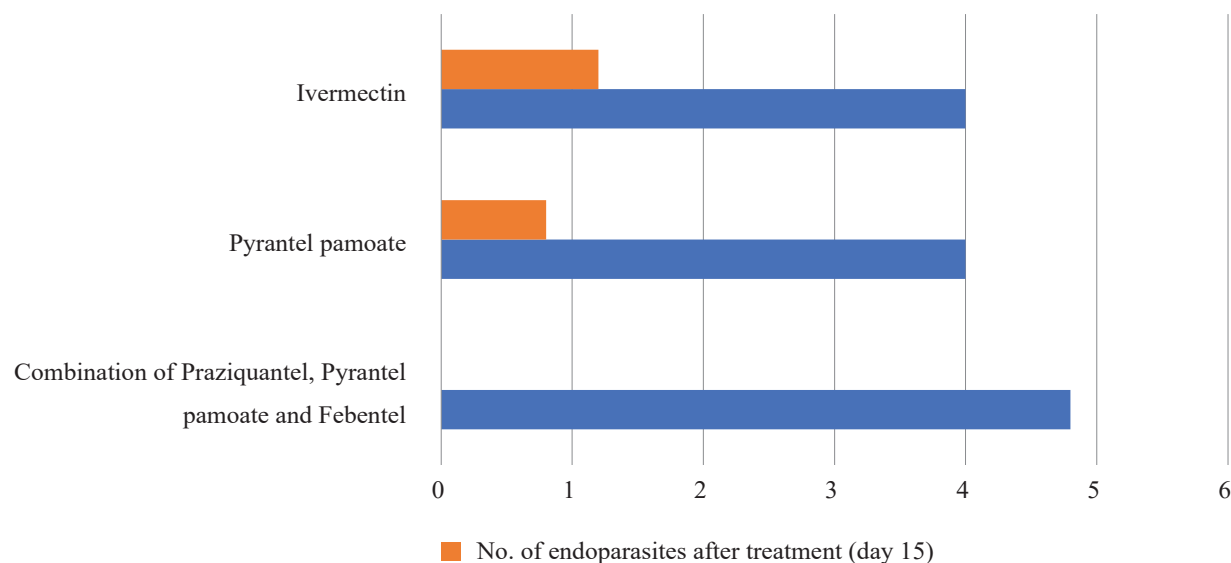


Figure 4. Therapeutic efficacy of combination of praziquantel, pyrantel pamoate, and febentel, pyrantel pamoate and ivermectin against endoparasites.

On the fecal sample test, only nematode eggs were found. The nematode eggs were classified as *Toxocara cati* and *Ancylostoma spp.* eggs. Between these two, *Toxocara cati* prevalence was 78.57% (Table 2). The prevalence of *Ancylostoma spp.* was 14.29%. Mixed infection was observed on 1 case (prevalence 7.14%) having both of the before-mentioned parasites. 73.33% prevalence was observed for *Toxocara cati* in a study conducted in the pet markets in Dhaka (Barua *et al.* 2020). Mukutmoni *et al.* 2022, found *Ancylostoma spp.* to be the most prevalent (9.26 %) helminth in cats (Mukutmoni *et al.* 2022). In another study conducted in Mymensingh district, the prevalence of *Toxocara cati* was 17.7% and for *Ancylostoma spp.* it was 6.5% (Mehedi *et al.* 2020). Islam *et al.* 2018 the popularity of cats as a pet is increasing in Bangladesh specially in megacities where keeping large pets is difficult. However, this popular pet is being affected by various intestinal parasitism that may threaten public health by spreading zoonotic parasitic diseases. But surprisingly, no comprehensive study has been documented yet detailing the status of parasitic infections in Bangladeshi domestic cats and their public health importance. Therefore, the study was conducted to evaluate the prevalence of intestinal parasitism in household cats in

Dhaka, Bangladesh to find out the associated risk factors and evaluate the perception of cat owners on the zoonotic potential of the associated diseases. Questionnaire based survey was conducted among the cat owners to reveal their perception on parasitic diseases and potential health hazards. Besides, five hundred seventy nine (579, found *Toxocara cati* as the most prevalent endoparasite having a prevalence rate of 71.9% and for *Ancylostoma spp.*, it was 26.8% (Islam *et al.* 2018) the popularity of cats as a pet is increasing in Bangladesh specially in megacities where keeping large pets is difficult. However, this popular pet is being affected by various intestinal parasitism that may threaten public health by spreading zoonotic parasitic diseases. But surprisingly, no comprehensive study has been documented yet detailing the status of parasitic infections in Bangladeshi domestic cats and their public health importance. Therefore, the study was conducted to evaluate the prevalence of intestinal parasitism in household cats in Dhaka, Bangladesh to find out the associated risk factors and evaluate the perception of cat owners on the zoonotic potential of the associated diseases. Questionnaire based survey was conducted among the cat owners to reveal their perception on parasitic diseases and potential health hazards. Besides, five hundred seventy nine (579.

Experiment 2: Therapeutic efficacy of drugs against ectoparasites: The alterations in the number of parasites in the control group between days 1 and 15 were not statistically significant (Table 3). The number of parasites was increasing with days passing by.

Eprinomectin solution significantly reduced the number of ectoparasites in the cats. Before treatment, the average number of ectoparasites from the particular area of the cat's skin was 5.8 whereas after treatment the average number significantly reduced to 0.4. The efficacy was 93.1% (Table 4). In cats, the use of eprinomectin is commonly used with other agents like praziquantel, fipronil, etc. In a study by Tielemans *et al.* 2021, the efficacy of a combination of esafloxolaner, eprinomectin, and praziquantel against fleas in cats was 97.7% (Tielemans *et al.* 2021). Baker *et al.* 2014(S, reported the efficacy of topical combination of fipronil, (S)-methoprene, eprinomectin and praziquantel to be 94.3% after a single dose (Baker *et al.* 2014)

(S. Similarly, in cattle the efficacy of eprinomectin in controlling ectoparasites was 94-99% (Shoop *et al.* 1996).

Fipronil spray was administered on the assigned cats where the average number of ectoparasites was 1. After treatment, there were no ectoparasites on these cats (Table 4). Medleau *et al.* 2002, reported the efficacy of fipronil to be 70% for the control of fleas in cats (Medleau *et al.* 2002). According to Ritzhaupt *et al.*, 2000(30, 60, 90, and 120, sixteen cats (8 pairs/treatment group, the efficacy of fipronil after a single dose was 71.2% and after 44 days the efficacy was 100% (Ritzhaupt *et al.* 2000)30, 60, 90, and 120, sixteen cats (8 pairs/treatment group. Dryden *et al.* 2000, found the efficacy of fipronil to be 96.5% in controlling fleas in cats (Dryden *et al.* 2000).

Ivermectin injection also reduced the ectoparasites significantly ($p < 0.05$) and the efficacy was 88%. According to Shehzad 2019, the efficacy after 15 days

Table 3. The Level of significance of different parasites in the control groups (Group 1 and group 5)

Types of Treatment	Average no. of parasites on day 1	Average no. of parasites on day 15
Control (Group 1)	5.4	6.2
Level of significance (p)	0.12	
Control (Group 5)	4.8	3.6
Level of significance (p)	0.14	

*Not significant ($p > 0.05$).

Table 4. Therapeutic efficacy of antiparasitic drugs against ecto and endo parasites in cats

	Types of treatment	Average no. of ectoparasites on day 1	Average no. of ectoparasites on day 15	Efficacy (%)	Level of significance (p)
Therapeutic efficacy of anti-parasitic drugs against ectoparasites	Eprinomectin	5.8	0.4	93.1	0.0098
	Fipronil	1	0	100	0.01
	Ivermectin	5	0.6	88	0.02
Therapeutic efficacy of anti-parasitic drugs against endo-parasites	A combination of Praziquantel, Pyrantel pamoate and Febentel	4.8	0	100	0.02
	Pyrantel Pamoate	4	0.8	80	0.03
	Ivermectin	4	1.2	70	0.04

*Significant ($p < 0.05$).

of ivermectin administration was 90% (Shehzad 2019). Pagé *et al.* 2000, reported the efficacy of ivermectin in controlling ectoparasites to be 96% (Pagé *et al.* 2000).

The amount of parasites in the control group did not significantly vary between day 1 and day 15 (Table 3).

The combination of Praziquantel, Pyrantel pamoate, and Febentel considerably lowered endoparasite count in cats. Before therapy, the specific area of the cat's skin had an average of 4.8 endoparasites; however, following treatment, the average number drastically decreased to 0 which showed the efficacy to be 100%. Barr *et al.*, 1998, reported 100% efficacy in controlling endoparasites in dogs by using this combination (Barr *et al.* 1998). Similarly, Çetin *et al.* 2022, found the efficacy of the combination of Praziquantel, Pyrantel pamoate, and Fenbendazole to be over 98% (Çetin *et al.* 2022).

The cats who were assigned were given Pyrantel Pamoate, and the average number of endoparasites was 4. These cats have 0.8 endoparasites in average after therapy. The efficacy of pyrantel pamoate in paste form was 99.3 to 99.7% in cats (Ridley *et al.* 1991). Reinemeyer & DeNovo 1990, reported the efficacy of pyrantel pamoate against *Toxocara cati* to be 78.2% (Reinemeyer and DeNovo 1990). According to Patil *et al.* 2024, the efficacy of pyrantel pamoate was 97.16% (Patil *et al.* 2024).

The endoparasites were also considerably decreased by Ivermectin injection ($p < 0.05$). According to Roberson *et al.* 1992, the efficacy of ivermectin against hookworm infestation in cats was 90.7% (Roberson *et al.* 1992). Blagburn *et al.* 1987 (100 (n = 6), reported that single dose of SC ivermectin injection was effective in removing *Ancylostoma spp.* and *Toxocara cati* in cats (Blagburn *et al.* 1987) 100 (n = 6). The efficacy of ivermectin for the treatment of endoparasites in cats at 0.25 mg/kg body weight was 86.1% (Iqbal 2017).

Conclusion

Parasitic infestation is a common and serious health issue in cats that, if neglected, can lead to zoonotic health problems in humans. In our study, we found that Tangail had a higher prevalence of ecto- and endoparasitic infestations compared to Gazipur. *Ctenocephalides felis*

was the most prevalent ectoparasite, while *Toxocara cati* was the most prevalent endoparasite among all zoonotic parasites. Eprinomectin proved to be the most effective treatment for ectoparasites, and the combination of Praziquantel, Pyrantel pamoate, and Febentel was the most effective for controlling endoparasites.

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Recent trend analysis of rainfall pattern in Dhaka city using linear regression

Sajeeb Hossain^{1,2*}, Md. Ibrahim Khalil¹, Md Younus Khan¹, Md. Abdus Samad² and M. A. K Mallik³

¹Department of Applied Mathematics, University of Dhaka, Dhaka-1000, Bangladesh, ²IUBAT- International University of Business Agriculture and Technology, Dhaka, Bangladesh, ³Bangladesh Meteorological Department (BMD), Dhaka, Bangladesh

*Corresponding email: sajeebhossain113@gmail.com

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Abstract

One of the warmest places in Bangladesh is Dhaka. We have examined the recent rainfall trend in Dhaka city (1996–2021) in this study. MS-Excel was utilized to complete the necessary computation and charting, and the simple linear regression method was employed as the statistical technique. The outcome demonstrates that the trend of rainfall is declining. The average annual rainfall is declining at a rate of 0.0366 millimeters per year. While yearly total winter rainfall is increasing at a pace of 1.6096 mm/year, total pre-monsoon rainfall is declining at a rate of 5.0031 mm/year, annual total monsoon rainfall is falling at a rate of 7.8868 mm/year, and total post-monsoon rainfall is decreasing at a rate of 2.1453 mm/year. However, the annual total winter rainfall is increasing at a rate of 1.6096 mm/year. Every variation in the rainfall pattern has a major impact on Dhaka's climate and weather. It has now grown to be one of the biggest environmental issues. These rainfall pattern tendencies indicate that the future climate will vary, resulting in a varied weather pattern across the city's seasons.

Keywords: Meteorology, trend analysis, regression analysis

Introduction

The climate of Bangladesh, which lies in the tropical monsoon zone is defined by temperature, relative humidity, rainfall, and dew temperature, with some noticeable seasonal fluctuations. The primary natural factor influencing Bangladesh's agricultural output is rainfall. An important aspect of agriculture and our nation's economy is the fluctuation of rainfall and the trend of abnormally high or low precipitation (Karl *et al.* 2008). Rainfall patterns are altering globally and regionally. As a result, of global warming, as is widely known. The main physical mechanism connecting weather, climate, and hydrological cycles is rainfall, which returns water from the atmosphere to the Earth's surface (Solomon *et al.* 2007). Bangladesh's rainfall-dominated climate receives the world's most intense rainfall. The monthly, seasonal, and yearly rainfall in Bangladesh did not show any discernible trends. The main rainy seasons in Bangladesh are the summer and monsoon, which together provide around 84% of the country's yearly precipitation. The most pressing issue of recent time is climate change. Due to global warming, the climate is changing daily on both a regional and

global scale (Karl *et al.* 2008). In many parts of the world, especially Bangladesh, where hydrological disasters are frequent, the effects of climate change are profound. Bangladesh is one of the most negatively impacted nations by climate change. However, the study reveals that the monsoon season accounts for almost 57% of rainfall. Finding patterns in long-term hydrological data sets is extremely important from a scientific and practical standpoint. The quality of the datasets—most importantly, their homogeneity—also affects the outcomes of climate analyses (Chen *et al.* 2011). The magnitude of the anticipated changes makes it appear foolish to rely solely on antiquated methods of extreme estimation. According to estimates, climate change will cause temperatures to rise significantly and alter rainfall patterns, which will undoubtedly have an impact on both public health and our agricultural industries (Samad *et al.* 2017). The climate of Bangladesh, which is in the tropical monsoon zone is typified by high temperatures, a lot of rainfall, a lot of humidity, and very noticeable seasonal fluctuations (Monirul *et al.*). Bangladesh's capital is Dhaka. It is located at the nation's center. The weather in Dhaka has a significant effect on the entire nation (Bangledia 2014). The climate has been quickly changing over the past few

decades for a variety of causes (IPCC. Climate Change, 2007). This study employed simple regression analysis to create a graph of the relatable data for the last 26 years (1996–2021) in the Dhaka region in order to determine trends in the annual mean pre-monsoon rainfall, annual mean monsoon rainfall, and annual mean post-monsoon rainfall.

Methodology

Regression analysis: A set of statistical methods, which are used for the estimation of relationships between a dependent variable and one or more independent variables is called regression analysis. In this study, we have used simple linear regression to approximate equation of the trend. The linear regression equation has the following form: $Y = \alpha x + \beta$

$$\text{with } \alpha = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

$$\beta = \bar{y} - \alpha \bar{x}$$

where α is the slope of the trendline and β is the intercept of this line with y axis. x_i and y_i are the independent and dependent variables respectively and $\bar{x}$ is the average of the dependent variable and $\bar{y}$ is the mean value of the independent variables.

Coefficient of determination (R^2): R-squared is a statistic which provides a measure of how well observed outcomes have been replicated by the model. The formula to compute this statistic is:

$$R^2 = 1 - \frac{SS_{\text{res}}}{SS_{\text{total}}}$$

Here, SS_{res} is the residual sum of squares and SS_{total} is the total sum of squares which are calculated by:

$$SS_{\text{res}} = \sum_{i=1}^n (y_i - \hat{f}_i)^2 = \sum_{i=1}^n (e_i)^2$$

$$SS_{\text{total}} = \sum_{i=1}^n (y_i - \bar{y})^2$$

The value of r-squared normally varies from 0 to 1. If the regression line fits the data set properly then the value of r-squared will be closer to 1 (<https://corporatefinanceinstitute.com/resources/knowledge/other/rsquared/>.)

Results and discussion

In this study we have divided the whole year into four different categories for better analysis of rainfall. The year has been divided into four categories according to different seasonal rainfall (<https://www.bmd.gov.bd>). They are-

- **The Summer:** The summer season is considered from March to May. It is also called the pre-monsoon season of rainfall.
- **The Monsoon:** The monsoon is considered from June to September
- **The Post Monsoon:** The post-monsoon is considered from October to December.
- **The Winter:** The winter is considered from January to February.

The annual maximum, minimum and mean rainfall of Dhaka city has been determined using the historic available data provided by Bangladesh Meteorological Department (BMD). To analyze the recent trend of rainfall we have used linear regression with yearly average, maximum and minimum rainfall. To determine the rate of change of trend we have used linear regression. We have also computed the R-Squared statistic to determine how good the trend line fits the data points. For seasonal analysis we have also used linear regression and R-Squared statistic.

We found that the highest annual total pre-monsoon rainfall was 969 mm in 2000, while the lowest total rainfall was 225 mm in 2009. The trend of the average annual rainfall has been examined in this study. Over the specified period, the annual average rainfall trend is declining over the examined area; this is a negative trend that is statistically significant with an R-Squared value of 0.0564. Figure 1 illustrates the 5.0031 mm/year decline in the yearly total pre-monsoon rainfall. There has been a notable shift in the city's pre-monsoon rainfall (Ahmed 1989).

According to the study, 2007 saw the highest annual total monsoon rainfall of 2065 mm, while 2012 saw the lowest total rainfall of 764 mm. The trend of the annual total monsoon rainfall has been examined in this study. With an R-Squared value of 0.0298, the trend of yearly total monsoon rainfall is declining over the examined area

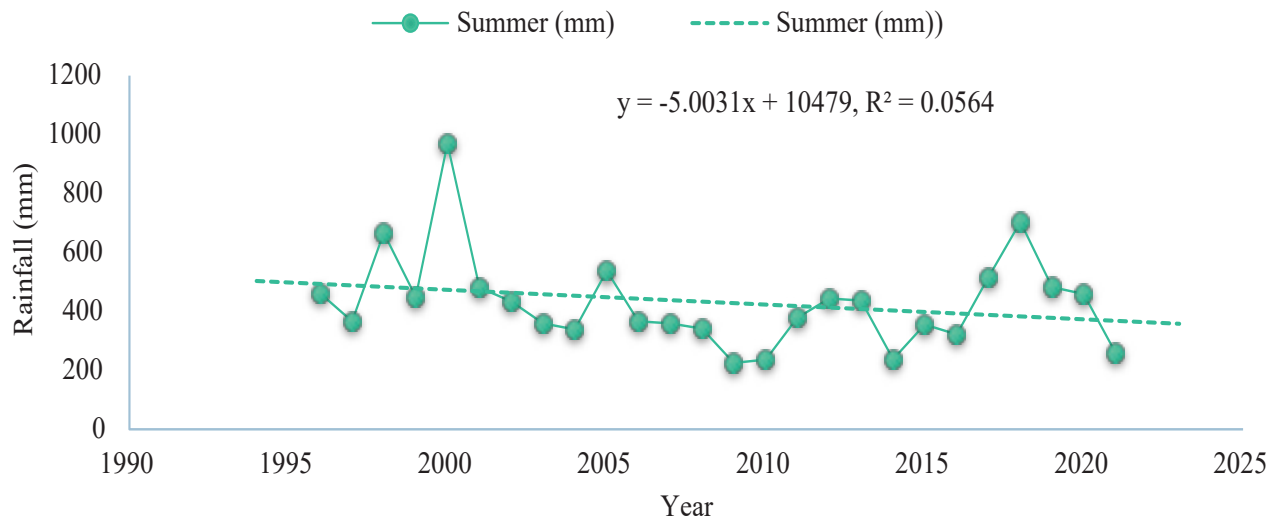


Figure 1. Analysis of the trend of mean total rainfall in pre-monsoon season of Dhaka city.

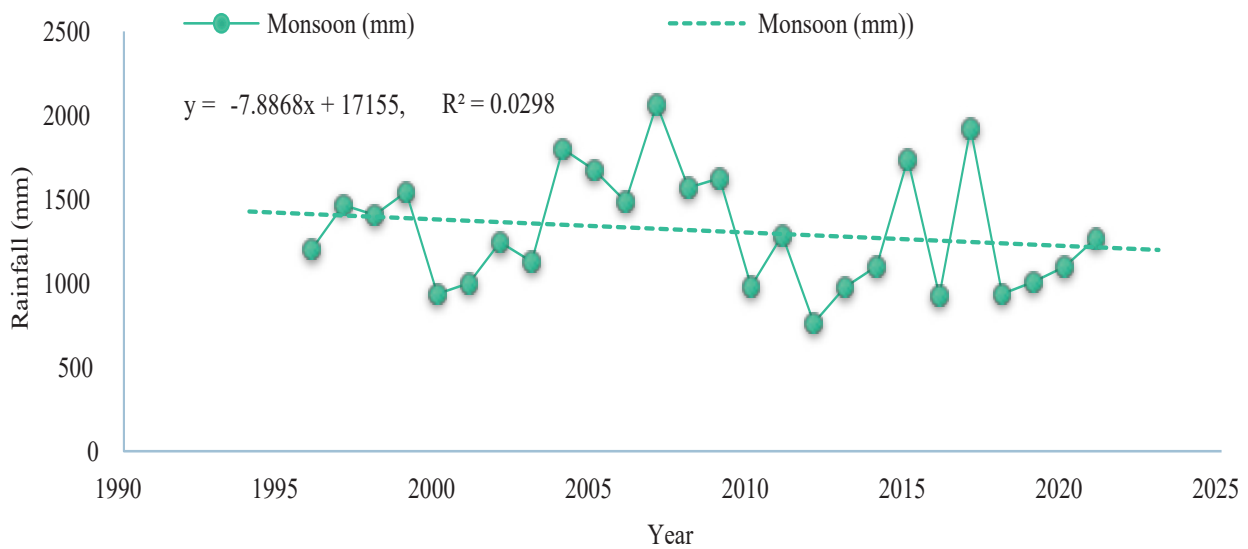


Figure 2. Analysis of the trend of mean total rainfall in monsoon season of Dhaka city.

during the specified period, indicating a negative trend and statistical significance. The annual total monsoon rainfall is declining at a rate of 7.8868 mm/year, as illustrated in Fig 2. The city's monsoon rainfall has changed significantly.

Total post-monsoon rainfall ranges from a minimum of 31 mm in 1997 to a maximum of 431 mm in 2007. The trend of the average annual rainfall has been examined in this study. Over the specified period, the yearly total post-

monsoon rainfall trend is declining over the analyzed area; this is a negative trend that is statistically significant, with an R-Squared value of 0.0165. At a rate of 2.1453 mm/year, the annual total post-monsoon rainfall is declining, as seen in Fig 3.

