BJAR

Volume 48 Number 4

Bangladesh Journal of

Agricultural Research

Please visit our website : www.bari.gov.bd

BANGLADESH JOURNAL OF AGRICULTURAL RESEARCH

Vol. 48　　　　　**December 2023**　　　　　**No. 4**

C O N T E N T S

NUTRITIONAL PROFILING OF AVOCADO (*Persea americana)* CULTIVARS CULTIVATED IN BANGLADESH

M. S. Hossain[1], M. Z. Rahman[2], N. A. Jeany[3]
M. B. Rahman[4] and M. M. Masud[5]

Abstract

The rising demand for avocado fruit from its recognized nutritional value which has significant positive impacts on human health. The current investigation was undertaken to analyze the nutritional values, chemical composition, fatty acids profile and minerals content of avocado fruit cultivars cultivated in Bangladesh. The findings revealed varying levels of key components across different cultivars where cultivar PA-Joy002 had a higher content of dry matter 30.92%, total soluble solids 7.31° Brix, oil 18.57%, crude protein 4.44%, carbohydrate 4.14%, and fibre 4.50% than the BARI released var. BARI Avocado-1. The major fatty acids profile of pulp-oil of avocado cultivar PA-Joy002 revealed that the oil contained high amount of oleic acid 35.99%, linoleic acid 25.02%, palmitic acid 28.25%, palmitoleic acid 9.85%, and lenolenic acid 2.30%, respectively. Moreover, cultivar PA-Joy002 contained significantly higher amount of unsaturated (UFAs, 71.35 %) fatty acids than saturated (SFAs, 32.58 %) fatty acids, and the ratio of UFAs to SFAs was also higher 2.19. The results also indicated that 100 g of dry pulp of avocado sample contains calcium 861.19 mg, potassium 1374.63 mg, magnesium 503.02 mg, phosphorus 341.14 mg, sodium 7.10 mg, iron 9.30 mg, and zinc 3.72 mg of the same cultivar. Findings of this study indicated that cultivar PA-Joy002 was nutritionally rich and promising to use as a functional food due to their high content of nutritional elements, essential fatty acids and minerals, and versatile applications of its pulp.

Introduction

Avocado (*Persea americana* Mill.*)* a member of the Lauraceae family, is gaining popularity worldwide due to its exceptional nutritional composition and health benefits. In Bangladesh, although relatively new, its' demand is steadily increasing owing to its recognized nutraceutical properties and positive impacts on human health or multiple application (Ge *et al.*, 2017b). The sweet and pleasant taste of mature avocado pulp makes it a popular food choice. Scientific studies have consistently highlighted the health benefits of avocado oil, often drawing parallels

[1]Senior Scientific Officer, Central Laboratory, Research Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, [2]Senior Scientific Officer, Horticulture Research Centre, BARI, Gazipur, Bangladesh, [3]Scientific Officer, Central Laboratory, Research Wing, BARI, Gazipur, Bangladesh, [4]Senior Scientific Officer, Research Wing, BARI, Gazipur, Bangladesh, [5]Senior Scientific Officer, Soil Science Division, BARI, Gazipur, Bangladesh.

between its nutritional properties and those of olive oil. Consumption of avocado oil has been linked to favorable changes in blood lipid profiles, including decreased levels of low-density lipoproteins and increased levels of high-density lipoproteins. These changes contribute to lower blood triglycerides levels, thus reducing the risk of vascular disease (Gokkaya *et al.,* 2021). Moreover, avocados are esteemed for their high mineral content, with notable levels of potassium (K), magnesium (Mg), phosphorus (P) and calcium (Ca) found in the pulp (Arackal and Parameshwari, 2021). This minerals composition offers several health benefits; K and Mg aid reducing hypertension and preventing cardiovascular diseases, and alleviate symptoms of asthma and migraine attacks (Dembitsky *et al.,* 2011). Phosphorus is involved in various biological processes; and Ca is essential for proper functioning of the human body (Ciosek *et al.,* 2021). Avocado fruit is reach in lipids, comprising up to 10% to 25% of its fresh weight (Ge *et al.,* 2017a), with a significant portion being unsaturated fatty acids (60 to 65%) like linoleic, palmitoleic, linolenic acids, known for their health benefits (Ramos-Aguilar *et al.,* 2019). The consumption of monounsaturated fatty acids such as oleic acids contributes to reducing blood pressure, preventing body weight increase, and controlling the development of hyperglycemia (Yang *et al.,* 2011). Various factors affect the chemical composition of avocados, including cultivation location, cultivar type, maturity condition, and fruit part measured (Nasri *et al.,* 2021; Ramos-Aguilar *et al.,* 2021). The economic value of avocados as a promising crop in Bangladesh, it is required to undertake a comparative analysis of the chemical differences between avocado cultivars based on its nutritional value. Hence, this study aims to determine and compare the major constituents of the avocado variety and promising cultivar available in Bangladesh.

Materials and Methods

Experiments were carried out with two avocado cultivars, BARI Avocado-1 and PA-Joy002, which were domestically grown in Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur. Upon reaching proper maturity, fruit samples were collected and analyzed at Central Laboratory, Research Wing, BARI, Gazipur. All the fruits were washed with fresh water, and sanitized with 1% chlorine solution, and selected according to the absence of injuries. Subsequently, the fruits were cut into half and separated into the pulp, peel and core. The fruit samples were preserved in refrigerator maintaining at 5°C to 6°C temperature. The pulps were separated from the fruits, homogenized and mashed using a blender. The samples were oven dried at 70°C until getting constant weight, and then stored at 4°C for a maximum of one week before analysis.

Determination of moisture and dry matter of avocado fruit pulp

The moisture content of the samples was determined, following the method outlined by the Association of Official Analytical Chemists (AOAC, 1990). Ten gram of fresh pulp was weighed and dried in an oven at 70ºC for 16 h. The data

were calculated by determining the difference in weight and reported as percentages. The dry matter was calculated by determining differences in the percentages of humidity.

Measurement of total soluble solid

A Pocket Pal-1 portable digital refractometer (Atago, USA), with a scale from 0 to 35°Brix, was used to determine the total soluble solids of the samples. The readings were taken directly from the equipment and the results were expressed in °Brix (method ADAC 925.09) (Latimer, 2016).

Extraction of oil from pulps and determination of percentage yield

Oil content was estimated using the method described by Ge *et al.,* (2017b). Nine mature fruits were randomly collected from each cultivar, and the pulps were separated and mixed respectively. The homogenized pulps were dried in an oven at 70°C for 12 h and ground into powder. The dried powder (5 g) was put into the round bottom flask and 100 ml of solvent petroleum ether was added. The mixture was transferred into the Soxhlet extractor and the oil was extracted. Finally, the extracted solutions were evaporated using a rotary evaporator, and the residue was weighed. The percentage oil yield was determined as:

$$\% \text{ oil yield} = W_{oil} / W_{pulp} \times 100$$

Determination of proximate composition of pulp

Proximal analysis was carried out using the methods described by AOAC, 1990. Fiber content was determined by weighing 2 g of each sample in porous glass crucibles and placing them in a automated fiber analyzer (Fibertec 8000, FOSS, Hillerod, Denmark); the samples were subjected to acid digestion (sulfuric acid 1.25% v/v) and alkaline digestion (NaOH 1.25% v/v) for 1 h. After this time, the samples underwent a washing process with distilled water; the crucibles with the digested samples were removed and placed in an oven at 105°C for 1 h. Finally, they were placed in a desiccator, cooled and weighed, and were expressed the results as percentage. In terms of protein content, 1 g of each sample was weighed in a tube, and 2 tablets of catalyst mixture (Na_2SO4 + $CuSO_4$) and 15 ml of concentrated sulfuric acid were added. The tubes were placed in a digestion block and heated at 400°C for 1 h and were cooled. They were placed in a protein analyzer (Kjeltec model 8400, FOSS, Denmark) where distillation and titration were carried out, and the results were expressed as percentage. Carbohydrate content was determined anthrone colorimetric method by AOAC, 935.08. The absorbance of the samples and standard were read from a spectrophotometer at 630 nm against the blank. To determine the ash content, 2 g of each sample was weighed using porcelain crucibles with a 25 ml capacity, and subjected to a calcination process at 500°C in a muffle (48000, Thermolyne, Dubuque, IA, USA) for 12 h. The calcinated samples were cooled for 1 h and transferred to desiccators.

After that, each crucible was weighed. The ash content was calculated by determining the difference in weight.

Determination of fatty acid composition of oil from pulps

Fatty acid extraction procedure was previously described by the authors Hossain *et al.,* 2023. The fruit pulp powder (1 g) was treated with 5 ml of ethylated reagent and vortex a tubes, and were kept in overnight at normal temperature. After, then 5 ml of salt solution was added and mixed well. The upper oily layer was transferred to a capped and labeled glass vial for gas chromatography (GC) analysis. Chromatographic analysis of the fatty acid methyl esters (FAMEs) from the samples was conducted using a gas chromatograph (Thermo Scientific Company) apparatus equipped with an auto sampler, flame–ionization detector (FID) and supelco wax column (30 m x 0.25 μm film coating). The samples (2 μl) were injected with helium (1.2 ml/min) as a carrier gas, which was programmed for operating conditions such as column oven temperature 160°C @ with subsequent increase of 3°C/min until 180-220°C. Split ratio was 50% with injector 240°C and detector 250°C temperatures. The peak areas and total fatty acids composition were calculated for each sample by retention time using Thermo Scientific software. The standards of fatty acids methyl esters purchased from Sigma-Aldrich were also run under the same conditions for comparison with experimental samples. For calculation, the fatty acids were normalized to 100%, considering the composition (moles %) from fatty acid data (area %) and was expressed as percentage of total fatty acid methyl ester in the oil.

Mineral content of pulp

A mineralization process was applied to the samples according to the method proposed by Petersen, 2002. The dry pulp samples (1 g) were treated with conc. nitric (HNO_3) and perchloric acid ($HClO_4$) kept in normal temperature at overnight. The solution was digested at 160°C to 240°C, cooled, diluted to an appropriate concentration, and filtered. This filtrate was considered as the stock solution for further analysis. Ca and Mg were determined by KCl extractable method. K, Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction followed by Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Japan). Boron (B) was determined by $CaCl_2$ extraction method. P was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. Individual minerals were quantified by comparing the corresponding standard mineral procured from the Sigma Aldrich Chemical Co., USA.

Statistical analysis

Data obtained for each analysis were expressed in triplicate. Mean values and standard deviation (SD) were used to express the results. Data was analyzed by One-way analysis of variance (ANOVA) using Turkey Multiple Comparisons Test by 5% level of significance.

Results and Discussions

Moisture and dry matter:

Moisture content is a key indicator of fruit maturity and perishability, with lower moisture content often indicating greater ripeness and longer shelf life (Kassim *et al.,* 2013). In present study, moisture content ranged from 69.08 to 71.44% in PA-Joy002 and BARI Avocado-1 cultivars (Table 1). Correspondingly, dry matter content was observed to be 28.56% in BARI Avocado-1 and 30.92 % in PA-Joy002 cultivar, respectively. Notably, dry matter content serves as a significant (P<0.05) for avocado fruits ripeness. As fruits mature, their oil content typically increases, leading to a rise in total dry matter. The dry matter concentration of avocado fruit pulp is wide contrast, varying from less than 20% for not good-tasting fruit that should be excluded for consumption to greater a 35% in fruit that is potentially appropriate for food processing treatments (Clark *et al.,* 2007). Consistent with existing literature, dry matter content in flesh avocado fruits in the study fell within a wide range from 13.25 to 31.4%, influenced by factors such as harvest date, region, and cultivar (Nair and Chandran, 2018).

The total soluble solids in fresh avocado pulp

The total soluble solids (TSS) content of both cultivars were similar. The TSS content was found 6.56°Brix in BARI Avocado-1 and 7.31°Brix in PA-Joy002 cultivar, respectively (Table 1). Among the various components of fruit, the total soluble solids (i.e., the percentage of solids that are dissolved in the matrix of the food) in °Brix, have a primary role in their quality due to the influence on thermophysical, chemical, and biological properties. It is also a parameter which tends to increase with the progress of ripening due to the biosynthesis of the plant and degradation of polysaccharides. As expected, given that this physico-chemical parameter represents one of the best ways to evaluate the degree of sweetness of the fruit, and the fruit pulp is the only edible part of the avocado. The TSS are higher in the pulp. The suggestion to use TSS as indication for fruit ripeness, quality, and sweetness sprang from a desire for an accessible and rapid analytical method to assess sugar concentration. The findings align closely with those of El-Moniem *et al.,* (2022), who reported a TSS value of 9.50°Brix in avocado fruit.

The proximate analysis of avocado pulp

Avocado fruits are renowned for their high oil content compared to other fruits and vegetables. Table 1 illustrates the oil content of the flesh in the avocado cultivars revealing significant differences (P <0.05) between them. PA-Joy002 exhibited higher oil content (18.57% on the wet basis) compared to BARI Avocado-1 (16.26% on the wet basis). Variability in oil content among avocado cultivars is well-documented in the literature, with reported ranges from 8 to 25% depending on factors such as cultivar, environment and agricultural practices (Magwaza and Tesfay, 2015). Furthermore, when considering dry weight, the oil

content of avocado flesh can be 70%, with variations attributed to factors like regions of growth, cultivar, maturing and ripening season, harvest times, agricultural and climatic factors, time of picking and portion of fruit (Ferreyra *et al.,* 2016). The ash contents were also similar (P>0.05) with values of 1.64% (in BARI Avocado-1) and 1.58% (in PA-Joy002). The crude fiber contents of the two cultivars were similar and BARI Avocado-1 and PA-Joy002 were values of 4.02% and 4.50%, respectively (Table 1). These results are high as compared to the presented by Krumreich *et al.,* (2018).The protein content of both cultivars showed no significantly difference (P>0.05) with values of 4.44% and 4.25% of BARI Avocado-1 and PA-Joy002, respectively. Carbohydrate content varied between the cultivars, with values of 3.37% BARI Avocado-1 and 4.14% for PA-Joy002 (Table 1).

Table 1. Chemical composition (DW) of the pulp of avocado cultivars

Nutritional components	BARI Avocado-1	PA-Joy002
Moisture (%)	71.44 ± 1.15a	69.08 ± 0.94a
Dry matter (%)	28.56 ± 0.92b	30.92 ± 0.89a
TSS (°Brix)	6.56 ± 0.44a	7.31 ± 0.29a
Crude Fat/lipid (%)	16.26 ± 1.14b	18.57 ± 1.63a
Crude Protein (%)	4.44 ± 0.53a	4.25 ± 0.76a
Crude Fiber (%)	4.02 ± 0.72a	4.50 ± 0.47a
Ash (%)	1.64 ± 0.27a	1.58 ± 0.22a
Carbohydrate (%)	3.37 ± 0.48a	4.14 ± 0.27a

- Values (Mean ± standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at P<0.05.

Fatty acid composition of avocado fruits

Regarding fatty acids composition of the avocado cultivars were presented in Table 2. The major fatty acids in the avocado pulp oil quantified in the present study palmitic acid (32.86% and 28.25%), linoleic acid (22.82% and 25.02%), oleic acid (30.27% and 35.99%), and intermediate amounts of palmitoleic acid (9.85% and 8.04%), linolenic acid (1.89% and 2.30%), and stearic acid (1.90% and 1.45%) were found in BARI Avocado-1 and PA-Joy002 cultivars (Table 2, Fig 1, and Fig 2). Small amounts of arachidic acid (0.19% and 0.37%) and myristic acid (0.26% and 0.51%) were also found in the same cultivars. Palmitic and stearic acids are the predominant saturated fatty acids among the interesterified fats, and they have been related to cholesterol levels in the body (Van Rooijen *et al.,* 2020). Oleic acid has beneficial effects for human health, such as reducing blood pressure, bad cholesterol levels (Lopez-Huertas, 2010) and thus, food consumption, which also means avoiding obesity (Tutunchi *et al.,* 2020). The present results, palmitic, palmitoleic, oleic and linoleic acids were observed dominant fatty acids in avocado pulp oil of present results (Fig 1 and Fig 2) and were found similar results reported by Rohman *et al.,* 2016. However, more than 65 to 71% of the total fatty acids

(TFA) in the avocado pulp oil were unsaturated, with the remaining 30 to 35% being saturated (Table 2). The total content of unsaturated fatty acids (ΣUFA) 64.83% in BARI Avocado-1 and 71.35% in PA-Joy002 cultivars. The total content of saturated fatty acids (ΣSFA) varied between 35.21% in BARI Avocado-1 and 32.58% in PA-Joy002. The polyunsaturated fatty acids content was less than 30%. This value can be considered good for the stability of the oil because the double bonds in fatty acids are susceptible to oxidation. Among these studied, PA-Joy002 highest value of polyunsaturated fatty acids (27.32%), and BARI Avocado-1 lowest value (24.71%). According to Salgado *et al.,* (2008b), the fatty acid composition of avocado oil confirms the possibility of using it as a substitute for olive oil or as a raw material by the food industry, due to its physicochemical similarity and taste. On the other hand, the ΣUFA/ΣSFA ratios in the avocado cultivars ranged from 1.85 to 2.19, which were in accordance with those of the Collinson and Barker cultivars but below that of the Fortuna cultivar (3.49) (Galvao *et al.,* 2014).

Table 2 Fatty acid profile of oil from avocado cultivars.

Fatty acids	Content (%)	
	BARI Avocado-1	PA-Joy002
Monounsaturated fatty acids (MUFA)		
Oleic/ω-9 ($C_{18:1}$)	$30.27 \pm 1.71b$	$35.99 \pm 1.69a$
Palmitolic ($C_{16:1}$)	$9.85 \pm 0.37a$	$8.04 \pm 0.59b$
Polyunsaturated fatty acids (PUFA)		
Lenoleic/ω-6 ($C_{18:2}$)	$22.82 \pm 1.84a$	$25.02 \pm 1.48a$
Lenolenic/ω-3 ($C_{18:2}$)	$1.89 \pm 0.04a$	$2.30 \pm 0.22b$
Saturated fatty acids (SFA)		
Palmitic ($C_{16:0}$)	$32.86 \pm 1.28a$	$28.25 \pm 1.35b$
Stearic ($C_{18:0}$)	$1.90 \pm 0.06a$	$1.45 \pm 0.09b$
Myristic ($C_{14:0}$)	$0.26 \pm 0.03b$	$0.51 \pm 0.08a$
Arachidic ($C_{20:0}$)	$0.19 \pm 0.03b$	$0.37 \pm 0.04a$
ΣSFA	35.21	32.58
ΣMUFA	40.12	44.03
ΣPUFA	24.71	27.32
ΣUFA	64.83	71.35
ΣUFA/ ΣSFA	1.85	2.19

* ΣSFA = total saturated fatty acids; ΣUFA = total unsaturated fatty acids; ΣMUFA = total monounsaturated fatty acids; ΣPUFA = total polyunsaturated fatty acids. Values (Mean $\pm$ standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at $P<0.05$. % (w/w) dry matter basis.
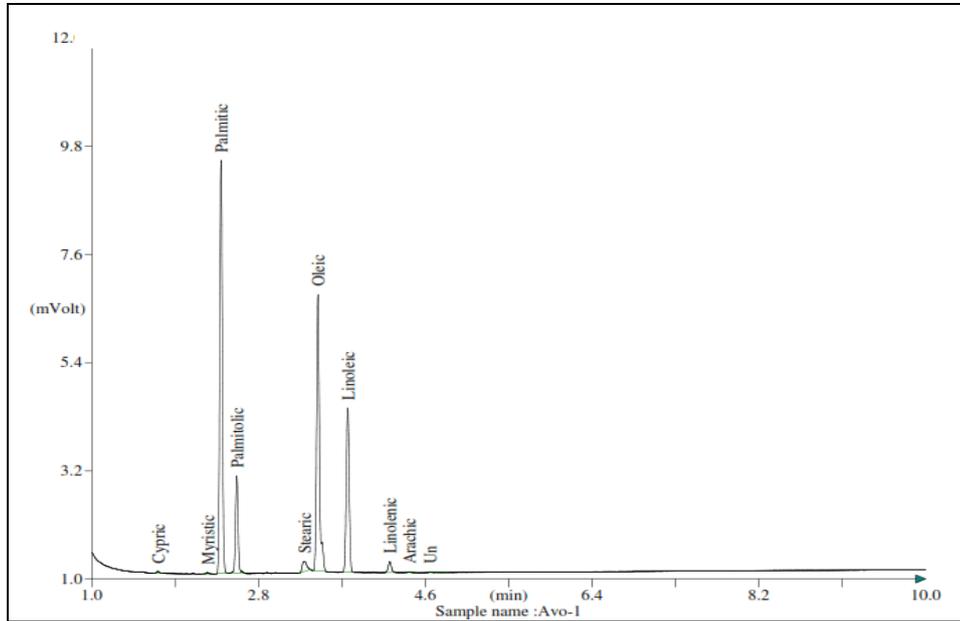
Fig 1. Chromatogram of fatty acid composition of the pulp oil of BARI Avocado-1,
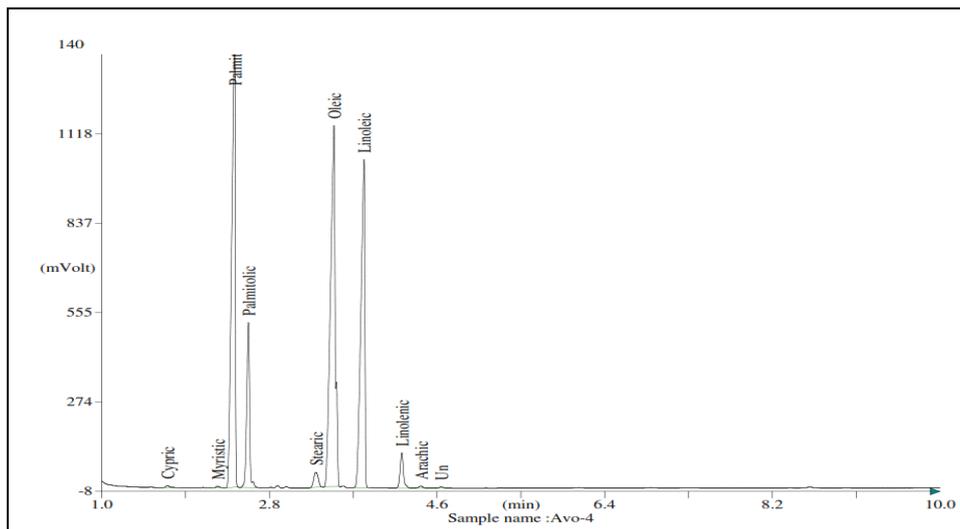
Fig 2. Chromatogram of fatty acid composition of the pulp oil of PA-Joy002 cultivar.

Mineral content of avocado fruit pulp

Minerals are essential inorganic substances needed at a certain amount for the proper functioning of human cells. Mineral composition of the two different samples of avocado pulp is shown in Table 3, for comparison of the results obtained with avocado selected lines and variety values are also included. The

average results indicated that 100 g of dry pulp of avocado sample contains calcium (838.03 and 861.19 mg), potassium (1416.82 and 1374.63 mg), magnesium (512.11 and 503.02 mg), phosphorus (361.01 and 341.14 mg), sodium (8.00 and 7.10 mg), iron (8.35 and 9.30 mg), zinc (4.55 and 3.72 mg), manganese (0.18 and 0.25 mg) and copper (0.54 and 0.65 mg) of BARI Avocado-1 and PA-Joy002 cultivars, respectively. Comparing the BARI Avocado-1 and PA-Joy002 avocado cultivar, the PA-Joy002 cultivar has greater calcium, iron, manganese, and copper content but less magnesium, phosphorus, potassium, and zinc. These minerals play vital roles in human health, and their consumption through fruits is recommended. Mg, Fe, P, K, Na has a strong presence in plant foods, and also plays an essential role in human body maintenance; it is associated with energy metabolism, enzyme cofactors and the prevention of chronic disease. Zinc found in varying concentrations in plant foods, is essential for enzyme structure and activity. Its consumption is known to boost the immune system and may hold promise in enhancing immunity against diseases like COVID-19 (Nedjimi, 2021).

Table 3. Mineral content of avocado pulps

Minerals	Amount in mg / 100g	
	BARI Avocado-1	PA-Joy002
Macro-elements		
Calcium (Ca)	838.03 ±2.84b	861.19 ± 3.17a
Magnesium (Mg)	512.11 ± 2.93a	503.02 ± 3.15b
Phosphorus (P)	361.01 ± 1.13a	341.14 ± 2.03b
Sodium (Na)	8.00 ± 0.39a	7.10 ± 0.26b
Potassium (K)	1416.82 ± 3.02a	1374.63 ± 4.34b
Micro-elements		
Iron (Fe)	8.35 ± 0.37b	9.30 ± 0.51a
Zinc (Zn)	4.55 ± 0.51a	3.72 ± 0.04b
Copper (Cu)	0.54 ± 0.03b	0.65 ± 0.04a
Manganese (Mn)	0.18 ± 0.04a	0.25 ± 0.04a

- Values (Mean ± standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at $P<0.05$ % (w/w) dry matter basis.

Conclusion

Avocados are highly nutritious and functional fruits, rich in a wide number of chemical constituents, phytochemicals, and essential micro and macronutrients that play important roles in helping to promote human health. The edible fruit (mesocarp) of avocado has high essential oil (fatty acids) which contain high amounts of anti-cholesterol agents and nutrients. In this study, results showed significant differences between the different avocado cultivars ($p < 0.05$) and were detected, with palmitic, oleic, and linoleic acids being predominant in all avocado cultivars, accounting for 90–95% of the fatty acid compositions. The study

revealed significant differences among avocado cultivars, with palmitic, oleic, and linoleic acids being predominant in fatty acid compositions. Avocado pulp oil was found to be abundant in unsaturated fatty acids, making up over 65 to 71% of the total fatty acids, suggesting potential benefits for cardiovascular health. The ratios of ΣUFA/ΣSFA were larger than reference values, which indicated that avocado could serve as a food supplement in the diet to decrease the level of cholesterol and fats, preventing the risk of cardiovascular disease. Additionally, all cultivars proved to be excellent sources of key minerals such as Ca, K, P, Mg, Na, Fe and Zn. Besides, the new cultivars, PA-Joy002 exhibited particularly high level of unsaturated fatty acids (UFA, 71%), and low content of saturated fatty acids (SFA, 29%) and favorable ratio of UFAs to SFAs 2.19 indicating its potential as a nutritionally rich option. Thus, the new cultivar, PA-Joy002 was identified as the promising and nutritionally rich cultivar; hence, the cultivar can be utilized in breeding programs to develop as a variety.

References

AOAC. 1990. Official Methods of Analysis. Association of Official Analytical Chemists International. In: Horwitz, W. (Ed), AOAC Press, Washington, DC.

Arackal, J. J. and S. Parameshwari. 2021. A detailed evaluation of fatty acid profile and micronutrient analysis of chapattis incorporated with avocado fruit pulp. *Mater. Today Proc.* **45:** 3268–3273.

Ciosek, Z. K. Kot, D. Kosik-Bogacka, N. Lanocha-Arendarczyk and I. Rotter. 2021. The effects of calcium, magnesium, phosphorus, fluoride, and lead on bone tissue. *Biomolecules.* **11:** 506.

Clark, C. J., A. White, R. B. Jordan and A. B. Woolf. 2007. Challenges associated with segregation of avocados of differing maturity using density sorting at harvest. *Postharvest Biol. Technol.* **46:** 119-127.

Dembitsky, V. M., S. Poovarodom, H. Leontowicz, M. Leontowicz, S. Vearasilp, S. Trakhtenberg and S. Gorinstein. 2011. The multiple nutrition properties of some exotic fruits: Biological activity and active metabolites. *Food Res. Int.* **44:** 1671–1701.

El-Moniem, E. A. A. A., A. Y. I. Thabet *et al*. 2022. Reducing chemical fertilizers partially by using natural alternative sources of organic fertilizers and its impact on "Hass" avocado trees. *Egypt J. Chem.* **65:** 1255–1264.

Ferreyra, R., G. Selles, J. Saavedra, J. Ortiz, C. Zuniga, *et al.* 2016. Identification of pre-harvest factors that affect fatty acid profiles of avocado fruit (*Persea americana* Mill) cv. "Hass" at harvest. *S. Afr. J. Bot.* **104:** 15-20.

Galvao, M. D. S., N. Narain and N. Nigam. 2014. Influence of different cultivars on oil quality and chemical characteristics of avocado fruit. Food Sci. Techno. Campinas. **34:** 539-546.

Ge, Y., X. Y. Si, X. E. Lin, J. S. Wang, X. P. Zang and W. H. Ma. 2017a. Advances in avocado (*Persea americana* Mill.). *China South Fruit.* **46:** 63-70.

Ge, Y., X. Y.Si, J. Q. Cao, Z. X. Zhou, W. L. Wang and W. H. Ma. 2017b. Morphological characteristics, nutritional quality, and bioactive constituents in fruits of two avocado (*Persea americana*) varieties from hainan province, China. *J. Agril. Sci.* **9:** 8-17.

Gokkaya, E. O., S. Yesilot, M. Ozgocmen, R. Aslankoc and C. A. Acar. 2021. Protective effects of resveratrol and avocado oil against paracetamol-induced hepatotoxicity in rats. *Drug Chem. Toxicol.* **8:** 1-9.

Hossain, M. S., K. C. Saha, M. M. Islam, M. Z. Noor and D. A. Choudhury. 2023. Assessment of nutritional composition, bioactive compounds and antioxidant activity of chia seeds grown in Bangladesh. *Bangladesh J. Agric. Res*. **48(2):** 259-270.

Kassim, A., T. S. Workneh and C. N. Bezuidenhout. 2013. A review on postharvest handling of avocado fruit. *Afr. J. Agric. Res.* **8:** 2385-2402.

Latimer, G.W. 2016. Official methods of analysis of Association of Official Analytical Chemists (20th ed.). Rockville: AOAC International.

Magwaza, L. S. and S. Z. Tesfay. 2015. A review of destructive and non-destructive methods for determining avocado fruit maturity. *Food Bioproc. Technol.* **8:** 1995-2011.

Nair, S. S. and A. Chandran. 2018. Nutrient composition of avocado fruits of selected cultivars grown in Kerala. *Int. J. Food Sci. Nutr*. **3:** 65-67.

Nasri, C., Y. Halabi, H. Harhar, F. Mohammed, A. Bellaouchou, A. Guenbour and M. Tabyaoui. 2021. Chemical characterization of oil from four avocado varieties cultivated in Morocco. *OCL*. **28:** 19.