We found that the total lowest rainfall in 1999, 2004, and 2006 was 0 mm, while the greatest annual total winter rainfall in 2021 was 153 mm. The yearly average rainfall trend has been examined in this study. With an R-Squared

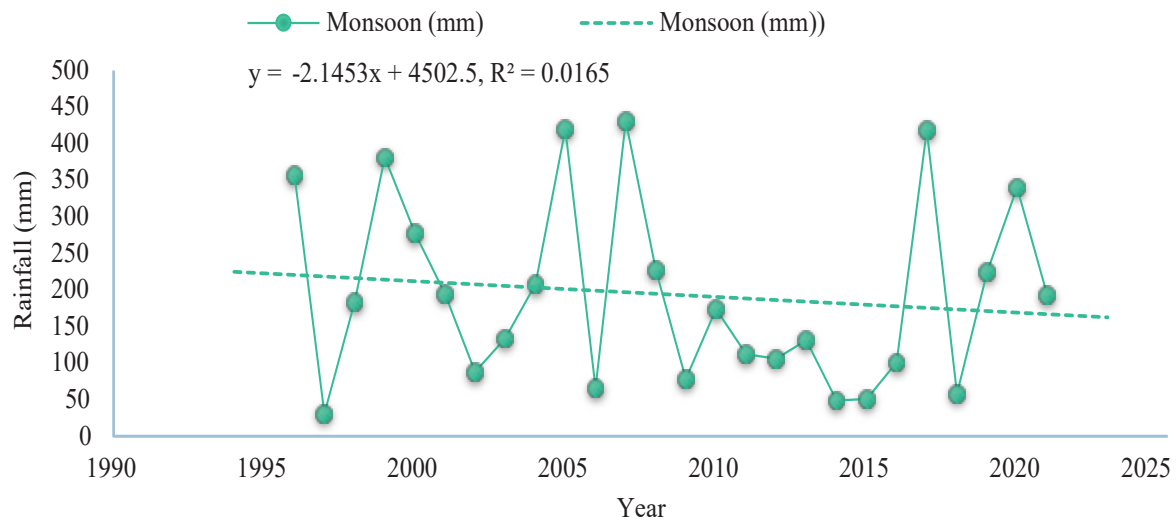


Figure 3. Analysis of the trend of mean total rainfall in post-monsoon season of Dhaka city.

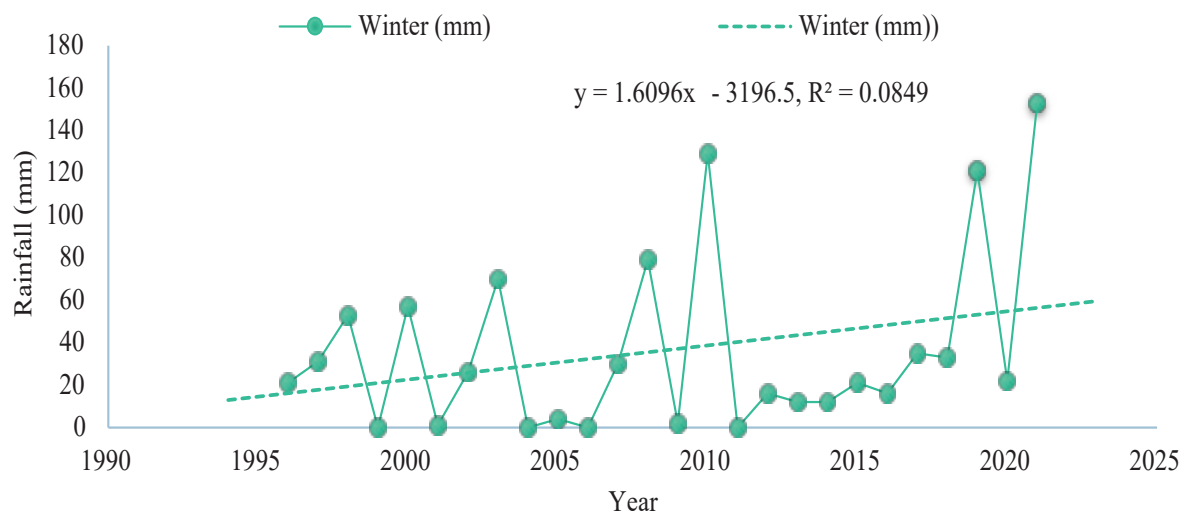


Figure 4. Analysis of the trend of mean total rainfall in winter season of Dhaka city.

value of 0.0849, the trend of annual average rainfall is rising over the examined area over the specified period, indicating a positive trend and statistical significance. The yearly total winter rainfall is rising at a rate of 1.6096 mm/year, as seen in Fig 4. The city's winter rainfall has changed significantly. It also suggests that the city's weather and climate have changed significantly. The winter rainfall has increased dramatically in the last few years.

Observing the data, we have found that the maximum rainfall was 969 mm in summer in 2000, 2065 mm in Monsoon in 2007, 431 mm in Post Monsoon in 2007, and

153 mm in winter in 2021. The minimum rainfall was 225 mm in summer in 2009, 764 mm in Monsoon in 2012, 31 mm in Post Monsoon in 1997, and no rainfall in winter in 1999. The average rainfall throughout the period was 429.85 mm in summer, 1314.65 mm in Monsoon, 193.65 mm in Post Monsoon, and 36.31 mm in winter.

It was evident that Monsoon is the highest rainfall period and winter is the lowest rainfall period.

The Linear regression line is and the value of is 0.0564 in summer. It shows a downward trend.

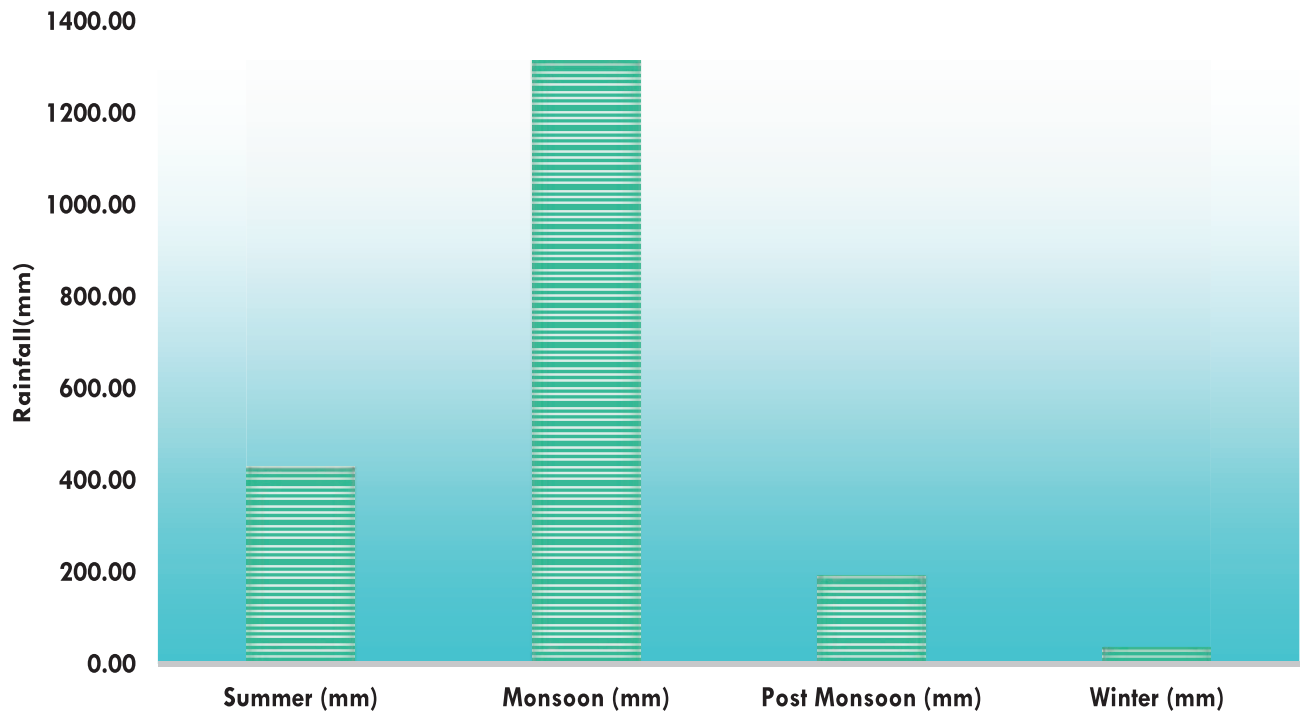


Figure 5. Analysis of mean total rainfall in different seasons of Dhaka city.

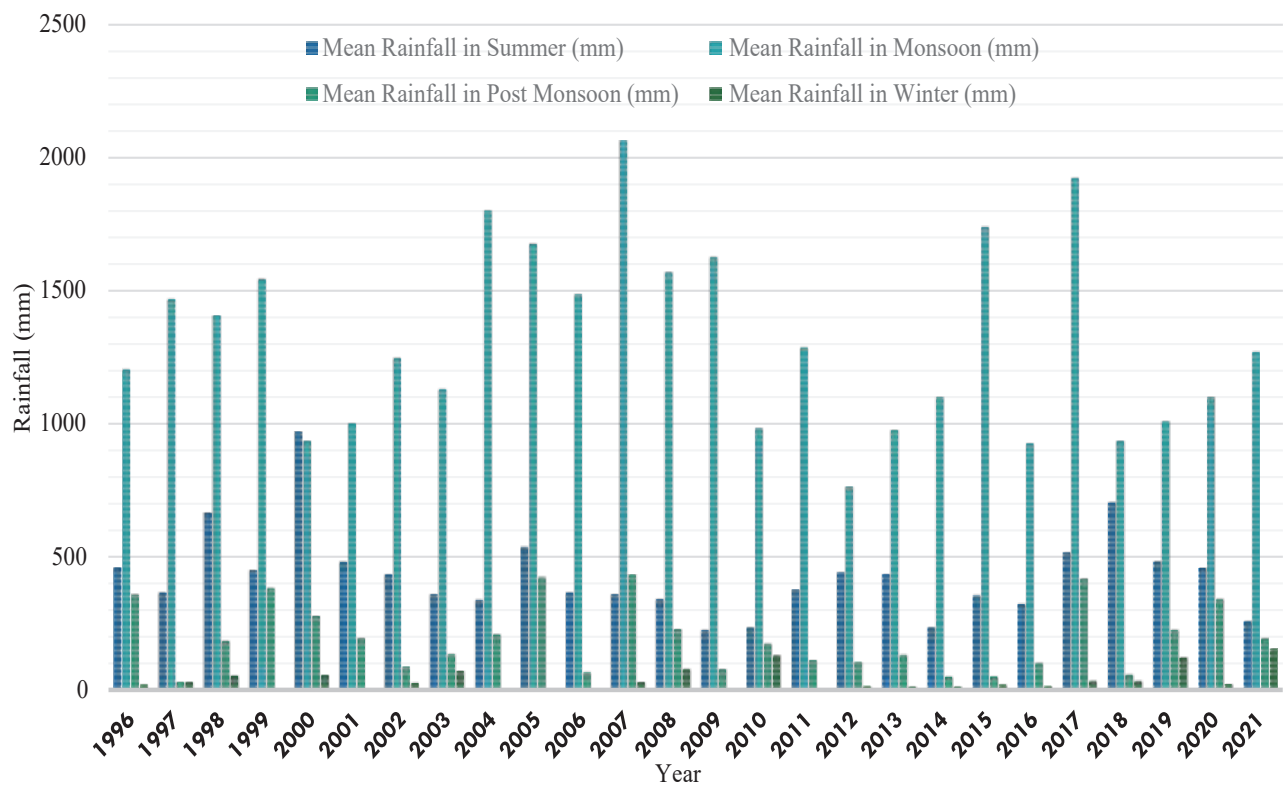


Figure 6. Analysis of the seasonal rainfall of Dhaka city.

The Linear regression line is $y = -0.0298x + 10.1$ and the value of r is 0.0298 in Monsoon. It shows a downward trend.

The Linear regression line is $y = -0.0165x + 10.1$ and the value of r is 0.0165 in Post Monsoon. It shows a downward trend.

The Linear regression line is $y = 0.0849x + 10.1$ and the value of r is 0.0849 in winter. It shows an upward trend.

Table 1. Relation between meteorological parameters

Parameters	Correlation coefficient (r)
Pre-monsoon vs monsoon rainfall	-0.218561472
Post-monsoon vs monsoon rainfall	0.388246857
Rainfall vs humidity	
Annual (monthly data)	0.693356088
Annual	0.435361262
Pre-monsoon	0.610923751
Monsoon	0.376780227
Post-monsoon	0.598688162
Winter	-0.084064364
Rainfall vs temperature	
Rainfall vs Temperature in Monsoon	-0.497483767
Rainfall vs Temperature in Winter	-0.171837211
Rainfall vs Temperature in Pre-monsoon	-0.641475807
Rainfall vs Temperature in Post-monsoon	-0.103831093
Rainfall vs Temperature Annual	-0.203720852

Conclusion

The recent rainfall trend of Dhaka city was analyzed this study. It was found that the trend of rainfall in Dhaka city is declining. Though the average annual rainfall is declining, The yearly winter rainfall is increasing. The rainfall pattern indicates that the future climate will vary in the Dhaka city area.

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Diversity of insects in insecticide treated sweet corn ecosystem

Chandan Kumar Roy¹, Md. Shamim Hossain¹, M. Abdul Karim² and Md Ruhul Amin^{1*}

¹Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, ²Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

Corresponding email : mramin@bsmrau.edu.bd

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Abstract

Maize (*Zea mays* L.) is an annual cereal crop grown for supplementation of diet for human. Cultivation of sweet corn in Bangladesh is increasing with different hybrid varieties, and the crops are infested by fall armyworm. Farmers apply different insecticides to overcome the attack of fall armyworm without considering the impact of the insecticides on the diversity of pest and beneficial insect species. This study was undertaken from November 2023 to April 2024 to evaluate the effectiveness of eight different insecticides for managing fall armyworm in a sweet corn variety BU sweet corn 1 field, and investigated the biodiversity of the insects species in the sweet corn ecosystem. A total of 19 insect species were identified belonging to 17 families of 7 orders. The highest percentage was observed in minor pest (41%) followed by major pest (31%) and lowest was the beneficial insects (11%). In case of taxonomic orders, the highest abundance (24.3±3.3), richness (3.9±0.0), dominance (1.0±0.0) and diversity (0.7±0.0) were observed in Lepidoptera, Hemiptera, Ephemeroptera and Lepidoptera, Diptera order respectively. Vayego 20SC+Bio-chamak 1% E.W. yielded the highest beneficiary insect abundance (11.0±0.6), while control had the most minor insects (42.7±1.2) but Nitro 505EC alone attracted the highest casual insect count (16.3±0.9).

Keywords: *Spodoptera frugiperda*, sweet corn, beneficiary insects, taxonomic orders, abundance

Introduction

Corn, (*Zea mays* L.), cereal plant of the grass family (Poaceae) and its edible grain. Corn is used as livestock feed, as human food, as biofuel, and as raw material in industry. It is a third leading crop of the world after rice and wheat (Sandhu *et al.* 2007). It is known globally as queen of cereals. The center of origin for maize is the Mesoamerican region (Mexico and Central America) from where it spread rapidly (De Vries 2000). Invasive fall armyworm (*Spodoptera frugiperda*) is a polyphagous crop pest native to America and later reported in West Africa in 2016. In Bangladesh, the cultivation area, per hectare yield and total production of Rabi maize, in the fiscal year 2022-2023 was around 496549.3 ha, 10.1 ton and 4563 thousand MT (BBS 2023). The yield potentiality of maize in Bangladesh is low compared to other countries. This may be due to several abiotic and biotic constraints. Among the biotic factors, different insect pests cause serious damage to maize crops every year in Bangladesh resulting huge yield loss (Sarker and Dutta 2022).

In Bangladesh, approximately 30-35% of maize fields were affected by fall armyworm, leading to a 5% cob infestation in 2019 (CIMMYT 2020). Globally, the socioeconomic impact of fall armyworm is substantial, with crop losses ranging from 70% to 100% (Kirprop 2017, Shylesha *et al.* 2018). Prodhan *et al.* (2020) listed 12 species of insect pests including invasive fall armyworm (FAW) to be injurious to maize crop in Bangladesh. FAW has a wide host range of more than 353 recorded plants from 76 families, principally Poaceae (106), Asteraceae (31) and Fabaceae (31) (Wan *et al.* 2021). Among them, it has strong preference for maize, rice, sorghum, cotton, pasture grasses and sugarcane, which are all major cultivated crops in America, Africa and Asia (Montezano *et al.*, 2018). Therefore, this study was conducted to identify the insect species present in sweet corn fields treated with various insecticides and to assess their abundance, along with analyzing the diversity indices of these insect populations.

Materials and methods

The research was carried out between July 2023 and June 2024 in both the laboratory and field of the Department

of Entomology at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) in Gazipur, Bangladesh. The study location is situated at 25°25' North latitude and 89°05' East longitude, in the heart of Bangladesh. Amin *et al.* (2015) reported that the average highest and lowest temperatures throughout the year are 36 and 12.7°C, respectively. The relative humidity is 65.8%, and the annual rainfall is 237.6 cm.

Experimental materials and design: The maize variety BU Misti Vutta 1 were cultivated in the experimental plots from November 2023 to March 2024. The experiment was conducted following randomized complete block design following three replications. The size of the experimental plots was of 4.0 m × 4.0 m. Plot to plot and block to block distance was 1 m.

Land preparation: Weeds and stubbles were removed from the land. The land was ploughed 3 times followed by laddering. The experimental plots were divided according to the experimental design. The land was divided into a total of 27 different plots for eight insecticidal treatments and one control.

Cultivation of maize: The maize seeds were sown in different plots. Intercultural operations such as irrigation, weeding, thinning etc. were done whenever necessary in the experimental field. The plants were regularly watered, especially during tasseling and cob formation stage. Fertilizers were applied according to the Fertilizer Recommendation Guide (Guide 2018).

Spraying of insecticides: There were four insecticides and out of which 8 treatments were prepared along with a control.

Observation of abundance of different insects and calculation of biodiversity indices: Following the emergence of seedlings, a weekly field survey was conducted. Visual observation as well as sweeping net was used to collect and identify different species of insect and counted every day. To assess the diversity and richness of insects, indices like Shannon-Weaver and Margalef were applied following Amin (2023).

Statistical analysis: The statistical software package IBM SPSS 22.0 was used for data analysis. A one-way analysis of variance (ANOVA) was conducted, followed by a Tukey HSD post hoc test at a significance level of 5%.

Results and discussion

The table 1 provides details on trade names, active ingredients, modes of action, recommended doses, and toxicity categories for each insecticide.

In total of 1 species belonging to 1 family in 1 order (Lepidoptera) and 7 species belonging to 6 families of 4 orders (Lepidoptera, Coleoptera, Thysanoptera, Hemiptera) were found as major and minor pests respectively (Table 2).

In total of 6 species belonging to 6 families under 4 orders (Coleoptera, Hemiptera and Hymenoptera, Diptera) were found as beneficiary insects (Table 3).

In total of 5 species belonging to 5 families of 3 orders (Diptera, Hymenoptera, Ephemeroptera) were found as casual visitors (Table 4).

Table 1. Basic information of the studied insecticides

Trade name	Active ingredient	Mode of action	Recommended dose(ppm)	Toxicity category
Bio-chamak 1% E.W.	Celastrus angulatus	Contact and stomach action	2500	Class IV (Practically Non-Toxic)
Nitro 505EC	Chlorpyrifos + Cypermethrin	Contact, stomach and respiratory action	1000	Class II (Highly toxic)
Vayego 20SC	Tetraniliprole	Systemic and translaminar	400	Class II (Highly toxic)
Transform 24SC	Sulfoximine	Systemic, contact and translaminar	750	Class II (Highly toxic)

Table 2. List of the major and minor pests prevailed in sweet corn ecosystem treated with different insecticides

Pest		Taxonomic position
Major	Minor	
Fall army worm	-	<i>Spodoptera frugiperda</i> (Lepidoptera: Noctuidae)
	Stem borer	<i>Busseola fusca</i> (Lepidoptera: Noctuidae)
	Cut worm	<i>Agrotis ipsilon</i> (Lepidoptera: Noctuidae)
	Cob borer	<i>Stenachroia elongella</i> (Lepidoptera: Pyralidae)
	Aphid	<i>Rhodalosiphum maidis</i> (Hemiptera: Aphididae)
	Thrips	<i>Caliothrips phaseoli</i> (Thysanoptera: Thripidae)
	Brown stink bug	<i>Halyomorpha halys</i> (Hemiptera: Pentatomidae)
	Corn flea beetle	<i>Chaetonema pulicaria</i> (Coleoptera: Chrysomelidae)

Table 3. List of the predator insects prevailed in sweet corn ecosystem treated with different insecticides

Beneficial insects	Taxonomic position
Lady bird beetle	<i>Coccinella septempunctata</i> (Coleoptera: Coccinellidae)
Minute pirate bug	<i>Orius insidiosus</i> (Hemiptera: Anthocoridae)
Damsel bug	<i>Nabis capsiformis</i> (Hemiptera: Nabidae)
Braconid wasp	<i>Aphidius colemani</i> (Hymenoptera: Crabronidae)
Minute wasp	<i>Trichogramma</i> spp. (Hymenoptera: Trichogrammatidae)
Robber fly	<i>Efferia aestuans</i> (Diptera: Asilidae)

Table 4. List of the pollinator insects prevailed in sweet corn ecosystem treated with different insecticides

Casual visitor	Taxonomic position
Horse fly	<i>Tabanus bovinus</i> (Diptera: Tabanidae)
Blow fly	<i>Calliphora</i> spp. (Diptera: Calliphoridae)
House fly	<i>Musca domestica</i> (Diptera: Muscidae)
Ant	<i>Lasius niger</i> (Hymenoptera: Formicidae)
May fly	<i>Ephemera invaria</i> (Ephemeroptera: Ephemeridae)

A total of 19 species of insects were identified in the present study of which 1 species of insect was as major pest, 7 species as minor pest, 6 species as predator, and 5 species as casual visitors. The highest percentage was observed in minor pest (41%) followed by major pest (31%), casual visitors (17%) and lowest was the beneficiary insect (11%) (Figure 1).

A total of 19 insect species were identified belonging to 17 families of 7 orders. The percentage of insects in different taxonomic orders varied from 2 to 32%. Among the taxonomic orders, Lepidoptera was the most dominant order followed by Hemiptera, Diptera, Thysanoptera and Coleoptera. Other orders namely Hymenoptera and Ephemeroptera showed insignificant abundance (Figure 2).

The abundance, richness, dominance and diversity of different orders showed significant variation ($F_{6,14}=24.2$, $p \leq 0.001$, $F_{6,14}=67.4$, $p \leq 0.01$, $F_{6,14}=66.7$, $p \leq 0.001$ and $F_{6,14}=569.7$, $p \leq 0.001$ respectively) which ranged from 1.4 ± 0.6 to 24.3 ± 3.3 , 0.0 ± 0.0 to 3.9 ± 0.0 , 0.3 ± 0.0 to 1.0 ± 0.0 and 0.0 ± 0.0 to 0.7 ± 0.0 respectively. Highest abundance, richness, dominance and diversity was observed in Lepidoptera, Hemiptera, Ephemeroptera and Lepidoptera, Diptera order respectively (Table 5).

Significant variation was observed in the abundance of beneficiary ($F_{8,18}=15.7$, ≤ 0.001), minor ($F_{8,18}=5.7$, ≤ 0.001) and casual insects ($F_{8,18}=6.7$, ≤ 0.001) treated with different insecticides (Table 6). The highest abundance of predators was observed in Vayego 20SC+Bio-chamak 1% E.W. (11.0 ± 0.6), followed closely by Nitro 505EC

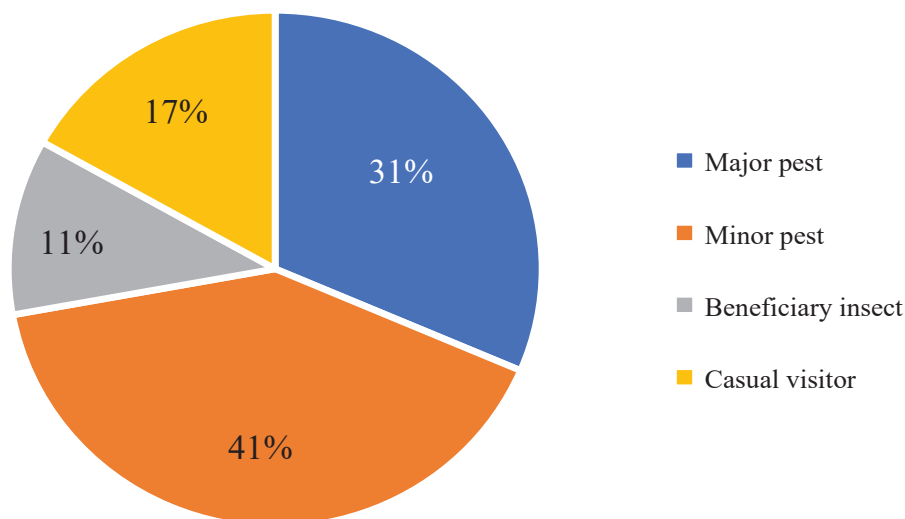


Figure 1. Percent Abundance of different categories of insect found in sweet corn ecosystem.

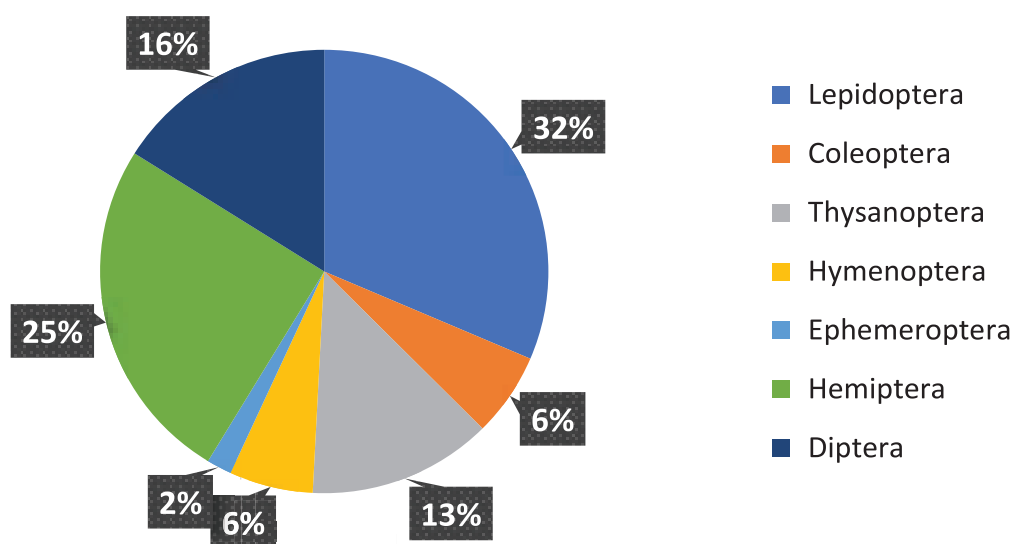


Figure 2. Abundance of insects belonging to different taxonomic orders found in sweet corn ecosystem.

(10.7 ± 0.9). The control group had the lowest beneficiary insect abundance (2.7 ± 0.7). The control group had the highest count of minor insects (42.7 ± 1.2), highlighting the effectiveness of treatments in reducing their abundance. Casual insects were highest in Nitro 505EC (16.0 ± 1.2), with other treatments like Bio-chamak 1% E.W. showing reduced counts, reflecting the treatments' varied effects on insect categories.

Conclusion

From the present study, it can be concluded that total 19 insect species across 17 families and 7 orders were prevailed in the sweet corn field where 1 species was a major pest, 7 were minor pests, 6 were predators, and 5 were casual visitors. Minor pests made up the highest proportion and the highest abundance were observed in the order Lepidoptera (24.3 ± 3.3). The study highlighted the abundance and diversity analysis of insects found in the sweet corn field.

Table 5. Diversity indices of insects of different orders observed in sweet corn ecosystem

Orders	Abundance	Richness	Dominance	Diversity
Lepidoptera	24.3±3.3a	0.0±0.0c	1.0±0.0a	0.0±0.0d
Coleoptera	4.7±0.3cd	1.5±0.1b	0.6±0.4b	0.3±0.0c
Thysanoptera	10.3±2.3c	0.0±0.0c	1.0±0.0a	0.0±0.0d
Hymenoptera	4.7±1.0cd	3.3±0.6a	0.5±0.1b	0.4±0.0b
Ephemeroptera	1.4±0.6d	0.0±0.0c	1.0±0.0a	0.0±0.0d
Hemiptera	19.5±0.5ab	3.9±0.0a	0.5±0.0b	0.6±0.0a
Diptera	12.4±1.6bc	3.7±0.2a	0.3±0.0c	0.7±0.0a

Data expressed as mean ± SE (standard error), DF=Degree of freedom, F statistic= Critical values of the F distribution, P value = Significance.

Table 6. Effect of different insecticides on the abundance of various categories of found in sweet corn ecosystem insects

Treatment	Beneficial insects	Pest insects	Casual visitor insects
Vayego 20SC+Nitro 505EC	9.0±0.6ab	36.7±6.2ab	13.7±0.7ac
Vayego 20SC+Transform 24SC	7.7±0.3b	26.7±2.2bc	11.7±0.3c
Vayego 20SC+Bio-chamak 1% E.W.	11.0±0.6a	35.0±2.6ac	10.3±0.9c
Nitro 505EC	10.7±0.9ab	36.7±2.7ab	16.3±0.9a
Transform 24SC	9.0±0.6ab	28.0±1.7ac	13.0±0.6ac
Bio-chamak 1% E.W.	9.0±0.6ab	32.3±0.3ac	11.3±0.7c
Vayego 20SC+Nitro 505EC+Bio-chamak 1% E.W.	9.7±0.7ab	21.3±3.8c	12.3±0.9bc
Vayego 20SC+Transform 24SC+Bio-chamak 1% E.W.	8.0±0.6ab	23.0±1.5bc	11.7±0.9c
Control	2.7±0.7c	42.7±1.2a	16.0±1.2ab

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

Acknowledgements

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Impact of foliar fertilization on growth, yield, nutrient dynamics and seed quality of soybean

M. Jahangir Alam¹ and M. Moynul Haque^{2*}

¹Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh; ²Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

Corresponding email: moynul60@bsmrau.edu.bd

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Abstract

The study hypothesized that foliar fertilization reduced nutrient depletion from leaves during seed development stage and thereby enhancing soybean yield and seed quality. To evaluating this, the experiment included seventeen treatments combination of nitrogen, phosphorus, potassium, sulphur and boron (NPKSB) aiming to determine the optimum foliar fertilizer concentration for improving growth, nutrient composition, yield and seed quality of soybean. The experiment was set in randomized complete block design (RCBD) with three replications and nutrient was sprayed during the seed filling period of soybean. Results of the experiment indicated that soybean plants treated with 240-200-400-350-200 mg L⁻¹ of NPKSB in water exhibited higher growth values including roots weight (0.669 g), leaf weight (3.319 g), stem weight (4.661 g), pod weight (4.647 g) and whole plant weight (13.32 g). Additionally, this treatment produced the highest seed yield of 2684 kg ha⁻¹. Foliar fertilization at this concentration also improved the nutrient composition of the seed and enhanced seed quality, as evidenced by higher protein content (42.05%), seed viability (97.98%) and vigour. However, excessive concentration of foliar fertilizer may lead to leaf burn and negatively impact the yield and seed quality of soybean.

Keywords: Foliar fertilizer, soybean, yield, seed quality

Introduction

Soybean (*Glycine max* [L.] (Merr.) is multipurpose grain legume widely used all over the world as it has dietetic, industrial, medicinal and many other economic importance. Consumption of soybean products has been linked to decrease of some dangerous diseases such as heart diseases and certain types of cancer (Wu *et al.* 1998). It is the only grain legume that contains the highest proportion of protein and oil (David, 1984). Thus, in modern agriculture soybean folds dual importance; it serves as a source of oil and seed protein for human consumption as well as a protein-rich feed for animals. In the future, soybean may also emerge as a significant source for bio-fuel production (JFA 2007).

Although, demand of soybean is increasing day by day in Bangladesh, its average yield is decreasing due to many biotic and abiotic causes (AVRDC 1990). For example, soil fertility is declining as a result of continuous crop cultivation. In the soils, the main nutritional limitations are nitrogen, phosphorus and potassium. Other nutrients like sulphur and boron may also be limiting when the soil is planted for several successive years, due to crop removal (Penas and Wiese 1996). Therefore, it is essential to apply fertilizers during soybean cultivation to replenish the soil nutrients.

Apart from soil fertilization, foliar fertilization has been to be a unique means to replenishing the reservoir of nutrients in leaves of legumes during pod development stage. It is evident that large yield (27-31%) increased from foliar application of NPKS fertilizer mixture during reproductive stages of soybean (Garcia and Hamway 1976). They suggested that root activity decreased during the pod-filling stage, limiting nutrient uptake and preventing optimal yields. Foliar fertilization during this critical period was proposed as a method of increase total nutrients availability without relying on root absorption.

The efficiency of nutrient uptake through foliar applications is not well understood. Additionally, it is crucial to determine the optimal proportion of each nutrient to achieve the desired effects of foliar fertilization. Therefore, the objective of this study was to identify the effective proportion of NPKSB foliar fertilizer to enhance the growth, yield and seed quality of soybean.

Materials and methods

The field trial was conducted at research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during rabi season as

a subsequent experiment of previous five experiments. From the results of those experiments, it was suggested for further research to confirm and to determine optimum proportion for foliar fertilization of soybean. Based on the previous results, the present experiment consisted of 17 treatment combination including control as presented in Table 1.

The experiment was arranged in randomized complete block design (RCBD) with three replications. Unit plot size was 2.4 m × 2 m, plant to plant distance was 5 cm, row to row distance was 30 cm. The soybean seeds were planted on 13 January, 2010. The excess seedlings were thinned out and necessary gaps were filled out within 20 days after sowing. Light irrigation was given just after sowing to establish the stand properly. Two weeding were also done at 20 and 35 days after sowing. Insecticide and fungicide were sprayed as precautionary measure to protect the crop from insect and diseases. Foliar fertilization was done according to the morphological stage of plant development between stages R₃ and R₇ as described by Fehr *et al.* (1971).

The soybeans were harvested from each unit plot at 83 days after sowing for growth analysis. For growth data viz. dry weight of leaf, shoot, root, pod and total dry weight were recorded. For determination of yield contributing characters of soybean, seven plants were randomly selected from each plot and number of pods per plant, seeds per pod, 100 seeds weight seed and yield per plant were recorded. Seed yield of soybean was determined by harvesting whole plot and converted into kg ha⁻¹ at 7.5 % moisture content. Grain quality was determined considering protein and oil content in seed. The oil percentage of seed was estimated as per Gadgil *et al.* (1980). Nitrogen percentage of soybean seed was estimated by Kjeldahl method. The estimated result was multiplied by the factor 6.25 to obtained protein percent. Seed quality of freshly harvested soybean seeds were assessed by germination test (Krishnasamy and Seshu, 1990) and electrical conductivity test as per Ali *et al.* (2005).

Statistical analysis: All data were subjected to statistical analysis by analysis of variance (ANOVA). Microsoft EXCEL and MSTAT software programs were used

Table 1. Treatment combinations containing element of nitrogen, phosphorus, potassium, sulphur and boron for foliar fertilization

Treatments	Treatment combination (mg L ⁻¹ water)				
	N	P	K	S	B
T ₀	0	0	0	0	0
T ₁	0	200	400	400	200
T ₂	210	200	400	400	200
T ₃	240	200	400	400	200
T ₄	270	200	400	400	200
T ₅	240	0	400	400	200
T ₆	240	150	400	400	200
T ₇	240	200	400	400	200
T ₈	240	250	0	400	200
T ₉	240	200	300	400	200
T ₁₀	240	200	500	400	200
T ₁₁	240	200	400	0	200
T ₁₂	240	200	400	350	200
T ₁₃	240	200	400	450	200
T ₁₄	240	200	400	400	0
T ₁₅	240	200	400	400	250
T ₁₆	240	200	400	400	300

wherever appropriate and the means were compared according to Duncan's Multiple Range Test (DMRT). Functional relationships among the parameters were established through correlation and regression analysis by using SPSS software program.

Results and discussion

Foliar fertilizer application had advantages over control as it brought direct improvement in growth of soybean plant (Figure. 1). Plants treated with 240-200-400-350-200 NPKSB mg L⁻¹ water recorded higher growth values

indicating as an optimal requirement for better growth of soybean. The dry matter accumulation in roots (0.669 g), leaves (3.319 g), stem (4.661 g), pods (4.647 g) and whole plant (13.32 g) reached at peak which received this concentration as foliar fertilization. The application of 240-200-400-350-200 NPKSB mg L⁻¹ water to soybean plants might increase chlorophyll content, carboxylating activity, net photosynthesis and protein synthesis. These illustrated the integral role of foliar nutrients in better processes of dry matter accumulation in soybean plants (Sharma and Tanuja, 1990). Effect of foliar fertilizer on

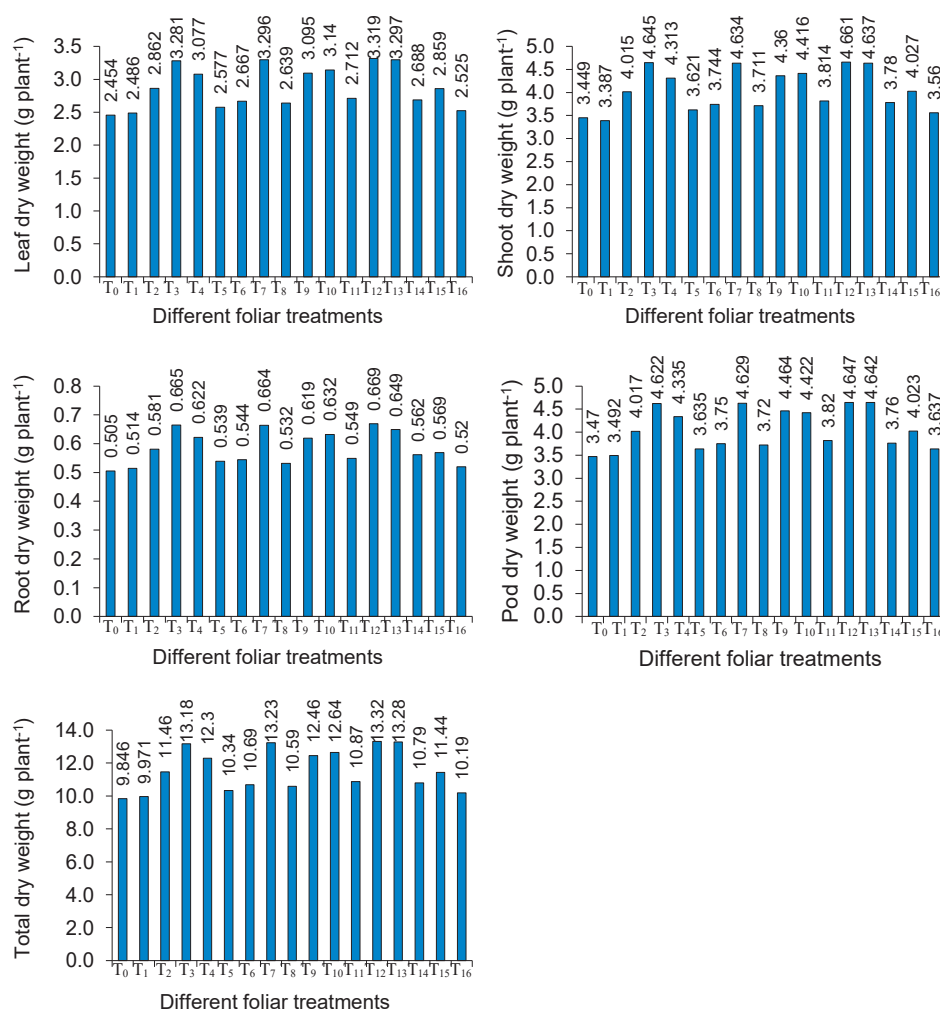


Figure 1. Dry matter accumulation of soybean plants under different concentrations of foliar fertilizer application.

Where,

T₀=0-0-0-0-0; T₁=0-200-400-400-200; T₂=210-200-400-400-200; T₃=240-200-400-400-200; T₄=270-200-400-400-200; T₅=240-0-400-400-200; T₆=240-150-400-400-200; T₇=240-200-400-400-200; T₈=240-250-0-400-200; T₉=240-200-300-400-200; T₁₀=240-200-500-400-200; T₁₁=240-200-400-0-200; T₁₂=240-200-400-350-200; T₁₃=240-200-400-450-200; T₁₄=240-200-400-400-0; T₁₅=240-200-400-400-250; T₁₆=240-200-400-400-300 NPKSB mg L⁻¹ water.

general growth and development of crop plant has been studied by other workers (Pilbean and Kirkbz 1983). These elements involve in hormone synthesis and translocation, carbohydrate metabolism and DNA synthesis which probably contributed to additional growth compared to controls (Krueger *et al.*, 1987).

The proportion of nutrient accumulated in soybean seed at maturity for different treatments are reported in Table 2. In general, nutrient accumulation in soybean seeds increased with higher concentration of foliar NPKSB application peaking at 240-200-400-350-200 mg L⁻¹ NPKSB in water after which it declined slightly. The contribution of this foliar nutrient combination in the highest seed nutrient accumulation might be due to its better growth when it was applied at reproductive stage of soybean. Foliar application at reproductive stage could

increase nutrient supplies at a time when root systems are not well developed (Demooy *et al.* 1973). Such nutrient supplies due to foliar fertilization also increased nutrient accumulation in soybean seed.

Nutrient accumulation in seed has great implication in yield formation as there are positive relationship between seed nutrient content and yield of soybean (Figure 2). The yield increases from foliar application of nutrient solution during reproductive period resulted primarily from an increase in number of harvestable seeds and then increase in seed nutrient content (Lawn and Brun, 1974).

Foliar fertilizer application caused significant increase in number of pods per plant, number of seeds per pod, seed size and seed yield of soybean as compare with control treatment. Like growth attributes, the treatment combination 240-200-400-350-200 NPKSB mg L⁻¹ water

Table 2. Accumulation of nutrient in soybean seed as influenced by foliar fertilizer application

Treatment combination	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Boron (ppm)
T ₀	5.83 j	0.193 h	0.54 e	0.170 g	73.16 fg
T ₁	7.027 fg	0.260 b-e	0.64 cd	0.190 f	92.86 cd
T ₂	7.23 efg	0.251 def	0.65 cd	0.210 e	82.76 ef
T ₃	8.46 ab	0.276 ab	0.73 b	0.270 ab	108.60 b
T ₄	7.96 cd	0.263 b-e	0.63 cd	0.190 f	82.93 ef
T ₅	6.06 ij	0.254 c-f	0.64 cd	0.230 de	101.10 bc
T ₆	6.13 ij	0.271 abc	0.61 d	0.140 h	64.82 gh
T ₇	8.26 bc	0.273 abc	0.72 b	0.260 ab	88.53 de
T ₈	7.50 def	0.261 b-e	0.63 cd	0.250 bc	102.90 b
T ₉	6.31 ij	0.245 ef	0.62 cd	0.175 fg	100.80 bc
T ₁₀	7.04 fg	0.237 f	0.64 cd	0.172 g	80.78 ef
T ₁₁	7.73 d	0.180 h	0.61 d	0.244 cd	66.08 gh
T ₁₂	8.85 a	0.289 a	0.80 a	0.281 a	119.03 a
T ₁₃	7.55 de	0.266 bcd	0.68 bc	0.261 bc	104.70 b
T ₁₄	6.47 hi	0.212 g	0.63 cd	0.179 fg	62.86 h
T ₁₅	6.83 gh	0.252 def	0.61 d	0.144 h	68.83 gh
T ₁₆	6.91 gh	0.241 f	0.63 cd	0.145 h	80.76 ef
CV (%)	3.74	7.35	4.01	5.28	5.12

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,

T₀=0-0-0-0-0; T₁=0-200-400-400-200; T₂=210-200-400-400-200; T₃=240-200-400-400-200; T₄=270-200-400-400-200; T₅=240-0-400-400-200; T₆=240-150-400-400-200; T₇=240-200-400-400-200; T₈=240-250-0-400-200; T₉=240-200-300-400-200; T₁₀=240-200-500-400-200; T₁₁=240-200-400-0-200; T₁₂=240-200-400-350-200; T₁₃=240-200-400-450-200; T₁₄=240-200-400-400-0; T₁₅=240-200-400-400-250; T₁₆=240-200-400-400-300 NPKSB mg L⁻¹ water.