Nedjimi, B. 2021. Can trace element supplementations (Cu, Se, and Zn) enhance human immunity against COVID-19 and its new variants? *J. Basic Appl. Sci.* **10:** 33.

Petersen, L. 2002. Analytical methods Soil, Water, Plant material, Fertilizer. p. 61-70. Bangladesh: Soil Resource Management and Analytical Services, Soil Resources Development Institute, Danida, Dhaka.

Ramos-Aguilar, A. L., J. Ornelas-Paz, *et al.* 2021. Effect of cultivar on the content of selected phytochemicals in avocado peels. *Food Res. Int.* **140:** 110024.

Richard, D., K. Kefi, U. Barbe, P. Bausero and F. Visioli. 2008. Polyunsaturated fatty acids as antioxidants. *Pharm. Res.* **57:** 451-455.

Rohman, A., A. Windarsih, S. Riyanto *et al.* 2016. Fourier transforms infrared spectroscopy combined with multivariate calibrations for the authentication of avocado oil. *Int. J. Food Properties.* **19:** 680-687.

Salgado, J. M., F. Danieli, M. A. B. Regitano-D'arce, A. Frias and D. N. Mansi. 2008b. Ooleo de abacate (*Persea Americana* Mill.) comomateria-prima para a industria alimenticia. *Food Sci. Technol.* **28:** 20-26.

Tutunchi, H., A. Ostadrahimi and M. Saghafi-Asl. 2020. The effects of diets enriched in monounsaturated oleic acid on the management and prevention of obesity: A systematic review of human intervention studies. *Adv. Nutr.* **11:** 864–877.

Van Rooijen, M. A and R. P. Mensink. 2020. Palmitic acid versus stearic acid: Effects of interesterification and intakes on cardiometabolic risk markers-A systematic review. *Nutrients* **12:** 615.

Yang, Z. H., H. Miyahara and A. Hatanaka. 2011. Chronic administration of palmitoleic acid reduces insulin resistance and hepatic lipid accumulation in KK-A y Mice with genetic type 2 diabetes. *Lipids Health Dis.* **10:** 120.

EFFECT OF PLANT EXTRACTS AND FUNGICIDES ON ASSOCIATED PATHOGENS OF CAPSICUM (*Capsicum annum*) SEED IN STORAGE

M. Islam[1], M. N. Islam[2], N. Akter[3], M. S. Rahman[4]
AND P. C. Sarker[5]

Abstract

The effects of seed treatment on the prevalence of seed borne pathogens and quality of capsicum seed was studied with Autostin 50 WP (Carbendazim), Dithane M-45 (Mancozeb) @ 2.2 g/kg, Rovral50 WP (Iprodione) @ 2.0 g/kg, Provax-200 WP (Carboxin+ Thiram) @ 3.0 g/kg, Garlic extract @ 1:1, Garlic extract @ 1:2 , Neem leaf extract @ 1:1, Neem leaf extract @ 1:2, Zinger rhizome extract @ 1:1, Zinger rhizome extract @ 1:2 under storage condition. Prevalence of seed-borne pathogens, seed germination, speed of germination and vigour index of seedling were recorded at 0 day, 75 days and 150 days after storage.The fungi *Alternaria sp., Aspergillus sp., Fusarium sp., Carvularia sp., Colletotrichum sp., Penicillium sp. and Rhizopus sp.* were identified from the treated seeds during different storage periods, where the untreated control showed maximum prevalence of the pathogens throughout the storage period. Provax-200WP (Carboxin + Thiram) treated seeds were free from infection though Garlic extract @ 1:1 w/v, Zinger rhizome extract @ 1:2 w/v and Zinger rhizome extract @ 1:1 w/v gave better germination, speed of germination, seedling dry weight and vigour index.

Keywords: Prevalence, incidence, seed treatment, germination, vigour index.

Introduction

Bell pepper (*Capsicum annuum* L.) is an important spice-cum vegetable crop grown under various agro climatic conditions in Bangladesh and worldwide. Loss in vigor and viability as well as disease is a major problem in storage of capsicum seed. There are so many features like loss of seed vigor and viability, low germination and pathogens prevalence which may impair seed health status and quality during storage (Justice and Bass, 1979; Ahmed, 1982 and Asalmol *et al.,* 2001). However, its production is often hindered by various biotic and abiotic stresses, among which seed-borne pathogens play a significant role. Pathogens propagated by seeds cause significant losses in seed yield and quality, resulting in lower germination capacity and even damage to seedlings (Sarika *et al,* 2019). Among various hindering factors, diseases are predominant for the crop. Chili and pepper suffer from many diseases caused by fungi, bacteria, viruses, nematodes

[1&4]Scientific Officer, [5]Chief Scientific Officer, Seed Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Scientific Officer, Plant Pathology Division, BARI, Gazipur, [3]Assistant Professor, Department of Plant Pathology, Faculty of Agriculture, Sher e Bangla Agricultural University, Dhaka, Bangladesh.

and also abiotic stresses. Fungal diseases play a vital role in reducing the germination of pepper. Among the fungal diseases, damping off, anthracnose or fruit rot, powdery mildew and leaf spots are the most prevalent ones. The fungi *Fusarium oxysporum*, *Sclerotium rolfsii*, *Aspergillus niger* and *Rhizoctonia solani* are soil inhabiting pathogens with a wide host range and very difficult to control. These pathogens are frequently transmitted through seeds (Fakir, 1998). *Aspergillus* spp. *Penicillium* spp. and *Fusarium* spp. can cause loss of quality of capsicum seeds in storage. Ahmed and Hossain (1985) stated that the fungus can affect seed germination and seedling growth. Seed-borne fungi adversely affect seeds in storage and causes discolor of seeds, enhance biochemical changes, and accumulate toxins, and results in loss of weight (Neergaard, 1979). Thus, management of pathogens infection in seeds during storage is one of the crucial factors to maintain proper germination, vigour and health status of seeds. Among recommended practices, seed treatment probably the cheapest and easiest method of plant disease control at seedling stage. Treatment of seeds with chemicals has been proved to be effective in reducing seed-borne infection (Dubey and Singh, 2005; Barua *et al.,* 2007). Application of fungicides effectively inhibits *F. oxysporum* and *A. niger* and contributes to higher seed germination and vigour index (Patra, 2017; Saranya *et al.*, 2017). Plant extract is a promising alternative for pathogens control associated with seeds, reducing costs and impacts to the environment (Silva *et al.,* 2019). Various authors also reported that fungicides and plant extracts application significantly reduced seed-borne infection and increased the percentage germination and vigor index (Saranya *et al.,* 2017) of capsicum seed. Plant extracts act directly or indirectly on pathogens growth in the seed due to their bioactive compounds. Pre-storage seed treatment may reduce the prevalence of seed-borne pathogens and protect seeds from the invasion of mainly fungi in storage condition.

Therefore, present research work was undertaken to evaluate the effect of seed treatment with chemical fungicides and botanical agents on prevalence of major seed borne fungi, seed germination rate, seedling health, and seedling vigour index of capsicum during storage.

Materials and Methods

The research work was executed in the Laboratory of Seed Technology Division as well as Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during October 2020 to June 2021. The experiment was laid out in Completely Randomized Design (CRD) with 11 treatments including a control and each treatment was replicated 4 times. Seeds of chili var. BARI Mishtimorich-1 were treated with fungicides namely Autostin 50 WP

(Carbendazim) @ 2.2 g/kg (T_1), Dithane M-45 (Mancozeb) @ 2.2 g/kg (T_2), Rovral (Iprodione) @ 2.0 g/kg (T_3), Provax-200WP (Carboxin+ Thiram) @ 3.0 g/kg of seeds (T_4), and botanicals viz. Garlic extract @ 1:1 w/v (T_5), Garlic extract @ 1:2 w/v (T_6), Neem leaf extract @ 1:1 w/v (T_7), Neem leaf extract @ 1:2 w/v (T_8), Zinger rhizome extract @ 1:1(T_9), Zinger rhizome extract @ 1:2 w/v (T_{10}) and untreated control (T_{11}). The botanicals of 1:1 (w/v) ratio were made in, 100 ml of distilled water with 100 g plant parts and so on. Seeds were treated with fungicides and plant extracts with specified dose as well as distilled water for one hour, respectively. Each treatment consisted of twenty grams of capsicum seed. All the treated seeds were dried back to original moisture content at room temperature. The treated seeds were then kept in storage (15 ^{0}C temperature and 40-60% RH) and seed health status, germination rate and vigor index were tested according to standard methods (ISTA, 1996) just before storage (0 day), 75 days and 150 days after storage (DAS).

Seed health test: Seed health test of capsicum seeds was carried out by standard blotter method (ISTA, 1996). In this method, three layers of blotter papers (Whatman No. 1) were soaked in sterilized distilled water and placed on the bottom of the 9 cm diameter Pyrex glass Petri dish. Four hundred seeds from each treatment were taken randomly and then placed on the moist blotter paper at the rate of 25 seeds per plate. The experiment was laid out following Completely Randomized Design (CRD) with four replications. The Petri-dishes with seeds were then incubated at 25 ± 2 °C temperature in 12/12 hours alternating cycles of light and darkness for seven days. After incubation, the seeds were examined under stereo-microscope for the presence of seed-borne pathogens and identified by observing their growth characters. In case of confusion, temporary slide was prepared and examined under a compound microscope and identified the pathogens using appropriate keys of Mathur and Kongsdal (2003). Results were expressed in percentage of seeds infected by the pathogens.

Germination percentage: Seed germination test was conducted in the Seed Technology Division laboratory of BARI using three layered moistened blotter paper on Petri-dishes. Hundred seeds were placed on each petri dish and kept at 25^{0}C temperature for fourteen days for germination. Four replications were used for germination test. The first and final count was taken on 4th and 14th day of the test, respectively. Germination percentage was counted by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Normal seedlings germinated}}{\text{Seeds kept for germination}} \times 100$$

Germination speed: Speed of germination was computed by recording daily observations on 100- seeds sown in sand medium until the final count day (14

days). The germination speed (GS)was calculated as total number of seedlings emerged on day basis, and the mean was calculated as suggested by Copeland (1976)

$$GS = \frac{\text{No. of germinated seeds at first count}}{\text{Days of first count}} + \cdots$$
$$+ \frac{\text{No. of germinated seeds at final count}}{\text{Days of final count}}$$

Seedling vigour index: For calculating seedling vigour index, 10 normal seedlings were randomly selected on 14th day of germination test and seedlings were dried in an oven at 71 ℃ for 72 hr. Then cooled and weighed in an electronic weighing balance and expressed in mg. Vigour index was calculated on the basis of mean seedling dry weight by adopting the formula (Abdul-Baki and Anderson, 1973).

Vigour index = Germination (%) × Seedling dry weight (mg).

Statistical Analysis: The collected data on different parameters were analyzed statistically by analysis of variance (ANOVA) using Statistix 10 software program. The significance of the difference among the treatment means was calculated by LSD (Least Significance Difference) test.

Results and Discussion

Effect of seed treatment on the prevalence of seed- borne fungi :

All the capsicum seeds sample were infected with different levels of infection except T_4 (Table 1). There were seven different fungi viz., *Alternaria* sp*., Aspergillus* sp*., Fusarium* sp*., Carvularia* sp*., Colletotrichum* sp*., Penicillium* sp. *and Rhizopus* sp. were identified from the seeds placed in blotter method in laboratory conditions. Asalmol *et al.,* (2001) reported that *Aspergillus flavus, Rhizopus stolonifer, Fusarium moniliforme, Colletotrichum capsici and Aspergillus niger* were the predominant seed borne fungi in the chili seeds. The results also supported the findings of Solanke *et al.* (2001) who reported presence of *Fusarium moniliforme, Colletotrichum capsici, Aspergillus niger* (van Tieghem), *Aspergillus flavus* (Linkex Fries), *Alternaria alternata and Curvularia lunata* from the seed samples of different chili cultivars.

The prevalence of fungal pathogens in seeds increased with the increase in storage time. The prevalence of pathogens was minimal just after treatment (0 DAS) with different fungicides and botanical agents. The untreated control showed highest incidence of all the observed pathogens in an upward trend with storage period. The lowest disease incidence was found in T_5 and T_{10} treatments with only one pathogen, *Colletotrichum* sp. The treatment T_5 and T_{10} showed identical results throughout the storage period. There was no pathogenic infection in T_4 treatment even at 150 days after storagethat was treated with Provax-200 (Carboxin + Thiram) @ 3.0g/kg.

Table 1. Effect of different treatments on percent incidence of different pathogens in capsicum seeds at different storage period

Treatments	Isolated pathogens	Percent incidence of fungi		
		0 DAS	75 DAS	150 DAS
T_1	*Alternaria* sp.	-	2.15	5.33
	Carvularia sp.	-	3	4
	Fusarium sp.	-	3.55	5. 57
T_2	*Colletotrichum* sp.	1.25	3.45	7.10
	Fusarium sp.	-	4	6.50
T_3	*Carvularia* sp.	-	2	5
	Alternaria sp.	-	3	7
	Colletotrichum sp.	-	4	9
T_4	-	-	-	-
T_5	*Colletotrichum* sp.	-	1.25	2.75
T_6	*Penicillium* sp.	-	2.0	4.0
	Rhizopus sp.	-	2.0	5.0
	Aspergillus sp.	1.55	3.10	9.15
T_7	*Colletotrichum* sp.	-	2.0	5.1
	Aspergillus sp.	1.33	2	4.25
T_8	*Alternaria* sp.	-	2	5
	Colletotrichum sp.	1.00	2.50	6.50
T_9	*Alternaria* sp.	-	2.15	5.0
	Rhizopus sp.	-	1.50	2.0
	Fusarium sp.	1.25	1.50	2.75
T_{10}	*Colletotrichum* sp.	-	1.50	2.25
Control	*Alternaria* sp.	1.50	4.25	7.25
	Penicillium sp.	1.25	3.0	5.0
	Fusarium sp.	1.75	3.75	7.50
	Colletotrichum sp.	1.50	4.0	9.15
	Aspergillus sp.	1.50	3.2	8.0

DAS- Days after storage; T_1- Autostin 50 WP @ 2.2 g/kg, T_2 -Dithane M-45 @ 2.2 g/kg, T_3 - Rovral @ 2.0 g/kg, T_4-Provax 200 WP @ 3.0 g/kg of seeds, T_5 -Garlic extract @ 1:1 w/v, T_6 -Garlic extract @ 1:2 w/v, T_7 -Neem leaf extract @ 1:1 w/v, T_8 -Neem leaf extract @ 1:2 w/v, T_9 -Zinger rhizome extract @ 1:1, T_{10} -Zinger rhizome extract @ 1:2 w/v and T_{11} -untreated control.

Effect of seed treatment on germination:

At the time of storage, the average initial germination of capsicum seeds was 84%. The treated seeds after 75 days of storage showed significant difference in

germination that ranged from 55.00 to 81.25% (Table 2). Maximum 81.25% seed germination was recorded in seed treated with Zinger rhizome extract @ 1:1 w/v. Seed treated with Neem leaf extract @1:2w/v showed 76.25% germination that was similar to seed treatment with Rovral. The lowest germination (55%) was recorded from the untreated control. In case of 150 DAS, considerably different results in germination rate were observed among the treatments. The higher germination(80.50%) was recorded in the seeds treated with Zinger rhizome extract @ 1:1 w/v followed by Neem leaf extract (74.50%) treated seeds @1:2 w/v while minimum germination was found in control treatment (50.50%).

Table 2. Effect of seed treatment on germination (%) of capsicum seeds at different storage period

Treatments	0 DAS	75 DAS	150 DAS
T_1		70.25	69.50
T_2		64.50	64.75
T_3		74.00	69.50
T_4		65.00	63.50
T_5	84.00	66.00	64.00
T_6		64.25	62.00
T_7		73.50	70.50
T_8		76.25	74.50
T_9		81.25	80.50
T_{10}		63.50	61.50
Control		55.00	50.50
LSD (0.05%)		2.7204	2.3592
CV (%)		2.47	4.54

DAS- Days after storage; T_1- Autostin 50 WP @ 2.2 g/kg, T_2 -Dithane M-45 @ 2.2 g/kg, T_3 - Rovral @ 2.0 g/kg, T_4-Provax 200 WP @ 3.0 g/kg of seeds, T_5 -Garlic extract @ 1:1 w/v, T_6 -Garlic extract @ 1:2 w/v, T_7 -Neem leaf extract @ 1:1 w/v,T_8 -Neem leaf extract @ 1:2 w/v, T_9 -Zinger rhizome extract @ 1:1, T_{10} -Zinger rhizome extract @ 1:2 w/v and T_{11} -untreated control.

Effect of seed treatment on germination speed:

Significant variation in germination speed of capsicum seed was observed in different storage period due to seed treatment with different fungicides and plant extracts (Figure 1). Initial germination speed of capsicum seed was 8.657 that reduced to 4.124 in untreated control after 75 DAS. Maximum speed of germination (7.625)was found in the seed treated with Zinger rhizome extract @ 1:1 w/v that was similar to seed treatment with Rovral (7.014) and Provex 200WP (7.180). Germination speed was gradually declined with the increase of storage period. After 150 DAS germination speed of capsicum was reduced to 3.478 in

untreated control. Significantly higher speed of germination (6.619)was found in the seed treated with Zinger rhizome extract @ 1:1 w/v that was also similar to seed treatment with Rovral (6.600) and Provex 200WP (6.365).
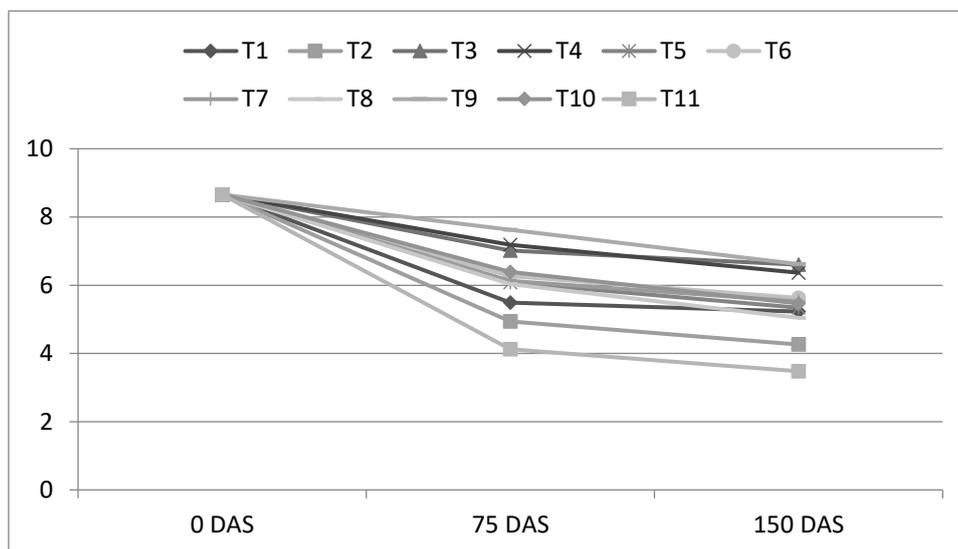
Fig. 1. Germination speed (GS) of capsicum seed due to different storage period.

DAS- Days after storage; T_1- Autostin 50 WP @ 2.2 g/kg, T_2 -Dithane M-45 @ 2.2 g/kg, T_3 - Rovral @ 2.0 g/kg, T_4-Provax 200 WP @ 3.0 g/kg of seeds, T_5 -Garlic extract @ 1:1 w/v, T_6 -Garlic extract @ 1:2 w/v, T_7 -Neem leaf extract @ 1:1 w/v,T_8 -Neem leaf extract @ 1:2 w/v, T_9 -Zinger rhizome extract @ 1:1, T_{10} -Zinger rhizome extract @ 1:2 w/v and T_{11} -untreated control.

Effect of seed treatment on dry weight of seedling:

The initial mean dry weight of 10 seedlings was 36 mg that decreased with the increase of storage period in all treatments (Table 3). The dry weight of capsicum seedlings ranged from 29.25 mg to 36.25 mg after 75 days of storage. Maximum dry weight of seedling was 36.25mg in seed treatment with zinger rhizome extract @1:1 w/v followed by 35.50 mg in Neem leaf extract @ 1:2 w/v that was statistically similar to Zinger rhizome extract @ 1:2 w/v (35.50 mg) and Neem leaf extract @ 1:1 w/v (35.00mg). At 150days of storage the seedling dry weight ranged from 27.00mg to 35.50mg. Statistically similar result was found in case of seedling dry weight from Neem leaf extract @ 1:2 w/v (34.25mg), Zinger rhizome extract @ 1:1 (35.50mg) and Zinger rhizome extract @ 1:2 w/v (33.50mg) where minimum seedling dry weight was recorded from control treatment.

Table 3. Effect of seed treatment on dry weight of capsicum seedlings at different storage period

Treatments	0 DAS	75 DAS	150 DAS
T_1		32.50	30.75
T_2		33.75	31.00
T_3		33.00	30.75
T_4		33.25	32.25
T_5	36.00	31.50	29.75
T_6		31.25	31.00
T_7		35.00	32.75
T_8		35.50	34.25
T_9		36.25	35.50
T_{10}		35.50	33.50
Control		29.25	27.00
LSD (0.05%)		1.8015	2.1323
CV (%)		3.76	4.68

DAS- Days after storage; T_1- Autostin 50 WP @ 2.2 g/kg, T_2 -Dithane M-45 @ 2.2 g/kg, T_3 - Rovral @ 2.0 g/kg, T_4-Provax 200 WP @ 3.0 g/kg of seeds, T_5 -Garlic extract @ 1:1 w/v, T_6 -Garlic extract @ 1:2 w/v, T_7 -Neem leaf extract @ 1:1 w/v,T_8 -Neem leaf extract @ 1:2 w/v, T_9 -Zinger rhizome extract @ 1:1, T_{10} -Zinger rhizome extract @ 1:2 w/v and T_{11} -untreated control.

Effect of seed treatment on seedling vigour index

Initial vigour index value of capsicum seedlings was 3025 before storing of seeds (Figure 2). A decreased trend of seedling vigour index value was found with the storage period increased. After 75 days of storage, the vigor index of capsicum seedlings was 2945 in case of Zinger rhizome extract @ 1:1w/v treated seeds and the lowest vigour index value 1610 was found in untreated control. In case of 150 days of storage, the vigour index value was decreased to 2858 in Zinger rhizome extract @ 1:1 w/v treated seeds that was significantly higher than the other treatments. Lower value of seed vigour index value (1362) was observed in control.

Provax-200, Rovral, Dithane M-45, Autostin 50 WP and the plant extracts were found effective in controlling seed-borne pathogens of capsicum seeds in storage condition and also improved seedling germination and seedling vigour index to a considerable extend. Provax-200WP (Carboxin+ Thiram) @ 3.0g/kg, Garlic extract @ 1:1 w/v, Zinger rhizome extract @ 1:1 w/v, and Zinger rhizome extract @ 1:2 w/v showed promising result in case of pathogens reduction, germination rate, speed of germination, seedling dry weight and vigour index throughout the storage period of capsicum seed. Efficacy of Autostin 50 WP, Rovral 50 WP and Provax-200 was reported against *F. oxysporum* and *Aspergillus* sp.
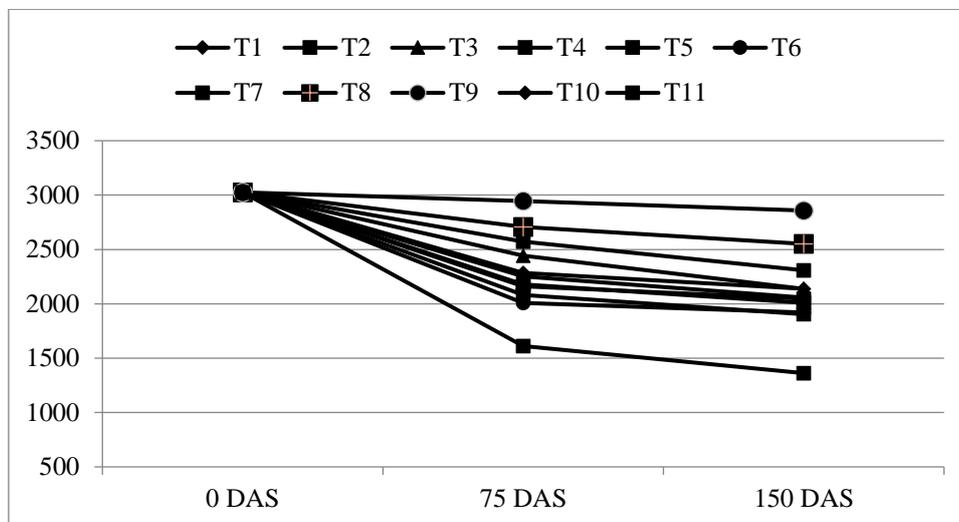
Fig. 2. Seedling vigor index at different storage period.

DAS- Days after storage; T_1- Autostin 50 WP @ 2.2 g/kg, T_2-Dithane M-45 @ 2.2 g/kg, T_3- Rovral @ 2.0 g/kg, T_4-Provax 200 WP @ 3.0 g/kg of seeds, T_5-Garlic extract @ 1:1 w/v, T_6-Garlic extract @ 1:2 w/v, T_7-Neem leaf extract @ 1:1 w/v, T_8-Neem leaf extract @ 1:2 w/v, T_9-Zinger rhizome extract @ 1:1, T_{10}-Zinger rhizome extract @ 1:2 w/v and T_{11}-untreated control.

Fungicides like Carbendazim, Thiophanate-methyl, Benomyl, Prochloraz and Tebuconazole showed inhibiting effects against *F. oxysporum* and their application increased the emergence of seedlings (Song *et al*., 2004; Ozer and Koycu, 2004; Rajput *et al.,* 2006; Chandel and Deepika, 2010). Abbas *et al.* (2020) reported that seed treatment with Mancozeb 80% WP effectively control seed borne fungi and increase the seed germination in capsicum. Plant extract was a promising alternative for pathogens control associated with seeds, reducing costs and impacts to the environment (Silva *et al.,* 2019). Plant extracts act directly or indirectly on pathogens growth in the seed due to their bioactive compounds. In the present study; all the botanicals especially Zinger rhizome extract @ 1:1 w/v and Zinger rhizome extract @ 1:2 w/v significantly reduced seed borne fungal pathogens of capsicum in storage and enhanced the growth of capsicum seedling. The similar results in reducing percent seed borne fungal pathogens and enhancing growth characters of vegetable seedling were also found by others (Islam *et al*., (2006); Hossain *et al.,* (2005); Howlader (2003); Rahman *et al.,* (2012); Khan *et al.,* (1995).

Conclusions

Seed treatment with different plant extracts and fungicides greatly contributed to seed health status and quality of capsicum seed during storage period. It was revealed that Provax-200 (Carboxin + Thiram) @ 3.0g/kg was the most effective

fungicide which reduced seed-borne pathogen infection in capsicum seed during storage. Significantly higher germination rate, speed of germination, seedling dry weight and vigour index was found in capsicum seed treated with zinger rhizome extract @ 1:1 w/v up to 150 days of storage. Therefore, pre-storage seed treatments with Provax-200 (Carboxin + Thiram) @ 3.0g/kg was suggested as effective fungicide to control seed borne fungi where zinger rhizome extract@ 1:1 w/v was also good for germination rate, vigour index and quality of capsicum seeds in storage.

References

Abbas, A., H. Saddam, I. Asim, A. Muhammad, S. Amir, U. Muhammad, I. Pervaizand Z. Chenri.2020, Seed Treatment of Capsicum annuum with Two Different Fungicides to Evaluate the Seed Germination Rate, *Journal of Biology, Agriculture and Healthcare*, 10(4): 22-27. www.iiste.org. ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)

Abdul-Baki A. A. and J. D. Anderson. (1973). Vigor determination in soybean seed by multiple criteria. *Crop Sci.,* **13:** 630-633.

Ahmed, H. U. and M. M. Hossain.1985. Final report of the project crop disease survey and establishment of a herbarium at BARI. Plant Pathology Division. Bangladesh Agricultural Research Institute.Gazipur.170 p.

Ahmed, S. S. 1982. Studies on Seed Borne Aspects of Anthracnose of Chillies Caused by *Colletotrichumcapsici* (Sydow.) Butler and Bisby.M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Bangalore.

Asalmol, M. N., V. P. Kale, and S. T. Ingle. 2001. Seed Borne Fungi of Chilli, Incidence and Effect on Seed Germination. Seed Res., **29(1):** 76-79.

Barua, J., M. M.Hossain, I., Hossain, A. A. M. S. Rahmanand M. A. T. Sahel.2007. Control of mycoflora of farmer's stored seeds of mungbean. *Asian Journal of Plant Science,* **6:** 115-121.

Chandel, S. and R. Deepika. 2010. Recent advances in management and control of Fusarium yellows in Gladiolus species. *Journal of Fruit Ornamental Plant Research*, **18(2):** 361-380.

Dubey, S. C. and B. Singh. 2005. Integrated management of diseases of mungbean. *Indian Phytopathology*, **58:** 345-346.

Fakir, G. A. 1998.An annotated list of seed borne diseases in Bangladesh. Bangladesh Agricultural University. Mymensingh, 25p.

Hossain, M. M., K. M. Khalequzzaman, F. M. Aminuzzaman, M. R. A. Mollahand G. M. M. Rahman.2005. Effect of Plant Extract on the Incidence of Seed-Borne Fungi of Wheat. *J. of Agric. and Rural Dev.,* **3(1,2):** 39-43.

Howlader, A.N. 2003.Effect of Seed Selection and Seed Treatment on the Development of *Phomopsis* Blight and Fruit Rot of Egg Plant. MS Thesis. Dept. of Plant Pathology, BAU, Mymensingh, Bangladesh.

Islam, M. A., F.M. Aminuzzaman, M.R. Islamand M.S.Zamal. 2006. Seed Treatment with Plant Extract and Vitavax-200 in Controlling Leaf Spot (*BipolarisSorokiniana*) with Increasing Grain Yield of Wheat. *Int. J. of Sustain. Agril. Tech.*, **2(8):** 15-20.

ISTA. 1996. International Rules of Seed Testing Association. In. Proc. Int. Seed Test. Assoc. P. 19-41.

Justice, O. L. and L. N. Bass 1979. Principles and practices of seed storage. Castle House Publication Ltd.

Khan, A. A. and G. A. Fakir.1995. Seed Treatment with Garlic Extract to Control Seed-Borne Pathogen of Jute. *Bangladesh Journal of Plant Pathology*, **11(1-2).**

Mathur, S. B. and O. Kongsdal. 2003. Common laboratory seed health testing method for detecting fungi.1stedn, International Seed Testing Association, Bassersdorf, Switzerland, 425 p.