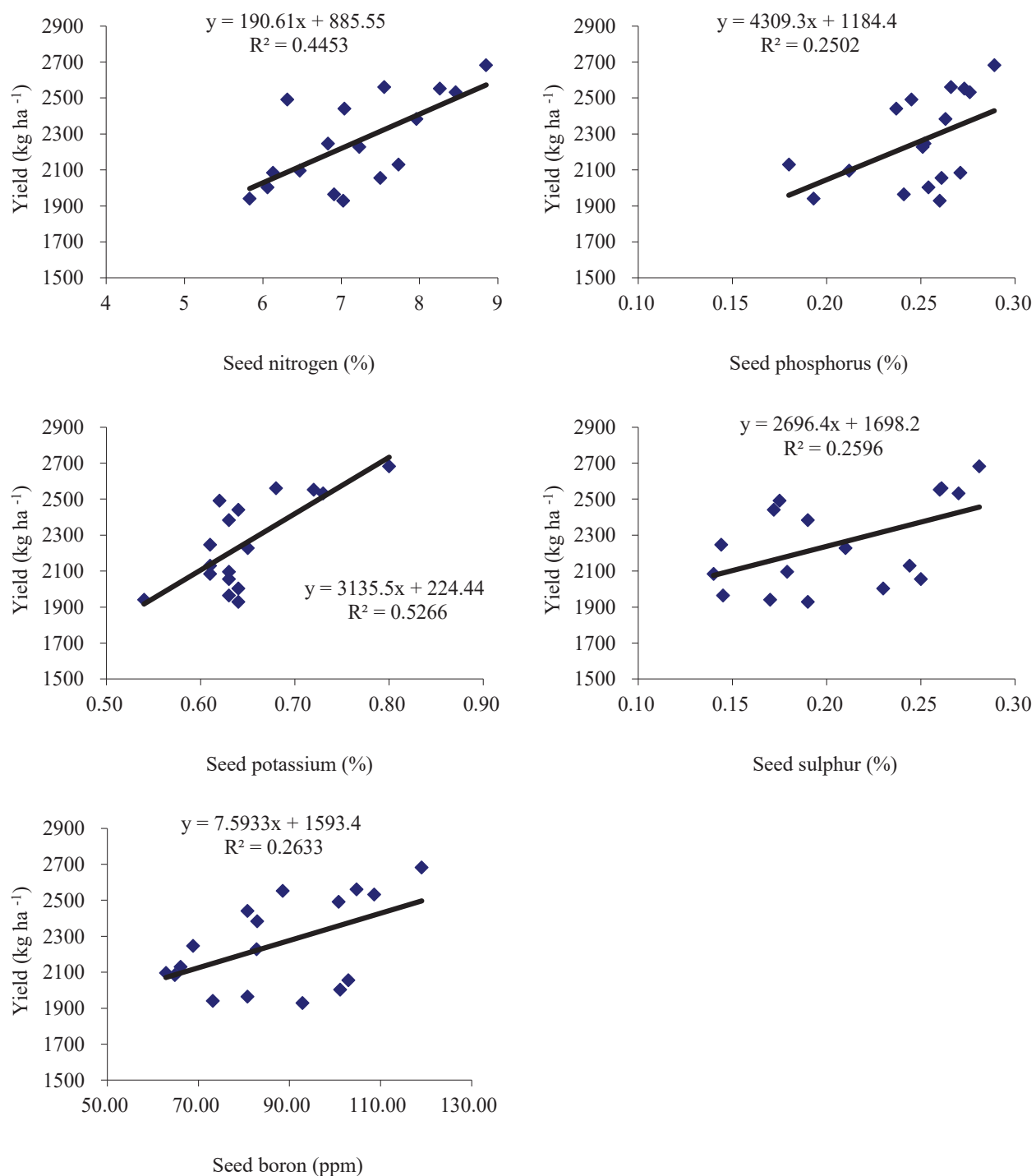


Figure 2. Relationship between seed nutrient concentration and seed yield of soybean.

produced the highest number of pods per plant (42.62), seeds per pod (2.55), seed size (11.70 g) and ultimately seed yield (2684 kg ha⁻¹) as shown in Table 3. The superiority of the treatment combination in improving yield attributes and seed yield of soybean might be attributed to its higher content of macro (NPKS) and micro (B) element in plant tissue. Therefore, this affects the photosynthesis of leaves which may account for higher accumulation of metabolites in different organs of soybean plants (Schon and Blevins 1990). Consequently, promoting rapid growth, increasing pod formation and seed development and finally improving the yield of soybean. The results suggested that soybean plants must be provided with a balanced nutrient supply via foliar application during seed filling, because photosynthate sugar is channeled to the developing seeds on the expense of the roots and nodules, which led to receive little food to serve as energy source for taking up nutrients from the soil (Garcia and Hanway 1976).

Concerning the effect of foliar fertilizer treatments on protein and oil percentage of soybean seed, the effect was very inconsistent on oil content. The effect was however consistent on protein percentage where the treatment 240-200-400-350-200 NPKSB mg L⁻¹ water showed the highest percentage (42.05) of protein as compared with the other treatments applied as foliar fertilizer (Table 4). The increase in protein content at this treatment may be ascribed as better involvement of foliar NPKSB in the process of protein synthesis. For example, N and S are part of protein, P activates coenzymes for amino acid production that are used in protein synthesis. However, K activates enzymes to metabolize carbohydrates to manufacture amino acids and proteins. Nevertheless, B is required for symbiotic nitrogen fixation and reduction in nitrates for protein synthesis (Abady *et al.* 2008).

Table 3. Yield attributes and seed yield of soybean as influenced by different concentrations of foliar fertilization

Treatment combinations	Pods plant ⁻¹	Seeds pod ⁻¹	100 seed weight (g)	Seed yield (kg ha ⁻¹)
T ₀	30.72 j	2.01 h	7.621 g	1942 k
T ₁	31.38 j	2.21 g	7.750 g	1929 k
T ₂	37.64 d	2.20 g	9.589 c	2228 f
T ₃	42.58 a	2.39 de	10.65 b	2533 bc
T ₄	40.39 b	2.31 f	8.871 c-f	2385 e
T ₅	33.62 i	2.40 d	7.912 g	2004 ij
T ₆	34.15 hi	2.41 d	8.261 efg	2085 gh
T ₇	42.98 a	2.47 bc	10.67 b	2554 b
T ₈	33.35 i	2.34 ef	8.073 fg	2056 hi
T ₉	38.90 c	2.43 cd	9.036 cde	2493 cd
T ₁₀	40.67 b	2.43 cd	8.921 c-f	2442 d
T ₁₁	35.53 fg	2.40 d	8.228 efg	2131 g
T ₁₂	42.62 a	2.55 a	11.70 a	2684 a
T ₁₃	42.29 a	2.52 ab	10.40 b	2561 b
T ₁₄	34.83 gh	2.39 de	9.137 cd	2097 gh
T ₁₅	36.42 ef	2.48 bc	8.352 d-g	2248 f
T ₁₆	37.21 de	2.49 b	8.121 fg	1965 jk
CV (%)	7.68	2.94	5.08	9.43

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,

T₀=0-0-0-0-0; T₁=0-200-400-400-200; T₂=210-200-400-400-200; T₃=240-200-400-400-200; T₄=270-200-400-400-200; T₅=240-0-400-400-200; T₆=240-150-400-400-200; T₇=240-200-400-400-200; T₈=240-250-0-400-200; T₉=240-200-300-400-200; T₁₀=240-200-500-400-200; T₁₁=240-200-400-0-200; T₁₂=240-200-400-350-200; T₁₃=240-200-400-450-200; T₁₄=240-200-400-400-0; T₁₅=240-200-400-400-250; T₁₆=240-200-400-400-300 NPKSB mg L⁻¹ water.

Table 4. Effects of foliar fertilizer application on grain quality of soybean

Treatment combinations (NPKSB mg L ⁻¹ water)	Seed protein (%)	Seed oil (%)
T ₀	26.72 h	20.33 ab
T ₁	32.93 ef	20.76 a
T ₂	34.82 de	20.11 abc
T ₃	39.05 bc	19.76 bc
T ₄	37.33 bcd	20.10 abc
T ₅	28.43 gh	20.24 ab
T ₆	27.98 gh	20.29 ab
T ₇	38.62 bc	19.62 bc
T ₈	35.10 de	19.96 abc
T ₉	30.39 fg	19.93 abc
T ₁₀	32.57 ef	20.03 abc
T ₁₁	36.74 cd	19.27 c
T ₁₂	42.05 a	19.54 bc
T ₁₃	39.87 ab	19.76 bc
T ₁₄	30.19 fg	19.86 bc
T ₁₅	32.47 ef	19.74 bc
T ₁₆	31.91 f	20.28 ab
CV (%)	4.44	2.25

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,

T₀=0-0-0-0-0; T₁=0-200-400-400-200; T₂=210-200-400-400-200; T₃=240-200-400-400-200; T₄=270-200-400-400-200; T₅=240-0-400-400-200; T₆=240-150-400-400-200; T₇=240-200-400-400-200; T₈=240-250-0-400-200; T₉=240-200-300-400-200; T₁₀=240-200-500-400-200; T₁₁=240-200-400-0-200; T₁₂=240-200-400-350-200; T₁₃=240-200-400-450-200; T₁₄=240-200-400-400-0; T₁₅=240-200-400-400-250; T₁₆=240-200-400-400-300 NPKSB mg L⁻¹ water.

Relationship between oil concentration and grain yield was negative but it was positive between protein concentration and grain yield of soybean (Figure 3). In another relationship, it was observed that oil concentration decreases with the increase of protein concentration in soybean seed. Such relationship suggests that, for that condition in this study, factors that increase yield do not necessarily decrease oil or protein concentration. The negative correlation between oil and protein concentrations agrees with similar negative correlations found before (Burton 1985; Brumm and Hurburgh 2003).

Foliar spraying with NPKSB caused little improvement in seed viability (germination) but appeared to increase vigour of soybean seed (Figure 4). Seed viability ranged from 87.64 to 97.98 % over different treatment

combinations which indicated that degree of viability of freshly harvested soybean seeds did not affect profoundly due to foliar fertilization. Seed vigour measured by electrical conductivity revealed some inconsistent values but it is fact that the treatment combination 240-200-400-350-200 mg NPKSB L⁻¹ water contributed the lowest (191µ S cm⁻¹g⁻¹) electrical conductivity of leachates of fresh soybean seed. As lowest is the electrical conductivity value highest is the vigour index (Lowe and Ries, 1972), high vigour seeds harvested from this treatment might be due to high accumulation of metabolites and nutrients in seeds harvested from well-proportioned NPKSB foliar fertilization.

Beneficial effects on seed vigour obtained from this foliar application of NPKSB may be attributed to their

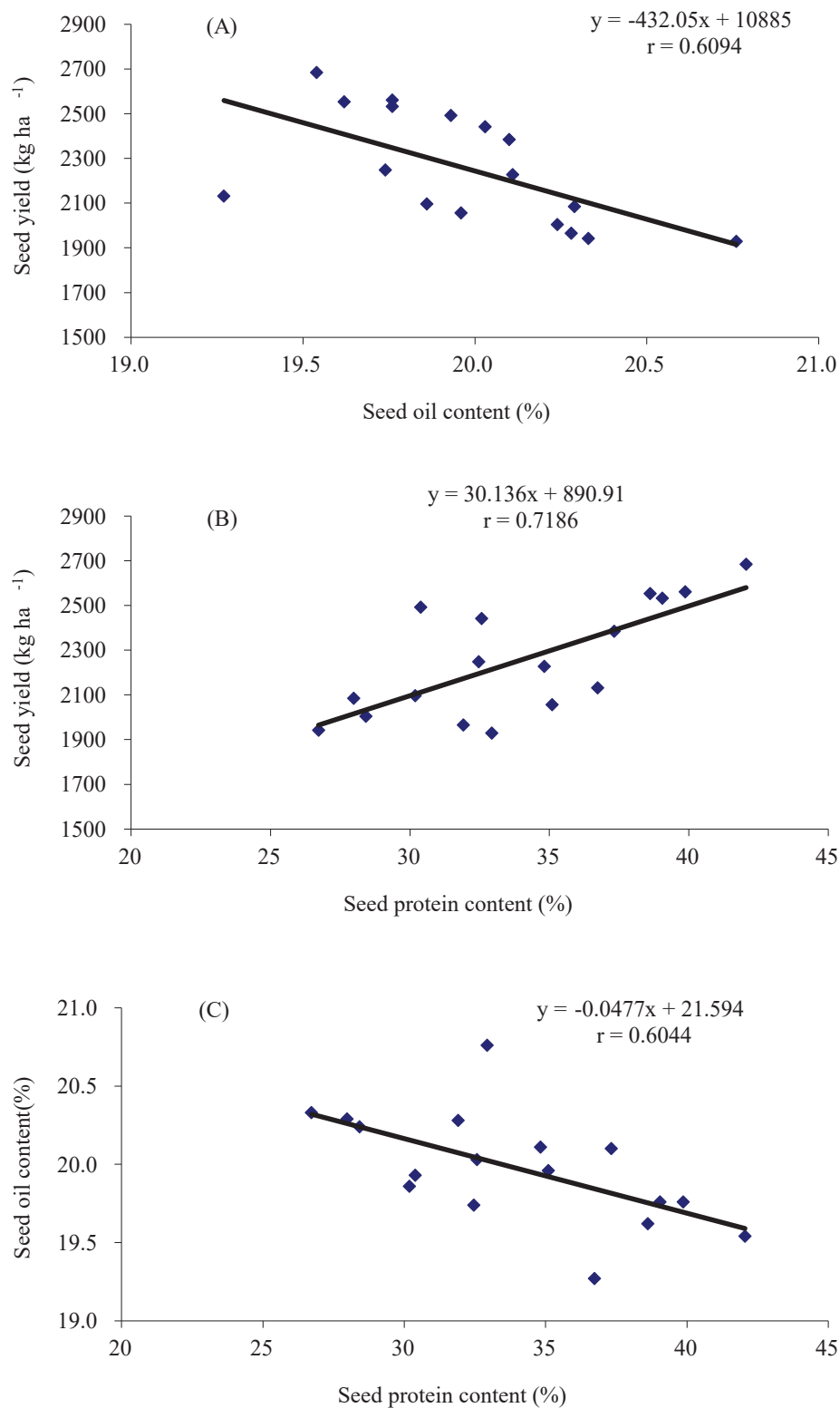


Figure 3. Relationship between (A) oil and seed yield, (B) protein and seed yield, (C) oil and seed protein under foliar fertilizer application of soybean.

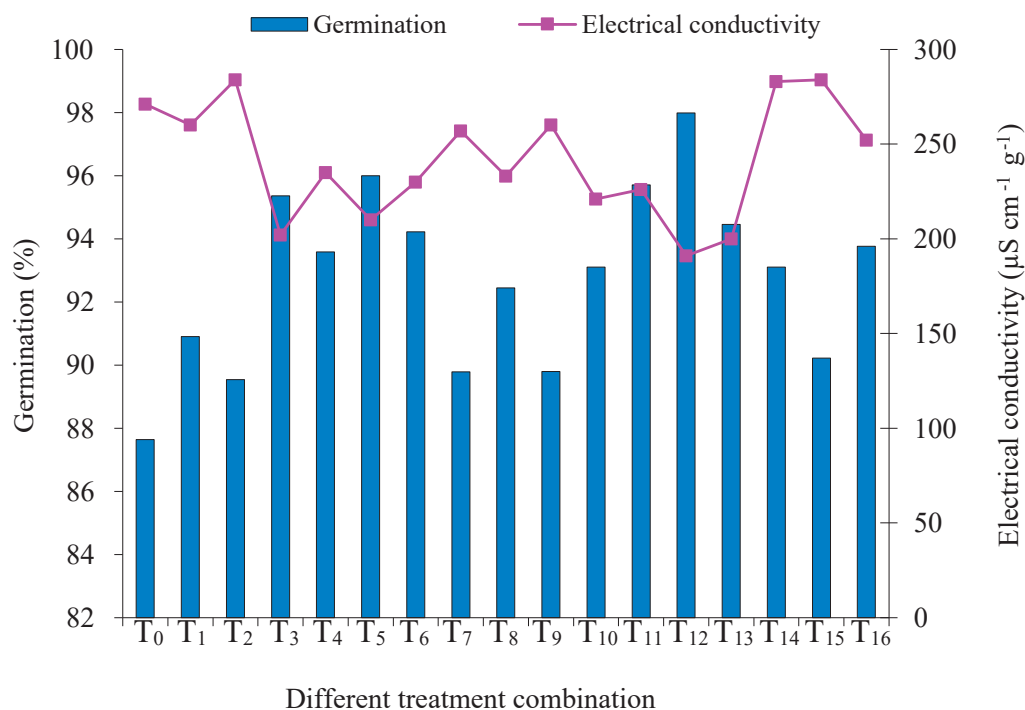


Figure 4. Seed quality of soybean harvested from different combination of foliar fertilization.

Where,

T₀=0-0-0-0-0; T₁=0-200-400-400-200; T₂=210-200-400-400-200; T₃=240-200-400-400-200; T₄=270-200-400-400-200; T₅=240-0-400-400-200; T₆=240-150-400-400-200; T₇=240-200-400-400-200; T₈=240-250-0-400-200; T₉=240-200-300-400-200; T₁₀=240-200-500-400-200; T₁₁=240-200-400-0-200; T₁₂=240-200-400-350-200; T₁₃=240-200-400-450-200; T₁₄=240-200-400-400-0; T₁₅=240-200-400-400-250; T₁₆=240-200-400-400-300 NPKSB mg L⁻¹ water.

favorable effects on the metabolism of nucleic acids, protein, vitamins and other growth substances (Vlasynk *et al.* 1978). These effects are manifested in metabolites formed in plant tissues which have direct impact on growth development and may be reflected in distinct improvement in seed quality (Sawan *et al.* 1989).

Conclusion

Foliar fertilizer application directly improved the growth, yield and seed quality of soybean compared to control. The treatment combination of 240-200-400-350-200 mg L⁻¹ NPKSB in water produced the highest seed yield and enhanced grain and seed quality by promoting the accumulation of various nutrients and metabolites in seed reserves. However, excessive nutrient application may cause leaf burn and reduce the yield and seed quality of soybean.

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Seasonal incidence of stem fly insect on soybean plants

Amal Kumar Das¹, Hasan Fuad El Taj² and Md. Alamgir Hossain^{2*}

¹Breeder Seed Production Centre, Bangladesh Agricultural Research Institute, Debiganj, Panchagarh, Bangladesh; ²Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

Corresponding email: alamgir@hstu.ac.bd

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Abstract

The experiment was conducted to determine the seasonal incidence of stem fly, *Ophiomyia phaseoli* Tryon in the soybean field of Breeder Seed Production Center, Bangladesh Agricultural Research Institute, Debiganj, Panchagarh. Seeds were sown on six different dates from early August to mid September, 2014 maintained intervals of 7 days at August 09 to September 13. There was no significant ($P > 0.05$) effect observed among the sowing times on the abundance of stem fly population. The number of larva and pupa per plant were recorded from 1.17 to 1.33 and 0.85 to 1.02, respectively. However, the percentage of infested plant and stem tunneling differed significantly among the sowing dates. The highest infested plant (83.71%) and stem tunneling (40.87%) were obtained from the crop sown on mid September. But the lowest infested plant (70.64%) and stem tunneling (25.31%) were obtained from the crop sown on 23 August. The maximum (2.20 t/ha) and minimum yield (1.60 t/ha) were obtained from crop planted at the 3rd week of August and 2nd week of September, respectively.

Keywords: Seasonal incidence, sowing time, stem fly, soybean

Introduction

Soybean is a surprise crop of twentieth century. It contains about 40-42% protein and 20- 22% oil (Harish *et al.* 2013). The protein quality of soybean is equivalent to that of meat, milk products and eggs. But one of the major limitations to the successful soybean production in Bangladesh is the damage caused by insect pests. Research revealed that 15-20 percent of the total soybean production is lost by thirty-nine species of insect pests attack at their different growth stages in Bangladesh (Biswas 2008, Biswas 2013). Among them, the stem fly including *Ophiomyia phaseoli* Tryon (Diptera: Agromyzidae), is a very destructive pest causes 100% infestation of soybean plants (Biswas 2001, Abdallah *et al.* 2014, Hanan Alfy *et al.* 2016, and Hanan Alfy 2016).

So, it is great importance to develop economically feasible, environmentally sound and socially acceptable pest management strategies for soybean. For this, inclusive information on the pest complex, their status and sequential appearance during the crop period, losses and type of damage is need to be known (Jayanthi *et al.* 1993). Investigation on the fluctuation pattern of *O. phaseoli* on mungbean revealed that the peak infestation period occurred around late August and mid September. Biswas

(2013) stated that *O. phaseoli* appeared during vegetative to flowering stages at 30-50 days after sowing and severely attacked during flowering and podding stages. However, information about insect pests of soybean and their succession in relation to crop stages are scanty in Bangladesh (Biswas 2013). Keeping these in view, the present research works was therefore planned and design to record the insect pests of soybean, their incidence, infestation and time of appearance with the crop stages.

Materials and methods

The research work was conducted in the field of Breeder Seed Production Centre (BSPC), Bangladesh Agricultural Research Institute (BARI), Debiganj, Panchagarh, Bangladesh during August to September, 2014.

Land preparation: The experimental plot was opened with a tractor driven disc plough and cross ploughing followed by laddering for a good tilth. The subsequent operations were done with harrow, spade, hammer etc. until the desired tilth. The weeds and stubbles were removed. Proper irrigation and drainage system was maintained. Fertilizers and manures were applied as suggested by Oilseed Research Centre (ORC), BARI (Annual Report, ORC, BARI, 2010).

Crop culture: Seeds of soybean variety (BARI soybean 6) were collected from the ORC, BARI, Joydebpur, Gazipur. The experiment was laid out in RCBD with three replications. The unit plot size maintained 3.0×3.0 m. Previously collected soybean seeds were uniformly sown in rows with seeder started on 9 August 2014 at an interval of seven days (August 09, 16, 23, 30 and September 06, 13) maintained spacing from row to row and seed to seed 30cm and 10cm, respectively. Each sowing date was considered as an individual treatment with replicated thrice. The recommended agronomic practices for culture the crop were maintained following Mondal and Wahhab (2001).

Data collection: Ten seedlings were selected randomly and tagged. The tagged plants were uprooted and brought in the laboratory. The roots and stems of each plant were dissected with a scalpel after cleaned. Then the length of tunnel, number of larvae and pupae present in the tunnel were carefully observed and recorded. Data were recorded after germination and continued up to harvest at 7 days of intervals maintained up to 9 weeks of each sowing. The stem fly infested plant in each sample was calculated by using the following formula.

$$\text{Infested plant (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants}} \times 100$$

Harvesting: The crop was harvested at proper maturity from 10 to 15 December 2014. The pods were manually threshed. Grains were cleaned and dried in sunlight and maintained moisture $12 \pm 1\%$ content. The seed weighed by an electric balance and recorded the yield.

Statistical Analysis: Data were analyzed using MSTAT computer program. Statistical analyses were done following Gomez and Gomez (1984). Duncan's Multiple Range Test (DMRT) was used for separating the means.

Results

Effect of sowing dates on the incidence of stem fly:

Different sowing dates had no statistical significant ($P > 0.05$) effects on the abundance of larva and pupa of stem fly of soybean per plant which ranged from 1.17 to 1.33 and 0.85 to 1.02, respectively (Table 1). But percent of infested plants, stem tunneling and yield differed significantly ($P > 0.05$) among the different showing dates. The lowest (70.64%) infested plant was observed from the crop sown on August 23 while the highest (83.71%) on September 13 which statistically similar with sowing date of September 06 (Table 1). The lowest (25.31%) stem tunneling per plant were found on August 23, whereas the highest (40.87%) on September 13. Similarly, the highest (2.20 t/ha) yield of soybean was computed on August 23 but the lowest (1.60 t/ha) on September 13.

Incidence of stem flies at growth stages of plants: The stem fly infestation was started from the second weeks of plant age (Figure 1). Among six different sowing dates, the late sowing (September 13) appeared the most vulnerable to stem fly when 100% plants was infested. The stem fly caused 100% infestation at the planting dates of August 09, 16, and 30 and September 06 and 13 while the crops attained at five weeks old. Maximum (65.33%) stem tunneling was recorded at the September 13 planting date but minimum (8.10 %) at August 23 (Figure 2). Generally,

Table 1. Incidence of stem fly in the soybean field in different sowing dates

Sowing dates	Larvae/plant	Pupae/plant	Infested plant (%)	Stem tunneling/plant (%)	Yield (t/ha)
Aug 09	1.18*	0.87*	72.46 b	26.43 de	2.12 a
Aug 16	1.20*	0.92*	72.52 b	29.46 cd	2.00 b
Aug 23	1.17*	0.85*	70.64 b	25.31 e	2.20 a
Aug 30	1.23*	0.98*	74.09 b	31.72 c	1.95 b
Sep 06	1.27*	0.99*	82.50 a	36.51 b	1.80 c
Sep13	1.33*	1.02*	83.71 a	40.87 a	1.60 d
CV%	4.65	10.31	4.14	6.84	3.37
LSD(0.05)	0.099	0.172	5.729	3.949	0.115

Means in a column having * marks and same letter(s) did not differ significantly at 5% level by DMRT

stem tunneling increased up to fourth week but noticeable increase was recorded at third week after sowing reached peak (2.8) at fifth week of plant age (Figure 3). Then the decreasing trend of larval population (2.2/plant) were observed with increasing of plant age but disappeared

at ninth week. Similarly, pupae were first detected from second week of sowing in all treatments. After then they increased and reached the highest (2.4) at the six week of plant age on sowing 13 September but disappeared at ninth week (Figure 4).

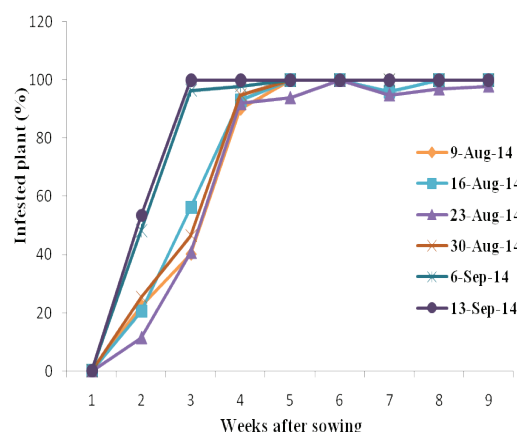


Figure 1. Stem fly infestation in relation to different sowing times

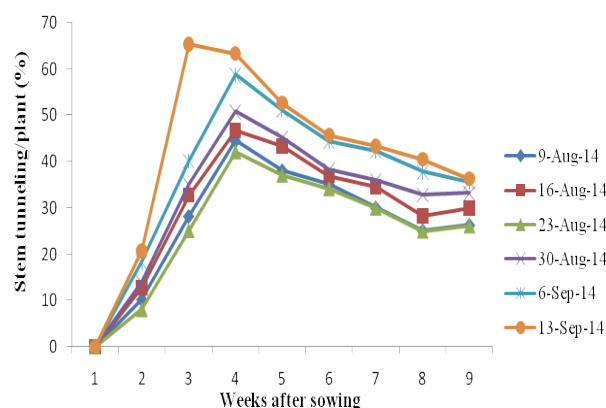


Figure 2. Stem tunneling plant in relation to different sowing times

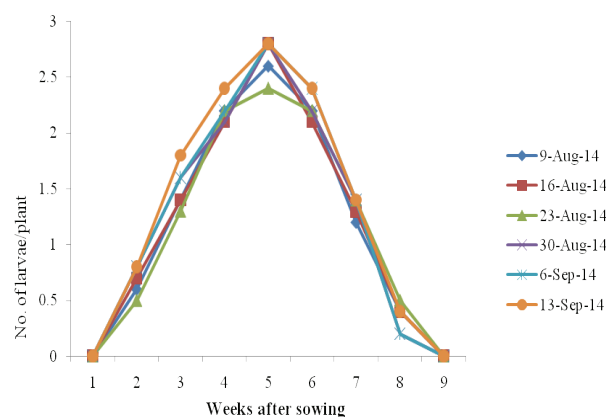


Figure 3. Abundance of stem fly larvae in relation to different sowing times

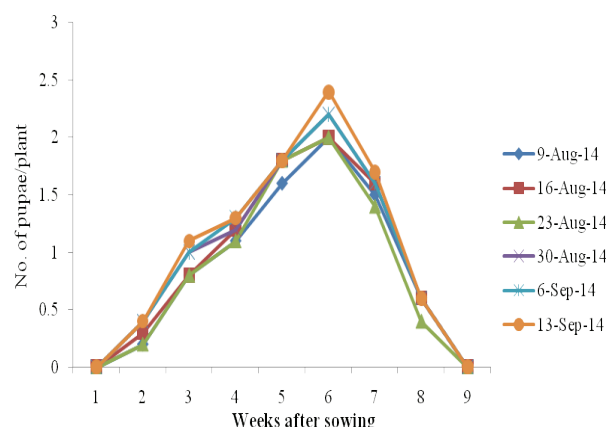


Figure 4. Abundance of stem fly pupae in relation to different sowing times

Incidence of stem flies on different sowing times: Figure 5 showed the larval population of stem fly which reached the highest (1.42) at October 11. Same trend was found in case of pupae (Figure 6). Similarly, stem tunneling reached the peak (53.44%) on October 11 (Figure 7). During the crop growing period 100% plant infested on October 11 (Figure 8).

Effect of sowing dates on yield: The yield of soybean differed significantly among the sowing dates. The highest yield (2.2 t/ha) was obtained from plot seeding at Aug

23 which is statistically similar to Aug 9. But the lowest yield (1.6 t/ha) was obtained from seeding at Sep 13 and statistically different with other sowing dates.

Discussion

Results of the present investigation indicated that among the six planting dates, August 23 appeared the best one to minimize the incidence of stem fly infestation. All the observed parameters like numbers of larvae and pupae, percent stem tunneling and infested plant were the lowest

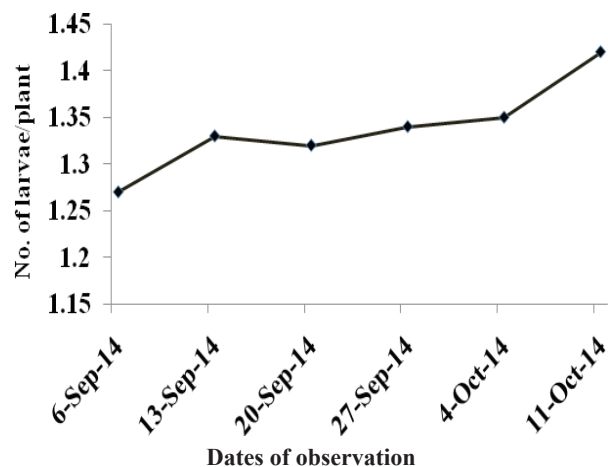


Figure 5. Effect of sowing times on the fluctuation of stem flies larvae

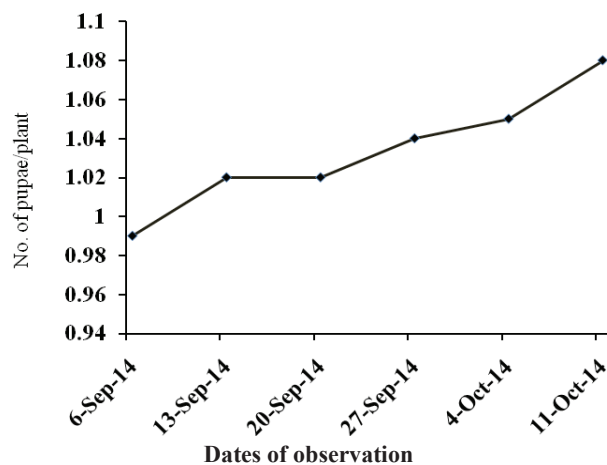


Figure 6. Effect of sowing times on the fluctuation of stem flies pupae

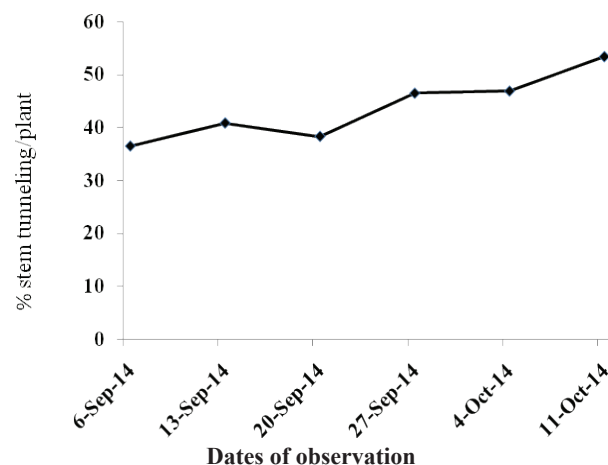


Figure 7. Stem tunneling (%) per plant at different sowing times

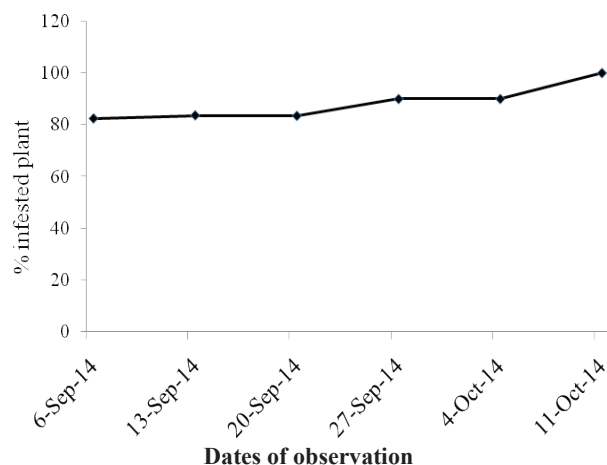


Figure 8. Infested (%) plants at different sowing times

and hence maximize the seed yield. Soybean planting on August 09 and 16 ranked next to August 23. In general, late sowing of September stem fly infestation increased heavily that adversely affect on seed yield.

Pipithsangchan and Sittisak (1985) reported the pattern of fluctuation of *O. phaseoli* on mungbean revealed that the peak infestation period occurred around late August and mid September. The number of maggots and pupae decreased quite rapidly in late September. A significant difference was found between the number of maggots and pupae in the low and high rainfall periods. The infestation levels decreased remarkably during rainy months.

The growing stage of the crop had greater influenced of the stem fly incidence. Irrespective of planting times, pest incidence was detected when the crops attained two weeks

old. Cent percent plant became affected at 3 weeks of plant age on September 13 planting while in rest planting that was observed when the plants attained 5 to 6 weeks old. From this data it can be concluded that the stem fly infestation caused in definite time and early sowing was better than late sowing because prior to infestation of stem fly crop can pass the vegetative phase and thus infestation can be avoided (Negasi and Abate 1986). Although presence of larvae and pupae per plant and stem tunneling were detected at second week after sowing regardless of sowing times but their successive development varied widely among the sowing times. Gradual increasing of larva and pupal population was estimated, respectively up to 5th and 6th weeks and disappeared at 9th week of sowing. The sowing date August 23 demonstrated the minimum where only 25.31% of stems were tunneled.

In general, third-fourth week of crop age was the most vulnerable for stem tunnelling by stem fly. The study revealed that the stem fly attack at earliest stage of plant growth became high during third week after germination. This is corroborated with the findings of Thapa and Timsina (1990) and Prodhan *et al.* (2000). According to them stem fly attacked the plant immediately after germination and infestation became high during the third week of germination. Bhattacharjee (1980) examined the stem fly infestation in soybean at the different stages of plant growth and claimed that 15% plant population attacked at the cotyledon stage, 22.37% in the unifoliate stage and the rest in trifoliate stage. Songa and Ampofo (1999) reported that population (egg, larvae and pupae) of stem fly increased and peaked at 5-6 weeks after plant emergence and declined thereafter which clearly supports the present investigation. Prodhan *et al.* (2000) reported that the larvae of *O. phaseoli* appeared in black gram at 10 days after germination, their incidence and percent stem tunneling increased rapidly with the increasing of plant age while 50 days after germination the incidence of larvae and percent stem tunneling declined gradually.

The results of the present study revealed that early planting (up to 23 August) of soybean resulted lower infestation of stem fly and late planting showed higher infestation. Crop under early plantings received more rainfall than late plantings. Insect movement and egg deposition may hamper due to rainfall. For this reason infestation were lower at early plantings compared to late plantings. This is in lines with Nderitu *et al.* (1990) and Prodhan *et al.* (2000). They reported that the numbers of leaf punctures, eggs, larvae and puparia of *O. phaseoli* were found high in late than in early planted crops and the crop planted late in the season was severely damaged due to generally higher population levels which had been building up in the course of the season. Prodhan *et al.* (2000) also observed lower infestation of stem fly and higher yield of black gram when the crop sown on August 23.

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Understanding the life cycle and benefits of black soldier fly and its prospect in Bangladesh

Rinki Akter, Farha Tammana Ila Haque, Priyanka Roy, Hania Binta Aslam and Md Ruhul Amin*

Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

Corresponding email: mramin@bsmrau.edu.bd

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Abstract

Black soldier fly *Hermetia illucens* (Diptera: Stratiomyidae), an insect that most commonly used as animal feed, consume copious amounts of organic waste to develop their bodies, which are composed of 40–48% protein, 30–38% fat, and a variety of vital minerals. While the higher fat content of black soldier fly may be a necessary component for the manufacture of organic fertilizer, the higher protein content may be utilized to either fully or partially replace the very costly fishmeal. In addition, the black soldier fly eliminates some hazardous bacteria and insect pests and has a better capacity to convert organic waste. The population of world continues to rise, hence there is a rising demand for animal proteins, surpassing supply and leading to the production of organic waste. Larvae may also remove trace elements like copper and zinc, and produce high-value products with low quantities of heavy metals. There are new and inventive applications for black soldier fly byproducts in fields like bioplastics, medicine, and renewable energy. Black soldier fly pre-pupae samples were processed and examined by a number of researchers in Bangladesh to determine their proximate compositions, minerals, amino acids, and fatty acids. Pre-pupae of cultivated black soldier flies have a significant concentration of certain minerals (Ca, Ni, and Co), suggesting that they might serve as a valuable source of mineralized animal feed. Significant amounts of both necessary and non-essential amino acids were found in the pre-pupae, indicating that the cultured black soldier fly was in a healthy state. Pre-pupae were found to be a potential source of essential fatty acids. Their cultivation required minimal resources, making it affordable for local farmers. Additionally, with the global rise in demand for insect-based feed, Bangladesh could position itself as a supplier in this emerging industry. Expansion of this sector could drive job creation and improve food security. The aim of this review is to understand the prospects of this emerging technology, evaluates its constraints and respond to open research questions by means of lab scale experiments in Bangladesh.

Keywords: *Hermetia illucens*, rearing, challenges, aquaculture, animal feed, waste management

Introduction

The rapid population growth of the world is driving the need for sustainable protein sources. Animal-based foods (dairy products, eggs, fish, and meats) and plant-based foods (cereals, beans, potatoes, vegetables and fruits) are the main sources of protein for human consumption (Wu *et al.* 2014). In Bangladesh, total fresh water fish production is 40.53 lakh metric tonnes (DoF 2024) and contribution in GDP is 2.8%. In case of poultry industry total production is 3857.04 lakh with GDP of 1.5% (BBS 2023). On the other hand, another big sector, livestock contributes around 1.80% in GDP where total production is 453.595 million (BBS 2024). However, these sectors face many problems, such as fresh water fish production constraints including–lack of quality seed, disease outbreaks, environmental degradation, pollution, predation, inadequate infrastructure, improper management practices, traditional cultural strategies and

others. Some major problem of poultry industry are disease outbreaks like bird flu, high feed prices, lack of access to credit, competition from imports, market volatility, poor management, qualities of chicks-vaccines, security of investment etc. Furthermore, livestock deals with the challenges like animal diseases, climate change, poor quality feed, lack of pasture, scarcity of water resources, poor veterinary care, lack of organized market, inadequate business plan, poor technology adaption, gender inequality and others. A wide range of insect species are being utilized in aquaculture, poultry, and livestock industry as feed ingredients. Among them black soldier fly has vast potential to contribute in these sectors. Black soldier fly, (*Hermetia illucens*, Diptera: Stratiomyidae) is a harmless insect. Due to their ravenous desire for organic waste, such as food scraps and agricultural leftovers, these larvae reduce trash buildup by turning them into usable biomass (Surendra *et al.* 2015). Black soldier fly larvae have a remarkable nutritional profile and abundant

in vitamins, minerals, vital amino acids, and protein sources like soybean meal and fish meal (Barragan *et al.* 2017). A key component of the black soldier fly larvae has potential for bioconversion which is their capacity for material reduction. Through digestion, these larvae have an amazing capacity to decrease the weight and amount of organic waste. Farmers and small business owners may become more resilient to market swings and natural dangers by developing new value chains and making extra money from the sale of pre-pupae gathered for animal husbandry or other uses. Conversion of organic refuse by saprophages has been an issue over the last few decades (Elissen *et al.* 2006). The Conversion of organic refuse by saprophyges initiative, which uses the BSFL technique, converts waste and remaining organic biomass into secondary raw materials, such as molecules of interest for green chemistry (Santangelo *et al.* 2024). Changing to different poultry species, such water flows, which may be reared with different feed (snails, water hyacinth), is one way to combat excessive feed prices. The fly has potential to utilize and boost the economy of low and middle income nations. Based on the commercial production and unitization, it is utmost need to learn about the current status of rearing method, and to understand the future opportunities, prospects and challenges of black soldier fly rearing in Bangladesh.

Black soldier fly

The harmless insect black soldier fly, *Hermetia illucens*, is a true fly (Diptera) of the family Stratiomyidae. This insect has the potential to address two vital issues in modern agriculture: it can handle organic wastes responsibly, provide an alternate source of protein for animal feed, and produce a large number of byproducts and fertilizers (Taiwo and Otoo 2013). The black soldier fly was first identified in France by Chevin (1986) in the southeast, then by Dauphin (2003) in the southwest, and Richoux (2009) in the Rhone valley (Richoux 2009) in the vicinity of Poitiers (Maquart *et al.* 2020). The fly originated in North America, but climate change and human activities, animals, goods, foods, and fruit transportation worldwide facilitated its spread to other continents such as Europe, Asia, and Australia (Olivier 2009, Leek 2017).

Life cycle of black soldier fly

The five unique life cycle phases of the black soldier fly insect are egg, larvae, pre-pupae, pupae and adult (Newton *et al.* 2005). Black soldier fly takes 40–44 days to complete the whole life cycle. The fertilized eggs hatch at a temperature of 24°C in 102–105 hours (Tumpa *et al.* 2021). Larvae that have just hatched are opaque-white in color and eagerly move toward the substrate to feed on whatever food is accessible at that stage of their lives. The larvae achieve maturity in about two weeks (Sheppard *et al.* 2002, Myers *et al.* 2008).

Egg: Eggs are usually creamy yellow in color and take 4 days to incubate and hatch under optimum conditions of around 20°C to 30°C (Newton *et al.* 2005).

Larva: Because of photophobic nature, the larvae have a dull, yellowish hue just after hatching and attempt to hide from light (Newton 2015). For the majority of their existence, it consume food scraps and manure wastes, quickly converting them into calcium, protein, and fat. The ideal temperature range for larvae to effectively use feed is between 27 and 33°C (Alvarez 2012). Lower temperatures are probably feasible since the metabolism of larvae and feeding activity will provide some heat, enabling their growth in colder regions (Newton 2015). Larvae attain full size (20 to 25 mm) in about 4 weeks at ideal conditions; but, if temperature and sufficient nourishment are not available, it may take up to 2-4 months (Newton 2015). The moisture level of ideal feed varies from 60% to 90% which is crucial for the growth of black soldier fly.

Pre-pupa: When the black soldier fly larvae (12.5 mm-long grubs) reach their maximum size (Burtle *et al.* 2012), the larvae cease eating, turn black, and harden their skin; at this stage, known as the pre-pupa stage. Migratory larvae secrete chemicals that other maggots can follow which form a migration pattern. This pattern depends on humidity and temperature also (Myers *et al.* 2008).

Pupa: In addition to becoming drier, the pupation location needs ambient humidity values of around 60% in order for the adults to emerge. Pupation may take five to seven days,

depending on the surrounding humidity and temperature (Myers *et al.* 2014).

Adult: After 10–14 days at 27–36 °C, adults emerge from their pupae cases (Myers *et al.* 2014). The adults rely on the lipids accumulated from the larval stage for their activities and do not eat; instead, they consume water or other liquids when available (Newton 2015). Two days after emerging from the pupal stage, adults mate (Myers *et al.* 2014) and after copulation, females deposit their eggs in dry cracks and crevices close to their larval home. The fly is similar in size to a honeybee, measuring between 13 and 20 mm, and it only lives for 6 to 10 days in adulthood. As they are photophilic, adult flies need temperatures between 5°C and 35 °C as well as bright sunshine spectrums in order to facilitate mating (Newton *et al.* 2005)..

Importance of black soldier fly

It can take the place of 10%–20% soybean meal for broiler chickens that exhibit similar productivity, feed efficiency, mortality, and carcass characteristics as chickens given commercial feed (Cullere *et al.* 2016). Moreover, Arango *et al.* (2005) recommended that based on their mineral needs, the black soldier fly larvae contain a reasonable quantity of minerals for domestic bird diet.

Larvae as fish feed: In Bangladesh, total aquaculture production is 4.62 million metric tonnes (DoF 2021). Black soldier fly larvae can be used as a protein replacement in fish diets. Various researches have been done on this sector and the outcome is positive. Bangladesh has abundant fisheries scope where black soldier fly larvae can be utilized as a supplement to fish diet.

Larvae as poultry feed: Poultry industry size in Bangladesh is approximately over 3.7 million (BBS 2023). Black soldier fly larvae grown on organic waste or kitchen residues, have been shown a satisfactory result as a feed supplement for poultry chicks (Hale, 1973). In the experimental diets, black soldier fly larvae or pre-pupae were substituted for soybean meal (47.4%) and soybean oil (100%) (Kawasaki *et al.* 2019). For broiler chickens that demonstrated similar production performance, feed efficiency, mortality, and carcass features as those fed on commercial feed, it can be used in place of the 10%–20% soybean meal (Cullere *et al.* 2016).

Recycle food waste: Nguyen *et al.* (2015) found that the pre-pupae stage of this insect can be harvested and used as a valuable nutritious feed for animal livestock. Five waste types with a wide range of organic source matter were specifically chosen to evaluate the consumption and reduction ability of black soldier fly larvae. *H. illucens* was able to reduce all waste types. Among them waste reduction was highest in fruits and vegetables (30%) and lowest in manure waste (13%) while others included fish rendering (22%), kitchen waste (20%), and pig liver (15%).