Neergaard, P. 1979. Seed Pathology.Vol. 1. The Macmillan Press Ltd., London and Basingstoke.

Ozer, N. and N. D. Koycu.2004. Seed-borne fungal diseases of onion and their control. Kluwer Academic Publishers.*The Netherlands*, 281-306 pp.

Patra, S. 2017. Effect of pre-storage seed invigoration treatment in onion (*Alliumcepa*l., cv. Agrifounddarkred) for improved germinability and field performance.*International Journal of Current Microbiology and AppliedSciences,* **6(6):** 478-482.

Rahman, M. A., R. Sultana, M. F. Begum, M. F, Alam. 2012. Effects of Culture Filtrates of *Trichoderma* on Seed Germination and Seedling Growth in Chilli. *International Journal of Biosciences*, **2(4):** 46-55.

Rajput, A. Q., M. H.Arain, M. A.Pathan, M. M. Jiskaniand A. M. Lodhi.2006. Efficacy of different fungicides against Fusarium wilt of cotton caused by Fusarium oxysporumf.sp. vasinfectum. *Pakistan Journal of Botany*, **38(3):** 875-880.

Saranya, R., V. B.Anadani, L. F.Akbari, and M. Vanthana.2017. Management of black mold of onion (*Aspergillusniger*(Van Teigh) by using various fungicides. *International Journal of Current Microbiology and Applied Sciences,* **6(3):** 1621-1627.

Sarika, G., N. Amruta, H. K.Kandikattu, G. V.Basavaraju, H. K.Suma, B. L.Manjunath, andC. H. Sravani.2019. Chemical profiling of camptothecin and methoxycamptothecin in NothapodytesnimmonianaGrah. (Mabb.) during seed development, seed germination and their effects on seed-borne pathogens. *South African Journal of Botany*, 113–123. https://doi.org/10.1016/j.sajb.2019.02.003

Silva, I. N., A. J. Christ, S. S.Silva, J. W. P.Carvalhoand L. C. Pascuali. 2019. Physiological Quality of Rice Seeds Treated with Essential Oils And Vegetable Extracts*, Biological and Health Sciences* **11(3):** 259–271. http://dx.doi.org/10.22410/issn.21763070.v11i3a2019.2333

Solanke, R. B., D. B. Deosarkar and L. N. Jawale.2001. Seed Borne Fungi of Chili and Response of Fusarium moniliform to Various Seed Dressers. J. Maharashtra Agric. Univ., **26(2):** 187-188.

Song, W., L. Zhou, C., Yang, X. Cao, L. Zhang, and X. liu.2004. Tomato Fusarium wilt and its chemical control strategies in a hydroponic system. *Crop Protection*, **23(3):** 243-274.

A MODEL OF ESTIMATION MAIZE YIELD BASED ON WEATHER, AGRONOMICAL AND SATELLITE DATA

N. Mohammad[1], M. A. Islam[2], M. M. Rahman[3]
I. Ahmed[4] and M. G. Mahboob[5]

Abstract

A timely and reliable system of maize yield forecasting well in advance is prime emphasis to farmers and other people who are dependent on cereal crop. The best model was generated using maize field experiment trial which was conducted at Dorbasta union of Gobindagonj upazila, Gaibandha during two consecutive Rabi crops growing season 2018-19 and 2019-20. Randomized Complete Block Design (RCBD) along with five treatments (or varieties) and three replications were considered for maize yield performance. The agronomical and weather parameters and also, satellite data (Landsat 8 OLI) were used for the required maize field experiment. We found that Normalized Difference Vegetation Index (NDVI) was strongly positively correlated with the weather variables in this study. Stepwise regression method was applied for generating best estimated model. Best estimated model (Backward elimination) showed that only five controlled variables which were variety 5 (BHM 13), 1000 grain weight, diameter of cob, plant height and NDVI that were factors to the yield of maize. The developed maize yield forecast model (ideal model) including agronomical, weather and satellite data give the better results of yield estimation at regional level on the basis of best model criterion. Therefore, the ideal model used in specific region including all types of data that gives more precise result on maize yield or production that should be more significant and reliable in national level. So, the researcher, policymaker can use this maize yield prediction model forty to fifty days earlier of harvesting time.

Keywords: Landsat 8, NDVI, BHM13, Multicollinearity, Stepwise regression.

Introduction

The effects of weather change on crop production are global concerns, but they are particularly significant for the sustainable agricultural development of Bangladesh (Hossain et al., 2013). This is a country of variant weather conditions year-round due to its geographic position and physiographic status. Agriculture in Bangladesh is already under pressure, both from huge and increasing demands for food as well as from obstacles related to the degradation of agricultural land and water endowments (Ahmed and Ryosuke, 2000). Bangladesh is one of the countries where crop production especially maize, rice, wheat and potato are most likely to suffer adverse impacts from anthropogenic climate change. Besides, due to the

[1,3,4]Agricultural Statistics & ICT Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, [2]Department of Agricultural and Applied Statistics, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh, [5]Forestry Unit, Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh.

large share of the agricultural sector in the overall output of the country's economy, the study of weather modification impacts on Bangladesh agriculture has achieved recent attention (Chowdhury and Khan, 2015).

In rice based cropping system, maize is becoming a prominent crop in Bangladesh. Maize is become more popular among the farmers usually due to high yield, higher financial return and numerous uses in recent years. In Bangladesh, maize production and area have grown significantly over the past ten years, and it still growing quickly at an average rate of 20% each year (CIMMYT, 2008; BBS, 2020). It is found that hybrid maize is an emerging high-value crop, having the highest average farm yields in Asia. Economically, hybrid maize is much more profitable than Boro rice, wheat, or most other competing Rabi crops. The hybrid varieties of maize have the highest yield potentiality among cereals. Cultivation of hybrid maize sometimes becomes difficult for many farmers due to unavailability of high quality seed. To fulfill the requirement, a huge amount of hybrid maize seed is now being imported from abroad at a very high cost. Farmers are now growing maize mostly in Rabi season. So, it is necessary to develop maize yield estimation model on the basis of agronomical, weather and satellite parameters in regional level of Bangladesh. The pre harvest forecasting of the crop productivity is a chief precedence to know about the market demand of the crops (Kumar and Shitap, 2020).

The best variable selection/stepwise method is applied to determine the factor(s) that contributed more to crop production in Bangladesh. The factors were the predictor variables and crop production was the dependent variable. Steps were taken to be able to diagnose the identical factors benefaction to the crop production and possibly the combination of factors contribution to crop production. This is in order to establish the factor(s) to give more awareness to increase crop production for lucrative investment in agriculture and food security (Udokang, 2020). The stepwise regression analysis reveals a few variables that have a significant impact on mango and banana yields. The government or policymakers should concentrate a major emphasis on these variables to support the overall development of the cropping system under consideration (Rathod and Mishra 2018). Peiris et al. (2008) predicted coconut production in Sri Lanka using seasonal climate information. Mijinyawa and AkpenPuun (2015) observed in Kwara State, Nigeria that the impact of climate on crop yield was significant for maize and rice yield at 95% probability level while the impact of climate on the yield of millet, sorghum and cowpea was insignificant. So, it is recommended that to escalate the cultivation of crops on which climate had no significant impact on their yield. Kumar and Shitap (2020) used stepwise regression method for forecasting the groundnut productivity in the Junagadh district of Gujarat in India.

Agarwal et al. (1986), Yang et al. (1992), Dixon et al. (1994), Garde *et al.* (2012), Rathod *et al.* (2012) and Kandiannan *et al.* (2002) proposed methods based on multiple weather-based regression analysis to capture the effect of climate

variables on crop yields. Tannura et al. (2008) explored that the explanatory power of the MLR models were much better and they revealed how crop yield and weather conditions were related to one another. Thus, the accuracy of the multiple regression process is much better than the simulation approach and it is also much easier to deal with a multiple regression process as compared to a simulation process. In most of the prior studies linear regression was applied to predict the crop yield, area and production. Therefore, if we consider the number variables, it leads to over fitting of the model and may lead to the problems of multicoliniarity. To overcome these problems stepwise regression is used in this study.

However, the methods of studying the relationship of maize agronomical data, weather parameters as well as remote sensing data were employed in this research. The objectives are to examine the relationship between selected weather or climatic elements and the agronomical parameter of maize crops in the selected location i.e., experiment site and generate the predicted regression model based on the contribution of weather element, remote sensing data as well as yield and yield contributing characters of maize data. All statistical analyses were done using R programme while satellite image processing and NDVI value calculation were done by QGIS software.

Materials and Methods

Study Area

The maize experiment field was set up at Dorbasta union of Gobindagonj upazila, Gaibandha during two consecutive crops growing season 2018-19 and 2019-20. This field was selected through On Farm Research Division (OFRD), Gaibandha. The latitude and longitude of this experiment field were 25° 10′ N and 89° 23′ E respectively which are represented in Figure 1.
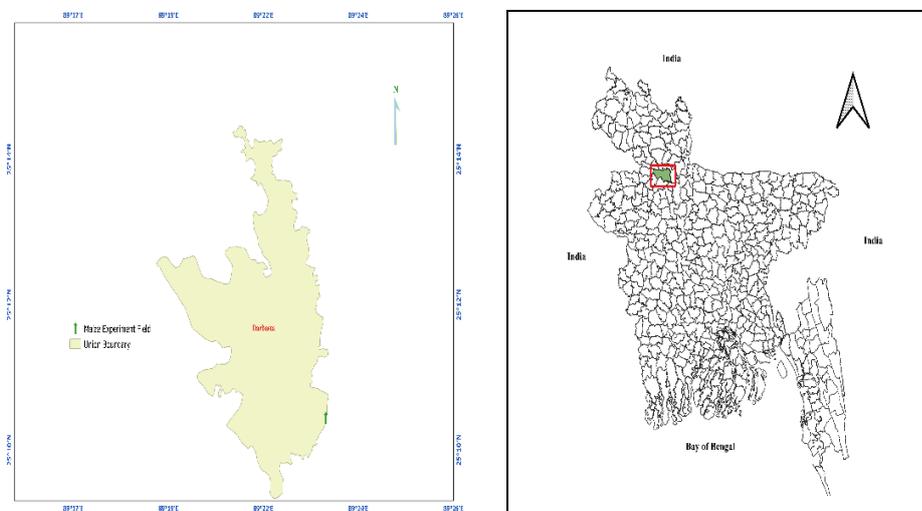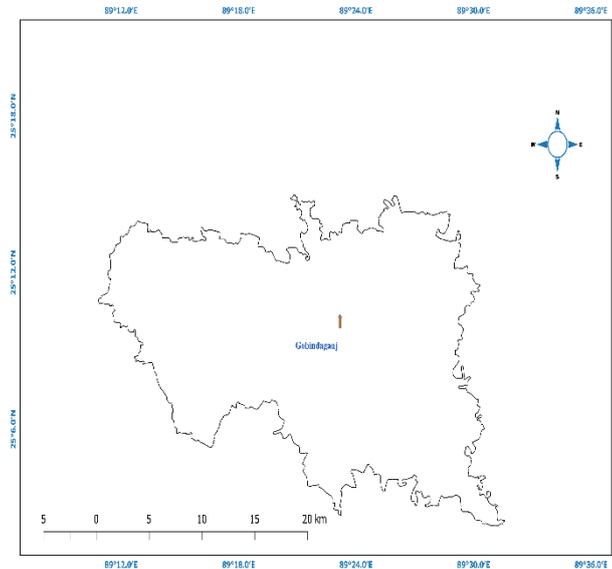
Fig. 1. Study area at Dorbasta union, Gobindagonj, Gaibandha

Field Data

Five treatments (or varieties viz. PS-999, VISHAL-6405, EUREKA, BHM9 and BHM13) were set up at experimental field in Dorbasta union of Gobindagonj upazila, Gaibandha during Rabi season of two consecutive crop growing seasons 2018-19 and 2019-20. Maize seeds were sown on 7th November, 2018 as well as on 7th November, 2019 for two consecutive crop growing seasons. Plot Size was taken 4.2mx5m (7 Lines per Plot). Spacing was 60×20 cm between rows and hills, respectively. After seedling emergence one healthy plant per hill was kept. Fertilizers dose and irrigation management were applied as per recommendation. All intercultural operations were done according to the necessity. Agronomical parameter viz. yield and yield contributing parameters of maize viz., days to maturity (DM), plant height (PH), no. of grain/cob (NGC), 1000 grain weight (TGW), length of cob (LOC), diameter of cob (DOC) and grain yield (GY) were collected from maize experiment during two crop growing seasons. Data on plant height (cm), 1000 grain weight (g), length of cob (cm), diameter of cob (cm) and grain yield (t/ha) were recorded from five randomly selected plants. Experimental design was Randomized Complete Block Design (RCBD) with three replications.

Weather Data

The weather parameters viz., maximum temperature (°C), minimum temperature (°C), sunshine hours (h) and relative humidity data (%) are collected from regional weather station at Rangpur of Bangladesh Meteorological Department (BMD). All weather parameters were collected during the maize growing seasons 2018-19 and 2019-20.

Satellite Data

Landsat 8 images (OLI) were obtained from the United States Geological Survey (USGS) Earth Explorer website (http:// earthexplorer.usgs.gov/). We downloaded total 2 (Two) images, which was maximum cloud free, collected from Landsat 8 OLI satellite data for Dorbasta union of Gobindagonj upazila, Gaibandha during Rabi season of two consecutive crop growing seasons 2018-19 and 2019-20. A total of 2 images were suitable for two experimentation period and used in the consequent analyses (Table 1).

Table 1. Satellite data used in this experiment field

Satellite/Sensor	Acquisition Date (Year-Month-Day)	Spatial Resolution (m)	Path Number	Row Number	Spectral Resolution
Landsat 8 OLI	2019-03-03	30	138	043	9
	2020-02-18				

The single date of image acquisition based on maximum greenness was used for each of the maize experimentation periods i.e. 2018-2019 and 2019-2020 (Figure 2). The maize sowing and harvesting date were considered to be the first week of November and the first week of April for maize experimentation periods i.e. 2018-2019 and 2019-2020 respectively for the entire study site based on the information taken from the location visits.

a   b
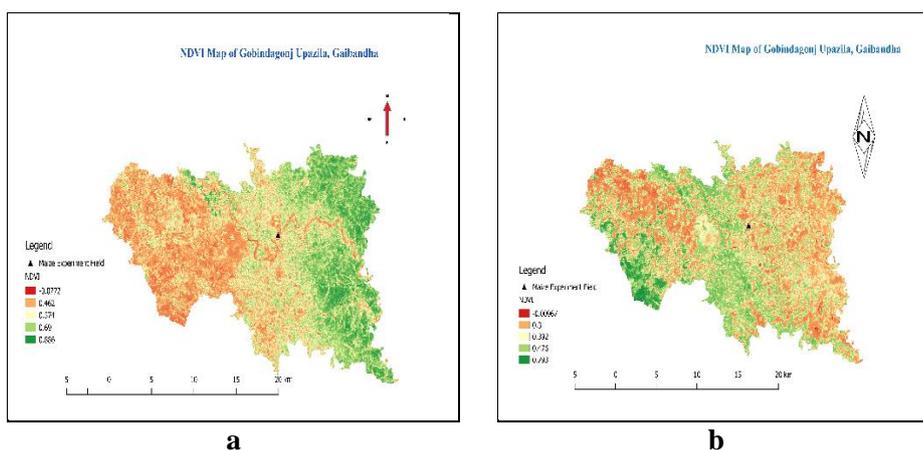
Fig. 2. Spatial distribution of the NDVI map at Gobindagonj upazila, Gaibandha for Landsat 8 satellite images during growing seasons 2018-19 and 2019-20.[a. 116th days after plantation during 2018-19; b. 101th days after plantation during 2019-20.]

Normalized Difference Vegetation Index (NDVI)

NDVI is a ratio of near-infrared and red band reflectance and is accepted as a surrogate for primary production and has served as a good measure of seasonal

vegetation changes, even at coarse scales. The formula for computing NDVI is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$ (1)

Where RED (Visible red) and NIR (Near infrared) are reflectance measurements for RED and NIR bands, respectively. Here for Landsat 8/OLI, band 4 and band 5 represented RED and NIR bands. NDVI are related to vegetation amount until saturation at full canopy cover and are therefore related to the biophysically active radiation, efficiencies and productivity (Rondeaux et al., 1996).

Multiple Linear Regressions (MLR) model

The Multiple Linear Regression (MLR) models are applied when two or more independent variables are influencing the dependent variable. It uses a few variables or all variables for prediction as necessary to get a reasonably accurate forecast. The MLR model is presented as follows:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + e_t$$ (2)

Where, b_0 is the intercept, b_i's are the coefficients representing the contribution of the independent variables on the dependent variable Y and e_t is the error at time t is N (i i d) with zero mean and finite variance (Drapper and Smith 1966). R^2 refers the proportion of all variation in the n observed values of the response variable that is expressed by the overall regression model (Bowerman et al., 2005). The higher the R^2, the better the model fits the data (Levin & Rubin, 1994).

Stepwise Regression Analysis

The identification of regressors that are actually influencing the target variable is a crucial aspect of regression modeling. Stepwise regression analysis (SRA) is most often used in exploratory research (Armstrong, 1970). There are numerous methods for selection; stepwise regression analysis is one of the most popular used variable identification algorithms in regression methods. There are two main approaches to analyzing data using stepwise regression (Wang & Jain, 2003). Forward selection and backward elimination are combined in the stepwise regression approach. This is a refinement on forward selection in which at each step all independent variables that have formally been entered into the model are appraised again using their partial F-statistics. An independent variable added at a previous stage may now be superfluous because of the relationships between it and most recent variable entered in the model; backward elimination is a method of stepwise regression where all independent variables begin in the model and subsequent variables are eliminated (Montgomery et al.,

2003). By referring Formulas, standard stepwise regression both adds and removes independent variables as needed for each step. According to analysis procedure when all variables not in the model have p-value that are less than the specified Alpha-to-Enter value and when all variables in the model have p-value that are greater than or equal to the specified Alpha-to-Remove value. Alpha-to-Enter is a value that determines if any of the predictors that is not currently in the model should be added to the model. While Alpha-to-Remove is a value that determines if any of the predictors in the model should be removed from the model (Ghani and Ahmad 2010). The predictor variables finally preferred by the stepwise algorithm were incorporated into the final model (Equation 2).

Results and Discussion

Maize yield performance in experiment field

The performance of five hybrids maize varieties at experimental field of two consecutive crops growing seasons 2018-19 and 2019-20, respectively is presented in Table 2. Highly and statistically significant differences were found for all the studied traits during the crop growing season 2018-19 as well as highly and statistically significant differences were found except length of cob during the crop growing season 2019-20. Days to maturity ranged from 148 to 152 and 149 to 152 days during two consecutive crops growing seasons 2018-19 and 2019-20, respectively. The lowest days to maturity (148 days) was found in BARI hybrid maize (BHM9) as well as 149 days for VISHAL-6405 and BHM9 and the highest was in local hybrid variety PS-999 (152 days) in two consecutive crops growing season 2018-19 and 2019-20, respectively.

Plant height was the lowest (176.53 cm) in BHM9 and the highest (181.40 cm) in EUREKA for season of 2018-19 and that was the lowest (177.97 cm) in BHM9 and the highest (182.73 cm) in EUREKA for season of 2019-20. Length of cob is maximum (19.83 cm) for variety VISHAL-6405 and minimum (19.10 cm) for BHM13 for season of 2018-19 and highest (19.57 cm) and lowest (18.70 cm) for variety for VISHAL-6405 for season of 2019-20. The lowest thousand grain weight were found 393 g and 395 g in BHM9 and the highest were found 480 g and 482 g in PS-999 during crops growing season 2018-19 and 2019-20, respectively. The hybrid variety VISHAL-6405 showed the highest yield which was (12.43 t/ha) and (12.52 t/ha) followed by BHM 13 which were (10.83 t/ha) and (10.82 t/ha) during crops growing seasons 2018-19 and 2019-20, respectively.

Table 2. Performance of maize hybrids for different traits under the maize experimental field at Dorbasta union of Gobindagonj upazila, Gaibandha during the season of 2018-19 to 2019-20

Maize Growing Season 2018-2019								
Sl. No.	Variety	DM	NGC	PH (cm)	TGW(g)	LOC (cm)	DOC (cm)	GY(t/ha)
1	PS-999	152	453	178.63	480	19.17	17.03	11.84
2	VISHAL-6405	149	632	177.43	461	19.83	17.33	12.43
3	EUREKA	151	468	181.40	418	19.37	17.03	11.81
4	BHM9	148	495	178.77	393	18.57	16.70	11.22
5	BHM13	150	505	176.53	443	19.10	17.27	10.83
	Min	148	453	176.53	393	19.10	16.70	10.83
	Max	152	632	181.40	480	19.83	17.33	12.43
	LSD (0.05)	1.19	7.60	0.99	4.25	0.52	0.27	0.82
	CV (%)	0.422	0.79	0.29	0.51	1.45	0.84	3.73
	F-test	***	***	***	***	**	**	**
Maize Growing Season 2019-2020								
Sl. No.	Variety	DM	NGC	PH (cm)	TGW(g)	LOC (cm)	DOC (cm)	GY(t/ha)
1	PS-999	152	461	180.03	482	19.50	16.97	12.03
2	VISHAL-6405	149	632	179.80	453	19.57	17.47	12.52
3	EUREKA	151	478	182.73	417	19.23	16.67	12.24
4	BHM9	149	496	179.23	395	18.70	17.30	11.62
5	BHM13	150	509	177.97	442	19.10	17.27	10.82
	Min	149	461	177.97	395	18.70	16.67	10.82
	Max	152	632	182.73	482	19.57	17.47	12.52
	LSD(0.05)	1.68	7.55	0.93	10.68	0.63	0.29	0.59
	CV (%)	0.59	0.78	0.27	1.29	1.75	0.89	2.66
	F-test	**	***	***	***	NS	**	**

*** <0.001, ** <0.01, * <0.05; NS= Non Significant; Note: DM = Days to maturity, NGC = No. of grain/cob, PH = Plant height, TGW = 1000 grain weight, LOC= length of cob, DOC = Diameter of cob and GY = Grain yield

Variable classification of maize experiment in regression analysis

Regression analysis has been carried out to know the factors influencing yield of maize at experiment field in Dorbasta union of Gobindagonj upazila, Gaibandha

during two maize growing seasons viz. 2018-19 and 2019-20, respectively. Regression model was fitted for yield of maize. The response variables in the study are yield of maize, whereas independent variables include agronomical variables, weather variables and satellite parameter like NDVI value listed in Table 3. Here explanatory variables variety and year were treated as dummy. The NDVI values were taken from single date of maximum NDVI distribution on high resolution spatial satellite image like Landsat 8 OLI during two years maize experiment. Here, the NDVI values in maize experimental location were 0.66 and 0.54 after 116th and 101th days after plantation during two maize growing years. The weather data was marked on this date when NDVI values are taken from this date during two years' maize experiment viz. 2018-19 and 2019-20, respectively.

Table 3: Variables considered for classical regression analysis

Notation	Variables	Units
Y	Yield of maize (GY)	Ton per hectare (T ha^{-1})
X_1	Plant height (PH)	Centimeter (cm)
X_2	Days to maturity (DM)	Numbers
X_3	Number of grain/cob (NGC)	Numbers
X_4	1000 grain weight (TGW)	Gram (g)
X_5	Length of cob (LOC)	Centimeter (cm)
X_6	Diameter of cob (DOC)	Centimeter (cm)
X_7	NDVI	
X_8	Maximum temperature (MAT)	Degree Celsius (°C)
X_9	Minimum temperature (MIT)	Degree Celsius (°C)
X_{10}	Sunshine hour (SSH)	Hour (h)
X_{11}	Relative humidity (HD)	Percentage (%)
	Variety (Dummy)	
X_{12}	V2 (VISHAL-6405)	
X_{13}	V3 (EUREKA)	
X_{14}	V4 (BHM9)	
X_{15}	V5 (BHM13)	
X_{16}	Year (Dummy)	

Note: Variety V_1 (PS-999) is considered as reference in all dummy for varieties (X_{12} to X_{15}).

Correlation analysis and Multicollinearity

A correlation analysis is the method in regression that is used to look the strength of the relationship between two variables. Pearson linear correlation was applied to check the existence of relationship between two variables in this research. The

Pearson correlation coefficient (r) between the agronomical parameters, weather parameters, satellite data and the selected maize yields were computed.

From the correlation matrix (Figure 3), we saw that weather parameter like maximum temperature, minimum temperature, sunshine hour and relative humidity were perfectly positively correlated (r =1) with NDVI and other agronomical parameters as well as the three dummy of variety like V2 and V3 and year were also positively correlated with other agronomical parameters. Excluding these variables (7 variables) which are highly positively or negatively correlated and the variables which are insignificant in this correlation matrix. VIF (variation inflation factor) value for those variables was very high or undefined in the regression model. So, it is clearly seen that the multicollinearity problem is strongly present among the independent variables. Multicollinearity refers a situation that has significant degree of correlation between the predictor variables. Any analysis can detect multicollinearity by examining the variance inflation factor's value (VIF). Multicollinearity is not a severe issue when the value of VIF is less than 5. While multicollinearity is noticeable if VIF is more than 5. When the value of VIF exceeds 10, multicollinearity becomes more problematic.
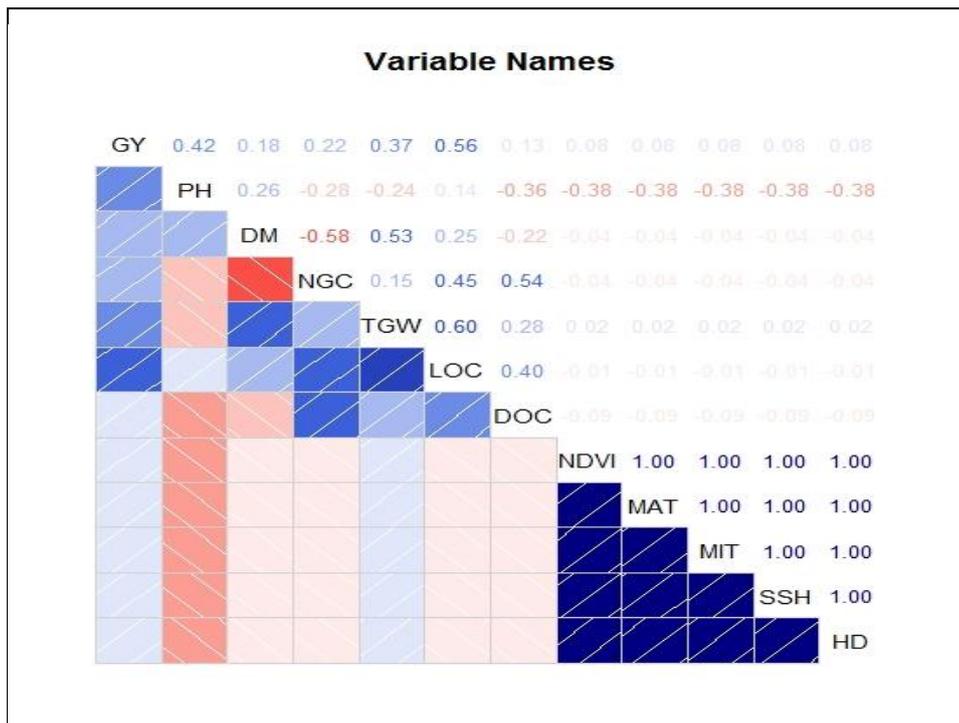
Fig. 3. Correlogram of correlation matrix

Regression analysis of maize yield time series

A total number of 9 independent variables were used in this study. Firstly the multiple linear regression (MLR) analysis was carried out by considering all the explanatory variables. The R^2 of MLR model obtained in Table 4 shows that all predictor variables considered in the study explains 79.90 percent of the variation in response variable. Though the R^2 of MLR model is very high but all of the variables in the model are non-significant and variance inflation factor (VIF) is also high in majority of the variable. This clearly denotes the multicollinearity problem among the explanatory variables. To overcome the same, one of the measures is to remove unimportant variables which are explaining less variation in dependent variables in the model (Gujarati et al., 2013). The dropping and adding of variable can be done using the stepwise regression analysis.

Table 4. Multiple linear regression analysis of maize yield

Variable	Coefficient	Std. Error	t-test	P-value	VIF
Constant	-38.341836	28.840282	-1.329	0.1987	
X_1	0.193471	0.119094	1.625	0.1199	9.974900
X_2	-0.020304	0.110233	-0.184	0.8557	5.836325
X_3	0.001151	0.002904	0.396	0.6962	6.972129
X_4	0.010471	0.006708	1.561	0.1342	8.917560
X_5	0.091040	0.303554	0.300	0.7673	4.000540
X_6	0.542524	0.301391	1.800	0.0870	1.999086
X_7	3.406770	1.817878	1.874	0.0756	2.525861
X_{14}	0.115507	0.505741	0.228	0.8217	8.688687
X_{15}	-0.803040	0.417701	-1.923	0.0689	5.926925
R^2			0.799		
F Statistic			8.83		
P-value			0.0003		

Note: X_1 = Plant height (PH), X_2 = Days to maturity (DM), X_3 = Number of grain/cob (NGC), X_4 = 1000 grain weight (TGW), X_5 = Length of cob (LOC), X_6 = Diameter of cob (DOC), X_7 = NDVI, X_{14} = V4 (BHM9) and X_{15} = V5 (BHM13)

Stepwise regression analysis: Generating maize yield model

The statistical significance of each predictor variable in a linear regression model is iteratively examined through stepwise regression. The forward selection procedure starts from zero and gradually integrates each additional variable while evaluating for statistical significance. The backward elimination method begins with a full model that is loaded with many variables, and then it eliminates one variable to determine its significance in regard to the overall outputs. Stepwise regression is a technique for fitting data into a model to generate the desired output, but it has drawbacks as well.

Hence, stepwise regression analysis was carried out to fit the model. The detailed summary of stepwise regression for backward elimination process is given in Table 5.

Table 5. Stepwise regression (Backward elimination) analysis of maize yield

Variable	Coefficient	Std. Error	t-test	P-value	VIF
Constant	-36.099913	11.785032	-3.063	0.005338	
X_{15}	-0.962188	0.202358	-4.755	0.000078	1.569513
X_4	0.009194	0.002241	4.102	0.000407	1.123281
X_6	0.730373	0.228328	3.199	0.003852	1.294541
X_1	0.163468	0.052317	3.125	0.004607	2.171904
X_7	3.129348	1.259195	2.485	0.020312	1.367392

Note: X_1 = Plant height (PH), X_4 = 1000 grain weight (TGW), X_6 = Diameter of cob (DOC), X_7 = NDVI and X_{15} = V5 (BHM13).

The stepwise regression for maize yield data was completed in five steps, the maximum R^2 was increased in each step and it was obtained 78.6 percent in final steps. The unexplained or non-significant variables are removed from the model so that we can get maximum error degrees of freedom. In this stepwise regression analysis i.e., backward elimination process, we obtained total five significant independent variables in Table 5 as compare to MLR model in Table 4 in which no one of the variables were significant. Here the result from the Table 5 shows that multicollinearity is not present among the desired predicted variables i.e., (1 < VIF < 5). The results of stepwise regression for backward elimination illustrate that the variable like variety 5 (X_{15}) i.e., BHM13 significantly influence the changes in the maize yield which explains highly significant in this model. Based on this result we can say that as the variety BHM13 significantly contributes the changes in maize yield (t/ha). The variable like 1000 grain weight (X_4), diameter of cob (X_6), plant height (X_1) and NDVI values (X_7) also significantly influence the changes in maize yield and also production.

Table 6. Stepwise regression (Forward selection) analysis of maize yield

Variable	Coefficient	Std. Error	t-test	P-value	VIF
Constant	-26.473339	11.553187	-2.291	0.031015	
X_4	0.010329	0.002367	4.364	0.000209	1.082183
X_{15}	-0.783426	0.229129	-3.419	0.002249	1.738747
X_1	0.168722	0.058789	2.870	0.008434	2.369708
X_3	0.002939	0.001244	2.362	0.026628	1.247862
X_7	2.933192	1.355513	2.164	0.040646	1.369191

Note: X_1 = Plant height (PH), X_3 = Number of grain/cob (NGC), X_4 = 1000 grain weight (TGW), X_7 = NDVI and X_{15} = V5 (BHM13)

Analogously, the precise summary of stepwise regression for forward selection approach is given in Table 6. The forward selection for maize yield data was executed in ten steps, the maximum R^2 obtained was 75.26 percent and it was presented in last step. The unimportant or insignificant variables are dropped from the model so that we can get maximum error degrees of freedom. In this forward selection approach, we obtained total five significant explanatory variables (Table 6). Here the output show that multicollinearity is not present among the desired controlled variables i.e., $(1 < VIF < 5)$. Outputs of stepwise regression for forward selection demonstrate that the variable like 1000 grain weight (X_4) significantly contributes in increasing the maize yield which explains highly significant in this model. Based on this output we can say that as 1000 grain weight (TGW) increases, the maize yield (t/ha) also increases. The variable like variety 5 (X_{15}), the plant height (X_1), number of grain/cob (X_3) and NDVI values (X_7) also significantly influence the changes in maize yield as well as production.

According to Table 5 and Table 6, we can develop two model using MLR equation based on the stepwise regression including backward elimination and forward selection process which are given bellow:

Model 1 (Backward elimination):

$$\hat{Y} = -36.099913 - 0.962188\,X_{15} + 0.009194\,X_4 + 0.730373\,X_6 + 0.163468\,X_1 + 3.129348\,X_7$$

Model 2 (Forward selection):

$$\hat{Y} = -26.473339 + 0.010329\,X_4 - 0.783426\,X_{15} + 0.168722\,X_1 + 0.002939\,X_3 + 2.933192\,X_7$$

Based on the Model 1, the coefficients for variety 5, 1000 grain weight, diameter of cob, plant height and NDVI values were $(P<0.05)$ significant. This explained that these coefficients are factor to the maize yield for backward elimination. While in Model 2, the coefficients for 1000 grain weight, variety 5, the plant height, number of grain/cob and NDVI values were $(P<0.05)$ significant. This explained that these coefficients are factor to the maize yield for forward selection.

Model simulation and best model assessment

According to Table 5 and Table 6, it presents the result of stepwise regression using open source program R. There are two approaches that used to select the independent variables. In the approach 1, X_{15} indicates smallest p-value than Alpha-to-Enter $(p=.000<.05)$. Therefore X_{15} is the first variable that enters into the model (backward elimination). In the approach 2, the p-value for X_4 shows 0.000209 which is smallest than 0.05. Therefore X_4 is the first variable that enters into the model (forward selection). Model 1 and model 2 both includes 5 predicted variables after running step wise regression. After that there are no controlled

variables that enter and remove from those models. The best model is selected after model simulation from model 1 and model 2 based on model accuracy criteria which are presented in Table 7.

Table 7. Best model selection based on model selection criteria

Model	R^2	$\overline{R^2}$	Cp	NRMSE	MAE	RMSE	MAPE
Model 1	0.79	0.74	6	2.77	2.57	0.317	0.022
Model 2	0.75	0.70	9.78	2.98	2.64	0.341	0.023

Note: AIC- MAE- Mean Absolute Error; NRMSE- Normalized Root Mean Square Error; RMSE- Root Mean Square Error; MAPE- Mean Absolute Percentage Error; Cp- Mallows Cp.

For the results of maize yield in Table 7, the value of R^2 and adjusted R^2 (79% and 74%) higher for model 1 than model 2 (R^2=75% and adjusted R^2=70%). MAE, NRMSE, RMSE and MAPE values of model 1 are smaller than model and Mallows Cp in model 1 is closer to number of controlled variables than model 2. Hence, these statistics indicates model 1 which containing controlled variables variety 5 (X_{15}), 1000 grain weight (X_4), diameter of cob (X_6), plant height (X_1) and NDVI (X_7) values are provided better fits to the data. Weather variables are not significantly effect in this model. The final model (best model) shows only five controlled variables by using stepwise regression (backward elimination) and produced regression model such as follows:

$$\hat{Y} = -36.099913 - 0.962188\,X_{15} + 0.009194\,X_4 + 0.730373\,X_6 + 0.163468\,X_1 + 3.129348\,X_7$$

However, depending on the availability of information, on necessary variables (X_3, X_6) alter model (Model 2) may be used in practice. The stepwise regression analysis suggested two competing models both of which including X_{15} (Variety BHM13). However, despite being the best possible models these two lack the prediction efficiency for the entire country /region where different varieties are cultivated.

Conclusions

The crop yield forecast models have been improved by considering experimental data on the maize crop at Dorbasta union of Gobindagonj upazila, Gaibandha in this study during two consecutive crops growing season 2018-19 and 2019-20, respectively. Five hybrids maize varieties like viz. PS-999, VISHAL-6405, EUREKA, BHM9 and BHM13 are performed almost better during the maize growing period. Highly and statistically significant differences were found for all the studied variables during the crop growing season 2018-19 and except length of cob during the crop growing season 2019-20.

Local or regional based crop yield forecasting conveys the maximum emphasis than national level crop yield estimation as NDVI varies field to field. We found that NDVI was perfectly positive correlated ($r=1$) with the weather variables in this research. And also weather variables were not significant in this model. Actually, NDVI is a cumulative contribution of weather parameters (Hao et al., 2012; Pei et al., 2019). In this study multiple linear regressions (MLR) like the stepwise regression analysis was used for maize yield forecasting. Stepwise regression viz., forward selection and backward elimination were generated to build forecasting model or ideal model for maize yield. Backward elimination (Model 1) obtained totally five significant predictor variables and similarly for Forward selection (Model 2). Multicollinearity was not happened strongly among the desired predicted variables for both. By comparing two models, Backward elimination (suggest as a best model) is a better model fits to the data than Forward selection. Therefore, the best model or the forecast developed maize yield model used in specific region including all types of data that gives more precise result on maize yield or production that should be more significant and reliable in national level. This best model which can be used by the researcher, policymaker for maize yield prediction.

References

Agrawal, R., R.C. Jain, and M.P. Jha. 1986. Models for studying rice crop weather relationship. Mausam, **37(1):** 67-70.

Ahmed, A., S. Ryosuke. 2000. Climate Change and Agricultural Food Production of Bangladesh:An Impact Assessment Using GIS-Based Biophysical Crop. Simulation Model; Center for Spatial Information Science, University of Tokyo: Komaba, Japan, 2000.

Armstrong, J. 1970. How to avoid exploratory research. *Journal of Advertising Research*, **10(4):** 27–30.

BBS, 2020. Yearbook of Agricultural Statistics, 2020. 32nd series, published: 21th May, 2021. Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Bowerman, B.L., R.T. O'Connell and A.B. Koehler. 2005. Forecasting, time series and regression. 4th ed. United States of America: Brooks/Cole Thomson Learning Inc.

Chowdhury, I.U.A. and M.A.E. Khan. 2015. The Impact of Climate Change on Rice Yield in Bangladesh: a Time Series Analysis. *RJOAS,* 4(40), April 2015.

CIMMYT Bangladesh, 2008. Maize whole family training. In: Food Security in Bangladesh: Improving Wheat, Maize and Papaya Production and Impacts of Arsenic Contamination. Project Annual Report for 2007-2008, pp.31-44.

Dixon, B.L., S.E. Hollinger, P. Garcia and V. Tirupattur. 1994. Estimating Corn Yield Response Models to Predict Impact of Climate Change, *Journal of Agricultural and Resource Economics*, **19(1):** 58-68.

Draper, N.R. and H. Smith. 1998. *Applied Regression Analysis*, 3rd Edition, John Wiley & Sons, New York.

Garde, Y.A., S. Singh, G.C. Mishra and T. Singh. 2012. Weather Based Pre-Harvest Forecasting of Wheat at Ghazipur (U.P.), *International Journal of Agricultural Sciences*, **8(2):** 325-328.

Ghani, I.M.M. and S. Ahmad. 2010. Stepwise Multiple Regression Method to Forecast Fish Landing. *Procedia Social and Behavioral Sciences* 8 (2010) 549–554.

Gujarati, D.N., D.C. Porter and S. Gunasekar. 2013. Basic Econometrics (Fifth Edition), Tata McGraw-Hill Education Pvt. Ltd, ISBN 10: 0071333452 / ISBN 13: 9780071333450

Hao, F., Z. Xuan, O. Wei, K. S. Andrew and A. G.Toxopeus. 2012. Vegetation NDVI linked to temperature and precipitation in the upper catchments of yellow river. *Environ model assess* (2012) **17:** 389-398.

Hossain, A., Teixeira da Silva, J.A. Phenology.2013. Growth and Yield of Three Wheat (*Triticum.*aestivum L.) Varieties As Affected by High Temperature Stress. *Not. Sci. Biol.* **2013**, 4, 97–106.

Kandiannan, K., R. Karithikeyan, R. Krishnan, C. Kailasam and T.N. Balasubramanian. 2002. A Crop-Weather Model for Prediction of Rice Yield Using an Empirical-Statistical Technique, *Journal of Agronomy and Crop Science*, **188:** 59-62.

Kumar, K. S. and M. Shitap. 2020. Statistical evaluation of stepwise regression method and autoregressive integrated moving average method for forecasting of groundnut (arachis hypogaea l.) productivity in Junagadh district of Gujarat. *Int.J.Curr.Microbiol.App.Sci* (2020) **9(11):** 84-93.

Levin R.I. and D.S. Rubin. 1994. Statistics for management. 6th ed. Englewood Cliffs, N.J.: Prentice Hall.

Mijinyawa, Y. and T. D. Akpenpuun. 2015. Climate change and its effect on grain crops yields in the middle belt in Nigeria. *African Journal of Environmental Science and Technology.* Vol. 9(7), pp. 641-645, July, 2015.

Montgomery, D. C., E.A. Peck and G. Vining. 2003. *Introduction to Linear Regression Analysis.* 3rd Edition, John Wiley and Sons (Asia) Pte. Ltd.

Pei, Z., F. Shibo, Y. Wunian, W. Lei, W. Mingyan, Z. Qifei, H. Wei and N. K. Dao. 2019. The relationship between NDVI and climate factors at different monthly time scales: A case study of grasslands in inner Mongolia, China (1982-2015). *Sustainability* 2019,11,7243.

Peiris, T. S. G., J. W. Hansen and L. Zubair. 2008. Use of Seasonal Climate Information to Predict Coconut Production in Sri Lanka. *Int. J. Climatol.*, 28: 103–110. doi: 10.1002/joc.1517.

Rathod, S. and G. C. Mishra. 2018. Statistical Models for Forecasting Mango and Banana Yield of Karnataka, India. *J. Agr. Sci. Tech*. (2018) Vol.20: 803-816.

Rathod, S., H.S. Surendra, R. Munirajappa, and K.B. Murthy. 2012. Statistical Assessment on the Factors Influencing Agriculture Diversification in Different Districts of Karnataka. *Environment and Ecology*, 30 (3A): 790-794.

Rondeaux, G., M. Steven & F. Baret. 1996. Optimization of soil-adjusted vegetation indices. *Remote Sensing of Environment,* **55(2):** 95-107.

Tannura, M.A., S.H. Irwin and D.L. Good. 2008. Weather technology and corn and soybean yield in the U.S. Corn Belt, Marketing and Outlook Research Report 2008–2011, Department of Agricultural and ConsumerEconomics, University of Illionis, Illionis.

Udokang, A. E. 2020. A stepwise approach of factors affecting agricultural production in Nigeria. *Science Journal of Business and Management* 2020; 8(3): 149-153 http://www.sciencepublishinggroup.com/j/sjbm doi: 10.11648/j.sjbm.20200803.17.

Wang, G. C., & C. L. Jain. 2003. Regression analysis: Modeling & forecasting. Institute of Business Forec.

Yang, S.R., W.W. Koo and W.W. Wilson. 1992. Heteroscedasticity in crop yield models, *Agricultural and Resource Economics*, **17(1):** 103-109.

DIVERSITY OF HOMESTEAD FRUIT CROPS IN THE SOUTH-CENTRAL COASTAL REGION OF BANGLADESH

M. Z. Rahman[1], M. Robbani[2], M. F. Hasan[3]
and M. M. Rashid[4]

Abstract

South-Central Coastal region of Bangladesh rich in homestead forest as traditional multi-layered agro-forestry practices. With a view to assess the diversity, richness, distribution, and relative prevalence of fruits & agroforestry species, a survey was conducted during July 2021 to October 2021 in 300 households of five upazilas, Bakergonj, Dumki, Kalapara and Patuakhali Sadar and Amtali of Barishal, Patuakhali and Barguna districts consisting of nine major and 31 minor fruits existed in the south central coast of Bangladesh. The survey results showed significant variation amongst the studied upazilas in relation to fruit crops diversity. The largest household area (47.87 decimal) was noticed in Bakergonj with maximum number of fruits and timbers (75.1) where the numbers of fruit trees were 24.5 per household. The smallest household (30.82 decimal) was found in Kalapara with an accommodation of 34.92 numbers of fruit and timber having the lowest number of fruit trees (18.7). The maximum number of fruit species was observed in the households of Bakergonj (7.22) followed by Amtali (6.55) and the lowest (5.07) in Kalapara upazila. Among the major fruits, the maximum distribution in the homestead areas of five upazilas was recorded as mango (100%) followed by banana (98.67%), papaya (98.67%) and coconut (98.33%), whereas among the minor fruits the maximum distribution was found as velvet apple (98.67%) followed by seeded banana and golden apple (97.67%). The highest species diversity (0.825) of major fruits was recorded in Bakergonj and the lowest (0.773) in Kalapara upazila. But, in case of minor fruits, the highest (81.6) species diversity was recorded in Dumki and the lowest (0.771) in Kalapara upazila. Maximum diversity was found in banana, mango and coconut in respect of major fruits, whereas velvet apple and seeded banana in regard to minor fruit species. The mean dominance of the major fruit population showed that banana ranked top followed by mango and coconut whereas velvet apple ranked top followed by seeded banana among the minor fruits.

Keywords: Fruit species, homesteads, south central coastal areas, diversity,

Introduction

Bangladesh is a rich repository of plant genetic pools and has conceived more than 5000 species of higher plants (Rahman *et al.,* 2009). There are 321.74 lakh

---

[1]PhD Student and Senior Scientific Officer, Pomology Division, HRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, [2]Professor, Department of Horticulture, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali, Bangladesh, [3]Professor, Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh, [4]Professor, Department of Agricultural Extension and Rural Development, PSTU, Dumki, Patuakhali, Bangladesh.

households in Bangladesh and three districts, namely Barishal, Barguna and Patuakhali comprise 10.76 lakh household. (Anon., 2023). Almost every household facilitates various fruits, mainly minor fruits and agroforestry tree species. The southern-central area of Bangladesh adjacent to the sea, the coastal region where about 20 percent of the country's land area is situated and about 30 percent of the total cultivable land is in the coastal areas (Anon., 2022). Due to the soil salinity in this region, which is inundated by the tidal waters of the sea, it is not possible to cultivate many kinds of crops and fruits like other parts of the country. Huge potentiality exists in the central coastal region for future agricultural development where fruits like guava, mango, coconut, jujubee, pummelo, malta, etc. have been helpful in changing the fortunes of many farmers (Anon., 2022).

Sarker *et al.* (2022) mentioned that Bangladesh has produced 51.4 lakh metric tons fruits from 4.02 lakh hectares of land and 14.3 lakh metric tons (28% of total production) contributed by the outside garden production (homestead and roadside plantation). A homestead is used as a dwelling place as well as a production unit for plants, animals and fish under an integrated farming system (Foysal *et al.,* 2013). In Bangladesh, there are varieties of local fruits with good nutritional values grown in homesteads, forest areas, roadsides and near railway without much care. These fruits are termed as minor/underutilized fruits because of less awareness to its nutrient value among the mass people. Meanwhile, fruits are rich in different vitamins and minerals to ensure food quality, dietary diversity and can also provide household income (Abebe *et al*., 2019; Elfrida *et al.,* 2020).

Rahim *et al.* (2011) reported 67 minor fruit yielding plants of Bangladesh that are being grown in the Germplasm Centre at Bangladesh Agricultural University. Rahman and Rahman (2014) reported that a total of 70 fruits are presently grown in Bangladesh; among them 42 are minor fruit species. From a survey of 80 homesteads Roy *et al.* (2013) obtained 62 plant species (trees, herbs and shrubs) belonging 36 families, among which there were only 21 fruit species (major and minor).

The identification of major and minor fruits species adapted to coastal saline affected areas and conservation of different major as well minor fruits germplasm in homestead areas helps not only to enrich their germplasm but also helps to protect them from genetic extinction. So the household survey was done with a view to identifying the promising fruit species (major and minor) which are not only adapted but giving maximum yield inhabitant to this climate change vulnerable coastal areas. Therefore, the study was carried out to update and provide the available information on species diversity, species richness and relative prevalence of fruits available in these vulnerable coastal upazilas of Bangladesh.

Materials and Methods

Experimental sites

The survey was conducted in the five upazilas (Bakergonj, Dumki, Patuakhali Sadar, Kalapara and Amtali) situated in central three coastal districts, namely

Barishal, Patuakhali and Borguna of Bangladesh during 2021. Ten farmers' households from each union were selected and finally 300 samplings (10 farmers for each union × 6 unions for each upazila × 5 upazilas) were taken for the study. Geographic position including Latitudes and Longitudes of the study areas are presented in Table1.

Table.1 Details of the study area

Sl. No.	District (3)	Upazila (5)	Union (30)	Latitudes and Longitudes
1.	Barishal	Bakergonj	Dudhal, Nalua, Padri shibpur, Rangoshree, Bhorpasha	22°14' and 22°29' N 90°12' and 90°28' E
2.	Patuakhai	Dumki	Angaria, Pangashia, Muradia, Lebukhali, Sreerampur.	22°23' and 22°30' N 90°17' and 90°27' E
		Patuakhali Sadar	Auliapur, Badarpur, Marichbunia, Kalikapur, Jainkati, Madarbunia	22°14' and 22°29' N 90°12' and 90°28' E
		Kalapara	Khaprabhanga, Dhankhali Chakamaiya, Tiakhali, Nilganj, Latachapli	21°48' and 22°05' N 90°05' and 90°20' E
3.	Borguna	Amtoli	Atharogashia, Amtali, Kukua, Gulishakhali, Chowra, Haldia	21°51' and 22°18' N 90°00' and 90°23' E

Fruit species percent in the homesteads

The total number of fruit species present in the homesteads of the study areas along with the total number of families of fruit species was identified. After that the total species and the total number of fruit plant populations were considered as the abundance.

Distribution of fruit species

The frequency of occurrence of a particular fruit species at the homesteads were measured. The distribution of fruit species was calculated in a particular homestead through interview schedule using a pretested questionnaire.

Percent homestead = (Particular existing fruit/No. of homesteads in an area) × 100

Species richness (SR)

The species richness is the number of species within an area, giving equal weight to each one as suggested by Heywood and Watson (1995). Fruits of the homesteads were grouped into two: major and minor fruits by personal communication with Chief Scientific Officer (CSO), Pomology Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI). After that the proportion of the two groups were calculated.

Species diversity (SD)

Species diversity was calculated following the formula of Simpson (1949). Where Simpson index (D) were used to calculate the species diversity, which is: $D = 1 - Pi^2$, where Pi is the proportional abundance of the *ith* species such as, $Pi^2 = Ni/N$, Where Ni = Fruit population of the *ith* species and $N = N_1 + N_2 + N_3 ....Nn$ where $n =$ is the number of species.

Relative prevalence (RP) of the species

The percent of homestead containing a particular species is one of the indicator of the relative prevalence of the particular species in that area. The percent of homesteads having the fruit species was calculated for all species. Then the relative prevalence of a species was calculated using the formula:

RP = Population of the species per homestead $\times$ % homestead with the species.

The relative prevalence value was calculated to rank the species into different groups according to Millat-e-Mustafa (1997).

Dominance rank (DR)

The dominance rank of the fruit species was determined by pooling the entire set of data from the study.

Data analysis

Before each interview the interviewer informed the respondent about the purpose of the survey and ensured verbal and written consent. Also the confidentiality of all information released by respondent was assured. Data were analyzed using the Statistical Package for Social Science (SPSS) (IBM SPSS Statistics 23) and Excel software. Sixty samples (Household) were used as treatment from each upazila, where it was replicated in five upazila (viz. Bakergonj, Dumki, Patuakhali Sadar, Kalapara and Amtali). Randomized Complete Block Design (RCBD) with five replications was used to analyze household area, fruit species and total number of fruit species data and mean separation was done by HSD Tukey Test using JMP - 14 pro software.

Results and Discussion

Household size and fruit species distribution of five upazilas under south central coast of Bangladesh

Household area, fruit species and total number of fruit trees existed in the studied household of different upazilas are presented in Table 3. The largest household was identified in Bakergonj (47.87 decimal) upazila, closely followed by Amtali (35.45 decimal), and Patuakhali Sadar (33.78 decimal) and the smallest household (30.82 decimal) was found in Kalapara (30.82 decimal).

Table 2. Household area, fruit species and total number of fruit trees existed in the studied household of different upazilas

Upazila	Household area (decimal)	Fruit species (no.)	Total fruits and timbers (No.)	Total fruit trees (no.)
Amtali	35.45 ab	6.55 ab	63.80 ab	32.35 a
Bakergonj	47.87 a	7.22 a	75.18 a	24.52 b
Dumki	33.78 ab	5.88 b	45.40 ab	23.00 bc
Kalapara	30.82 b	5.07 c	34.92 b	18.72 c
Patuakhali Sadar	31.50 b	6.38 b	51.37 ab	23.75 bc
Level of significance	**	**	*	*

Figures in a column having same letter (s) don't differ significantly at 5% and 1% level of probability by HSD Tukey Test.*= Significant at the 5% level of probability **= Significant at the 1% level of probability.

Maximum number of fruit species (7.22) was recorded in the households of Bakergonj followed by Amtali (6.55) and very few species at Kalapara (5.07). Total number of fruit and timbers was found maximum (75.18) in Bakergonj which was closely followed by Amtali (63.80), Dumki (51.37) and Patuakhali Sadar (45.40) and the minimum observed in Kalapara (34.92).. The total number of fruit trees was maximum in Amtali (32.35) followed by Bakergonj (24.52) and it was minimum (18.72 in Kalapara homestead.

During survey nine major fruits viz., mango, banana, jackfruit, coconut, litchi, guava, papaya pineapple and jujube and 31 minor fruits, namely lime, Lemon, Velvet apple, Monkey jack, golden apple, pomelo, stone apple, wax jambu, Indian olive, sweet orange, sapota, aonla, tamarind, jamun, wood apple, pomegranate, cowa, bullock's heart, palmyra palm, dragon fruit, carambola, buttercup, custard apple, cane palm , bilimbi, river ebony, date palm, seeded banana, star gooseberry, boichi and Indian almond were identified (Table 3).

Table 3. English, Bengali, Scientific name and families of different fruit species found in the study area

Sl. No.	English Name	Local Name/ Bengali Name	Scientific Name	Family
	Major fruits			
1.	Mango	Aam	*Mangifera indica*	Anacardiaceae
2.	Banana	Kola	*Musa sapientum*	Musaceae
3.	Jackfruit	Kanthal	*Artocarpus heterophyllus*	Moraceae
4.	Coconut	Narikel	*Cocos nucifera*	Palmaceae
5.	Litchi	Lichu	*Litchi chinensis*	Sapindaceae
6.	Guava	Peyara	*Psidium guajava*	Myrtaceae
7.	Papaya	Pepe	*Carica papaya*	Caricaceae
8.	Pineapple	Anarosh	*Ananus comosus*	Bromeliaceae
9.	Jujube	Boroi/Kul	*Zizyphus jujuba*	Rhamnaceae

Sl. No.	English Name	Local Name/ Bengali Name	Scientific Name	Family
	Minor fruits			
10.	Lime	Kagojilebu	*Citrus aruntifolia*	Rutaceae
11.	Lemon	Lebu	*Citrus limon*	Rutaceae
12.	Velvet apple	Bilatigab	*Diospyros discolor*	Ebemaceae
13.	Monkey jack	Dewa/Deophal	*Artocarpus lakoocha*	Moraceae
14.	Golden apple	Bilati amra	*Spondias dulcis*	Anacardiaceae
15.	Pomelo	Batabilebu	*Citrus grandis*	Rutaceae
16.	Stone apple	Kodbael	*Feronia limonia*	Rutaceae
17.	Wax Jambu	Jamrul	*Syzygium samarengense*	Myrtaceae
18.	Indian olive	Jalpai	*Elaeocarpus floribundus*	Elaeocarpaceae
19.	Sweet orange	Malta	*Citrus sinensis*	Rutaceae
20.	Sapota	Shafeda	*Achras sapota*	Sapotaceae
21.	Aonla	Amloki	*Emblica officinalis*	Euphorbiaceae
22.	Tamarind	Tentul	*Tamarindus indica*	Fabaceae
23.	Jamun	Jam	*Syzygium cumini*	Murtaceae
24.	Wood apple	Bael	*Aegle marmelos*	Rutaceae
25.	Pomegranate	Dalim	*Punica granatum*	Punicaceae
26.	Cowa	Kaufal	*Garcinia cowa*	*Cluciaceae*
27.	Bullock's heart	Ata	*Annona reticulata*	Annonaceae
28.	Palmyra palm	Taal	*Brassus flabellifer*	Palmaceae
29.	Dragon fruit	Dragan Phal	*Hylocereus spp*	Cactaceae
30.	Carambola	Kamranga	*Averrhoa carambola*	Averrhoaceae
31	Buttercup	Mahua	*Madhuca longifolia*	Sapotaceae
32.	Custard apple	Sharifa	*Annona squamosa*	Annonaceae
33.	Cane palm	Bet phol	*Calamus tenuis*	Arecaceae
34.	Bilimbi	Bilimbi	*Avenhoa bilimbi*	Averrhoaceae
35.	River ebony	Deshi gab	*Diospyros peregrina*	Ebenaceae
36.	Date palm	Khejur	*Phoenix sylvestris*	Palmaceae
37.	Seeded Banana	Bichikola	*Musa spp*	Musaceae
38.	Star gooseberry	Arboroi	*Phyllanthus distichus*	Phyllanthaceae
39.	Boichi/ Madagascar Plum	Boichi	*Flacourtia indica*	Flacourtiaceae
40.	Indian almond	Kathbadam	*Terminalia catappa*	Combretaceae

Diversity of fruit crops grown in the households of south central coast of Bangladesh

Existing fruit species abundance at the homesteads

The total number of fruit species with the total number of their plants were considered as their abundance of the respective upazila. Forty fruit species including nine major and 31 minor fruits were noticed (Table 4). A total 19,947

number of nine major fruits plants in five upazilas were identified where banana (7047 plants) ranked first followed by mango (5339 plants). Among the total fruit species (both major and minor) (32,279), major fruits occupied 61.80% and minor fruits occupied 38.20%, respectively.

Among major fruits, in consideration of percentage total Banana ranked first (21.83%) while Mango ranked second (16.54%) of total population, respectively. In case of total minor fruit species (12,332) velvet apple (6.62%) ranked top followed by Date palm (5.35%), seeded banana (4.52%) and river ebony (3.94%). Islam *et al.* (2013) reported that among the fruit tree species, coconut, betel nut, mango, jackfruit, guava and velvet apple were found in more than 80% households. Maximum mango trees were recorded from Bakerganj (1149 trees) followed by Kalapara (1120 trees), Amtali (1099 trees) and Patakhali Sadar (1073 trees) and the minimum from Dumki (899 trees). Banana was found the highest in Kalapara (1575 trees) followed by Amtali (1464 trees) and the lowest from Dumki (1242 trees). Among major fruits, only pineapple was not found in all upazilas and among minor fruits, Indian olive, pomegranate, dragon fruit, crambola, buttercup, custard apple, cane palm, bilimbi, Madagascar plum and Indian almond were not found in all upazilas.