Organic fertilizer from black soldier fly larvae: Choi *et al.* (2009) reported that the bioconversion of food waste produced promising results relating to the use of the waste residue as an imcompound for conventional fertilizer. Menino *et al.* (2021) found that black soldier fly showed a significant effect on ryegrass production with increase amount of organic matter and fertilizer with a constant increase of dehydrogenase activity.

Table 1. Mineral composition of black soldier fly pre-pupae on a dry matter basis

Mineral composition (mg kg ⁻¹) ± MU			
Elements	Concentrations	Elements	Concentrations
Na	0.26 ± 0.03	Mn	62.8 ± 4.4
P	1570.9 ± 282.8	Cu	8.26 ± 0.59
Ca	42,151 ± 3540.7	Co	0.26 ± 0.02
K	5838.3 ± 1261.1	Ni	0.97 ± 0.08
Fe	152 ± 12.2		
Zn	31.8 ± 3.69		

Financial benefits of black soldier fly larvae

Municipal waste management problems: Large chicken farm houses, pig farms, and cow farms are among the agricultural settings where black soldier fly maggots have been employed to stabilize troublesome wastes, such as swine, bovine, and poultry manures, (Sheppard and Newton 1994, Axtell 1999). An estimate from 2019 states that highest waste collection in Dhaka reach up to 89,235 tons in one month (Anonymous 2020). We can effectively satisfy the protein requirements of our fish and poultry diets by turning that waste into fertilizer and protein.

Solving antibiotics and pesticides problems: Poultry feed contains both harmful tannery waste and antibiotics which is harmful for human health. In addition, the overuse of chemical fertilizers, herbicides, and pesticides on agricultural land contaminates the vegetables being produced, leading to illnesses of the stomach, liver, and kidneys and a steady death toll. In this instance, the black soldier fly larvae can contribute to a sustainable ecosystem through farming (Pal *et al.* 2023).

Environmental factors for growth: A past study reports that the black soldier fly is sensitive to the abiotic factor of the environment (Mutafela 2015). The required parameters may vary with the development stages. The factors include temperature, relative humidity, light, diet, and pupation substrate.

Bangladesh has a favorable weather for black soldier fly culture : Bangladesh has a warm, humid climate that is regularly affected by tropical cyclones and high precipitation. The annual rainfall is about 237.6 cm. It is also subject to pre- monsoon, and post-monsoon circulations. In the past years, the average temperature of Bangladesh has been about 26°C, with annual variations between 15°C and 34°C. Bangladesh has up to 80% relative humidity on average between June and September. In some places, it varies from 60 % to 70 %. The climate of Bangladesh is therefore ideal for the development, incubation, and hatching of black soldier fly larvae.

Current status of the rearing of black soldier fly in Bangladesh : Ferdousi *et al.* (2022) reared black soldier fly pre-pupae to be used as a feed source for livestock

and fish. Larvae of black soldier fly with organic waste substrates were collected from the municipal dustbins situated at the laboratory road area of Dhaka metropolitan city, Bangladesh in July 2019. The experiment was conducted at $28 \pm 5^\circ\text{C}$ with $50\text{--}65 \pm 10\%$ relative humidity under a photoperiod of 14 h light and 10 h dark period. The gathered larvae were placed with substrate in a 10-liter plastic container with a cover that had four openings in the top. Next, the larvae container was set on top of a plastic dish that had sawdust inside of it. Mature larvae, also known as pre-pupae, ceased eating after 6–8 days and congregated in the sawdust. These were then gathered in a plastic container after being sieved to remove the pre-pupae from sawdust. The first harvest weighed 30 g on the sixth day, while the second and third harvests, which came on the seventh and eighth days, weighed 60 g and 20 g, respectively. For the analysis of nutrients in the laboratory, the black soldier fly pre-pupae were killed by freezing and stored at -20°C until analysis.

Several laboratories of the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh, processed and triple-analyzed all samples of the black soldier fly pre-pupae for proximate compositions, minerals, amino acids, and fatty acids. These were then oven-dried at about 70°C for 48 h. The dried samples were powdered in a quartz mortar with a pestle and collected to store at -4°C for further analysis.

The mineral composition of the black soldier fly pre-pupae is shown in Table 2. The level of Ca found the highest and the concentrations of Ni and Co were also higher. A considerable presence of some minerals (Ca, Ni, and Co) in cultured black soldier fly pre-pupae indicates that it may be used as a good source of mineralized animal feed (Ferdousi *et al.* 2022).

Leucine and methionine had the greatest and lowest amounts, respectively, among the necessary amino acids depicted in Table 2 of the black soldier fly pre-pupae. Glutamic acid and cysteine had the highest and lowest concentrations among the non-essential amino acids, respectively. The pre pupae were discovered to have significant levels of both necessary and nonessential amino acids, including alanine, arginine, aspartate, glycine, and proline. This suggested that the cultivated black soldier fly pre-pupae were in a healthy state (Ferdousi *et al.* 2022).

Table 2. Amino acid profile of black soldier fly pre-pupae on a dry matter basis

Amino acids (Essential)	Contents (g kg ⁻¹)	Amino acids (Nonessential)	Contents (g kg ⁻¹)
Histidine	9.2	Alanine	18.4
Isoleucine	13.1	Arginine	17.1
Leucine	21.3	Aspartate	29.1
Lysine	18.3	Cysteine	0.9
Methionine	1.3	Glutamic acid	33.1
Phenylalanine	8.2	Glycine	19.1
Threonine	9.8	Proline	17.2
Tryptophan	2.8	Serine	10.7
Valine	16.7	Total amino acids	246.3

Total unsaturated fatty acid (TUFA) content was found to be less than half that of total saturated fatty acid (TSFA) level in Table 3. Lauric acid (C12:0) was discovered to be the largest quantity among the TSFA, while Pentadecyclic acid (C15:0) was found to be the lowest. Compared to the other measured unsaturated fatty acids, the quantities of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in the TUFA were found to be almost similar. PUFA and linolenic acid were the two types of TUFA that had the largest and the lowest levels, respectively. It is possible to think of the increased black soldier fly pre-pupae as a reliable supply of important fatty acids. (Ferdousi *et al.* 2022).

Black soldier fly eggs cost

Hatchers can charge Tk 150 per kilogram for their eggs. The larvae are now gathered for fish and poultry farms. The cost of one kilogram of larvae would be Tk 200.

Black soldier fly farming in Bangladesh : There are perhaps a hundred small-scale insect farming efforts

across the nation, each with a different background and set of lessons learned, but none of them have connected waste management to the issue at hand. For instance, Duranta, a member of the agricultural and cooperative affairs subcommittee, started organic farming on his ancestral property in Purbadhala upazila in the Netrokona district. Later, he moved his property to the Keraniganj area during the Covid-19 epidemic. He gathered around a ton of larvae and pupae each month. The larvae are now served with Nuruzzaman's broiler chicken. There are about 600 hens on his farm. He began bug farming when the cost of traditional chicken feed increased to Tk 3,300 every 50-kilogram bag.

Sustainable business prospect : Food insecurity, a lack of protein, malnutrition, and poor sanitation are predicted to be the main worldwide dietary issues by 2050 (FAO, 2013). The constantly growing human population, together with a variety of agricultural farms, municipal markets, homes, supermarkets, industries, animal rising, and human settlements, create an enormous amount of

Table 3. Fatty acid profile (%) of black soldier fly pre-pupae on a dry matter basis

Fatty acids	Contents (%)	Fatty acids	Contents (%)
Decanoic acid (C10:0)	0.71	Palmitoleic acid (C16:1)	2.03
Lauric acid (C12:0)	45.26	Oleic acid (C18:1)	13.74
Myristic acid (C14:0)	6.90	Monounsaturated fatty acids	15.77
Pentadecyclic acid (C15:0)	0.10	Linoleic acid (C18:2) (Omega-6)	15.33
Palmitic acid (C16:0)	12.85	Linolenic acid (C18:3) (Omega-3)	1.64
Stearic acid (C18:0)	1.44	Polyunsaturated fatty acids	6.97
Total saturated fatty acids	67.26	Total unsaturated fatty acids	32.74

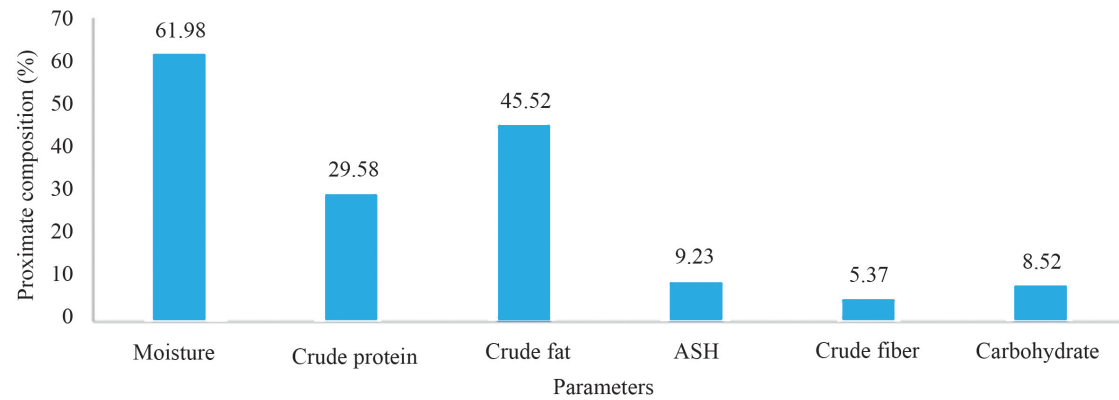


Figure 1. Proximate composition (mean $\pm$ SE) of black soldier fly pre-pupae on a dry matter basis.

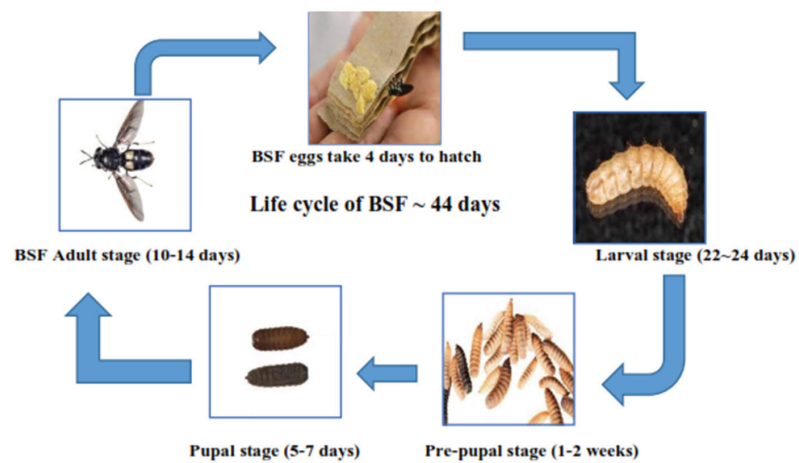


Figure 2. Life cycle of black soldier fly.

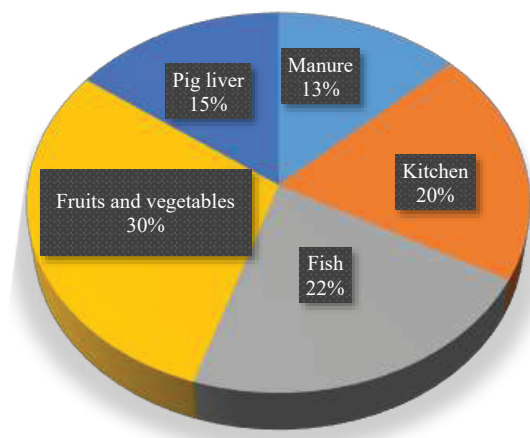


Figure 3. Waste reduction (%) by black soldier fly pre-pupae.

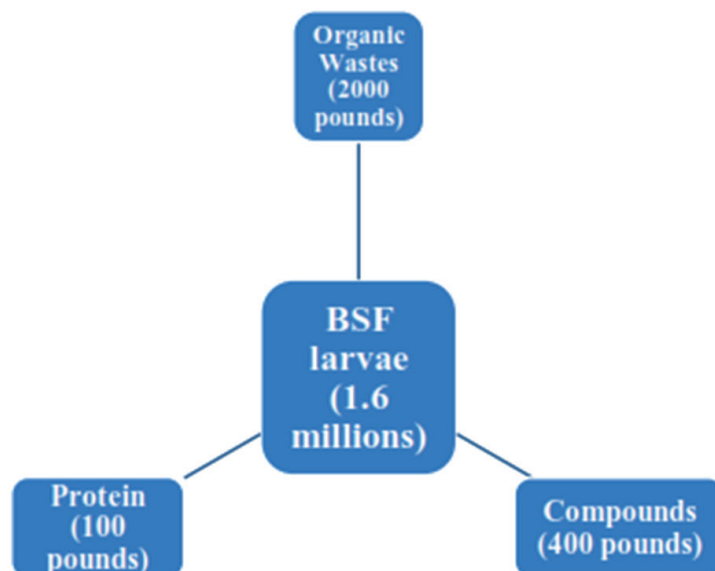


Figure 4. Efficiency of black soldier fly in waste management.

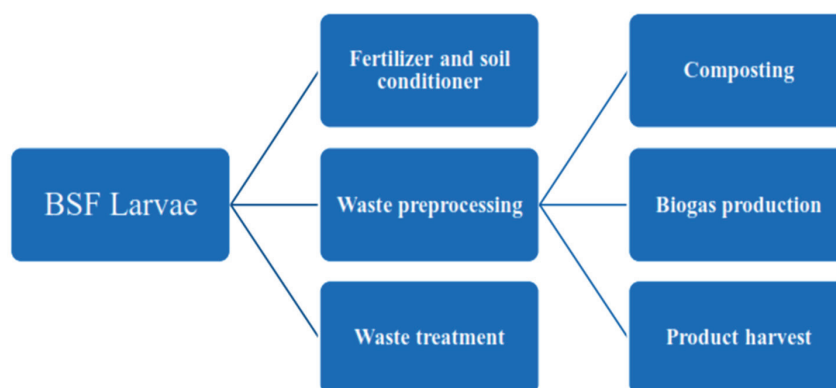


Figure 5. Conventional waste processing system using black soldier fly larvae.

organic waste (Van Huis *et al.*, 2013). Black soldier fly bioaccumulation might be exploited to repurpose this substantial amount of garbage. Women and low-income impoverished individuals might be employed in black soldier fly farming under such an initiative. Obtaining new, affordable black soldier fly production facilities would undoubtedly boost social and economic safety by creating job possibilities for the marginalized community. A staggering 70% increase in food production is required by 2050, according to some projections, in order to feed everyone on the world.

Prospects of rearing black soldier fly in Bangladesh

Sustainable waste management: Larvae of black soldier flies break down complex organic waste materials such as proteins, carbohydrates, lipids, and cellulose using specific digestive enzymes. The breakdown of waste is accelerated by this procedure.

Alternative protein source: In animal feed for fish, shrimp, pigs, and poultry, black soldier flies are utilized as an alternate source of protein. For instance, there is no adverse effect on chicken development, meat quality, or biochemical markers when less than 20% black soldier fly is added to chicken feed.

Circular economy model: Black soldier fly depends on organic waste, significantly reducing landfill reliance and the associated environmental issues. The black soldier flies then becomes a valuable resource – a nutrient-rich source of protein for poultry, fish, and even pet food.

Reduced environmental impact: Black soldier fly conserve water by utilizing less water than traditional livestock. Frass, which is a result of processing black soldier flies, can be utilized as an organic fertilizer. By boosting carbon content and enhancing water and mineral retention, frasses can enhance soil health. Organic waste conservation can lower greenhouse gas emissions, particularly methane.

Bioconversion technology: Black soldier fly larvae can convert organic waste into biomass that is high in protein and fat. It is a viable source of safe compost. Additionally, larvae can extract trace elements like copper, zinc, and create high-value products with low-heavy metal concentrations.

Research and innovation: Innovative applications of black soldier fly byproducts are emerging, including areas like bioplastics, pharmaceuticals, and renewable energy. Research is exploring the potential uses of chitin, lipids, and other compounds derived from black soldier fly, opening doors to new, sustainable industry solutions.

Food security: The black soldier fly, which is primarily used in animal feed, has a significant potential to provide a sustainable supply of nutrients for human use (Bessa *et al.* 2020). Their ability to transform waste materials into premium proteins, lipids, and minerals has led to significant research and cultivation.

Commercial interest and investment: Black soldier fly paved a way of significant commercial sectors such as, animal feed, fertilizer production, waste management, and cosmetics manufacturing.

Challenges of rearing black soldier fly in Bangladesh and solutions

Although accessibility and finding top-notch fodder for the black soldier fly larvae are significant obstacles, black soldier fly larvae can flourish on a range of organic resources including manure, food waste, and vegetable scraps.

Infrastructure: Black soldier fly farming requires specialized infrastructure, such as equipment for processing, waste management systems, and facilities for growing larvae.

Funding: Securing funding can be a challenge for farmers who may not have access to traditional financing options. Alternative funding sources, such as microloans or crowd funding, can provide a means for farmers to access the capital they need to start their businesses.

Regulatory barriers: Among the regulatory obstacles faced by farmers include obtaining permits and licenses to operate, abiding by environmental requirements, and safety and health rules. Simplifying the regulatory process and advocating for supporting policies can aid in addressing these issues.

Collaboration and knowledge-sharing: Creating a network of farmers or hosting industry gatherings may provide farmers a platform to exchange best practices, gain knowledge from one another, and work together on initiatives.

Awareness and support for black soldier fly farming: To address this issue, collaborations with neighborhood non-governmental organizations and educational initiatives might be formed to increase awareness and give farmers information.

Mass production scaling: Scaling up production to meet commercial demands can be challenging. Maintaining consistent and large-scale production of black soldier fly larvae requires efficient farming practices.

Feedstock quality and availability: The quality and availability of organic waste or feedstock significantly impact the growth and development of black soldier fly larvae. Inconsistent or poor-quality feed can lead to variations in larval development and nutritional content.

By-product utilization: Efficiently utilizing all by-products of black soldier fly rearing, such as frass and residual biomass, is important for maximizing the economic and environmental benefits of the process.

Disadvantages and constraints of rearing black soldier fly : The major drawback of black soldier fly for biodegradation is that it needs a warm habitat, which in temperate countries might be challenging or energy-intensive to maintain.

The very tiny parasitic wasps lay their eggs in young black soldier flies. The wasp eggs laid within the larvae of the black soldier fly will hatch, and the subsequent progeny will eat the fly until it is killed. Although they are not known as a disease vector, adult soldier flies are a potential mechanical vector of various pathogens.

Conclusion

The black soldier fly is a very helpful insect with very few detrimental effects on the ecosystem. Bangladesh, an impoverished nation, can use this insect to breakdown organic waste from municipal solid wastes, replace animal and poultry feed, and create biofertilizer. This mini-review provides a comprehensive summary of the most recent research on artificially rearing black soldier fly, the effects of various waste types and their co-digestion or waste stabilization performance, the effects of different organic waste fermentation with microorganisms in conjunction with black soldier fly, and the commercial applications of this technology. To guarantee prompt reaction to new developments and difficulties, it is imperative that this research be conducted with close collaboration between researchers, plant operators, and regional planners through tightly knit information exchange networks.

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Dynamics and threats to floral diversity in Bhawal national park

Sourav Kanti Bala, Shahriar Mannan Imon Talukder and Md. Abdul Karim*

College of Agricultural Sciences, International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh

*Corresponding email: akarim1506@gmail.com

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Abstract

Bhawal National Park (BNP) situated in Gazipur district of Bangladesh is a crucial site for biodiversity conservation, particularly its Sal (*Shorea robusta*) forests, which dominate the landscape and provide essential ecological services. This review synthesizes recent studies on BNP's floral dynamics and highlights the environmental challenges that threaten its biodiversity. BNP is facing significant biodiversity loss due to anthropogenic pressures such as industrial encroachment, illegal logging, and land-use changes, which have led to deforestation, habitat fragmentation, and the decline of native species. Additionally, climate change, characterized by rising temperatures and erratic rainfall, is further disrupting the park's floral composition by favoring drought-resistant plants over moisture-dependent ones. These threats have caused a significant reduction in species richness. This review emphasizes the urgent need for integrated conservation strategies, including climate adaptation measures, reforestation with native species, and stronger community involvement to preserve BNP's unique biodiversity. Continuous monitoring and research are essential for developing adaptive management strategies that ensure the park's resilience in the face of ongoing environmental changes.

Keywords: Biodiversity loss, climate change impact, floral dynamics, national park, sal forest

Introduction

Tropical forests, such as those in Bhawal National Park (BNP), are essential ecosystems that host a vast array of biodiversity, playing a crucial role in climate regulation and species conservation. However, these ecosystems are increasingly threatened by human activities and climate change, which put their ecological balance at serious risk. Sal forests, dominated by the Sal tree (*Shorea robusta*), are among South Asia's most important tropical ecosystems which is known for their rich biodiversity, and the vital ecological services they provide, remarkably include carbon sequestration and habitat provision (Mishra *et al.* 2021).

In Bangladesh, Bhawal National Park represents one of the largest remaining reserves of Sal Forest, housing a diverse range of flora that supports various ecological functions and species (Habib and Huda 2022). Despite its protected status, BNP faces significant environmental challenges that endanger its floral composition (Mukul *et al.* 2008). Human activities such as industrial expansion, urbanization, and illegal land encroachment have led to substantial habitat loss and fragmentation (Wilson *et al.* 2015). As a result, the park's Sal forests, which make

up about 90% of its tree canopy, have deteriorated, contributing to the decline of native species (Kabir and Ahmed 2005).

Rapid industrialization in the areas surrounding BNP, particularly in nearby urban centers, has exacerbated deforestation and increased land surface temperatures, thus altering the park's microclimate (Alam *et al.* 2021). This temperature rise, coupled with a reduced vegetation cover, has been linked to declining forest health and biodiversity (Grover and Singh 2015). Recent research indicates a marked decrease in mature Sal trees, an increase in invasive non-native species, and an overall loss of floral diversity within BNP (Hasan and Karim 2020; Alam *et al.* 2021).

Anthropogenic pressures such as illegal logging, agricultural expansion, and industrial encroachment further accelerate biodiversity loss, undermining the ecological integrity of this protected area (Mishra *et al.* 2021). Climate change also plays a critical role in altering BNP's floral dynamics. Rising temperatures and unpredictable rainfall patterns are expected to shift the distribution of key species, such as Sal, which could have far-reaching effects on the entire ecosystem (Rahman *et*

al. 2010). Research suggests that climate change may disrupt flowering cycles, alter species interactions, and shift plant community compositions, making adaptive management strategies crucial for the park's survival (Naughton-Treves *et al.* 2006).