Table 4. Fruit species (number/population) present at the homesteads of study area

Sl. No.	Fruit Species	Amtali	Bakergonj	Kalapara	Dumki	Patuakhali Sadar	Total	% Category	% Total
	Major Fruits								
1.	Mango	1099	1149	899	1120	1073	5339	26.76	16.54
2.	Banana	1464	1379	1242	1575	1388	7047	35.31	21.83
3.	Jackfruit	282	117	278	54	215	945	4.74	2.93
4.	Coconut	498	504	336	348	371	2057	10.31	6.37
5.	Litchi	62	41	53	38	65	257	1.29	0.79
6.	Guava	180	395	513	200	333	1620	8.12	5.02
7.	Papaya	306	287	242	188	278	1299	6.51	4.02
8.	Pine apple	233	300	0	255	0	788	3.95	2.44
9.	Jujubee	137	132	87	119	123	597	3.00	1.85
Sub-total		4261	4304	3650	3897	3846	19947	100.00	61.80
	Minor Fruits								
10.	Lime	345	113	38	87	128	710	5.75	2.20
11.	Lemon	27	17	23	24	35	125	1.01	0.39
12.	Velvet apple	494	455	398	414	377	2136	17.32	6.62
13.	Monkey jack	113	98	143	126	96	575	4.66	1.78
14.	Golden apple	185	270	144	279	174	1052	8.53	3.26
15.	Pomelo	38	27	38	50	36	188	1.52	0.58

Sl. No.	Fruit Species	Amtali	Bakergonj	Kalapara	Dumki	Patuakhali Sadar	Total	% Category	% Total
16.	Stone apple	36	23	21	27	30	137	1.11	0.42
17.	Wax Jambu	72	69	53	89	57	339	2.75	1.05
18.	Indian olive	0	2	9	0	0	11	0.09	0.03
19.	Sweet orange	21	20	38	32	53	162	1.31	0.50
20.	Sapota	24	48	35	48	27	182	1.47	0.56
21.	Aonla	78	83	56	71	96	383	3.10	1.18
22.	Tamarind	48	41	54	117	53	312	2.53	0.97
23.	Jamun	21	29	20	33	17	119	0.96	0.37
24.	Wood apple	36	57	48	56	80	276	2.24	0.86
25.	Pomegranate	2	0	2	8	12	23	0.18	0.07
26.	Cowa	27	42	72	56	33	230	1.86	0.71
27.	Bullock's heart	26	21	18	24	18	107	0.86	0.33
28.	Palmyra palm	38	35	72	66	78	288	2.34	0.89
29.	Dragon fruit	12	18	0	23	38	90	0.73	0.28
30.	Carambola	18	3	0	2	0	23	0.18	0.07
31.	Buttercup	23	0	0	0	12	35	0.28	0.11
32.	Custard apple	0	0	18	0	0	18	0.15	0.06
33.	Cane palm plant	6	0	21	0	0	27	0.22	0.08
34.	Bilimbi	53	0	68	0	32	152	1.23	0.47
35.	River ebony	282	248	255	249	237	1271	10.30	3.94
36.	Date palm	383	312	282	428	324	1728	14.01	5.35
37.	Seeded Banan	332	303	318	318	189	1460	11.84	4.52
38.	Star goosberry	33	24	17	23	18	114	0.92	0.35
39.	Boichi/Madagas car plum	12	0	0	0	0	12	0.10	0.04
40.	Indian almond	23	12	0	0	21	56	0.45	0.17
	Sub-total	2808	2370	2261	2650	2271	12332	100.00	38.20
	Total	7067	6672	5909	6546	6114	32279		100

Distribution of fruit species

The frequency of occurrence of a particular species in an area is one of the indications of its biodiversity. Homesteads in Bangladesh are delighted with an integrated production system and a stable ecosystem that maintain the fruit diversity as biological wealth. Distribution of different fruits in the household areas has been presented in Table 5. All of the households of studied coast consisted of 100% mango plants in all upazilas. Coconut occupied 100% in different households of four upazillas viz., Amtali, Bakergonj, Kalapara and Patuakhali Sadar except Dumki upazila which contained 91.67% and papaya contained 100% households of all upazilas except Kalapara. The least amount of major fruit species

was litchi fruits with a range of 20.00 to 51.67% followed by pineapple which ranged from 16.67 to 66.67% in the studied coast. Based on average of five upazilas, it was observed that mango had the highest distribution (100%) followed by papaya (98.67%), coconut (98.33%), banana (96.67%) and guava (95.00%), ant the lowest distribution by litchi (37.33%) and jujube (39.67%). Among the minor fruits, velvet apple was found in 100% households of Bakergonj, Dumki, Kalapara and Patuakhali Sadar upazila except Amtali. Seeded banana was also very much location specific carrying huge production of native species in this region consisting 100% households in three upazilas viz., Bakergonj, Kalapara and Patuakhali Sadar. Based on the average values over three districts, the maximum distribution was noticed in velvet apple (98.67%) which was closely followed by seeded banana (97.67%) and golden apple (97.67%), moderate was found in lime. The remaining minor fruits had the lower distribution and the minimum distribution was found in bullock's heart (18%). The present research results are supported by Rahman *et al.* (2009) who observed that mango and jujube were in 100% homesteads in Hatiya island followed by coconut (98.7%), guava (97.5%), betel nut (96.2%) and jackfruit (95%). Mannan *et al*. (2002) recorded coconut at 98.6% followed by mango at 96.72%, banana at 90.16%, jujube at 86.88% and date palm at 80.32% of homesteads in Noakhali coast. Islam *et al.* (2013) found that coconut possessed the highest distribution (100%) at Bhola and Patuakhali, and mango (100%) at Barguna coasts. Alam and Masum (2005) noted that coconut, guava, date palm and mango were cultivated more than 75% of the homesteads. Sarker (2016) observed from the survey of six upazilas that all of the households contained mango and guava whereas jackfruit and coconut were found in 5 upazilas.

Species richness (SR)

Fruit species richness at the homesteads of south central coast is presented in Table 6. All of the homesteads accommodated 8 to 9 major fruit species (21.93%) and 32-34 minor species (78.07%) were available in the homesteads of five upazilas and produced fruit in this coast. The highest number of major fruit population was found in Bakergonj (4407) followed by Amtali (4224) and the lowest number of major fruit species was found in households of Kalapara upazila (3623). Meanwhile, maximum number of minor fruit species were recorded in Dumki (2645) followed by Bakergonj (2625) and it was found minimum in the households of Kalapara (2254). In terms of number of species (major and minor fruits), Dumki and Patuakhali Sadar facilitated the highest number of different fruit species (43) followed by Bakergonj (41) in their households and the lowest number of fruit species (33) was in Kalapara upazila which agreed with the findings of Alam and Masum (2005), who recorded 34 fruit species in the Sandwip offshore island. Similar results were also observed by Islam *et al.* (2013) who identified 69 tree fruit species in three districts, namely Bhola, Borguna and Potuakhali, of which 31 were found in Bhola, 30 in Borguna and Patuakhali. Suresh *et al.* (2014) reported only 21 species of minor fruit yielding plants from India.

Table 5. Distribution of fruit species at the homestead areas of five upazilas under south central coast of Bangladesh

Sl. No.	Fruit species	Amtali	Bakergonj	Kalapara	Dumki	Patuakhali Sadar	Average
1.	Mango	100.00	100.00	100.00	100.00	100.00	100.00
2.	Banana	100.00	96.67	100.00	91.67	95.00	96.67
3.	Jackfruit	83.33	80.00	88.33	75.00	78.33	81.00
4.	Coconut	100.00	100.00	91.67	100.00	100.00	98.33
5.	Litchi	28.33	51.67	53.33	33.33	20.00	37.33
6.	Guava	91.67	100.00	100.00	83.33	100.00	95.00
7.	Papaya	100.00	100.00	100.00	93.33	100.00	98.67
8.	Jujubee	41.67	50.00	26.67	38.33	41.67	39.67
Sub-total		691.67	711.67	676.67	681.66	685	689.34
9.	Lime	100.00	100.00	33.33	83.33	100.00	83.33
10.	Lemon	25.00	16.67	25.00	26.67	33.33	25.33
11.	Seeded banana	96.67	100.00	100.00	91.67	100.00	97.67
12.	Dewa	75.00	41.67	50.00	50.00	66.67	56.67
13.	Golden apple	96.67	96.67	95.00	100.00	100.00	97.67
14.	Pomelo	25.00	26.67	41.67	55.00	41.67	38.00
15.	Wood apple	33.33	26.67	20.00	26.67	33.33	28.00
16.	Wax Jambu	25.00	75.00	58.33	45.00	58.33	52.33
17.	Sweet orange	20.00	20.00	33.33	33.33	51.67	31.67
18.	Sapota	25.00	41.67	33.33	50.00	30.00	36.00
19.	Aonla	33.33	20.00	25.00	25.00	36.67	28.00
20.	Tamarind	16.67	41.67	25.00	26.67	25.00	27.00
21.	Jamun	23.33	25.00	20.00	36.67	16.67	24.33
22.	Bael	33.33	58.33	50.00	60.00	70.00	54.33
23.	Cowa	25.00	41.67	66.67	56.67	33.33	44.67
24.	Custard apple	10.00	18.33	20.00	25.00	16.67	18.00
25.	Palmyra palm	36.67	33.33	66.67	66.67	83.33	57.33
26.	River ebony	70.00	91.67	83.33	58.33	91.67	79.00
27.	Date palm	96.67	100.00	91.67	100.00	100.00	97.67
28.	Velvet apple	93.33	100.00	100.00	100.00	100.00	98.67
29.	Star goosberry	33.33	25.00	16.67	20.00	20.00	23.00
	Total	993.33	1100.02	1055	1136.6	1208.34	1098.67

Note: The fruit pineapple was excluded from list of major fruits because it was not found in all upazilas. Ten minor fruits found in all upazilas were excluded from the list of minor fruits.

Table 6. Fruit species richness at the homesteads of south central coast in Bangladesh

Fruit Type	Bakergonj		Amtali		Kalapara		Dumki		Patuakhali Sadar		Total	
	Pop^n (no.)	Spp (no.)	Pop^n (no.)	Spp (no.)	Pop^n (no.)	Spp (no.)	Pop^n (no.)	Spp (no.)	Pop^n (no.)	Spp (no.)	Pop^n (no.)	Spp (no.)
Major	4407	9	4224	8	3623	9	4040	9	4014	8	20307 (62.56%)	43 (21.93%)
Minor	2625	32	2364	29	2254	24	2645	34	2267	34	12155 (37.44%)	153 (78.07%)
Total	7032	41	6588	37	5877	33	6684	43	6281	43	32462 (100%)	196 (100%)

Pop^n = population, spp. = species and no. = number

Species diversity (SD)

Species diversity of fruits cultivated in the homesteads of south central coast are presented in Table 7. As per Simpson (1949) index, the species diversity and variation were found among the different groups of species. The highest average genetic diversity of different major fruits was recorded in Bakergonj (0.825) followed by Dumki (0.809) and Amtali (0.800), whereas it was the lowest in Kalapara upazila (0.773). The maximum average genetic diversity of different minor fruits was recorded in Dumki (0.816) followed by Bakergonj (0.811) and the minimum from Kalapara (0.771). The average genetic diversity of minor fruits was found equal in both Amtoli (0.801) and Patuakhali Sadar (0.801). This result is supported by Sarker (2016) who reported that maximum diversity was found in banana (0.989) followed by mango (0.923), papaya (0.921) and coconut (0.901).

Table 7. Diversity of fruit species at the homesteads of south central coast in Bangladesh

Sl. No.	Fruit species	Amtoli	Bakergonj	Dumki	Kalapara	Patuakhali Sadar
Major Fruits						
1	Mango	0.785	0.790	0.832	0.794	0.799
2	Banana	0.804	0.777	0.824	0.792	0.803
3	Jackfruit	0.876	0.943	0.706	0.702	0.773
4	Coconut	0.755	0.831	0.837	0.758	0.820
5	Litchi	0.842	0.854	0.795	0.760	0.749
6	Guava	0.871	0.821	0.766	0.839	0.703
7	Papaya	0.779	0.856	0.814	0.764	0.786
8	Jujubee	0.779	0.802	0.854	0.771	0.794
Average		0.800	0.825	0.809	0.773	0.793

Sl. No.	Fruit species	Amtoli	Bakergonj	Dumki	Kalapara	Patuakhali Sadar
Minor Fruits						
9	Lime	0.789	0.685	0.930	0.837	0.761
10	Lemon	0.867	0.783	0.819	0.807	0.723
11	Seeded banana	0.787	0.769	0.814	0.806	0.824
12	Dewa	0.830	0.804	0.752	0.781	0.833
13	Golden apple	0.743	0.825	0.863	0.735	0.835
14	Pomelo	0.856	0.800	0.800	0.736	0.808
15	Stone apple	0.835	0.736	0.846	0.802	0.780
16	Wax Jambu	0.796	0.788	0.845	0.739	0.832
17	Sweet orange	0.880	0.870	0.769	0.806	0.676
18	Sapota	0.736	0.868	0.810	0.736	0.851
19	Aonla	0.784	0.796	0.855	0.816	0.749
20	Tamarind	0.870	0.846	0.827	0.625	0.832
21	Jamun	0.759	0.823	0.835	0.722	0.861
22	Wood apple	0.793	0.870	0.826	0.799	0.712
23	Cowa	0.817	0.882	0.686	0.758	0.856
24	Custard apple	0.803	0.761	0.831	0.775	0.831
25	Palmyra palm	0.880	0.870	0.750	0.771	0.729
26	River ebony	0.805	0.778	0.799	0.804	0.813
27	Velvet apple	0.819	0.779	0.837	0.753	0.813
28	Date palm	0.792	0.773	0.782	0.782	0.871
29	Star gooseberry	0.789	0.711	0.855	0.803	0.842
Average		0.811	0.801	0.816	0.771	0.801

Note: Pop^n = population. The fruit pineapple was excluded from list of major fruits because it was not found in all upazilas. Ten minor fruits not found in all upazilas were excluded from the list of minor fruits.

The results of Sarker (2016) also revealed that among the major fruits the highest genetic diversity estimated in Kalapara (0.935) upazila and it was lowest in Dumki (0.702). A good genetic diversity also exists in minor fruits spp. in the study areas.

Relative prevalence (RP) of the species

The relative prevalence of the fruit species was notable in the studied (300) homesteads (Table 8). Among the 40 species of both major and minor fruits, 29 (major-8 and minor-21) were common at all of the studied upazilas. The results revealed that, in respect of the relative prevalence, the most prevalent species was

mango followed by banana, coconut, velvet apple and seeded banana, whereas less common species were papaya, pineapple, lime, river ebony, date palm, lemon and golden apple. The present findings are in line with the findings of Sarker (2016), who opined that 36 species were common out of 57 in the studied upazilas and most prevalent species were found mango, banana, velvet apple, coconut and guava while less common species were papaya, pineapple, river ebony and monkey jack. Total 28329 fruit tress of both major and minor fruits of 29 fruits were recorded in the studied coast, where 19955 trees of 8 major fruits and 10322 trees of 21 minor fruits were identified. Meanwhile, the result revealed that most prevalent major fruit spp was banana (7047) followed by mango (53375) and among minor fruit spp, the most prevalent fruit sp was velvet apple (1949) followed by coconut (1800) but jamon (135) was the least prevalent fruit sp counted in the study. Similar results were recorded by Sarker (2016) where mango (5947) ranked top followed by banana (5059). In case of minor fruit population velvet apple (3798) ranked top and most prevalent ones but lemon (2) was the least one.

Table 8. Relative prevalence of fruit species at the homesteads of south central coast in Bangladesh

Sl. No.	Fruit species	Bakergonj	Amtali	Dumki	Kalapara	Patuakhali Sadar	Total
		Pop^n	Pop^n	Pop^n	Pop^n	Pop^n	Pop^n
Major Fruits							
1	Mango	1099	1149	899	1120	1073	5337
2	Banana	1464	1379	1242	1575	1388	7047
3	Jackfruit	282	117	277	54	215	945
4	Coconut	498	395	336	200	371	1800
5	Litchi	62	40	52	38	65	257
6	Guava	180	185	188	105	255	913
7	Papaya	306	157	177	188	278	1106
8	Jujubee	137	132	87	119	123	598
Sub-total		4308	4056	3782	3709	4100	19955
Minor Fruits							
9	Lime	208	132	56	102	187	685
10	Lemon	55	27	33	39	64	218
11	Seeded banana	207	286	336	348	278	1455
12	Dewa	65	32	47	50	62	256
13	Golden apple	187	125	177	165	125	779
14	Pomelo	42	35	53	70	55	255
15	Wood apple	55	32	35	43	55	220

Sl. No.	Fruit species	Bakergonj	Amtali	Dumki	Kalapara	Patuakhali Sadar	Total
		Pop^n	Pop^n	Pop^n	Pop^n	Pop^n	Pop^n
16	Wax Jambu	72	107	88	72	65	404
17	Sweet orange	26	30	56	47	75	234
18	Sapota	45	78	58	84	55	320
19	Aonla	88	57	68	77	92	382
20	Tamarind	25	40	35	43	48	191
21	Jamun	23	30	28	35	19	135
22	Bael	55	74	65	87	102	383
23	Cowa	34	55	76	55	42	262
24	Custard apple	18	25	51	55	53	202
25	Palmyra palm	55	65	70	75	66	331
26	River ebony	105	112	130	145	104	596
27	Velvet apple	280	504	525	310	330	1949
28	Date palm	188	153	145	187	175	848
29	Star goosberry	34	33	50	56	45	218
	Sub total	1867	2032	2182	2145	2097	10323
	Total	5895	5584	5439	5544	5867	28329

Note: Pop^n = population. The fruit pineapple was excluded from list of major fruits because it was not found in all upazilas. Ten minor fruits which were not found in all upazilas were excluded from the list of minor fruits.

Dominance rank (DR)

The mean dominance rank of the fruit species was determined pooling the entire set of data (Table 9). The mean dominance rank among all the studied fruits revealed that dominance rank (DR) of the banana population (1) ranked first followed by mango (2), velvet apple (3) and coconut (4) while jamun (27) was at the bottom line of ranked order.

Table 9. Dominance rank of fruit species at the homesteads of south central coast in Bangladesh

Sl. No.	Fruits species	Amtali	Bakergonj	Dumki	Kalapara	Patuakhali Sadar	Total
		Pop^n	Pop^n	Pop^n	Pop^n	Pop^n	Pop^n
1	Mango	2	2	2	2	2	2
2	Banana	1	1	1	1	1	1
3	Jackfruit	11	5	5	20	6	7
4	Coconut	3	3	6	5	3	4

Sl. No.	Fruits species	Amtali	Bakergonj	Dumki	Kalapara	Patuakhali Sadar	Total
		Pop^n	Pop^n	Pop^n	Pop^n	Pop^n	Pop^n
5	Litchi	19	17	20	25	15	20
6	Guava	6	11	7	11	5	8
7	Papaya	7	4	8	6	4	6
8	Jujubee	9	12	12	10	10	12
9	Lime	9	7	18	12	7	11
10	Lemon	24	18	25	24	16	25
11	Seeded banana	5	8	4	3	4	5
12	Dewa	22	16	23	21	17	21
13	Golden apple	10	10	8	8	9	9
14	Pomelo	20	20	19	17	18	22
15	Wood apple	22	18	24	23	18	24
16	Wax Jambu	13	15	11	16	15	14
17	Sweet orange	23	22	18	22	13	23
18	Sapota	14	19	17	13	18	18
19	Aonla	17	14	15	14	12	16
20	Tamarind	19	23	24	23	20	26
21	Jamun	23	24	26	26	23	27
22	Bael	15	18	16	12	12	15
23	Cowa	18	21	13	19	22	19
24	Custard apple	25	25	21	19	19	25
25	Palmyra palm	16	18	14	15	14	17
26	River ebony	12	13	10	9	11	13
27	Velvet apple	4	6	3	4	4	3
28	Date palm	8	9	9	7	8	10
29	Star goosberry	21	21	22	18	21	24

Note: Pop^n = population. The fruit pineapple was excluded from list of major fruits because it was not found in all upazillas. Ten minor fruits which were not found in all upazillas were excluded from the list of minor fruits.

Among the minor fruits, velvet apple ranked top (3) followed by seeded banana (5) while bullock's heart, tamarind, jamun ranked low. These results correlate with

the findings of Sarker (2016) who opined that mango (1) ranked top followed by banana (seedless) (2), coconut (3) and velvet apple (5) and jackfruit and guava lower at the population level.

Conclusion

The identification of the most prevalent and dominant fruit species was a significant finding of the study. Only a fewer number of fruit species such as mango, coconut, banana of both seedless and seeded, velvet apple and golden apple were identified in homesteads of south central coastal regions of Bangladesh. In addition of land improvement, homestead forestry ensures biodiversity conservation, environmental sustainability and economic security. Homesteads of interior coastal regions were found comparatively rich in diverse fruit species than those of exposed coasts. This diversity of homestead fruits could provide a prime opportunity for the inhabitants of the studied coast. A comprehensive homestead space planning, proper scientific management of fruit plants using diversified fruits of both major and minor cultivars are needed to promote homestead plant diversity and their productivity in central coast. As a result, a policy guideline is to be developed for production, distribution and plantation of fruit species which thrive best in the coastal region to enrich plant diversity of this region. Government should launch a program for conservation of homestead plant biodiversity at local and regional levels.

References

Abebe, A.M., M.W. Kassaw, F.A. Mengistu. 2019. Assessment of Factors Affecting the Implementation of Integrated Management of Neonatal and Childhood Illness for Treatment of under Five Children by Health Professional in Health Care Facilities in Yifat Cluster in North Shewa Zone, Amhara Region, *Ethiopia. Int J Pediatr.* **14**: 2019: 9474612. doi: 10.1155/2019/9474612.

Alam, M.S. and K.M. Masum. 2005. Status of homestead biodiversity in the offshore island of Bangladesh. *Research Journal of Agriculture and Biological Sciences.* **1(3):** 246-253.

Anonymous. 2022. Bangladesh Bureau of Statistics (BBS), Statistics & Informatics Division (SID), Ministry of Planning Government of the people's republic of Bangladesh Dhaka, Bangladesh. www.bbs.gov.bd.

Anonymous. 2023. Bangladesh Bureau of Statistics (BBS), Statistics & Informatics Division (SID), Ministry of Planning Government of the people's republic of Bangladesh Dhaka, Bangladesh. www.bbs.gov.bd. P. 50.

Elfrida, A. Mubarak, A. B. Suwardi. 2020. The fruit plant species diversity in the home gardens and their contribution to the livelihood of communities in rural area Biodiversitas. *Journal of Biological Diversity.***21(8):**3670-3675.

Foysal, M.A., M.L. Hossain, A. Rubaiyat, and M.B. Hasan. 2013. Economics of homestead forestry and their management activities at Fatickchari Upazila of Chittagong district, Bangladesh. *Agriculture, Forestry and Fisheries.* **2(4):** 161-176.

Heywood, V.H., and R.T. Watson. 1995. Global biodiversity assessment. United Nations Environment Program. Cambridge: *Cambridge university press*. 1140pp.

Islam, M. R. (ed.). 2004. Where Land Meets the Sea: A Profile of The Coastal Zone of Bangladesh. Integrated Coastal Zone Management Plan. Programme Development Office, Water Resources Planning Organization (Bangladesh). Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP), Water Resources Planning Organization (WARPO). University Press Limited, Dhaka. 317 ppUniversity Press Limited, Dhaka. 317 pp.

Islam S. K. A., M. A. Q. Miah and M.A. 2013. Diversity of fruit and timber tree species in the coastal homesteads of southern Bangladesh. *Journal of Asiatic Society of Bangladesh, Science.* **39(1):**83-94.

Mannan M. A. 2000. Plant biodiversity in the homesteads of Bangladesh and its utilization in crop improvement. A PhD Thesis, Department of Genetics and Plant Breeding, Salna, Gazipur, Bangladesh.

Mannan M. A., M. S. Uddin, M. J. Rahman, S. A. Begum, A. F. M. F. Rahman, and M. R. Uddin. 2002. Plant Biodiversity in the saline area of southern Bangladesh. *Pakisthan Journal of Biological Science.* **5:** 710-714.

Millat-e-Mustafa. 1997. Floristic and Indigenous Management Techniques of Homegarden in Bangladesh. *In*: Alam, M.K.; F.U. Ahmed and S.M.R Amin (Ed.). Agro forestry: Bangladesh Perspective. APAN, NAWG, BARC. Bangladesh.

Rahim M.A, M.S. Alam, A.K.M.A. Alam and M.M.A. Hossain 2011. Underutilized Fruits in Bangladesh. BAU-GPC, Bangladesh Agricultural University, Mymensingh, Bangladesh, Biodiversity International, Malaysia and Rural Development Administration (RDA), Korea. pp.105-108.

Rahman, M. and J. Rahman. 2014. Medicinal value and nutrient status of indigenous fruits in Bangladesh. *Nova Journal of Medical and Biological Sciences.* **2(6):** 1-19.

Rahman, M.L., M. Hasanuzzaman and M. K. Islam. 2009. Fruit distribution and diversity in the homestead of a southern island of Bangladesh. *Advances in Biological Research.* **3(5-6):** 208.

Sarker B.C. 2021. Personal communication. Chief Scientific Officer, Pomology Division, Horticulture Research Centre. Bangladesh Agricultural Research Institute, Gazipur-1701.

Sarker B.C and A.K. Azad 2022. Key note paper of National Fruit Fair -2022. Krishibid Institution, Khamarbari, Dhaka. Organized by Ministry of Agriculture, Dhaka.

Sarker C.R. 2016. Conservation and characterization of minor fruit germplasm available in Patuakhali coast of Bangladesh. A PhD Dissertation, Department of Horticulture, Patuakhali Science and Technology University, Patuakhali.

Simpson, E.H. 1949. Measurement of diversity. *Nature.* **163**:688.

Suresh, C.P., K.D. Bhatia, G. Sukla, K. Pradhanand S. Chakravarty. 2014. Wild edible tree fruits of Sikkim Himalayas. *J. Tree Sci.* **33(1):**12–33.

FUNCTIONAL RESPONSE OF *MENOCHILUS SEXMACULATUS* F. (COLEOPTERA: COCCINELLIDAE) TO DIFFERENT DENSITIES OF *APHIS CRACCIVORA* KOCH (HOMOPTERA: APHIDIDAE)

M. H. Sultana[1], M. A. Hossain[2], H. Fuad El Taj[3] and M. A. Alim[4]

Abstract

Investigations of the characteristics related to prey consumption and searching capacity of the predator could yield important information for the selection of efficient bio-control agents. The relationship between the consumption rate of the predator *Menochilus sexmaculatus* F. (Coleoptera: Coccinellidae) and its prey density of *Aphis craccivora* Koch (Homoptera: Aphididae) on country bean (*Lablab purpureus* L.) was studied under laboratory conditions. Functional responses of four larval instars as well as adult males and females of *M. sexmaculatus* following the type II Holling's model. Rates of searching efficiency were estimated and found to be as high as 1.19 d^{-1} for adult males while low as 0.58 d^{-1} in first instar larvae. Handling time for adult females was found the lowest (10.8 min) while the highest for first instar larvae (90.57 min) during the observations of 24 hrs. The most effective stages of *M. sexmaculatus* to capture the prey were adult males, and females and fourth instar larva. As regards functional response data, the model predicts a maximum number of 142.85, 78.74, 61.43, 34.13, 16.23 and 15.89 nymphs to be consumed per day by an individual adult female, fourth instar, adult male, third, second and first instar larvae, respectively. Adult females consumed the highest number of prey, followed by fourth instar larvae and adult males. The voracity of first, second, third, fourth instar larvae, adult males and females was estimated as 11.13, 12.332, 21.182, 32.51, 27.82 and 35.87 (aphids/d) when given 50 individuals of *A. craccivora*, respectively.

Keywords: Biological control, predator-prey interactions, lady bird beetle, *Aphis craccivora*.

Introduction

The number of prey killed by an individual predator is a function of prey density, and the relationship between prey density and consumption rate of predator is known as the functional response (Abrams and Ginzburg, 2000 and Jeschke *et al.*, 2002). It is the key factor of a predator in regulating the population dynamics of predator-prey interaction systems (Jafari and Goldasteh, 2009). Generally, three types of curves to model the functional response relationships of predators' as density-dependent yields are available (Trexler and Culloch, 1988 and Pervez and Omkar, 2005). These are: type I (linear), type II (curvilinear) and type III

[1]MS in Entomology, Department of Entomology, Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University (HMDSTU), Dinajpur, Bangladesh, [2,3&4]Professor, Department of Entomology, Faculty of Agriculture, (HMDSTU), Dinajpur-5200, Bangladesh.

(sigmoid) as correspond to density independence, inverse density dependence and density dependence, respectively (Juliano, 2001). An additional type (dome-shaped) of reaction occurs only when other prey interferes or shows some kinds of defence behaviour during predator handling (Jervis and Kidd, 1996). Yet, the main ecological interests, the functional responses of most arthropod predators have been suggested of type II or type III (Madahi *et al.*, 2013). But ecologists frequently face difficulties in determining the yield while the curves linking type II and III (Aukema and Raffa, 2004). In this study, the functional response of *Menochilus sexmaculatus* F. (Coleoptera: Coccinellidae) was evaluated on the bean aphid, *Aphis craccivora* Koch (Homoptera: Aphididae).

This species was found as a key pest on bean and other leguminous crops (Capinera, 2001). *A. craccivora* causes direct damage by feeding of plants sap, shown by a mottled appearance, leaf chlorosis, and reduction in plant vigour, stunting plant growth and stimulation of phytotoxic disorders. They also cause indirect damage by transmitting plant viruses with the result of significant yield loss (Blackman and Eastop, 2000; Akhtar *et al.*, 2010 and Razaq *et al.*, 2011). An alternative and ecologically sound control measure initiated against the *A. craccivora* is the utilization of predaceous lady bird beetle as bio-control agent. The objectives of studying the predation potential of *M. sexmaculatus* on five densities of *A. craccivora* were aimed through determining the type of its functional response, and its density dependence yield in relation to host population.

Therefore, the present study has investigated how the predator responds to changing prey density under simplified experimental conditions.

Materials and Methods

The experiment was conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University, (HSTU) Dinajpur, Bangladesh (Latitude: 25°37' 38.82"N and Longitude: 88° 38' 16.04" E), during December 2018 to January 2019. All experiments were carried out under laboratory conditions (21 ± 4 ^{0}C, 75 ± 5% RH and 13L: 11D photo phase).

Insect culture

To initiate the stock culture, aphids (*A. craccivora*) were collected from country bean (*Lablab perpureus* L.) fields of the university in 2018. The stock culture was then maintained on country bean leaves in the laboratory. Adult male and female of *M. sexmaculatus* were also collected from aphid infested bean plants. The predator species was maintained for several generations on bean leaf arena placed underside up on water-saturated foam mats in the Petri dishes (90 mm dia) under ambient room conditions. Everyday adequate aphids were supplied to the beetles as food. The oviposition of the beetles was examined daily. When oviposited, the

beetles were transferred into the new Petri dishes (120 mm) and the deposited eggs were counted and left undisturbed for hatching. The fresh hatched larvae were then transferred into the new Petri dishes. After having enclosed, new adults were sexed and confined in pairs (1 male: 1 female) into the Petri dishes for mating. This procedure was repeated to increase the number of larvae and adults for experimental use.

Experimental protocol of functional response

Healthy bean leaves were collected from the cultured potted bean plants and placed into Petri dish (90 mm). *M. sexmaculatus* larvae, adult males and females were collected from the stock colony and starved for four hours in clean Petri dishes. Then 1st, 2nd, 3rd, 4th instar larvae, adult males and females of the beetles were placed singly in Petri dishes (90 mm) supplied with 10, 20, 30, 40, 50 nymphs (4-5-days old) of *A. craccivora*, respectively. Nymphs were gently transferred to each experimental arena using a fine camel-hair brush. Each treatment was replicated ten times. After 24 hours all killed and alive aphids were recorded to determine predation efficiency. To avoid dryness, the under surface of the bean leaf was placed on a water-saturated cotton ball.

Data analysis

The relationships between rates of consumption ($Na / N \times 100$) by each developmental stage of predator; larval instars, adult males, females and its prey density were analysed by linear regression procedures using R studio 3.1.3. Holling (1959) curvilinear type II equation for calculation of the functional response. In this model, the number of prey consumed (Na) is a function of prey density (N) as follows:

$$Na = (aTN)/(1 + aThN)$$

Where, a is the attack rate (discovery) of the prey, T is the total time available (1 d or 24 h in this experiment), and Th is the handling time for one prey. The parameters of the handling time (Th) and the attack constant (a) was estimated using Holling's disc equation modified by reciprocal linear transformation (Livdahl and Stiven, 1983). The modified equation is as follows:

$$\frac{1}{Na} = \frac{1}{a} \cdot \frac{1}{NT} + \frac{Th}{T}$$

Where $\frac{1}{Na}$ represents y, $\frac{1}{a}$ represents α, $\frac{1}{NT}$ represents x and $\frac{Th}{T}$ represents *ß*. The linear regression form becomes y = αx + ß. The theoretical maximum number of prey consumption by predator can be asymptote to be H$a_{max} = \frac{T}{Th}$.

The fact of consuming or eagerness to consume large quantities of food is called the voracity of a predator. Voracity was determined according to the following equation (Cabral *et al.*, 2006 and Moura *et al.*, 2006):

$$Vo = (A - a24)ra24$$

Where V_O is the indicator of voracity, A is number of prey available, $a24$ is number of prey alive after 24 h or 1 day time, and $ra24$ is the ratio of prey found live after 24 h or 1 day in a control treatment without a predator (i.e., number of aphids live after 24 h/initial number of aphids). Analysis of variance (ANOVA) was accomplished to test differences in voracity at maximum densities of *A. craccivora* for different stages of the predator (at 50 aphids). Following significant ANOVA analysis, a Duncan's new multiple range test (R Studio 3.1.3) was used for pairwise comparisons of the means.

Results

The attack rates, handling time, prey consumption (asymptote) and regression coefficient (r^2) of life stages of predators are presented in Table 1. Adult males showed the maximum attack rate (1.19) followed by adult females (1.08), fourth instar larvae (1.03) while the lowest in first instar larvae (0.58). Handling time for adult females was the lowest (10.8 min) while it was the highest for the first instar larva (90.57 min) during 24 hours. Asymptotic maximum prey consumption increased respectively as larval development progressed up to 4th instar; 15.89, 16.23, 34.13, and 78.74, and for males adult while females reached maximum of 61.43 and 142.85, respectively.

Table 1. **Type II functional response parameters of *M. sexmaculatus* fed on *A. craccivora***

Life stages	a	Th (min)	T/Th	r^2
First instar larva	0.58	0.0629 (90.57)	15.89	0.96
Second instar larva	0.75	0.0616 (88.70)	16.23	0.88
Third instar larva	1.01	0.0293 (42.19)	34.13	0.99
Fourth instar larva	1.03	0.0127 (18.28)	78.74	0.99
Adult male	1.19	0.0163 (23.47)	61.43	0.98
Adult female	1.08	0.007 (10.08)	142.85	0.99

The value in the parenthesis indicates handling time of different instar larvae and adult male, female in minute. Here, a = Rate of attack (discovery), Th = Handling time for one prey, T/Th = Prediction of maximum prey consumption and r^2 = Regression coefficient
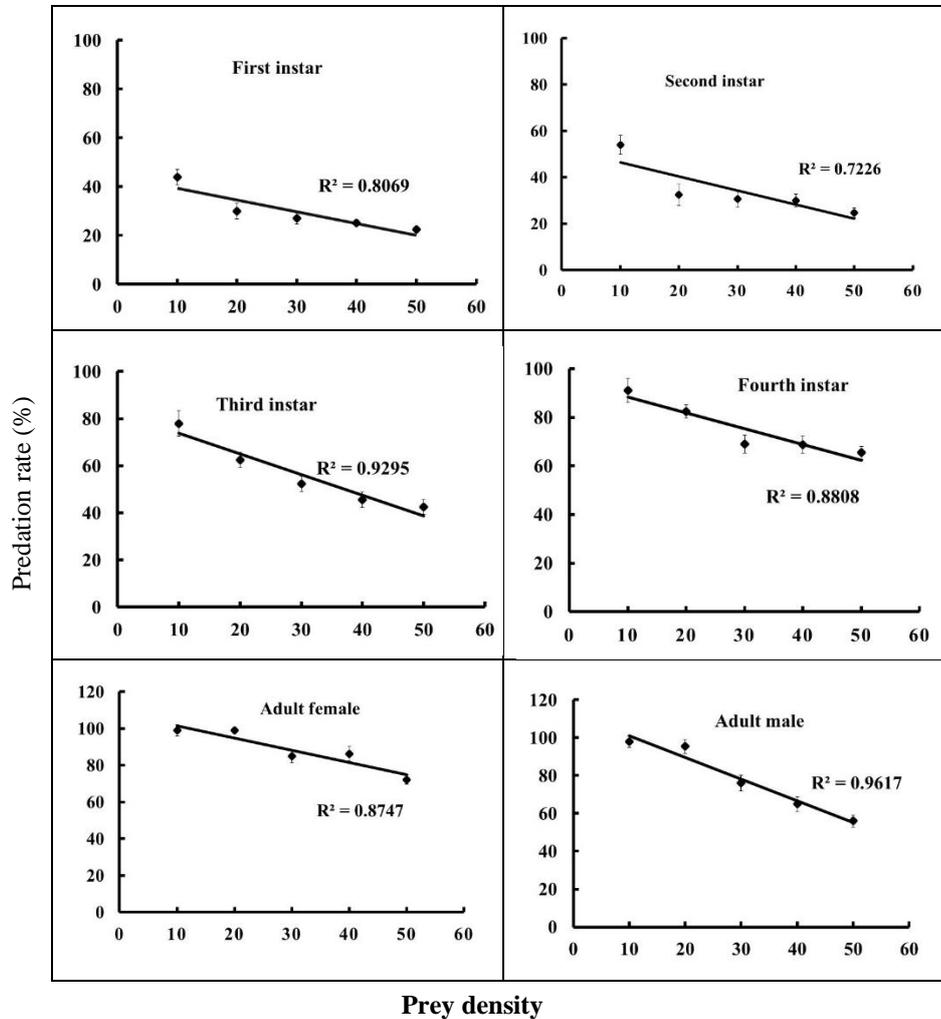
Fig. 1. Proportion of prey killed (%) by different stages of *M. sexmaculatus* to *A. craccivora* on country bean. Points show average number of aphids eaten or killed by *M. sexmaculatus* at each level of prey availability.

The prey consumed at different predatory stages (1st, 2nd, 3rd and 4th instar larvae, adult male and female) was negatively correlated with prey densities offered. The consumption rates at various predatory stages decreased with increasing prey densities (Figure 1). The functional response curve corresponds to prey consumption rate at different stages increased with increasing prey density (Figure 2) suggesting of type II functional response. The highest predation of 100% was evident by an adult female when offered 10 preys. Among the larval instars, fourth instar larva showed the highest predation rate (91.0%). Similarly, adult females (39.18) and fourth instar larvae (31.13) showed highest predation as offered 50 preys. The differences in prey consumption at various prey densities within a

developmental stages of *M. sexmaculatus* were significant for first ($F = 12.53$; $df = 3$; $P = 0.038$), third ($F = 39.55$; $df = 3$; $P = 0.008$), fourth instar larvae ($F = 22.17$; $df = 3$; $P = 0.018$), adult males ($F = 75.38$; $df = 3$; $P = 0.003$), and adult females ($F = 20.95$; $df = 3$; $P = 0.019$) while non-significant for second instar larva ($F = 7.81$; $df = 3$; $P = 0.068$) at 5% level of probability.
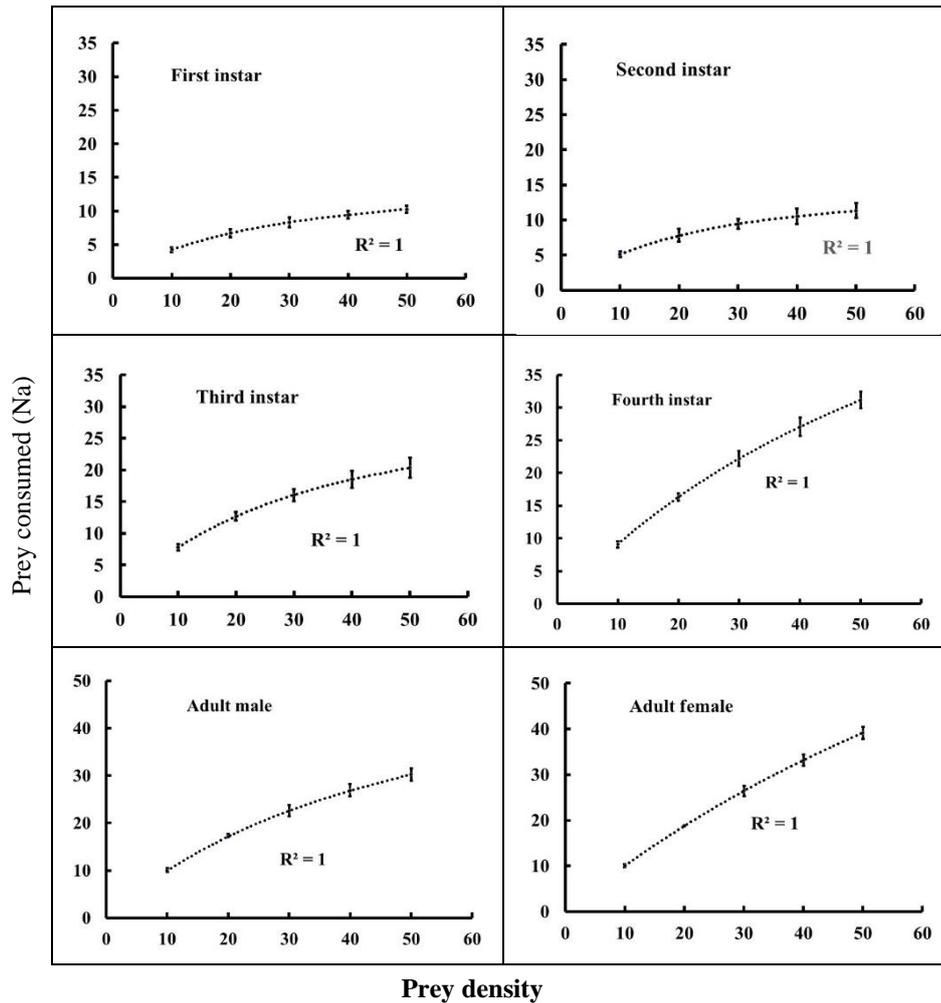

Fig. 2. Functional response of larval and adult stages of *M. sexmaculatus* to *A. craccivora*. Points show average number of aphids eaten or killed by *M. sexmaculatus* at each level of prey availability as Hollings equation for a type II functional response.

Voracity of different stages of *M. sexmaculatus* at maximum densities of *A. craccivora* during 24 hour varied significantly ($F = 64.54$; $P < 0.0016$) as shown in Figure 3. Voracity increased with larval age; moreover, adult female sex habited a greater voracity than adult males. There was no significant differences between

fourth instar larvae (32.51 ± 1.28) and adult females (35.87 ± 2.55) both recorded as the highest voracity. But the first instar larvae showed the lowest voracity of 11.13± 0.72 nymphs.
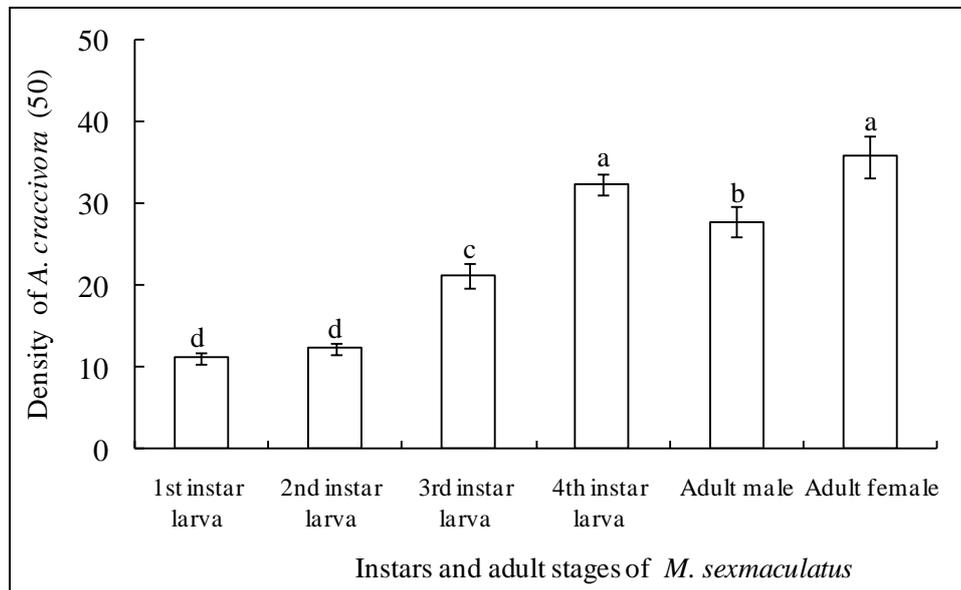

Fig. 3. Voracity (mean ± SE) of different stages of *M. sexmaculatus* at maximum *A. craccivora* density (50 aphids) at 21 ± 4 ^{0}C, 75 ± 5% RH and 13L: 11D

Discussions

The functional response can reveal information about the capacity of the predator to suppress prey population (Holling, 1959). It provides a relationship between numbers of prey consumed against prey availability, which influences the dynamics of the prey-predator interaction, thereby contributing to the stability of the ecosystem. The predator shows a negative density dependence on the proportion of the prey killed (*Na/N*) as the density increases. The functional response pattern of *M. sexmaculatus* to varying densities of *A. craccivora* revealed that it was of the type II (Holling, 1965) in all stages of predator. Then type II functional response is frequently observed in connection with a variety of predators including arthropods used as biological control agents (Aukema and Raffa, 2004 and Saleh *et al.*, 2010). Many coccinellid species show this type response, e.g. *Adalia bipunctata* preying on *Elatobium abietinum* Walker (Timms *et al.*, 2008), *Coccinella unidecimpunctata* preying on *A. fabae* and *Aleyrodes proletella* (Moura *et al.*, 2006). Among coccinellids, type III functional responses have been relatively rare (Isikber, 2005; Lanzoni *et al.*, 2004 and Sarmento *et al.*, 2007). For type III, one suggested mechanism is the concentration of a predator's search effort observed in high prey-density areas (Hertlein and Thorarinsson, 1987). No actual proof or signs were observed in the present research to suggest type III could have

been involved. Since the observations were conducted over a relatively short period involving single-prey species, and thereby not meeting the conditions and mechanisms essential for type III functional responses to occur, this could be a possible explanation.

Similar trends of predation relied on fourth instar larvae, adult females and males in other coccinellids like *Cydonia vicinanilotica* feeding on *A. craccivora*, *Adalia tetraspilota* and *Hippodamia variegate* feeding on *Aphis pomi* and *A. fabae, Brevicoryne brassicae* and *A. craccivora* (Jalalipour *et al.*, 2017 and Mandour *et al.*, 2006). Adult females of *Cheilomenes sexmaculatus, Propylea dissecta,* and *Coccinella transversalis* also consumed *Aphis craccivora* (Koch) or *Myzus persicae* Sulzer (Pervez and Omkar, 2005).

The coefficient of attack rate (*a*) and handling time (T_h) indicates the predator's ability to locate and treat the prey. Even the same species, different stages would have completely different predator's potential (Shah and Khan, 2013). The values of attack rate of adult female were 1.08 d^{-1} which peaked within 0.007 day (10.08 min). These results of attack rates and handling times compare well to those published by Omkar and Pervez (2003). The variations within the parametric values can be due to variation in species, size, prey density, voracity, satiation time, digestion ability, walking speed, etc. (Omkar and Pervez, 2003). Handling time is a good indicator of consumption rate and effectiveness of a predator because it reflects the cumulative effect of time taken during capturing, killing, suppressing and digesting the prey (Veeravel and Baskaran, 1997).

The asymptote maximum numbers of aphids attacked by fourth larval instars, adult males and females were determined as 78.7, 61.4 and 142.9 per day, respectively, with only handling time being considered. This result shows that the killing efficiency of adult females is as much as 2.3 times greater than that of adult males and suggests that the females' handling time, attack rate and consumption of prey is more efficient than that of the males. The present observation also showed that the higher prey killed was by adult females and fourth instar larvae. This agrees with observations on other coccinellids that reported the fourth instars captures over 60% of total prey by all larval stages (Lee *et al.*, 2004 and Farhadi *et al.*, 2010).

Voracity of *M. sexmaculatus* increased with increasing larval development and with adult females exhibiting a greater voracity than males. Voracity seemed to reflect the energy requirement regarding body size or metabolism. Adult females and fourth instar larvae showed the voracity levels being considerably higher than those of all other life stages. Similar voracity was cited in *Hippodamia variegate* hosted on *A. fabae* (Farhadi *et al.*, 2010). The handling time, attacked rate, and number of prey consumed suggested that the adult and fourth instar are most active predatory stages in killing the aphids and are thus suitable for field release. Similarly, the same stages yielded the highest functional response in *Nephaspis*

oculatus (Coleoptera: Coccinellidae) (Liu and Stansly, 2002) and *Stethorus gilvifrons* Mulsant (Coleoptera: Coccinellidae) (El-Basha and Mandour, 2005).

Assessing the pea aphid population potential (Jalalipour *et al.*, 2017), present data suggest that *M. sexmaculatus* could have potential of suppressing *A. craccivora* population with higher voracity and functional response. However, this study only focused on the predator response to variable prey densities in simplistic, laboratory-confined conditions. Field trials are, therefore, essential to evaluate the true potential of the predator's capacity to control the aphid pest in areas with the complexity of variable environmental as well as the spatial structural conditions over time.

Acknowledgements

References

Abrams, P. A. and L. R. Ginzburg. 2000. The nature of predation: prey dependent, ratio dependent, or neither. *Trends Ecol. Evol.* **15**: 337-341.

Akhtar, N., M. Ashfaque, W. A. Gillani and A. P. M. A. Shah. 2010. Antibiosis resistance in national uniform wheat yield trials against *Rhopalosiphum padi* (L.). *Pak. J. Agric. Res.* **23(1-2):** 59-63.

Aukema, B. H. and K. F. Raffa. 2004. Behavior of adult and larval *Platysoma cylindrica* (Coleoptera: Histeridae) and larval *Medetera bistriata* (Diptera: Dolichopodidae) during subcortical predation of *Ips pini* (Coleoptera: Scolytidae). *J. Insect Behav.* **17(1):** 115-128. 10.1023/B:JOIR.0000025136.73623.f5.

Blackman, R. and V. Eastop. 2000. Aphids on the world's crops-an identification and information guide. John Wiley and Sons, U.K.

Cabral, S., A. O., Soares, R. Moura and P. Garcia 2006. Suitability of *Aphis fabae, Myzus persicae* (Homoptera: Aphididae) and *Aleyrodes proletella* (Homoptera: Aleyrodidae) as prey for *Coccinella undecimpunctata* (Coleoptera: Coccinellidae). *Biol. Cont.* **39**: 434-440.

Capinera, J. L. 2001. Handbook of Vegetable Pests. San Diego: Academic. p. 729.

El-Basha, N. A. and N. S. Mandour. 2005. The predation of *Stethorus gilvifrons* (Muls.) (Coleoptera: Coccinellidae) on different egg densities of *Tetranychus urticae* (Koch) (Acari: Tetranychidae). *Agric. Res. J.* **5**: 97-103.

Farhadi, R., A. Hossein and S. Juliano. 2010. Functional response of larval and adult stages of *Hippodamia variegate* (Coleoptera: Coccinellidae) to different densities of *Aphis fabae* (Hemiptera: Aphididae). *Environ. Entomol.* **39(5):** 1586-1592. https://doi.org/10.1603/EN09285.

Hertlein, M. B. and K. Thorarinsson. 1987. Variable patch times and the functional response of *Leptopilin aboulardi* (Hymenoptera: Eucoilidae). *Environ. Entomol.* **16**: 593-598.

Holling, C.S. 1959. Some characteristics of simple types of predation and parasitism. *Can. Entomol.* **91(7):** 385-398.

Holling, C.S. 1965. Functional response of predators to prey density and its role in mimicry and population regulation. *Mem. Ent. Soc*. **45**: 3-60.

Isikber, A. A. 2005. Functional response of two coccinellid predators, *Scymnus levaillanti* and *Cyloneda sanguinea*, to the cotton aphid, *Aphis gossypii. Turk. J. Agric. For.* **29**(5): 347-355. https://agris.fao.org/agris-search/se

Jafari, R. and S. Goldasteh. 2009. Functional response of *Hippodamia variegate* (Goeze) (Coleoptera: Coccinellide) on *Aphis fabae* (Scopoli) (Homoptera: Aphididae) in laboratory condition. *Acta Entomol. Serbica.* **14(1):** 93-100. UDC 595.76:595.752.

Jalalipour, R., A. Sahragard, K. Madahi, and A. Karimi-Malati. 2017. Comparative life table of *Aphis craccivora* (Hem.: Aphididae) on host plant, *Robinia pseudoacacia* under natural and laboratory conditions. *J. Entomol. Soc. Iran.* **36(4):** 249-257.

Jervis, M. A. and N. A. C. Kidd. 1996. Insect Natural Enemies: Practical approaches to their study and evaluation. Chapman and Hall, London, United Kingdom. 15p.

Jeschke, J. N., M. Kopp and R. Tollrian 2002. Predator functional responses: Discriminating between handling and digesting prey. *Ecol Monogr.* **72**: 94-112. https://doi.org/10.1890/0012-9615(2002)072[0095:PFRDBH]2.0.CO;2

Juliano, S. A. 2001. Nonlinear Curve Fitting: Predation and Functional Response Curves. In: Cheiner, S.M. and Gurven, J., Eds., Design and Analysis of Ecological Experiments, 2nd Edition, Chapman and Hall, London, 178-196.

Lanzoni, A., G. Accinelli, G. G. Bazzocchi and G. Urgio. 2004. Biological traits and life table of the exotic *Harmonia axyridis* compared with *Hippodamia variegata* and *Adalia bipunctata* (Coleoptera: Coccinellidae). *J. Appl. Ent.* **128(4):** 298-306. https://doi.org/10.1111/j.1439-0418.2004.00847.x

Lee, J. C., F. D. Menalled and D. A. M. Landis. 2004. Refuge habitats modify impact of insecticide disturbance on carabid beetle communities. *J. App. Ecol.* **38**: 472-483.

Liu, T. X. and P. A. Stansly. 2002. Functional response and plant preference of *Nephaspis oculatus* (Coleoptera: Coccinellidae) preying on *Bemisia argentifolii* (Homoptera: Aleyrodidae) in the laboratory. *Entomol. Sin.* **9**: 1-9. DOI:10.1111/j.1744-7917.2002.tb00136.x.

Livdahl, T. P. and A. E. Stiven. 1983. Statistical difficulties in the analysis of predator functional response data. *Can. Entomol.* **115**: 1365-1370.

Madahi, K., A. Sahragard, and R. Hossieni. 2013. Prey density dependent life table of *Aphidoletes aphidomyza* Rondani (Diptera: Cecidomyiidae) feeding on *Aphis craccivora* Koch (Hemiptera: Aphididae) under laboratory conditions. *J. Plant Prot. Res.* **53(3):** 253-262.

Mandour, N. S., N. A. S. El-Basha, and T. X. Liu. 2006. Functional response of the ladybird, *Cydonia vicinanilotica* to cowpea aphid, *Aphis craccivora* in the laboratory. *Insect Sci.* **13**: 49-54.

Moura, R., P. Garcia, S. Cabral, and A. O. Soares. 2006. Does pirimicarb affect the voracity of the euriphagous predator, *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae)? *Biol. Cont.* **38(3):** 363-368.

Omkar and A. Pervez. 2003. Ecology and biocontrol potential of a scale-predator, *Chilocorus nigritus*. *Biocontrol Sci. Tech.* **13**: 379-390.

Pervez, A. and Omkar. 2005. Mating behavior of an aphidophagous ladybird beetle, *Propylea dissecta* (Mulsant). *Insect Sci.* **12**: 37-44.

Razaq, M., A. Mehmood, M. Aslam, M. Ismail, M. Afzal and S. Alishad. 2011. Losses in yield and yield components caused by aphids to late sown *Brassica napus*, *Brassica juncea* and *Brassica carrinata* braun at Multan, Punjab (Pakistan). *Pak. J. Bot.* **43(1):** 319-324.

Saleh, A., I. Ghabeish, F, Al-Zyoud, M. Ateyyat and M. Swais. 2010. Functional response of the predator *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) feeding on the aphid *Brachycaudus helichrysi* (Kaltenbach) infesting chrysanthemum in the Laboratory. *Jordan J. Biol. Sci.* **3**: 17-20.

Sarmento, R. A., A. Pallini, M. Venzon, O. F. Souza, A. J. Molina-Rugama and C. L. Oliveira. 2007. Functional response of the predator *Eriopis connexa* (Coleoptera: Coccinellidae) to different prey types. *Braz. Arch. Biol. Technol.* **50**: 121-126.

Shah, A. M. and A. A. Khan. 2013. Functional response, a function of predator and prey species. *BioScan.* **8(3):** 751-758.

Timms, J. E., T. H. Oliver, N. A. Straw and S. R. Leather. 2008. The effects of host plant on the coccinellid functional response: Is the conifer specialist *Aphidectao bliterate* L. (Coleoptera: Coccinellidae) better adapted to spruce than the generalist *Adaliabi punctate* (L.) (Coleoptera: Coccinellidae). *Biol. Cont.* **47**: 273-281.

Trexler, J. C. and Mc. C. E. Culloch. 1988. How can the functional-response best be determined? *Travis J.* **76**: 206-214.

Veeravel, R. and P. Baskaran. 1997. Functional and numerical responses of *Coccinella transversalis* Fab. and *Cheilomenes sexmaculata* Fab. feeding on the melon aphid, *Aphis gossypii* Glov. *Insect Sci. Appl.* **17**: 335-339.

EVALUATING BIO-PESTICIDES AGAINST SAP SUCKES OF YARD LONG BEAN

M. A. MONIM[1]

Abstract

A field experiment was undertaken at research field of Entomology Division at Regional Agricultural Research Station, Jashore to evaluate the effect of four bio-pesticides and a chemical insecticides namely Bio-catch (*Vertcillium lecani* 1.15 WP), Bio-power (*Beauvaria bassiana* 1.15 WP), Bio-Magic (*Metarhizium anisopliae* 1.15 WP), Bioclean (D- limonene 5%) and Imitaf (Imidacloprid 200 SL) against the sucking insect pests of yard long bean viz., aphid, jassid and thrips during the kharif-1 season (March to July) of 2022 and 2023. The chemical insecticides Imitaf @ 0.5 mlL^{-1} of water showed the best performance in reducing the infestation of the insect pests, resulting the higher yield and MBCR. The bio-pesticide, Bio-Magic @ 6 gL^{-1} of water offered second the best performance, while the other bio-pesticides offered intermediate level of performance. The Imitaf @ 0.5 mlL^{-1} of water appeared best as it provided the lowest abundance of aphid, jassid and thrips (0.83,1.67, 1.33) while the highest percent reduction over untreated control (91.70, 85.69, 82.66%). The highest yield increase over control was calculated from Imitaf @ 0.5 ml/L of water (46.07%) followed by treatment Bio-Magic @ 6 g/L of water (29.67%). Bio-Magic @ 6 gL^{-1} of water may be used in IPM program against aphid, jassid and thrips attacking yard long bean.