Given the growing pressures on BNP's biodiversity, it is imperative to develop integrated conservation strategies that address ecological and socio-economic factors. This review aims to provide a foundation for such conservation efforts, emphasizing the need for sustainable and adaptive management to safeguard Bhawal National Park's future.

Methodology

Study area: Bhawal National Park (BNP) is located in the Gazipur district of Bangladesh, covering an area of

5,022 hectares (Jahan *et al.*, 2017) between 24°02'N to 24°11'N latitude and 90°21'E to 90°28'E longitude (Fig.-1). Situated approximately 40 kilometers north of Dhaka along the Dhaka-Mymensingh highway, BNP serves as a critical conservation area in the central region of Bangladesh (Kabir and Ahmed 2005). Established on May 11, 1982, under the Bangladesh Wildlife (Preservation) (Amendment) Act of 1974, the park aims to protect the remaining Sal (*Shorea robusta*) forest and its associated biodiversity from increasing anthropogenic pressures (Rahman and Vacik 2010). It is classified under the International Union for Conservation of Nature's (IUCN) Management Category IV, underscoring its role in preserving Bangladesh's natural and cultural heritage (Mishra *et al.* 2021). BNP's topography consists mostly of plain land or low hills rising 3.0-4.5 meters above the

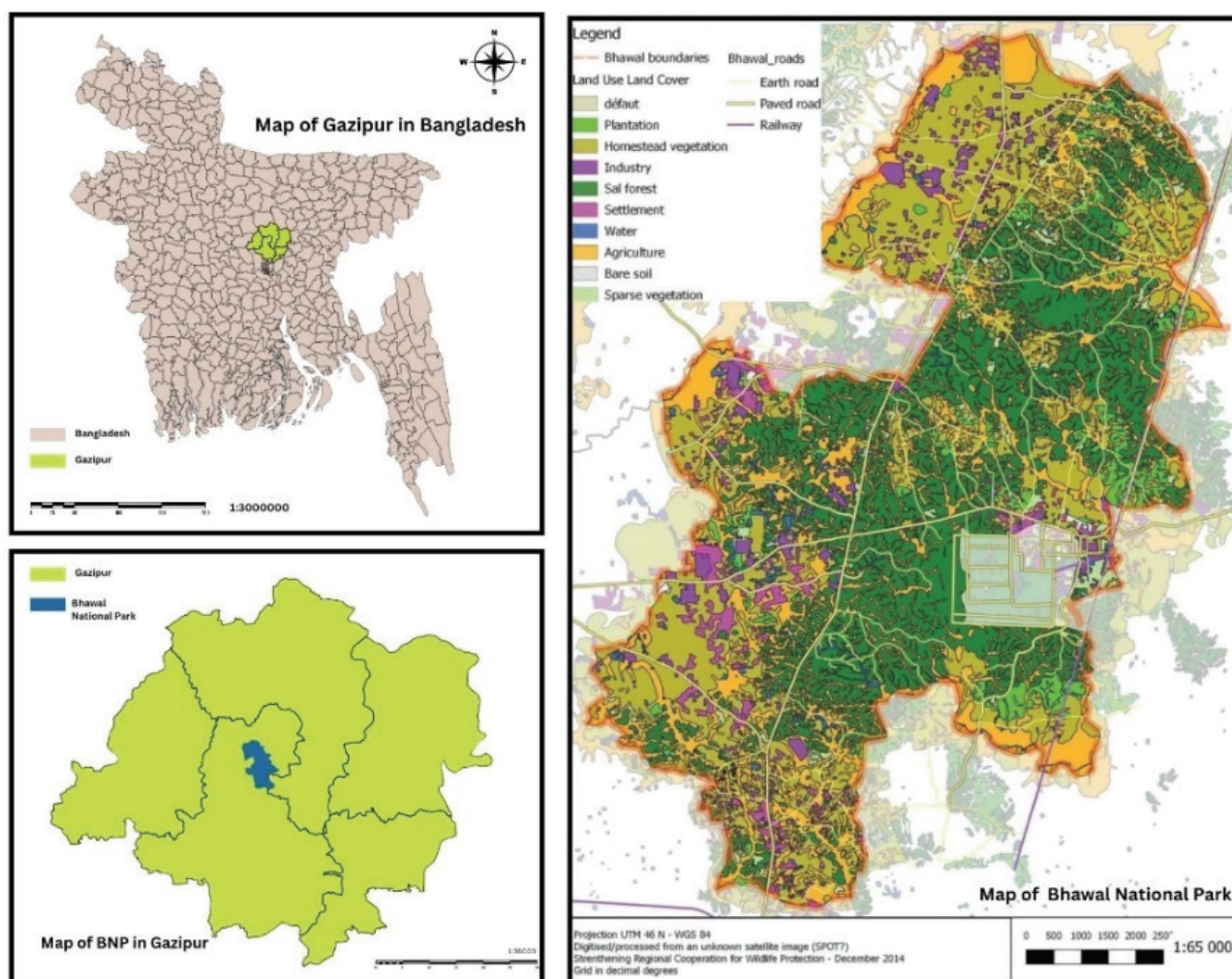


Figure 1: Study area map of Bhawal National Park.

surrounding paddy fields, locally known as ‘Chalas,’ which are interspersed with numerous depressions or ‘bails’ (Bhawal National Park Management Plan 2015-2025). The soils are generally acidic to strongly acidic (pH < 5.5), yellowish-red, sandy clay loam, mixed with scattered manganiferous iron ore. These soils are characterized by low organic matter (0.78%) and low fertility, with poor porosity resulting in the soil becoming soft and muddy during the monsoon season (Bhawal National Park Management Plan 2015-2025).

The climatic conditions in BNP are moderate, with temperatures ranging from 15°C in January-February to 42°C in April-June (World Weather Online). The area receives an average annual rainfall of approximately 1500 mm, with the highest precipitation occurring from June to August and the lowest from December to February. The annual relative humidity in the park typically ranges from 60% to 86% (Hasan and Karim 2020; Mondol, 2021). The park’s proximity to Dhaka’s urban expansion makes it the only protected area in Bangladesh with industrial establishments within its core zone, adding unique challenges to its conservation efforts (Alauddin *et al.* 2020)

A land cover analysis in BNP identified five major land cover classes, mainly influenced by human activities such as forest plantations, deforestation, settlements, industrialization, and cultivation. The park’s core zone is heavily forested, particularly in the Baroipara and Bhabanipur areas, while agricultural and urban development is more prevalent on the park’s periphery (Bhawal National Park Management Plan 2014).

Survey: The floral species identification survey was conducted in Bhawal National Park (BNP) from June to August 2024. The primary objective of this survey was to identify the floral species present within the park during the monsoon season. The timing allowed for a wide range of species to be observed, particularly those that are active or flowering during this period.

A stratified random sampling approach was used to ensure that different vegetation zones of the park were represented. The park was divided into five major zones

based on vegetation types, including dense Sal Forest, mixed forest patches, grasslands, degraded lands, and aquatic ecosystems. In each zone, field observations were made to document the species present.

Species identification was done visually, with the help of botanical field guides and expert consultation where necessary. Both the local (common) names and scientific names of the species were recorded. Identification tools such as plant keys and photographic records were employed to ensure accuracy.

No additional measurements or ecological parameters were collected during this survey, as the focus was solely on documenting the species present in the park. The results provide a comprehensive list of the floral species observed during the survey period, contributing to ongoing efforts to understand the biodiversity dynamics in Bhawal National Park.

Data analysis: In addition to the literature review, secondary data on BNP’s flora were collected through surveys conducted in 1994, 2005. These surveys documented the species present in BNP, including their local and scientific names. To assess changes in biodiversity over the 30 years, biodiversity indices were calculated using the following-methods:

The Rate of Species Decline measures the annual decrease in species numbers across different categories (trees, shrubs, herbs, climbers) over time. This method provides insight into the speed and extent of biodiversity loss.

$$\text{Rate of decline} = \frac{\text{End Value} - \text{Start value}}{\text{End Year} - \text{Start year}}$$

The Start Value is the species count in the earlier year. End Value is the species count in the later year. End Year and Start Year are the years between which the decline is measured (e.g., 1994 to 2024, 2005 to 2024).

Rates of decline were calculated for 1994 to 2024 and 2005 to 2024, to understand if the rate of species decline has accelerated or slowed. A negative rate of decline indicates a reduction in species numbers, while a positive rate (if applicable) would indicate an increase. These results help quantify how quickly biodiversity is lost in Bhawal National Park.

Results

The detailed survey report on the floral species composition of Bhawal National Park, documented during the study period, is provided in Appendix-1.

Species composition: The species composition in Bhawal National Park (BNP) has exhibited notable variation over the years, reflecting the combined impacts of environmental changes and human activities. Survey data from IUCN (1994), Kabir and Ahmed (2005), and our recent survey (2024) revealed significant changes in the distribution of trees, shrubs, herbs and climbers, as visualized in Figure-1 (IUCN 1994; Kabir and Ahmed 2005).

In 1994, the tree species diversity was at its peak, with *Shorea robusta* (Sal tree) as the dominant species. Other important trees included *Albizia lebbbeck* and *Gmelina arborea*. However, by 2005, the number of tree species had dropped to 43, largely due to deforestation and illegal logging. Our 2024 survey recorded a partial recovery, with the count rising to 88 species. While *Shorea robusta* remains present, it is increasingly being replaced by fast-growing plantation species like *Acacia auriculiformis*, which poses a threat to the native tree diversity (Kabir and Ahmed 2005). The overall tree decline rate between 1994 and 2024 is estimated at -1.56 trees per year.

Shrub diversity followed a similar trend, with the highest species richness observed in 1994, including species like *Clerodendrum viscosum* and *Lantana camara*. By 2005, shrub diversity had been significantly reduced

to 19 species. However, our 2024 survey showed an increase to 31 species. Unfortunately, many native shrubs have been displaced by invasive species, such as *Chromolaena odorata* (Hasan and Karim 2020; Alam *et al.* 2021). The decline rate for shrubs is calculated at -3.16 shrubs per year.

Herb species remained relatively stable between 1994 and 2005, with dominant species such as *Imperata cylindrica* and *Cynodon dactylon*. By 2024, however, the number of herb species had sharply declined to 20, reflecting significant losses in undergrowth vegetation and the impacts of changing land-use patterns (Mishra *et al.* 2021; Rahman and Vacik 2009). The rate of decline for herbs stands at -3.44 herbs per year.

Climbers, including species like *Pothos scandens* and *Tetrastigma leucostaphylum*, experienced a gradual decline from 25 species in 1994 to 24 in 2005. By 2024, this number had further dropped to 16 species, likely due to the loss of host trees and other support structures within the park's forest ecosystem (Hasan and Karim 2020; Alam *et al.* 2021). The decline rate for climbers was measured at -0.36 climbers per year.

Our 2024 survey has contributed to important updates by documenting 88 tree species, 31 shrub species, 20 herb species, and 16 climber species (Appendix-1, Figure 1).

A striking decline in the number of IUCN Red-listed species has been observed between 1994 and 2024. In 1994, 25 species in Bhawal National Park were categorized as IUCN Red-listed, indicating their vulnerability or endangerment. However, by 2024, only 5 of these species

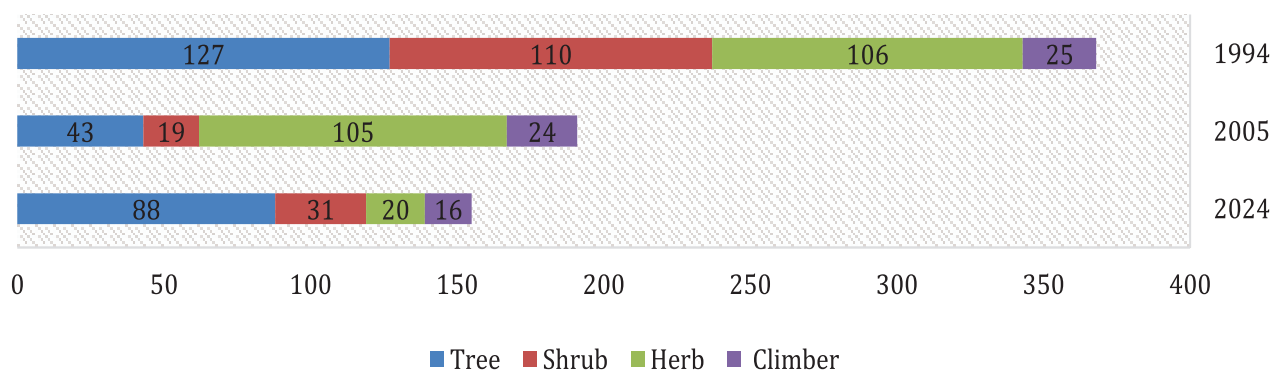


Figure 1. Species richness of Bhawal National park in different survey years.

Table 1. International Union for Conservation of Nature (IUCN) red listed species found in full, 2024

Scientific Name	Local Name	Conservation Status	Habit
<i>Dipterocarpus indicus</i>	Gorjon	Endangered	Tree
<i>Swietenia mahagoni</i>	Mehogony	Endangered	Tree
<i>Aquilaria agalloca</i>	Agar	Critically Endangered	Tree
<i>Dalbergia sissoo</i>	Sishu	Vulnerable	Tree
<i>Swietenia macrophylla</i>	Boro Mehogony	Vulnerable	Tree

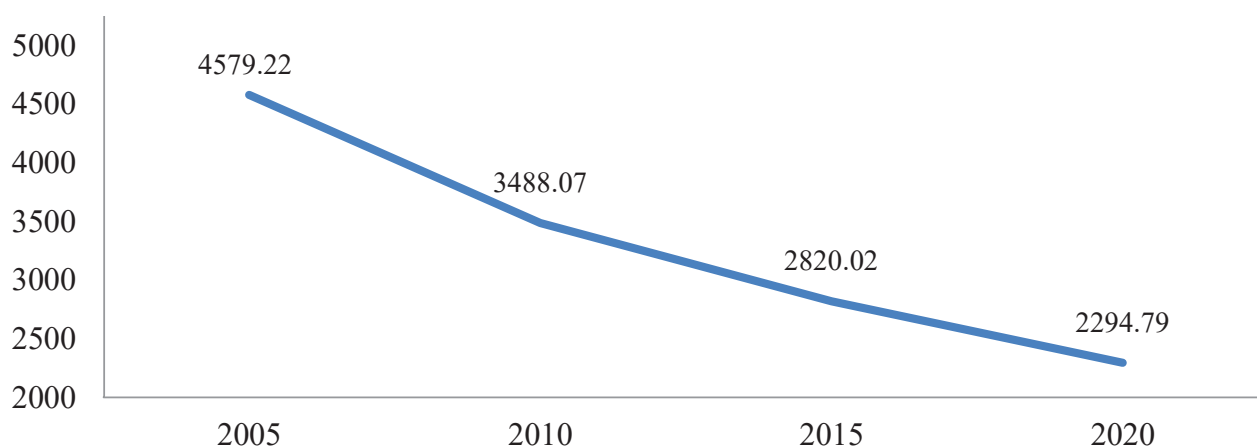
were still present in the park (Table-1). This significant reduction highlights the growing pressures on the park's biodiversity and the urgent need for conservation efforts.

Bhawal National Park's biodiversity has declined significantly over the past two decades. With native species like *Shorea robusta* under threat, there is an urgent need for conservation actions to prevent further losses and restore the ecological integrity of Bhawal National Park.

Forest cover change in BNP (2005-2020) : Over the period from 2005 to 2020, significant changes in land classes were observed in Bhawal National Park (Rahman *et al.* 2022). The total forest cover area decreased from 4579.2 ha to 2294.79 ha (Figure-2). In contrast, agricultural land has increased dramatically from 274.95 hectares in 2005 to 2064.24 hectares by 2020. Settlement areas have also expanded, reflecting human encroachment. The land class trends indicate a clear shift from forested areas to agricultural and settlement land uses.

Threats to biodiversity in BNP: Bhawal National Park (BNP) has faced a variety of ecological and anthropogenic pressures over the past few decades. These threats have resulted in a significant loss of biodiversity, including the drastic decline in native species and the proliferation of invasive species. Key threats to BNP's biodiversity include deforestation, land-use changes, industrial encroachment, climate change, and the introduction of invasive species (Table-2).

Anthropogenic Factors: Deforestation, primarily driven by illegal logging, agricultural expansion, and human settlements, poses a significant threat to biodiversity in Bhawal National Park (BNP). Rapid urbanization in nearby Dhaka has intensified demand for land and resources, leading to forest clearance for agriculture and infrastructure for human settlement and industry (Alauddin *et al.* 2020). This deforestation disrupts natural habitats, causing notable declines in species richness and diversity, as indicated by reduced tree and shrub populations (Rocha-Santos *et al.* 2017). Over

**Figure 2. Forest cover area of BNP over year 2005-2020.**

recent decades, nearly 70% of forest habitat has been lost, with industrial encroachment and military activities exacerbating the issue. Ground fires, often linked to these activities, destroy valuable flora, including medicinal herbs and shrubs, while firewood collection by local communities depletes essential species like *Shorea robusta*. Industrial establishments within BNP's core zone, such as a denim mill and a spinning mill, fragment habitats and increase pollution, negatively affecting flora and fauna (Roshni *et al.* 2022). Over 150 industries in the buffer zone contribute to habitat degradation and water pollution, further stressing the park's ecosystem. Urban sprawl from Dhaka adds to the pressure, intensifying resource depletion within BNP (Hasan and Karim 2020).

Climate change impacts: Climate change poses a significant threat to the biodiversity of BNP. Changes in temperature and rainfall patterns have altered the phenology of native species, leading to shifts in species distribution and abundance (Mishra *et al.* 2021). From 2017 to 2024, maximum temperatures during the summer months have increased significantly (Figure-4). For instance, April temperatures rose from 33°C in 2017 to 42°C in 2024. These rising temperatures stress moisture-dependent species like *Shorea robusta* and increase the risk of wildfires, threatening plant regeneration and biodiversity (Dhungana *et al.* 2023). Rainfall has steadily declined, particularly during the first half of the year (Figure-3). In 2017, there were 66 rainy days with 237.26 mm of rainfall (January-June), but by 2024, rainfall dropped to 92.7 mm with only 19 rainy days. The decreased water availability exacerbates drought conditions, leading to further stress on plant species and habitat degradation (Akıncı and Lösel 2013).

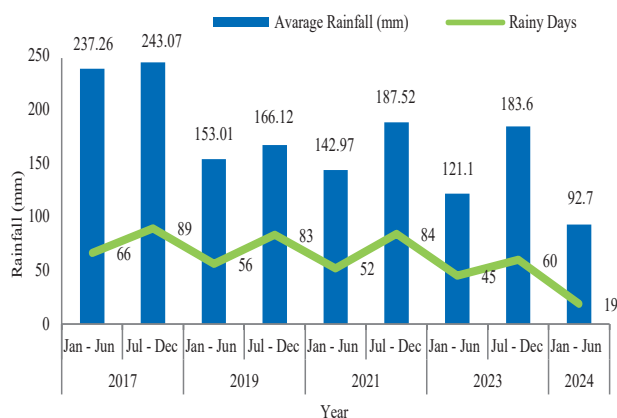


Figure 3. Yearly rainfall (2017-2024) in the study area.

The combination of rising temperatures and reduced rainfall creates drier conditions, threatening flora and fauna (Mantyka-pringle *et al.* 2011). Species requiring moist environments, such as native herbs and shrubs, are particularly vulnerable. Invasive species, resilient to these changes, may increasingly dominate the park's landscape (Mishra *et al.* 2021).

Invasive species: Non-native species such as *Acacia auriculiformis* and *Chromolaena odorata* pose significant threats to BNP's native flora. *Acacia auriculiformis*, a fast-growing species, has dominated some areas, replacing native trees like *Shorea robusta* (Banerjee *et al.* 2023). Similarly, *Chromolaena odorata*, an aggressive shrub, has spread in degraded areas, reducing native shrub and herb diversity (Hasan and Karim 2020; Kabir and Ahmed 2005).

In 2014, reforestation efforts introduced woody perennials like *Acacia hybrid*, *Mangium*, *Eucalyptus*, and *Akashmoni*.

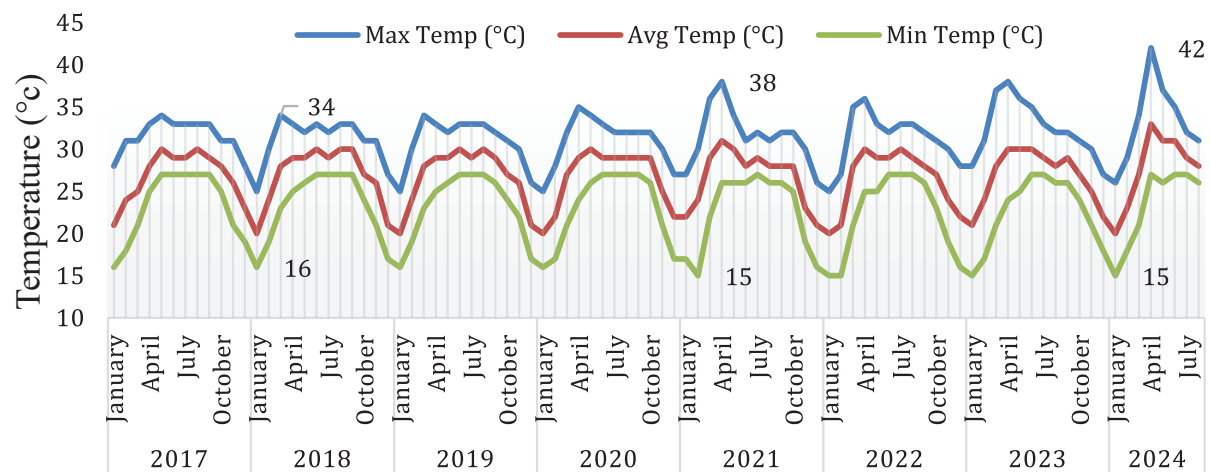
Threat Type Key Drivers Impact Deforestation & Human Activities Illegal logging, agricultural expansion, urbanization, firewood collection, industrialization Habitat loss, species decline, reduced biodiversity Climate Change Impact Rising temperatures, declining rainfall, wildfire risk, altered phenology Disrupted species distribution, increased stress on moisture-dependent plants

Invasive species *acacia auriculiformis*, *Chromolaena odorata*, competition with native flora Outcompete native species, alter soil conditions, reduce biodiversity Forest Encroachment Agricultural practices, illegal settlements, industrialization, military activities, human-wildlife conflict, soil erosion Loss of forest cover, habitat fragmentation, decreased plant diversity While these species grow quickly, they outcompete native plants, further altering soil conditions and reducing biodiversity (Hasan and Karim 2020).

Invasive species disrupt nutrient cycling and water availability, making it difficult for native plants to survive. These resilient species, coupled with changing climate conditions, exacerbate biodiversity loss (Alauddin *et al.* 2020).