Keywords: Aphid, jassid, thrips *Vigna unguiculata, biopesticides.*

Introduction

Yard long bean (*Vigna unguiculata* sub sp. *sesquipedalis*) (L.) Walp) is an important leguminous vegetable grown widely in summer season of Bangladesh. The area occupied by this crop was 5857.49 ha and the production was 21348 t during the year 2008- 2009 (Anon., 2010). It is cultivated in Chittagong, Chittagong Hill Tracts (CHTs), Faridpur, Noakhali, Camilla and Rangpur districts in Bangladesh (Uddin, 2013). But the production of yard long bean is increasing in Dhaka, Chittagong, Camilla, Narsingdi, and Jahsore districts and also other districts in Bangladesh day by day due to its increasing consumption as vegetable. It is extensively grown in kharif season when there is shortage of vegetables supply in the market. Yard long bean is one of the economically important vegetable crops in Bangladesh. But the production of this vegetable in Bangladesh is much lower compared to many Asian countries. It is an inexpensive source of vegetable protein, vitamin A, thiamin, riboflavin, calcium, vitamin C, phosphorus, sodium, potassium, magnesium and cobalt. It is a highly nutritive vegetable containing a good amount of digestible protein both in pods (23.5-26.3%) and in leaves (Ano and Ubochi, 2008). A serving of 100g of yard long bean contains 50 calories, 9.0g

[1]Entomology Division, Bangladesh Agricultural Research Institute, Jashore, Bangladesh.

of total carbohydrates, and 3.0g of proteins, 0.2g total fat and 0.8g of minerals (Anonymous, 2013). The attack of different insect pests has been reported as one of the serious problems to yard long bean cultivation in the country. At least 11 insect pests are injurious to yard long bean. It is attacked by a number of insects like aphid, pod borer, thrips, red mite, leaf miner, leaf beetle, green sting-bug, jute hairy caterpillar, hooded hopper and semi-looper in descending order in Bangladesh (Uddin *et al.,* 2013). *Amrasca biguttulais* an insect of southern Asia. On leaf surfaces, the insect tends to move about diagonally, when distributed it immediately jumps and fly away (Jayasimha *et al.*, 2012). Jassids are the sucking pest. The females lay their eggs within the leaf vein tissue, mostly on the underside of leaves. Nymphs and adults damage their hosts by sucking plant tissues. While sucking, the insects inject toxic compounds which may lead to blacked plant vessels. Jassid (*Amrasca biguttula*), Sucking insects pests are one of the serious pest of legume (Mukhtar, 2009). It was revealed that aphid and pod borer were the major insect pests. The production of yard-long bean is affected due to the frequent occurrence of these insect (Pedigo, 2002). But the production of Yard-long bean is affected due to the frequent occurrence of aphid, *Aphis sp.* (Homoptera:Aphididae), a ubiquitous group of arthropods (Pedigo, 2002). Yard long bean is especially attractive to aphids (*Aphis craccivora, Myzus persicae* and *Aphis gossypii*), jassids, thrips, green stink bug (*Nezara viridula*) and red spider mite (*Tetranychus* spp.). Aphid, the most destructive pest, causes damage by sucking sap from flowers, buds, pods and tender branches of the plants and reduces the viability of plant. Greasy cutworms (*Agrotis ipsilon*) often cause damage just after emergence Aphid, jassid, thrips and mites are gaining tremendous importance in the recent years due to their devastating damage. These pests suck the cell sap and prevent normal crop growth (Pedigo, 2002) the pointed that some botanical products used against the sucking pest. The treatment included Triazophos 40E.C. 0.04%, Neem oil 1 %, Achook 5 %, NSKE 5%, Karanj oil 1%, Eucalyptus oil 1% and an untreated control. Observation on population of sucking pests (aphids and jessed) was recorded before treatment and 3, 7 and 10 days after each spraying (Dehariya *et al*., 2018). Current pest management practices of yard long bean in Bangladesh include extensive use of chemicals known for their ability to cause negative health effects in humans and wildlife and to degrade the natural environment. In vegetable growing areas, farmers practice comprising indiscriminate use of pesticides, sometimes they spray 3-4 times in a week. But indiscriminate use of pesticides has not only complicated the management, but has also created several adverse effects such as pest resistance, outbreak of secondary pests and environmental pollution taking into consideration of the health and environmental effects of chemical pesticides, it is clear that the need for a new concept in agriculture is urgent. This new concept must be based on a drastic reduction of the application of chemical pesticides, and can result in health, environmental, and economic benefits (Pimentel & Burgess, 2014). In fact, the use of chemical pesticides has quickly become widespread worldwide and it is estimated that 35 billion kg of pesticides are applied annually (FAOSTAT, 2014).

However, it is also estimated that pests still cause the loss of 37% of 50 potential crop yield (Pimentel, 2005). Pesticides can also have many negative side effects including: human health impacts, water contamination, killing of nontarget species, residues in food, and the onset of pesticide resistance (Carvalho, 2006; Chagnon *et al*., 2015) there is renewed interest in the application of botanical pesticides for crop protection (Pedigo, 2002). Therefore, a strategic approach is needed for reduction in the use of agro-chemicals and for the implementation of sustainable practices. Furthermore, current agriculture has to implement environmentally friendlier practices that pose fewer public health risks. Cost effective crop production requires combination of optimum use of chemicals and no-chemical techniques of pest management. New chemical insecticides with novel mode of action and bio-pesticides in recent years have gained importance to overcome these problems so, to reduce unwarranted pesticide load in the environment and for sustainable production of this crop. With this view in mind, the present study was designed to select suitable bio-pesticides or new chemical insecticide against sucking insect pests attacking yard long bean.

Materials and Methods

The experiment was conducted in the research field at Regional Agricultural Research Station, Jashore (88°40'-89°50' E, 22°47'-23°470' N) during kharif-1 (March to July), season of 2022 and 2023. Yard long bean seeds of BARI Barboti-2 variety were sown in plots of 4m × 3m. The experiment was laid out in Randomize Complete Block Design having 3 replications. Four bio-pesticides and a chemical insecticide were evaluated in this study, so there were 5 treatments and an untreated control. The crop was fertilized with cowdung 15 t ha^{-1}, urea 50 kg ha^{-1}, gypsum 100 kg ha^{-1}, Zn sulphate 12 kg ha^{-1} and borax 12 kg ha^{-1} (Bangladesg Fertilizer Recommendation Guide, 2018). Weeding and other intercultural operations were done as and when necessary to raise a good crop. Treatment applications were started as soon as the infestation of sucking insects were noticed and continued at weekly interval upto last harvest of the crop. The treatments were Spraying Bio-catch (*Verticillium lecani* 1.15 WP) @ 6 gL^{-1} of water, Bio-power (*Beauvaria bassiana* 1.15 WP) @ 6 gL^{-1} of water, Bio-Magic (*Metarhizium anisopliae* 1.15 WP) @ 6 gL^{-1} of water, Bioclean (D- limonene 5%) @ 1 mlL^{-1} of water, Imitaf (Imidacloprid 200 SL) @ 0.5 ml/ litre of water, and untreated control (Water spray only). The observations of jassid were recorded on 10 randomly selected plants per plot. On each plant, six leaves (two from bottom and two each from middle and top canopy of the plant) were observed from lower canopy to record the pest count. The data on surviving population were reported on the basis of mean insect population/five leaves. For, aphid and thrips population count 10 inflorescences were randomly selected from each plot. Aphid population was counted from top 10 cm of inflorescence, while thrips population was recorded by holding the same stalk over a white piece of sticky paper and trapping it vigorously to dislodge insects. At each harvest number and weight of healthy and infested

pods were recorded and percent fruit infestation and yield (tha⁻¹) were calculated. Data were analyzed by using STAT-10 software for analysis of variance and treatment means were separated by applying LSD at 1% level of significance.

Results and Discussion

Results presented in Table 1 indicated that Imitaf treated plot had the lowest number of aphid population/ inflorescence (4.00) which was followed by Bio-power (*Beauvaria bassiana* 1.15 WP) and Bio-Magic (*Metarhizium anisopliae* 1.15 WP) treated plots (5.33) and these were followed by Bio-catch (*Verticillium lecani* 1.15 WP), Bioclean (D- limonene 5%) sprayed plot whereas the untreated control plot recorded (12.00) aphid population. The highest per cent reduction of aphid population over untreated control (66.67%) was recorded from Imitaf applied plot followed by Bio-Magic treated plots (55.58%). Almost similar results were obtained from Bio-power (55.58%), Bio-catch (52.75%), Bioclean (50%) sprayed plot. After second spray, Imitaf recorded the lowest number of aphid population/ inflorescence (2.00) which was followed Bio-catch (3.00), Bio-power (3.00), Bio-Magic (3.00), Bioclean (3.00) treated plots whereas untreated control plot recorded 11.00 the highest aphid population/ inflorescence. The highest per cent reduction of aphid population over untreated control (81.82%) was recorded from Imitaf treated plots followed Bio-catch (72.73%), Bio-power (72.73%), Bio-Magic treated plots (72.73%), Bioclean (72.73%) sprayed plot. After third spray, Imitaf recorded in the lowest number of aphid population/ inflorescence (0.83) which was followed Bio-Magic (1.83), Bio-power (2.00), Bioclean (2.00) and Bio-catch (2.17). Similarly, the highest per cent reduction of aphid population/ inflorescence over control (91.70%) was recorded from Imitaf treated plot which was followed by Bio-Magic (81.70%), Bio-power 98.0%). Almost similar result was shown by Bioclean (80%), Bio-catch (78%).

Results presented in Table 2 indicated the pooled mean of jassids population after first spray., Imitaf resulted the lowest number of jassid population (5.67/5 leaves) which was followed Bioclean (7.00/ 5 leaves), Bio-power (7.33/ 5 leaves) and similar result was recorded in Bio-Magic (7.33/5 leaves), Bio-catch (8.00/ 5 leaves) treated plot. But the untreated control plot recorded (13.00 Jassids/5 leaves). Similarly, the highest per cent reduction of jassid population/5 leaves over control (56.38%) was recorded from Imitaf applied plot which was followed by Bioclean (46.15%), Bio-power (43,62%), Bio-Magic (43,62%), Bio-catch (38.46%) treated plot. . After second spray, Imitaf spryed plot recorded the lowest number of jassid population (2.67/5 leaves) which was followed by Bioclean (3.67/ 5 leaves), Bio-Magic (3.83/ 5 leaves), Bio-catch (4.00/ 5 leaves), Bio-power (4.00/ 5 leaves) whereas untreated control plot recorded 12.67/ 5 leaves. Similarly, the highest per cent reduction of jassid population over control (78.93%) was recorded from Imitaf treated plot which was followed Bioclean (71.03%), Bio-Magic (69.77%), Bio-power (68.43%) and similar result showing Bio-catch (68,43%).

The pooled mean of jassids population, at 14 days after third spray, Imitaf recorded the lowest number of jassid population (1.67/5 leaves) which was statistically similar to Bio-Magic (2.33/ 5 leaves) which was followed by Bio-catch (2.67), Bio-power (2.67), Bioclean (2.67) whereas the untreated control recorded in (11.67). Similarly, the highest per cent reduction of jassid population over control (85.69%) was recorded from Imitaf which was followed Bio-Magic (80.03%), Bio-power (77,12%) and similar result showing Bioclean (77.12%), Bio-catch (77.12%).

Results of the study have been presented in Table 3. It was indicated that the pooled mean of thrips population at 24 hours after first spray, Imitaf recorded in the lowest number of thrips populatopn/ inflorescence (3.33) which was followed Bio-Magic (4.33) and almost similar result was found in Bioclean (4.33), Bio-catch (4.67), Bio-power (4.67) whereas untreated control plot recorded 7.67 population. Similarly, the highest per cent reduction of thrips population over control (56.58%) was recorded from Imitaf treated plot followed Bio-Magic (43.55%), Bioclean (43.55%), Bio-catch (39.11%) and similar result was found in Bio-power (39.11%). At seven days interval after second spray, Imitaf recorded the lowest thrips populatopn/ inflorescence (2.33) which was followed Bio-Magic (3.00), Bioclean (3.33) and similar result showed from Bio-catch (3.33), Bio-power (3.33) treated plot whereas the untreated control plot recorded 7.00 population. Similarly, the highest per cent reduction of thrips population over control (66.71%) was recorded from Imitaf treated plot which was followed by Bio-Magic (57.14%), Bioclean (52.43%) and similar result obtained from Bio-catch (52.43%), Bio-power (52.43%) sprayed plot. The pooled mean of thrips population, at 14 days after third spray, Imitaf sprayed plot recorded the lowest thrips population/inflorescence (1.33) which was followed by Bio-Magic (2.33) and almost similar result showed in Bioclean (2.33), Bio-catch (2.33), Bio-power (2.33) treated plot whereas the untreated control plot had 7.67 populations. Similarly, the highest per cent reduction of thrips population over control (82.66%) was recorded from Imitaf sprayed plot followed Bio-Magic (69.62%) and similar result was shown in Bioclean (69.62%), Bio- catch (69.62%), Bio-power (69.62%) treated plot.

Sucking insect pest infestation and réduction of infestation in yard long bean have been presented in Table 4. Result indicated that the Imitaf showed significantly the lowest flower infestation by aphid (2.99%) which was followed by Bio-Magic (3.62%) and Bio-power (4.10%), Bioclean (4.42), Bio- catch (4.72) whereas the untreated control showed significantly the highest flower infestation (15.13%) by aphid. It is also observed that the Imitaf showed significantly the lowest pod infestation by thrips (2.53%) which was followed Bio-Magic (3.39%) and Bio-power (3.65%) Bioclean(4.04), Bio-catch (4.08) whereas the untreated control showed significantly the highest flower infestation (15.77%) by thrips. Similarly, the Imitaf showed significantly the highest flower infestation reduction over

Table 1. Effect of different treatments bio-pesticides and chemical insecticide on the abundance of aphid in yard long bean at RARS, Jashore, in the kharif season of 2022 and 22-23

Treatments	Before spray Aphid population/ inflorescence	After first spray		After second spray		After third spray	
		Aphid population / inflorescence	% reduction of aphid population over control	Mean aphid population/ inflorescence	% reduction of aphid population over control	Mean aphid population/ inflorescence	% reduction of aphid population over control
Bio-catch (*Vertcillium lecani* 1.15 WP)	12.33ab	5.67b	52.75	3.00b	72.73	2.17b	78.30
Bio-power (*Beauvaria bassiana* 1.15 WP)	13.00ab	5.33bc	55.58	3.00b	72.73	2.00b	80.00
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	12.00ab	5.33bc	55.58	3.00b	72.73	1.83b	81.70
Bioclean (D- limonene 5%)	13.33a	6.00b	50.00	3.00b	72.73	2.00b	80.00
Imitaf (Imidacloprid 200 SL)	12.33ab	4.00c	66.67	2.00b	81.82	0.83c	91.70
Untreated control (Water spray)	11.67b	12.00a	-	11.00a	-	10.00a	-
CV%	6.83	13.30		9.60		5.30	

Mean having same letter(s) in a column are not significantly different at P> 0.01 followed by DMRT.

T_1= spraying of Bio-catch (*Vertcillium lecani* 1.15 WP) @ 6 gL^{-1} of water, T_2= spraying of Bio-power (*Beauvaria bassiana* 1.15 WP) @ 6 gL^{-1} of water, T_3= spraying of Bio-Magic (*Metarhizium anisopliae* 1.15 WP) @ gL^{-1} of water, T_4= spraying of Bioclean (D- limonene 5%) @ 0.5 mL^{-1} of water, T_5= spraying of Imitaf (Imidacloprid 200 SL) @ 1 mL^{-1} of water, T_6= Control (Water spray only).

Table 2. Effect of different treatments bio-pesticides and chemical insecticide on the abundance of jassid in yard long bean at RARS, Jashore, in the kharif season of 2022 and 22-23

Treatments	Before spray Jassid population/5 leaves	After first spray		After second spray		After third spray	
		Jassid population/ 5 leaves	% reduction of Jassid population over control	Jassid population/ 5 leaves	% reduction of Jassid population over control	Jassid population/ 5 leaves	% reduction of Jassid population over control
Bio-catch (*Vertcillium lecani* 1.15 WP)	16.33a	8.00b	38.46	4.00b	68.43	2.67b	77.12
Bio-power (*Beauvaria bassiana* 1.15 WP)	15.33ab	7.33b	43.62	4.00b	68.43	2.67b	77.12
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	15.00abc	7.33b	43.62	3.83b	69.77	2.33b	80.03
Bioclean (D- limonene 5%)	14.33bc	7.00b	46.15	3.67b	71.03	2.67b	77.12
Imitaf (Imidacloprid 200 SL)	15.33ab	5.67c	56.38	2.67b	78.93	1.67b	85.69
Control (Water spray)	13.67c	13.00a	-	12.67a	-	11.67a	-
CV%	5.31	8.68		2.31		2.04	

Mean having same letter(s) in a column are not significantly different at P> 0.01 followed by DMRT.

Table 3. Effect of different treatments bio-pesticides and chemical insecticide on the abundance of thrips in yard long bean at RARS, Jashore, in the kharif season of 2022 and 22-23

Treatments	Before spray thrips population/ inflorescence	After first spray		After second spray		After third spray	
		thrips population/ inflorescence	% reduction of thrips population over control	thrips population/ inflorescence	% reduction of thrips population over control	thrips population/ inflorescence	% reduction of thrips population over control
Bio-catch (*Verticillium lecani* 1.15 WP)	8.00a	4.67b	39.11	3.33b	52.43	2.33b	69.62
Bio-power (*Beauvaria bassiana* 1.15 WP)	7.33a	4.67b	39.11	3.33b	52.43	2.33b	69.62
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	7.33a	4.33b	43.55	3.00b	57.14	2.33b	69.62
Bioclean (D- limonene 5%)	7.00ab	4.33b	43.55	3.33b	52.43	2.33b	69.62
Imitaf (Imidacloprid 200 SL)	5.67b	3.33b	56.58	2.33b	66.71	1.33b	82.66
Untreated control (Water spray)	7.00ab	7.67a	-	7.00a	-	7.67a	-
CV%	11.18	2.37	-	9.41	-	3.75	-

Mean having same letter(s) in a column are not significantly different at P> 0.01 followed by DMRT.

untreated control (80.24%) which was followed by Bio-Magic (76.07%) and Bio-power (72.90%), Bioclean (70.79), Bio-catch (68.80) by thrips. It is also observed that the Imitaf showed significantly the highest pod infestation reduction over untreated control (83.96%) which was followed Bio-Magic (78.50%) and Bio-power (76.85%) Bioclean (74.38), Bio-catch (74.18) by thrips.

Table. 4. Effect of different bio-pesticides and chemical insecticide in the flower and pod infestation of yard long bean by sucking insect pest at RARS, Jashore, during 2021-22 and 2022-23.

Treatments	(%) Flower infestation	(%) Flower infestation reduction over control	(%) Pod infestation	(%) Pod infestation reduction over control
Bio-catch (*Vertcillium lecani* 1.15 WP)	4.72b	68.80	4.08b	74.18
Bio-power (*Beauvaria bassiana* 1.15 WP)	4.10bc	72.90	3.65b	76.85
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	3.62cd	76.07	3.39bc	78.50
Bioclean (D- limonene 5%)	4.42b	70.79	4.04b	74.38
Imitaf (Imidacloprid 200 SL)	2.99d	80.24	2.53c	83.96
Untreated control (Water spray)	15.13a	-	15.77a	-
CV%	7.08		8.02	

Means having same letter(s) in a column are not significantly different at P>0.05 followed by DMRT

Results of the study on natural enemy population have been presented in Table 5. It was revealed that Imitaf showed the lowest number of natural enemy/plant (0.33) after first spray which was followed by Bio-catch (0.67), Bio-power (0.67) and Bio-Magic (0.67), Bioclean (1.00) whereas the untreated control plot recorded 2.33 natural enemy population. The highest per cent reduction of natural enemy/plant over untreated control (85.84%) was recorded from Imitaf followed by Bio-catch (71.24%) and almost similar result was found in Bio-Magic (71.24%), Bio-power (71.24%), Bioclean (57.08%) treated plot. After second spray, Imitaf recorded the lowest number of natural enemy/plant (00) which was followed by Bio-catch (0.33), Bio-Magic (0.33), Bio-power (0.67), Bioclean (0.67) treated plot whereas the untreated control plot recorded 2.00 natural enemy/plant. Zero reduce than of natural enemy/plant over untreated control (00) was found in Imitaf which was followed by Bio-catch (84%) and Bio-Magic (84%), Bio-power (67%), Bioclean (67%) treated plot. After third spray, the natural enemy/plant (00) was not found in Imitaf treated plot which was followed by Bio-Magic (00), Bio-power (0.67), Bio-catch (0.67) and Bioclean (1.00) sprayed plot. Similarly, in Bio-Magic and Imitaf sprayed plot didnot shown any natural enemy/plant (00). The highest per cent reduction of natural enemy over control was recorded from Bio-catch and Bio-power (60%) and followed by Bioclean (40%) sprayed plots.

Table 5. Effectiveness of different treatments in reducing natural enemy in yard long bean at RARS, Jashore, during 2021-22 and 2022-23.

Treatments	Before spray Natural enemy / plant	After first spray		After second spray		After third spray	
		Natural enemy / plant	(%) Reduction of natural enemy over control	Natural enemy / plant	(%)Reduction of natural enemy over control	Natural enemy / plant	(%)Reduction of natural enemy over control
Bio-catch (*Vertcillium lecani* 1.15 WP)	2.00a	0.67b	71.24	0.33b	84	0.67b	60.00
Bio-power (*Beauvaria bassiana* 1.15 WP)	1.33a	0.67b	71.24	0.67b	67	0.67b	60.00
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	2.00a	0.67b	71.24	0.33b	84	0.00b	00
Bioclean (D- limonene 5%)	1.67a	1.00b	57.08	0.67b	67	1.00b	40.00
Imitaf (Imidacloprid 200 SL)	1.33a	0.33b	85.84	0.00b	00	0.00b	00
Untreated control (Water spray)	2.00a	2.33a		2.00a		1.67a	-
CV%	3.96	4.76		2.46		6.24	-

Mean having same letter(s) in a column are not significantly different at P> 0.01 followed by DMRT.

Table 6. Effect of different different treatments on the yield of yard long bean at RARS, Jashore, during 2021-22 and 2022-23.

Treatments	Yield (t/ha)	Yield increase over control (%)
Bio-catch (*Vertcillium lecani* 1.15 WP)	7.18b	25.31
Bio-power (*Beauvaria bassiana* 1.15 WP)	7.17b	25.13
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	7.43b	29.67
Bioclean (D- limonene 5%)	7.03b	22.69
Imitaf (Imidacloprid 200 SL)	8.37a	46.07
Untreated control (Water spray)	5.73c	-
CV%	6.42	-

Mean having same letter(s) in a column are not significantly different at P> 0.01 followed by DMRT.

Table 7. Benefit cost analysis of different treatments of the yard long bean sucking insect pest at RARS, Jashore, during 2021-22 and 2022-23.

Treatments	Marketable yield (t/ha)	[1]Gross return (Tk/ha)	[2]Cost of treatment (Tk/ha)	Net return (Tk/ha)	Adjusted return (Tk/ha)	M BCR
Bio-catch (*Vertcillium lecani* 1.15 WP)	7.18b	287200	11110	276090	46890	4.22
Bio-power (*Beauvaria bassiana* 1.15 WP)	7.17b	286800	10650	276150	46950	4.41
Bio-Magic (*Metarhizium anisopliae* 1.15 WP)	7.43b	297200	10730	286470	57270	5.34
Bioclean (D- limonene 5%)	7.03b	281200	10620	270580	41380	3.90
Imitaf (Imidacloprid 200 SL)	8.37a	334800	11210	323590	94390	8.42
Untreated control (Water spray)	5.73c	229200	-	229200	-	-
CV%	6.42	-	-	-	-	-

[1]Farmgate price of yard long bean @ Tk. 40.00 per kg.

[2][Cost of Bio-catch: @Tk. 380100 ml^{-1}; Cost of Bio-power (*Beauvaria bassiana* 1.15 WP): @ Tk. 3000kg^{-1}; Cost of Bio-Magic (*Metarhizium anisopliae* 1.15 WP): @ Tk.2500Kg^{-1}; Cost of Bioclean (D- limonene 5%): @ Tk. 230100ml^{-1}; Cost of Imitaf (Imidacloprid 200 SL): @ Tk. 450100 ml^{-1}; Cost of spray: Three laborers/spray/ha @ Tk 550.00labour^{-1}day^{-1}; Cost of hand picking: Three laborers/ha @ Tk 550.00labour^{-1}day^{-1}; Spray volume required: 500Lha^{-1}].

Effect of different treatments on the yield of yard long bean have been presented in Table 6. It was indicated that the result showing significantly highest pod yield (8.37tha^{-1}) was recorded in Imitaf treated plot which was followed Bio-Magic

(7.43 tha^{-1}), Bio-catch (7.18 t ha^{-1}), Bio-power (7.17 tha^{-1}), Bioclean (7.03 tha^{-1}) whereas the lowest pod yield was found in untreated control (5.73 tha^{-1}) plot. Similarly, the highest yield increase over control was calculated from Imitaf (46.07%) followed Bio-Magic (29.67%), Bio-catch (25,31%), Bio-power (25.13%) and the lowest yield increase over control was obtained in Bioclean (22.69%).

The benefit-cost ratio (BCR) as worked out based on the expenses incurred and value of crops obtained from the treated plots for the control of aphids, jassid and thrips of yard long bean is given in Table 7. It is to be noted here that expenses incurred reffered to those only on pest control. It is revealed that the highest (8.42) marginal benefit-cost ratio (MBCR) was calculated from treatment Imitaf which was followed Bio-Magic (5.34), Bio-power (4.41), Bio-catch (4.22), Bioclean (3.90). So, considering MBCR, Imitaf may be recommended for effective management of aphids, jassid and thrips attacking yard long bean.

Conclusion

The results indicated that the chemical, insecticide Imitaf showed the best efficacy providing reduced infestation of the sucking insect pests with the higher yield and the highest MBCR. The biopesticide spraying of Bio-Magic offered second best performance, while the other bio-pesticides offered intermediate level of performance. The biopesticide, Bio-Magic may be used in IPM against the sucking insect pests of yard long bean.

Acknowledgement

References

Anonymous, (2013). Krishi Diary (in Bangali) Agriculture information service, Khamarbari, Farmgate, Ministry of Agriculture, Dhaka, Bangladesh. p. 73.

Anonymous. (2010). Bangladesh Bureau of Statistics. Year book of Agricultural Statistics of Bangladesh 2009 (21st edition). Ministry of Planning. Government of the People's Republic of Bangladesh.

Ano, A. O. and C. I. Ubochi, (2008). Nutrient composition of climbing and prostrate veetable cowpea accessions. *Afr. J. Biotech.* 7: 3795-3798.

Chagnon, M., D. Kreutzweiser, E.A.D, Mitchell, C.A. Morrissey, D.A, Noome, J.P. Van der Sluijs, (2015). Risks of large-scale use of systemic insecticides to ecosystem functioning and services. *Environ. Sci. Pollut. Res.* **22**:119–134.

Carvalho, F.P., (2006). Agriculture, pesticides, food security and food safety. *Environ. Sci. Policy.***9**: 685–692.

Dehariya, S.K., Shukla, A., Barde, S.K. and Ahirwar, K. (2018). Efficacy of botanical pesticides against sucking insect pest in Brinjal. *Int. J. Curr. Microbiol. App. Sci.* **7(1):** 1930-1935.

Dutta, N.K., M. Mahmudunnabi, A.K.M.Z Rahman and S.N. Aalm, 2014. Development of a management approach against pod borer, *Euchrysops cnejus* F. attacking yard long bean. Annual Report, 2013-2014, Entomology Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur,Gazipur. P. 260.

Dutta N. K., M. R. U. Mian and M. Nasiruddin, 2004. Development of a management approach against the Pod borer, *Euchrysops cnejus* (F) attacking stringbean. Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. *Annual Report*, 2003-2004, 60- 63 pp.

Egho, E. O. 2010. Studies on the control of major insect pests and yield of cow pea (*Vigna unguiculata* (L.) walp under calendar and monitored application of synthetic chemical in ABRAKA, south Nigeria, *Archives of Applied Science Research*, **2(4),** 224-234.

FAOSTAT, (2014). FAOSTAT Statistics Database. FAO, Rome.

Grubben, G. J. H. 1993. *Vigna unguiculata* (L.) Walp. cv. group *Sesquipedalis*. *In:* Siemonsma, J.S. & KasemPiluek (Editors). Plant Resources of South-East Asia No 8. Vegetables. Pudoc Scientific Publishers, Wageningen, The Netherlands, 274–278 pp.

Jayasimha, R.R., R.R. Rachana, M.Manjunatha and V.B. Rajkuma. (2012). Biology and sesonal incidence of leafhopper, Amrasca biguttulea biguttulea (Ishida) (Homiptera: Cicadellidae) on okra. *Pest management in Horticulture Ecosystems.* **18**: 149-153.

Malacrino, A., K.H. Seng, C. An & S. Ong. 2019. Integrated pest management for yard-long bean (Vigna unguiculata subsp. Sesquipedalis) in Cambodia. *Crop Protection*, DOI: 10.1016/j.cropro.2019.05005.

Mukhtar, I. (2009). Sunflower disease and insect pests in Pakistan: A Review. *Afr. Crop Sci. J*. **17(2):** 109 – 118.

Pimentel, D. and M. Burgess, 2014. Environmental and economic benefits of reducing pesticide use. In: Pimentel D, Peshin R, editors. Integrated Pest Management. New York, Heidelberg, Dordrecht, London: Springer Science + Business Media Dordrecht. 127-139 pp.

Pimentel, D. (2005). Environmental and economic costs of the application of pesticides primarily in 527 the United States. *Environ. Dev. Sustain*. **7:** 229– 252.

Pedigo, L.P. (2002). Entomology and Pest Management. Princeton and Hall Incorporation, London.

Rashid, M.A., S. Ahmed, G.M.A. Halim, M.T. Rahman, M.N. Uddin, A.K.M.S.R. Mollick, M.A. Rahman, & S.N. Alam. 2009. Knowledge bank – based vegetable production training module. International Rice Research Institute (IRRI), Dhaka office, Bangladesh. P. 277.

Uddin, M.S., M.M. Rahman, M.Z. Alam, M.M. Hossain & M.E. Hoque. 2015. Survey on usage and effectiveness of chemicals for managing pod borer and aphids of yard long bean in Bangladesh. *Ann. Bangladesh Agric*. **19:** 1-11.

Uddin, M. S., M. M. Rahman, M. Z. Alam, A. Awal, and M. A Mazed,. 2013. Insect Pests of Yard Long Bean (*Vigna unguiculata* sub sp. *sesquipedalis* L.) in Major Growing Areas of Bangladesh. *The Agriculturists.* **11(2):** 66-73.

DEVELOPMENT OF BIO-RATIONAL MANAGEMENT PACKAGE FOR FUSARIUM WILT AND SIGATOKA DISEASE OF BANANA

M. H. Rahman[1], M. M. Islam[2], M. M. A. Patwary[3]
and R. Akter[4]

Abstract

Efficacy of different bio-rational based fungicides was studied at the Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Shibpur, Narsingdi during the period of April, 2021 to May, 2022 to find out the effective management package(s) against Fusarium wilt and sigatoka diseases of banana. Four treatments combinations were compared with the farmer's practices (control where no fungicide) under natural epiphytotic conditions. Among the tested treatments, T_4 = Decoprima (5g/pit) + Soil recharge (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre of watre) displayed maximum reduction of Fusarium wilt disease incidence (100%) at 180 days after planting (DAP). In case of sigatoka, the highest disease severity of 26.67 % was recorded in T_5 (Farmers practices) treated plants at 180 DAP and the lowest in T_4 treated plants where severity was 10%. The highest banana fruit yield (11 kg per bunch) was obtained from T_4 treated plants while the lowest yield (6.40 kg per bunch) in T_5 treated plants.

Keywords: BARI Tricho-compost, Dynamic WP, Decoprima, Recharge, and Tilt 250EC Fusarium wilt, Sigatoka, banana.