Table 2. Key threats to biodiversity of Bhawal National Park.

Threat Type	Key Drivers	Impact
Deforestation & Human Activities	Illegal logging, agricultural expansion, urbanization, firewood collection, industrialization	Habitat loss, species decline, reduced biodiversity
Climate Change Impact	Rising temperatures, declining rainfall, wildfire risk, altered phenology	Disrupted species distribution, increased stress on moisture-dependent plants
Invasive Species	Acacia auriculiformis, Chromolaena odorata, competition with native flora	Outcompete native species, alter soil conditions, reduce biodiversity
Forest Encroachment	Agricultural practices, illegal settlements, industrialization, military activities, human-wildlife conflict, soil erosion	Loss of forest cover, habitat fragmentation, decreased plant diversity

**Figure 4. Yearly temperature data of Bhawal National Park from 2017-2024.**

Forest encroachment: Agricultural practices and illegal settlements within the boundaries of BNP have resulted in significant forest encroachment (Masum *et al.* 2015). The conversion of forested areas into agricultural land for crops like rice and jute has reduced the park's forest cover, disrupted wildlife habitats and decreased plant diversity (Hasan and Karim 2020). Encroachment has also increased the incidence of human-wildlife conflict, further endangering both plant and animal species within the park.

Furthermore, forest encroachment has led to soil erosion and degradation, particularly in areas where traditional slash-and-burn agriculture is practiced. The removal of vegetation exposes the soil to erosion during the monsoon season, resulting in the loss of fertile topsoil and negatively affecting the regeneration of native species (DeVilleneuve *et al.* 2023).

Discussion

The findings from the literatures and surveys of Bhawal National Park are consistent with the global trends, where climate and land use are the major factors driving the changes in biological diversity (IUCN 2002). Species richness generally increases with higher air temperatures and greater precipitation. However, as climate shifts over the next century, biodiversity is expected to change significantly. Under various climate scenarios, many forest types currently adapted to monsoon temperatures are predicted to migrate northward. In contrast, isolated communities of species may face the risk of extinction within their current habitats.

This has serious implications for conservation strategies in protected areas like Bhawal National Park. As evidenced by

the forest cover area changes from 2005 to 2020 (Figure-2), the park has experienced a marked reduction in forest cover, alongside an increase in agricultural and settlement areas. These land-use changes, combined with shifting climate conditions, are likely to accelerate the loss of species and disrupt the ecological balance of the park. The following paragraphs outline the key considerations for conserving the resources of Bhawal National Park (BNP):

Effectiveness of conservation strategies: Community involvement programs like the Integrated Protected Area Co-management (IPAC) initiative have shown potential in engaging local populations in forest management. However, while these programs have reduced illegal logging and forest encroachment in some areas, their long-term success depends on continued funding and local incentives. High poverty levels in surrounding areas continue to drive unsustainable resource extraction (Alauddin *et al.* 2020). Thus, economic alternatives for forest-dependent communities should be prioritized to reduce pressures on BNP's natural resources.

Reforestation efforts, particularly those initiated in 2014, helped stabilize degraded areas, but these initiatives have often focused on fast-growing, non-native species like *Acacia auriculiformis* and *Eucalyptus*, which have limited biodiversity benefits (Hasan and Karim 2020). The dominance of such species has negatively impacted native flora like *Shorea robusta*, which is crucial for the long-term stability of BNP's ecosystem. Future reforestation efforts should prioritize native species to restore ecological balance and enhance biodiversity.

Impact of climate change on species distribution and ecosystem function: Climate change poses a substantial threat to BNP's biodiversity. Rising temperatures and erratic rainfall have altered the ecological balance, with significant impacts on moisture-dependent species such as *Shorea robusta*. Higher temperatures are stressing native species, increasing the risk of wildfires, and shifting species distributions to favor drought-resistant flora. These changes can disrupt the phenology (e.g., flowering and fruiting cycles) of native species, which in turn affects species interactions, pollination dynamics, and overall ecosystem function.

In line with global trends, BNP's biodiversity is expected to shift significantly as climate scenarios evolve. Species once suited to the monsoon climate may become restricted to smaller, more isolated areas, leading to increased extinction risk. Meanwhile, invasive species such as *Acacia auriculiformis*, more resilient to temperature fluctuations and lower water availability, may continue to increase, further altering the park's ecosystem.

Synergistic effects of climate change and land-use alterations: Land-use changes in BNP driven by urbanization, agricultural expansion, and industrial encroachment exacerbate the impacts of climate change on biodiversity. Deforestation and habitat fragmentation have not only reduced the area available for native flora but also increased the park's vulnerability to invasive species and climate variability. For instance, the reduction in forest cover leads to microclimatic shifts, such as increased soil temperatures and reduced humidity, further stressing plant species already coping with climatic changes.

This combination of climate change and land-use alteration creates a feedback loop, where reduced forest cover amplifies climate effects, and vice versa. This feedback accelerates biodiversity loss and disrupts the ecosystem services BNP provides, such as carbon sequestration and habitat provision. Thus, understanding the combined effects of these drivers is crucial for developing effective conservation strategies.

Anthropogenic and industrial pressures: Another significant factor contributing to the degradation of BNP is the presence of industries within and around the park. The presence of industries within and around BNP creates a complex challenge for conservation efforts. While industrial development offers economic benefits, it comes at the expense of significant environmental degradation. The expansion of industries has not only contributed to deforestation and habitat loss but has also contaminated the park's fertile soil and water bodies, further destabilizing the ecosystem. Effective governance and strict implementation of environmental rules and regulations are essential to mitigate these negative impacts (Roshni *et al.* 2022). The need for participatory forestry programs (PFP) and stronger forest governance is evident, particularly in areas with degraded Sal Forests, where

previous management strategies have shown limited success (Roshni *et al.* 2022).

Gaps in research and future conservation needs:

Despite extensive studies on Bhawal National Park (BNP), crucial research gaps persist, limiting the effectiveness of conservation strategies. Much of the existing research centers on the Sal tree (*Shorea robusta*), often overlooking the broader plant diversity, including shrubs, herbs, and climbers. A comprehensive inventory of BNP's vegetation is needed to fully understand its ecological interactions and to design inclusive conservation approaches. Another gap is the absence of long-term monitoring data; without it, assessing biodiversity trends and evaluating the success of conservation initiatives is challenging. Establishing a systematic monitoring program would improve conservation management by supporting adaptive practices.

Although threats like industrial pollution, illegal logging, and tourism have been recognized, detailed studies on their specific impacts on plant communities are limited. Understanding the effects of pollutants and disturbances on various species is essential for developing targeted mitigation strategies. Additionally, the ecology of BNP's water bodies, such as lakes and ponds, remains unstudied, though these aquatic habitats likely play a vital role in the park's biodiversity. This area presents an important avenue for future research.

Research on the impacts of climate change on BNP's vegetation is also minimal. While some studies address its effect on Sal distribution, broader concerns, such as shifts in plant-pollinator interactions, species composition, and phenology, are underexplored. Incorporating climate models into ecological studies would help predict these changes and inform conservation strategies. Addressing these gaps will deepen our understanding of BNP's ecological dynamics and support more effective, evidence-based conservation practices.

Strategies for floral conservation in BNP: Floral conservation in Bhawal National Park (BNP) requires a multifaceted approach, addressing both ecological and socio-economic factors. Below are several strategies aimed at preserving the park's unique biodiversity:

Prioritize the conservation of *shorea robusta* (Sal):

Instead of replacing *Shorea robusta* with other species, efforts should focus on increasing the productivity of Sal forests, as they are the species' natural habitat. Research shows that protected Sal coppices can be more productive per hectare than block plantations.

Agroforestry over woodlots: Agroforestry, which integrates trees and agriculture, should be prioritized over traditional woodlot management, as it offers a more financially viable solution and helps maintain biodiversity.

Replant with native species: Reforestation efforts should prioritize native species, particularly *Shorea robusta*, and its natural associates, including *Terminalia bellerica*, *Dillenia pentagyna*, *Albizia procera*, and *Lagerstroemia parviflora*, to maintain ecological balance.

Protect and study medicinal plants: BNP's Sal forests host a variety of medicinal plants. Identifying, protecting, and studying these plants can not only preserve biodiversity but also provide socio-economic benefits.

Mitigate anthropogenic disturbances: High levels of human disturbance, coupled with the introduction of invasive species, are detrimental to biodiversity. Reforestation efforts should avoid using fast-growing, non-native species that could threaten the natural flora and fauna.

Preserve old-growth forests: Old-growth forests tend to support higher species diversity than younger plantations, particularly in areas with moderate anthropogenic disturbance. Protecting these forests is crucial for maintaining biodiversity.

Engage local communities: Engaging local communities through co-management approaches can empower them to protect natural resources while also benefiting from sustainable practices. This can be key to ensuring long-term conservation success.

Address historical management challenges: Learning from past management mistakes is essential. For instance, the introduction of bamboo to BNP and the large-scale planting of exotic species have proven ineffective. Furthermore, picnicking and other recreational activities within BNP have contributed to its degradation.

Strengthen capacity and resources: Addressing the lack of well-trained human resources and securing political, legal, and financial support is crucial for effective management. Implementing well-researched, long-term conservation strategies requires adequate funding and political backing.

Conclusion

The review of floral dynamics and biodiversity threats in Bhawal National Park (BNP) highlights the urgent need for strategic conservation efforts. The park's Sal forests and diverse ecosystems are under immense pressure from deforestation, habitat fragmentation, industrial encroachment, and invasive species. These threats, compounded by the impacts of climate change, such as rising temperatures and erratic rainfall are altering species composition and stressing BNP's fragile ecosystems. The combined effects of natural and anthropogenic factors are accelerating the decline of native flora, disrupting habitats, and reducing biodiversity.

Conservation efforts so far have been inconsistent, with some interventions proving counterproductive. The large-scale planting of non-native species and the introduction of unsuitable flora, such as bamboo, have disturbed the park's natural balance. Industrial and recreational activities within BNP further degrade its habitats. However, opportunities remain for reversing these trends through sustainable management practices. A holistic approach combining ecological restoration, community involvement, and effective governance will be essential to preserve BNP's floral diversity. With timely interventions and adequate support, the park can continue to serve as a vital refuge for biodiversity in Bangladesh, safeguarding its natural heritage for future generations.

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Appendix 1. Species Checklist for Bhawal National Park (BNP): This checklist presents the tree, shrub, herb, and climber species identified in Bhawal National Park (BNP) during the survey conducted in 2024. The species

are categorized based on their local names, scientific names, family, and their place of occurrence in the park—whether in the sal forest, cultivated lands, or near human settlements.

Sl. no	Local name	Scientific name	Family	Place of occurrence		
				Sal forest	Cultivated land	Human settlement
1	Sal	<i>Shorea robusta</i>		√		
2	Garjan	<i>Dipterocarpus indicus</i>	Dipterocarpaceae	√		
3	Telsur	<i>Hopea odorata</i>		√		
4	Ata	<i>Annona squamosa</i>		√		√
5	Nona	<i>Annona reticulata</i>		√		√
6	Fonseti	<i>Alphonsea lutea</i>		√		
7	Gandhi gajari	<i>Miliusavelutina</i>	Annonaceae	√		
8	Debdaru	<i>Polyalthia longifolia</i>		√		√
9	Kuti kadam	<i>Miliusavelutina.</i>		√		
10	Pine	<i>Pinus carabiana</i>	Pinaceae	√		
11	Nagasher	<i>Maesa nagesarium</i>	Primulaceae	√		
12	Akashmoni	<i>Acacia auriculiformis</i>		√		√
13	Sonalu	<i>Acacia mangium</i>		√		√
14	Polash	<i>Butea monosperma</i>		√		
15	Radachura	<i>Caesalpinapulcherima</i>		√		√
16	Mingeri	<i>Cassia siamea</i>		√		√
17	Korai	<i>Albizia procera</i>		√		√
18	Asoke	<i>Saraca indica</i>		√		
19	Babla	<i>Acacia nilotica</i>		√		
20	Krishnochura	<i>Delonix regia</i>				√
21	Ban sonalu	<i>Cassia nodosa</i>	Fabaceae	√		
22	Sherish	<i>Albizia lebbeck</i>				√
23	Bador Lathi	<i>Cassia fistula</i>				√
24	Kalo korai	<i>Albizia odoratissima</i>				√
25	Shil korai	<i>Albizia procera</i>				√
26	Sisoo	<i>Dalbergia sisoo</i>		√		
27	Raintree Koroi	<i>Samanea saman</i>				√
28	Mander	<i>Erythrina variegata</i>				√
29	Tetul	<i>Tamarindus indica</i>				√
30	Mander	<i>Erythrina indica</i>				√

Sl no	Local name	Scientific name	Family	Place of occurrence		
				Tree	Sal forest	Cultivated land Human settlement
31	Belatikoroi	<i>Albizia odoratisema</i>	Fabaceae	√		√
32	Sheild koroī	<i>Albizia lucidia</i>			√	√
33	Sherish Koroī	<i>Albizia lebbeck</i>				√
34	Champa	<i>Bauhinia variegata</i>		√		√
35	Jam	<i>Syzygiumcumini</i>	Myrtaceae			√
36	Golap Jam	<i>Syzygiumjambos</i>		√		√
37	Eucalyptus	<i>Eucalyptus spp.</i>		√		√
38	Ban Jam	<i>Eugenia fruticosa</i>				√
39	Payera	<i>Psidium guajava</i>	Sapotaceae			√
40	Bakul	<i>Mimusopselengi</i>		√		√
41	Agar	<i>Aquilaria agalloca</i>	Thymelaeaceae	√		
42	Chalta	<i>Dillenia indicum</i>	Dilleniaceae			√
43	Kurchi	<i>Holarrhenaantidysestrica</i>	Apocynaceae			√
44	Satim	<i>Alastoniascholaris</i>				√
45	Dudhi	<i>Wrightia tomentosa</i>		√		√
46	Ghora Nim	<i>Melia samperbirans</i>				√
47	Deshi Nim	<i>Azadirachta indica</i>	Meliaceae			√
48	Boro Mehogoni	<i>Swietenia macrophylla</i>		√		
49	Mehogoni	<i>Swietenia mahagoni</i>		√		√
50	Royana	<i>Aphanamixispolystachya</i>				√
51	Bot	<i>Ficus bengalensis</i>	Moraceae	√		√
52	Chapalish	<i>Artocarpus chaplasha</i>				√
53	Pakur	<i>Ficus religiosa</i>				√
54	Jag Dumur	<i>Ficus recemosa</i>				√
55	Sheora	<i>Streblus aspera</i>	Anacardiaceae			√
56	Dehua	<i>Artocarpus lacucha</i>				√
57	Dumor	<i>Ficus hispida</i>		√		√
58	Kathal	<i>Artocarpus heterophyllus</i>				√
59	Amm	<i>Mangifera indica</i>	Arecaceae			√
60	Ziga	<i>Lanneacoromandelica</i>		√		√
61	Amra	<i>Spondius pinnata</i>		√		
62	Kakuasingh	<i>Rhus succedanea</i>		√		
63	Khajur	<i>Phoenix dactylifera</i>	Ebenaceae			√
64	Tal	<i>Borassus flabellifer</i>				√
65	Narikel	<i>Cocos nucifera</i>				√
66	Desi Gab	<i>Diospyros peregrina</i>				
67	Gab	<i>Diospyros spp.</i>	Oxalidaceae			
68	Kamranga	<i>Averrhoa carambola</i>				√

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		Sal forest	Cultivated land	Human settlement
69	Arjun	<i>Terminalia arjuna</i>		√		√
70	Kat Badam	<i>Terminalia catappa</i>	Combretaceae	√		
71	Hartoki	<i>Terminalia chebula</i>		√		
72	Bohera	<i>Terminalia bellerica</i>		√		
73	Shemul	<i>Salmaliamalabaricum</i>	Malvaceae			√
74	Shemul Tula	<i>Bombax ceiba</i>				
75	Sajna	<i>Moringa olitera</i>	Moringaceae			√
76	Kadam	<i>Anthrocephalus chinensis</i>	Gentianaceae			√
77	Jarul	<i>Lagerstroemia speciosa</i>	Lythraceae	√		√
78	Amloki	<i>Emblica officinalis</i>	Phyllanthaceae	√		
79	Kamela	<i>Mallotusphilippinensis</i>	Euphorbiaceae	√		
80	Ban Borai	<i>Zizyphus jujuba</i>	Rhamnaceae	√		
81	Baroi	<i>Zizyphusmauritiana</i>		√		
82	Bel	<i>Aegle marmelos</i>	Rutaceae			√
83	Jambura	<i>Citrus grandis</i>				
84	Bhui Kadam	<i>Hymenodictyonexcelsum</i>	Rubiaceae			√
85	Polash	<i>Adina cordifolia</i>		√		
86	Lichu	<i>Litchi cinensis</i>	Sapindaceae			√
87	Shegun	<i>Tectona grandis</i>	Oleaceae	√		
89	Bonak	<i>Schima wallichii</i>	Theaceae	√		√
Shrub						
1	Akanda	<i>Calotropis procera</i>	Apocynaceae			√
2	Nishinda	<i>Vitex negundo</i>	Oleaceae	√		
3	Dadmortan	<i>Cassia alata</i>	Fabaceae			√
4	Ban jam	<i>Ardisia solanacea</i>	Primulaceae			√
5	Jaba	<i>Hibiscus rosa-sinensis</i>				√
6	Bonghagra	<i>Urena lobata</i>	Malvaceae	√		
7	Dat majon	<i>Glycomis arborea</i>	Rutaceae			√
8	Khudi Jam	<i>Antidesmaghaesembilla</i>	Phyllanthaceae			√
9	Bilimbi	<i>Averrhoa bilimbi</i>	Oxalidaceae			√
10	Sitka	<i>Clerodendrum inerme</i>	Lamiaceae			√
11	Ulatkombal	<i>Abroma augusta</i>	Sterculiaceae			√
12	Dalim	<i>Punica grantum</i>	Lythraceae			√
13	Bala Dumur	<i>Ficus heterophylla</i>	Moraceae	√		√
14	Kola	<i>Musa sapientum</i>	Musaceae			√
15	Pepe	<i>Carica papaya</i>	Caricaceae		√	
16	Mushanda	<i>Mussendaroxburghii</i>	Rubiaceae	√		

Sl no	Local name	Scientific name	Family	Place of occurrence		
Tree				Sal forest	Cultivated land	Human settlement
17	Ban tejpatha	<i>Melastomamalabathricum</i>	<i>Melestomataceae</i>	√		
18	Tola Bas	<i>Bambusa tulda</i>		√		√
19	Basni Bas	<i>Bambusa vulgaris</i>	<i>Poaceae</i>	√		√
20	Muli Bas	<i>Melicannebaccifera</i>		√		√
Herb						
1	Sheal Kata	<i>Argemone mexicana</i>	<i>Papaveraceae</i>	√		√
2	Bhat	<i>Clerodendrum viscosum</i>		√		
3	Tulshi	<i>Ocimum sanctum</i>	<i>Lamiaceae</i>	√		
4	Ban tulshi	<i>Ocimum americanum</i>		√		
5	Teki Lata	<i>Stenchaena palustris</i>	<i>Blechnaceae</i>			√
6	Shetodrum	<i>Laucacephalotes</i>	<i>Arecaceae</i>		√	
7	Dolkolmi	<i>Ipomoea fistula</i>	<i>Convolvulaceae</i>		√	
8	Pitraj	<i>Aphanamixiaspolystachia</i>	<i>Meliaceae</i>		√	√
9	Dutura	<i>Duturametel</i>		√	√	
10	Ban tamak	<i>Nicotiana plumbaginifolia</i>	<i>Solanaceae</i>	√	√	
11	Forgacha	<i>Hoya parasitica</i>	<i>Apocynaceae</i>	√		
12	Kalomegh	<i>Andrgraphis paniculata</i>			√	
13	Jagatmorthon	<i>Justicia gendarusa</i>	<i>Acanthaceae</i>		√	
14	Bashak	<i>Adhatoda zeylanica</i>				√
15	Thankuni	<i>Centella asiatica</i>	<i>Apiaceae</i>		√	√
16	Hati Chara	<i>Elephantopus scaber</i>		√		√
17	Pesah	<i>Eupatorium odoratum</i>	<i>Asteraceae</i>	√		
18	Kumarialata	<i>Smilax zeylanica</i>	<i>Smilacaceae</i>	√		
19	Kachu	<i>Amaranthus gangeticus</i>	<i>Acanthus</i>		√	
20	Upathlengha	<i>Achyranthes aspera</i>	<i>Amaranthaceae</i>			
21	Pithapata	<i>Peperomia pellucida</i>	<i>Piperaceae</i>		√	√
22	Nilshapla	<i>Nymphaea nouchali</i>				√
23	Lal shapla	<i>Nymphaea rubra</i>	<i>Nymphaeaceae</i>	√		√
24	Mukhi kochu	<i>Pueraria phaseoloides</i>			√	√
25	Khesari	<i>Lathyrus sativus</i>	<i>Fabaceae</i>	√		
26	Alkushi	<i>Mucuna pruriens</i>		√		
27	Deotara	<i>Alpinia malaccensis</i>		√		
28	Ban haldi	<i>Curcuma aromatica</i>	<i>Zingiberaceae</i>	√		
29	Bon ada	<i>Zingiber zerumbet</i>		√		
30	Kachuripana	<i>Eichhornia crassipes</i>	<i>Pontederaceae</i>		√	√
31	Watermoss	<i>Salvinia auriculata</i>		√		√

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		Sal forest	Cultivated land	Human settlement
			Climber			
1	Anantamul	<i>Hemidesmus indicus</i>	<i>Apocynaceae</i>	√		
2	Sham Lata	<i>Ichnocarpus fruticens</i>		√		
3	Gojpipul	<i>Scindapus officinalis</i>	<i>Araceae</i>	√		
4	Jali Bet	<i>Calamus viminalis</i>		√		
5	Karak Bet	<i>Calamus latifolius</i>		√		
6	Kadam Bet	<i>Calamis erectus</i>	<i>Arecaceae</i>	√		
7	Sundi Bet	<i>Calamus guruba</i>		√		√
8	Gola Bet	<i>Daemonorops jenkinsianus</i>		√		
9	Assam Lata	<i>Mikania cordata</i>	<i>Asteraceae</i>	√		
10	Gila Lata	<i>Derris trifoliata</i>	<i>Fabaceae</i>	√		
11	Bish lata	<i>Millettia pachycarpa</i>		√		
12	Pipul Lata	<i>Piper longum</i>	<i>Piperaceae</i>	√		
13	Kanchan Lata	<i>Bauhinia nervosa</i>		√		
14	Shatamuli	<i>Asparagus racemosus</i>	<i>Asparagaceae</i>	√		
15	Telakucha	<i>Coccinia cordifolia</i>	<i>Cucurbitaceae</i>	√		
16	Makal	<i>Trichosanthes bracteata</i>		√		

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