Introduction

Banana (*Musa* spp.) is one of the most popular nutritious fruits in Bangladesh belongs to the family Musaceae. The fruit is available round the year with a great demand to the people for its lower price, easily digestible and palatable in nature In Bangladesh it is cultivated in 35,000 ha of land and produces nearly 2.6 million tons of banana annually (BBS, 2012). Banana production faces several constraints, and diseases play a significant role in limiting successful cultivation globally including Bangladesh. The most common and widely damaging diseases of banana in Bangladesh are Fuasarium wilt (*Fusarium oxysporum* f. sp. *cubense*), Sigatoka (*Mycosphaerella musicola*), burrowing nematode (*Rodopholus similis*), Mosaic and Streaks virus (Meah and Khan, 1987). Among the diseases Fusarium wilt disease is the most devastating disease which affecting commercial and subsistence banana production throughout the banana producing areas of the world (Ploetz, 2005). The disease is ranked as one of the top 6 important plant diseases in the world (Ploetz and Pegg, 1997). In Bangladesh, 24% disease incidence of fusarium wilt was

[1]On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Shibpur, Narsingdi, Bangladesh, [2]Plant Pathology Division, BARI, Gazipur, Bangladesh, [3]Farm Division, BARI, Gazipur, Bangladesh, [4]Regional Horticultural Research Station, BARI, Shibpur, Narsingdi, Bangladesh.

recorded from Jessore in Sabri variety (Hossain and Rashid, 1999). Sigatoka of banana caused drastic reduction in yield in terms of weight and quality of the fruits (Ramsey *et al.*, 1987) due to blighted of affected leaves and reduction of normal photosynthesis of the plant. Several management strategies have been developed in controlling the spread of Fusarium wilt and sigatoka diseases. However, they were unable to provide long-term solutions to the problem. Solely relying on chemical fungicides is not always effective for managing plant diseases. Moreover, chemical control can negatively impact the agro-ecosystem. On the other hand, utilizing biological agents offers several advantages such as reduced risk of adverse effects on the environment and human health. Therefore, the current research was aimed to develop bio-rational based management package(s) to combat the Fusarium wilt and sigatoka diseases of banana.

Materials and Methods

The experiment was conducted at the Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Shibpur, Narsingdi during the period of April, 2021 to May, 2022. Different combinations of BARI Tricho-compost, Dynamic WP, Decoprima, Recharge, and Tilt 250EC were tested against the Fusarium wilt and Sigatoka disease of banana under natural field conditions. The Dynamic WP, a biological fungicide contains *Bacillus amyloliquefaciens* that attacks cell walls of fungus and bacteria, deprives pathogenic fungi of space and nourishment by colonizing plant roots and produces metabolites that inhibit plant pathogens. The Decoprima, another bio-pesticide contains *Streptomyces* sp., *Geobacillus* sp. and *Trichoderma* sp. that act as bio-sterilization and aerobic decomposer ingredients, which can be used alone or in combination with fungicides or chemical insecticides. The Recharge (Lycomax) contains *Trichoderma harzianum, Trichoderma viride, Metarhizium anisopila* and *Beauveria bassiana* that can protect plants from the attack of pathogenic fungi. The experiment was conducted in randomized complete block design with three replications. The unit plot size was 4m × 10m and plant spacing was 2m × 2m. The banana (Sabri) plants were grown under uniform cultural practices . Four treatment combinations were compared with the farmers practice. The treatments were T_1: BARI Tricho-compost (10g/pit) + Sucker treatment with Dynamic WP (2g/litre of water) + Alternate foliar spray with Dynamic WP (2g/litre of water) and Tilt 250 EC (0.5ml/litre of water), T_2: Soil application of Recharge (5g/pit) + Sucker treatment with Dynamic WP (2g/pit) + Alternate foliar spray with Dynamic WP (2g/pit) and Tilt 250 EC (0.5ml/litre of water), T_3: Decoprima (5g/pit) + Alternate foliar spray with Dynamic WP (2g/pit) and Tilt 250EC (0.5ml/litre of water), T_4: Decoprima (5g/pit) + Soil Recharge (5g/pit) + Alternate foliar spray with Dynamic WP (2g/pit) and Tilt 250 EC (0.5ml/litre of water) and T_5: Farmers practices (control) where no fungicide was applied.

BARI Tricho-compost (10g/pit), Recharge (5g/pit) and Decoprima (5g/pit) were applied during sucker planting. Alternate foliar application of fungicides Tilt 250

EC (0.5ml/litre of water) and Dynamic (2g/litre of water) was started when first symptom of the disease was noticed and continued up to flower initiation stage at 30 days interval. The incidence of Fusarium wilt and Sigatoka disease was recorded at 120, 150 and 180 days after transplanting. The disease incidence of banana plants was determined by the following formula (Rai and Mamatha, 2005):

$$\text{Plant infection (\%)} = \frac{\text{Number of diseased plants}}{\text{Number of total plants observed}} \times 100$$

Percent Disease Severity (PDS) was determined by the following formula (Rai and Mamatha 2005):

$$\text{Percent disease severity (leaves)} = \frac{\text{Area of leaf tissue infected by disease}}{\text{Total leaf area of the plant}} \times 100$$

The percent data were transformed into square root and arc-sign transformed values and analyzed statistically using Statistix 10 software package.

Results and Discussion

Incidence of Fusarium wilt: The incidence of Fusarium wilt disease in banana plants varied significantly among the treatments (Table 1). The highest disease incidence 16.67, 41.67 and 41.67% was recorded at 120, 150 and 180 days after planting, respectively in T_5 (control) treated plants. No incidence of wilt disease (0%) was observed in T_1 and T_4 treatments even at 180 days after planting. The reduction in wilt incidence ranged 60-100% among the treatments at 180 days after planting. The reduction of wilt incidence at 180 DAP was maximum (100%) in both T_1 and T_4 treatments followed by T_3 treatment (80.01%). Thangavelu (1999) reported that the incidence of Fusarium wilt ranged from 0.5 to 20% in main crop and it was maximum (85%) in the second crop in India. The incidence of panama disease (Fusarium wilt) was found as 30% in Batticaloa district of Sri Lanka (Shanika and Prasannath, 2016).

Table 1. Effect of different fungicides on disease incidence of Fusarium wilt of banana at different days after planting

Treatments	Fusarium wilt disease incidence (%)			Disease reduction (%) over Control at 180 DAP
	at 120 DAP	at 150 DAP	at 180 DAP	
T_1	0.00	0.00	0.00	100.00
T_2	8.33	16.67	16.67	60.00
T_3	8.33	8.33	8.33	80.01
T_4	0.00	0.00	0.00	100.00
T_5	16.67	41.67	41.67	-

DAP = Days After Planting.

T_1: BARI Tricho-compost (10g/pit) + Sucker treatment with Dynamic WP (2g/litre water) + Alternate foliar spray with Dynamic (2g/litre water) and Tilt 250 EC (0.5ml/litre watre), T_2: Soil application of Recharge (5g/pit) + Sucker treatment with Dynamic (2g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre water), T_3:

Decoprima (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre of water), T_4: Decoprima (5g/pit) + Soil recharge (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250EC (0.5ml/litre water) and T_5: Farmers practices (control) where no fungicide.

Incidence and Severity of Sigatoka disease: The incidence of Sigatoka disease in banana plants at 180 days after transplanting did not differ significantly among the treatments and all banana plants under study were infected (100%) by Sigatoka disease at 180 days after planting (Table 2). Besides, the severity of Sigatoka disease varied significantly among the treatments at 180 days after planting where the highest disease severity of 16.67, 20.00 and 26.67% was recorded in T_5 treated plants at 120, 150 and 180 days after planting, respectively (Table 2). The treament T_2 treated plants showed severity of 10.00, 13.33 and 18.33% at 120, 150 and 180 days after planting, respectively. The lowest disease severity of 6.67, 9.67 and 10% was recorded in T_4 treated plants at 120, 150 and 180 days after planting (Table 2). . Islam *et. al*. (2017) reported that the sigatoka disease incidence ranged from 21.90 to 54.33% with the severity from 42.67 to 85.67% in eighteen upazillas of Narsingdi, Tangail, Gaibandha, Rangpur, Bogra, and Jhikorgacha, Jessore districts of Bangladesh. In India, Thammaiah (2003) conducted a survey on Sigatoka disease of banana and reported the highest severity in Munavalli village of Sindagi Taluk (66.96%) followed by Bijapur (64.56%). Shanika and Prasannath (2016) reported 42% infection of sigatoka disease in Batticaloa district of Sri Lanka.

Table 2. Effect of different fungicides on disease incidence and severity of sigatoka of banana at different days after planting

Treatments	Sigatoka disease incidence (%)			Sigatoka disease severity (%)		
	at 120 DAP	at 150 DAP	at 180 DAP	at 120 DAP	at 150 DAP	at 180 DAP
T_1	58.33 (55.00)	75.00 (70.00)	100.00 (90.00)	6.67 (14.76)	10.00 (18.43)	11.67 (19.95)
T_2	66.67 (60.00)	100.00 (90.00)	100.00 (90.00)	10.00 (18.43)	13.33 (21.15)	18.33 (24.81)
T_3	50.00 (41.35)	91.67 (80.00)	100.00 (90.00)	9.00 (17.44)	10.67 (19.05)	13.33 (21.34)
T_4	41.67 (41.35)	58.33 (55.00)	100.00 (90.00)	6.67 (14.76)	9.67 (18.08)	10.00 (18.38)
T_5	66.67 (60.00)	100.00 (90.00)	100.00 (90.00)	16.67 (23.36)	20.00 (26.19)	26.67 (31.00)
LSD (0.05)	51.55	37.18	-	8.93	7.03	8.58

DAP = Days After Planting; Values within the parentheses are arc-sign transformed values.

Fruit yield of banana: The fruit yield of banana was varied significantly among the treatments (Figure 1). The highest fruit yield of 11 kg per plant or bunch was found in T_4 treated plants and the lowest fruit yield of 6.40 kg per bunch in the T_5

treated plants (control plot). The fruit yield was higher where the banana plants showed lower incidence and severity of Fusarium wilt and Sigatoka disease. The highest disease severity of 26.67% was recorded in T_5 treated plants where the fruit yield was lowest of 6.4 kg. The results revealed that higher incidence and severity of diseases declined the development of banana finger and produced lower fruit yield.
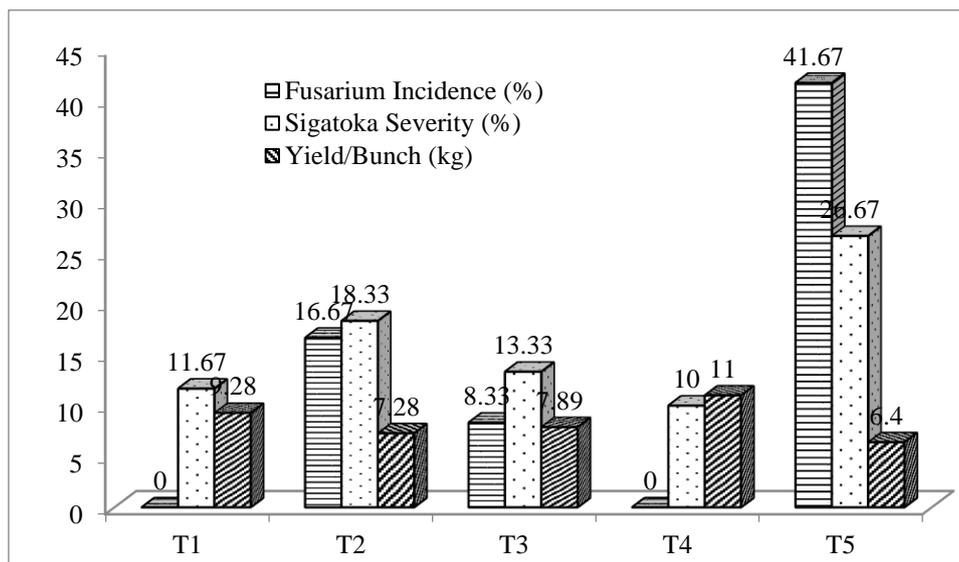

Fig. 1. Effect of different fungicides combinations on Fusarium wilt and Sigatoka diseases of banana and fruit yield of the crop.

T_1: BARI Tricho-compost (10g/pit) + Sucker treatment with Dynamic WP (2g/litre water) + Alternate foliar spray with Dynamic (2g/litre water) and Tilt 250 EC (0.5ml/litre watre),

T_2: Soil application of Recharge (5g/pit) + Sucker treatment with Dynamic (2g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre water),

T_3: Decoprima (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre of water),

T_4: Decoprima (5g/pit) + Soil recharge (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250EC (0.5ml/litre water)

T_5: Farmers practices (control) where no fungicide was used.

Conclusion

Results from the present study revealed that two treatments i.e. T_4 = Decoprima (5g/pit) + Soil recharge (5g/pit) + Alternate foliar spray with Dynamic (2g/pit) and Tilt 250 EC (0.5ml/litre of water) and T_1 = (BARI Tricho-compost (10g/pit) Sucker treatment with Dynamic (2g/litre of water) + Alternate foliar spray with Dynamic (2g/litre of water) and Tilt 250 EC (0.5ml/litre of water) were better for the

management of Fuasarium wilt disease of banana. Besides, T_4 treatment was better for controlling the sigatoka disease and increasing fruit yield of banana. Considering both of the diseases and yield performance the treatment T_4 was the best in reducing diseases and increase fruit yield of banana.

Acknowledgement

References

BBS. 2012. Statistics year book of Bangladesh. Bangladesh bureau of statistics. Ministry of Planning, Government of the people's Republic of Bangladesh, Dhaka.

Hossain, M.M. and M.H. Rashid. 1999. Status of fusarium wilt of banana in Bangladesh. *In: Banana fusarium wilt management, towards sustainable cultivation.* Genting Highlands Resort, Malaysia. 303p.

Hossain, M.F. 2014. A study of banana production in Bangladesh: Area, yield and major constraints. *ARPN J. Agric. Biol. Sci.* **9:** 206-210.

Islam, M. N., N. Akter, M. M. Karim, M. S. Akhter and M. M. E. Rahman. 2017. Panama and Sigatoka diseases of banana in selected locations of Bangladesh. *Bangladesh J. Plant Pathol.* **33 (1&2):** 5-10.

Meah, M. B. and A. A. Khan. 1987. Annual progress report (1986-87). Survey of diseases of some important fruit and vegetable crops of Bangladesh. Department of Plant Pathology, Bangladesh Agriculture University, Mymensingh, Bangladesh. pp: 12.

Ploetz, R. C. 2005. Panama disease, an old enemy rears its ugly head: Parts 1 and 2. In: Plant Health Progress, APSnet: Online doi:10.1049/PHP-2005-1221-01-RV.

Ploetz, R. C. and K. G. Pegg. 1997. Fusarium wilt of banana and Wallace's line: Was the disease originally restricted to his Indo-Malayan region? *Australas. Plant Pathol.* **26:** 239-249.

Rai, V. R and T. Mamatha. 2005. Seedling diseases of some important forest tree species and their management. *In. Working papers of the Finnish Forest Research Institue.* Ramsey *et al.* 1987. Work on the effect of yellow Sigatoka severity on production and green life of bananas

Shanika, W. and K. Prasannath. 2016. Survey on diseases of banana and their management in Batticaloa district, of Sri Lanka. *Int. J. of Res. & Review.* **3(2):**53-54.

Su, H. J., S. C. Hwang and W. H. Ko. 1986. Fusarium wilt of Cavendish banana in Taiwan. Plant Disease, 70:814-818.

Thangavelu, R., P. Sundararaju, S. Sathiyamoorthy, T. Reghucharnder, R. Velazhahan, S. Nakkeeran and A. Palaniswamy. 1999. Status of Fusarium wilt of banana in India. In: Proc. Inter. workshop on banana Fusarium wilt disease, p 58, 18-20 October, Mysore.

Thammaih, N., 2003. Studies on epidemiology and management of Sigatoka leaf spot of banana. Ph. D. Thesis, Univ. Agric. Sci., Dharwad (India).

EFFECT OF VARIETY AND SEED RATE ON YIELD AND QUALITY OF ONION (*Allium cepa* L.) SETS

M. A. KHAN[1], M. M. RAHMAN[2] AND R. SARKER[3]

Abstract

A field study was carried out at Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur in 2021-2022. The experiment was conducted to find out suitable variety and optimum seed rate for producing onion sets. The treatment consisted of four varieties viz. BARI Piaz-1, BARI Piaz-4, BARI Piaz-6 and LalTeer king and six seeding rate like 2g ^{2}, 4g , 6g , 8g^2, 10g seeds/m^2 and transplanting of seedlings densely (average 240 seedlings/m^2). The trial was laid out in a randomized complete block design with three replications. The result revealed that significant differences were found in all studied characters due to variety but exception, seed rate and their combined effect. The variety BARI Piaz-1 had the highest optimum sets (60.64%). The maximum bolting were counted from BARI Piaz-1 (2.96%) followed by BARI Piaz-6 (2.33%). LalTeer King produced the highest set yield (13.57t/ha). Onion sets were delay matured (154 days) in transplanting method. Seeding 10g/m^2 took the lowest time to mature of onion sets (130 days). The highest optimum set was obtained from seeding 6g/m^2 (65.74%). The set yield was increased with the increase in seeding rate up to 8g/m^2 and thereafter decreased. Finally, onion var. BARI Piaz-4 and BARI Piaz-6 are suitable for producing optimum onion sets with good yield of onion at 4-6g/m^2 seed rate.

Keywords: Variety, Seed rate, Yield, Quality, Onion sets

Introduction

Onion (*Allium cepa* L.) stands first among the spice crops in Bangladesh. Onion cultivation area in the country is about 0.194 million hectare with a total production of 2.269 million metric tonnes per annum. Average yield of onion is low, being 11.67 t/ha (BBS, 2022) as compared to India where 16.80 t/ha (NHB, 2019). The government of Bangladesh imports about 1.0 million metric tonnes of onion per year expending a huge foreign currency for meeting the demand of the country (Khan *et al*., 2020). About 25-35% onions are produced in the country through set to bulb method (Khan *et al*., 2023). Onions are largely planted as sets in many countries (Khokhar *et al*., 2002). Traditionally set is grown done in different districts such as Faridpur, Shariatpur, Rajbari, Pabna, Madaripur, Manikganj for growing only green onions but not for store purpose. Optimum set was found 3.5-6.5g for planting which are produced in previous season by seeding thickly for getting early crop (Khan *et al*., 2021). Farmers produce their sets using different

[1]Principal Scientific Officer, Spices Research Sub-Centre (SRSC), Bangladesh Agricultural Research Institute (BARI), Faridpur and [2&3]Scientific Officer, SRSC, BARI, Faridpur, Bangladesh.

rate of true seeds. The growth, yield and quality of onion sets are not only influenced by seed rate but also variety (Mohammedali *et al.*, 2022). Onion sets are influenced by cultivar, density and environmental conditions (Ansari, 2007). In Bangladesh, onion growers previously used only BARI Piaz-1 to produce onion through set method due to lack of other suitable varieties. Many alternative varieties viz. BARI Piaz-4, BARI Piaz-6 and LalTeer King are available at present. Scanty study was found earlier in Bangladesh with seed rate and variety for production of onion sets. The present experiment was, therefore, undertaken to find out optimum seed rate for getting desirable sets of onion varieties in producing onion sets in Bangladesh.

Materials and Methods

The study was conducted at Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur, Bangladesh during rabi season of 2021-2022 to find out optimum seed rate of onion varieties for getting quality onion sets (bulblets). The trial was carried out with four varieties viz. as V_1 = BARI Piaz-1, V_2 = BARI Piaz-4, V_3 = BARI Piaz-6 and V_4 = LalTeer king, and six seeding rate like as S_1 = 2g seeds/m^2, S_2 = 4g seeds/m^2, S_3 = 6g seeds/m^2, S_4 = 8g seeds/m^2, S_5 = 10g seeds/m^2 and S_6 = transplanting of seedlings densely (average 240 seedlings/m^2). Average thousand-seed weight of BARI Piaz-1, BARI Piaz-4, BARI Piaz-6 and LalTeer King were 3.14g, 3.42g, 2.87g and 3.89g, respectively. True seeds of onion were sown in the raised plot as per treatment. Sowing date for all treatments was 6 November 2021. Germination percent of those varieties were 90.21, 93.12, 86.97 and 97.76%, respectively. Transplanting was done densely (about 240 plants/m^2) on 15 December 2021 with 40-day old uniform and healthy seedlings for the treatment S_6. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 3.00 m x 1.00 m for each treatment. The experimental field was fertilized with 3000 kg well-decomposed cowdung, 220 kg Urea, 220 kg Triple super phosphate (TSP), 150 kg Muriate of potash (MOP), 110 kg Gypsum and 8 kg Boron fertilizer (solubor) per hectare. The entire quantity of cowdung, TSP, MOP, gypsum, boron and one third of urea were applied as basal during land preparation. The remaining urea was dressed in two equal splits on 5 January 2021 and 25 January 2022. All other recommended management practices (weeding, spraying of pesticides, irrigation etc.) were followed for each treatment. The data was recorded on plant height, number of leaves per plant, number of plants per square meter, percent of bolting, days to maturity of sets, polar and equatorial diameter of set, percent of undersized set, percent optimum set, percent medium set, percent oversized set, shape index, individual set weight, dry matter content of sets and set weight. Set yield was calculated and expressed in t/ha. The number of plants per square meter (population density) was counted at bulbing stage. The sets were harvested at maturity following the method of Brewster (2008) on several dates. The sets were matured when more than 80% neck fall and drying up of plants. The leaves of harvested onion were removed at seven days after shade curing by cutting 2.0-2.5

cm above the bulb (Brewster, 2008). Total fresh weight of sets was measured for each plot after curing as per method of Brewster (2008). Shape index of set is the ratio of set height (polar diameter) to equatorial diameter. The dry matter content of bulbs was calculated by dry weight basis as per procedure of Walle *et al*. (2018). The sets were categorized into four sizes as optimum (3.5-6.5g), medium (7-14g), undersized (<4g) and oversized (>14g) after counting the number of sets. The recorded data was analyzed statistically as suggested by Gomez and Gomez (1984). The means were compared by the Least Significant Difference (LSD) test.

Results and Discussion

Effects of variety

The variety had significant influence on the studied parameters except number of leaves per plant and individual set weight (Table 1 & 2). The maximum number of plants/m^2 (450) was observed in LalTeer King followed by BARI Piaz-4 (424). Significantly the lowest number of plants/m^2 (387) was obtained from BARI Piaz-1. Probable causes of variation in population density among the varieties might be due to thousand seed weight and percent germination of seeds. The variety LalTeer King exhibited the maximum plant height (53cm) followed by BARI Piaz-4 (51cm). The lowest plant height was recorded in BARI Piaz-1 (45cm). The variation in plant height could be attributed due to genetic inheritance among the varieties. Number of leaves was not responded by the variety but Mandal *et al*. (2018) observed significant difference in this character among the varieties. The var. BARI Piaz-4 required the maximum days to maturity of set (138 days) followed by LalTeer King (137 days) and BARI Piaz-1 (136 days). The variety BARI Piaz-6 had the minimum days to maturity of sets (134 days). The variation of days to maturity might be due to genetic character among the varieties. The results are in lines with the findings of Khan *et al*. (2022), Walle *et al*. (2038) and Arya *et al*. (2017).

Equatorial diameter of set ranged from 25.22mm to 26.91mm with the highest diameter at LalTeer King and the lowest at BARI Piaz-1. This variation was probably due to the genetic make-up of variety. Similar findings on the variation of diameter were also found by Mandal *et al*. (2018) and Ansari (2007). Insignificant variation was found on the individual set weight among the varieties which was differed by the results of Mandal *et al*. (2018) and Mohammedali *et al*. (2022). The highest dry matter of set was produced in BARI Piaz-1 (19.38%) which was statistically differed with other varieties.

The var. BARI Piaz-1 showed the maximum value of bolting (2.96%) which was identical to BARI Piaz-4 (2.76%) and LalTeer King (2.72%) but significantly different from BARI Piaz-6 (2.33%). The variety BARI Piaz-4 had the maximum shape index (1.49) and the minimum in BARI Piaz-1 (0.98). The results admitted the findings of others (Khan *et al*., 2022) who opined that shape index was governed by variety.

Table 1. Effect of variety on plants/m², plant height, leaves/plant, days to maturity, set diameter, individual set weight and dry matter of onion sets (2021-2022)

Variety	Plants/m²(no.)	Plant height (cm)	Leaves /plant (no.)	Days to maturity	Set diameter (mm)	Individual set weight (g)	Dry matter of set (%)
BARI Piaz-1	387	45	5.92	136	25.22	7.46	19.38
BARI Piaz-4	424	51	5.66	138	26.82	7.79	15.42
BARI Piaz-6	371	50	5.89	134	26.22	7.50	15.72
LalTeer king	450	53	5.77	137	26.91	7.99	15.33
LSD (0.05)	74.35	2.16	NS	1.22	1.33	NS	0.50
CV (%)	27.18	6.46	9.85	1.34	7.49	10.66	4.54

Table 2. Effect of variety on bolting, shape index, optimum set, medium set, oversized set, undersized set and yield of onion sets (2021-2022)

Variety	Bolting (%)	Shape index	Optimum set (%)	Medium set (%)	Oversized set (%)	Undersized set (%)	Set yield (t/ha)
BARI Piaz-1	2.96	0.98	60.64	19.11	5.62	14.61	11.65
BARI Piaz-4	2.76	1.49	57.53	15.23	9.53	17.69	12.86
BARI Piaz-6	2.33	1.29	57.50	16.66	6.28	19.54	12.24
LalTeer king	2.72	1.22	51.07	20.67	6.75	21.50	13.57
LSD (0.05)	0.47	0.07	1.59	1.31	0.90	1.26	0.55
CV (%)	26.22	8.35	4.17	10.89	19.03	10.26	6.46

The highest percent of optimum set size was recorded from BARI Piaz-1 (60.64%) while significantly the lowest percent of optimum set size (51.07%) in LalTeer King. The highest percent of medium set was obtained from LalTeer King (20.67%) while the lowest from BARI Piaz-4 (15.23%). The highest oversized set was found in BARI Piaz-4 (9.53(%) while e lowest in BARI Piaz-1 (5.62%). The undersized set ranged from 14.61 to 21.50% with the highest value in LalTeer King and lowest in BARI Piaz-1. The variation in set size might be due to characteristics of variety. Consistent results were found on the percent of set size by Mohammedali *et al*. (2022) and Mandal *et al*. (2018). The variety LalTeer King produced the maximum set yield (13.57t/ha) followed by BARI Piaz-4 (12.86t/ha) and BARI Piaz-6 (12.24t/ha). The minimum set yield was obtained from BARI Piaz-1 (11.65t/ha). The results agreed with the findings of Mohammedali *et al*. (2022) and Mandal *et al*. (2018).

Effect of seed rate

The seeding rates exerted significant influence on the studied characters on onion (Table 3 & 4). The highest number of plants/m^2 (620.57) was noticed in seeding @ 10g/m^2 (S_5) and lowest value (160.21) at seeding @ 2g/m^2 (S_1). The results confirmed the finding of Mohamed *et al*. (2012). Transplanting of seedlings gave the tallest plant height (53.57cm) which was followed by seeding @ 2g seeds/m^2 (51.05cm). On the other hand, seeding @ 10g seeds/m^2 produced the shortest plant height (46.07cm). It might be due to increased completion for nutrients, light, space and moisture. The results corroborated the previous findings of Aliyu *et al*. (2008).

The maximum number of leaves per plant was counted in transplanting method (6.69) followed by seeding @ 2g/m^2 (6.17). However, the lowest number of leaves was recorded from seeding @ 10g/m^2 (5.17). The widest plant spacing (lower plant density) produced the maximum plant height and leaves per plant (Jilani *et al*., 2010; Shock *et al*., 2004 and Khan *et al*., 2003).

Transplanting of seedlings required maximum time to mature of sets (154 days) followed by seeding @ 2g/m^2 (136 days). The minimum time was needed to mature of sets for seeding @ 10g/m^2 (130 days). Transplanted set were deeper in the soil while direct seeded onions developed at or near the soil surface (Boyhan *et al*., 2008). For these aforesaid reasons, transplanted plants are better able to survive as compared with direct seeded onions, also described by Boyhan *et al*. (2008). Macias-Duarte *et al*. (2004) observed earlier maturity in direct seeding in comparing to the transplanted method. Ketema *et al*. (2013) and Motallebi *et al*. (2001) stated that maturity was significantly more delayed in direct seeding method than that of transplant. Days to maturity decreased as density increased (Anonymous, 2010 and Brewster, 2008).

Table 3. Effect of seed rate on plants/m², plant height, leaves/plant, days to maturity, set diameter, individual set weight and dry matter of onion sets (2021-2022)

Seed rate	Plants/m² (no.)	Plant height (cm)	Leaves /plant (no.)	Days to maturity (days)	Set diameter (mm)	Individual set weight (g)	Dry matter of set (%)
S_1=2g seeds/m²	160.21	51.05	6.17	136	29.96	12.03	15.93
S_2=4g seeds/m²	375.02	49.95	5.77	135	27.82	8.81	15.99
S_3=6g seeds/m²	476.26	49.45	5.63	133	26.73	6.59	16.44
S_4=8g seeds/m²	573.92	49.15	5.45	131	24.83	5.02	16.66
S_5=10g seeds/m²	620.57	46.07	5.17	130	21.14	3.23	16.77
S_6=Transplanted seedlings	240.66	53.57	6.69	154	28.32	10.42	16.99
LSD (0.05)	91.07	2.65	0.48	1.50	1.62	0.67	0.61
CV (%)	27.18	6.46	9.85	1.34	7.49	10.66	4.54

Table 4. Effect of seed rate on bolting, shape index, optimum set, medium set, oversized set, undersized set and yield of onion sets (2021-2022)

Seed rate	Bolting (%)	Shape index	Optimum set (%)	Medium set (%)	Oversized set (%)	Undersized set (%)	Set yield (t/ha)
S_1=2g seeds/m²	3.72	1.10	42.02	27.65	19.92	10.40	9.71
S_2=4g seeds/m²	2.01	1.19	61.15	17.17	6.31	15.35	12.00
S_3=6g seeds/m²	1.71	1.27	65.74	13.79	3.01	17.45	13.29
S_4=8g seeds/m²	1.16	1.36	58.55	12.52	4.56	24.36	14.34
S_5=10g seeds/m²	1.07	1.38	52.06	13.64	1.13	33.15	12.62
S_6=Transplanted seedlings	6.48	1.16	60.59	22.74	7.36	9.29	13.50
LSD (0.05)	0.58	0.09	1.94	1.60	1.10	1.54	0.66
CV (%)	26.22	8.35	4.17	10.89	19.03	10.26	6.46

The equatorial set diameter ranged from 21.14mm to 29.96mm with the highest in seeding @ 2g/m^2 and the lowest in seeding @ 10g/m^2. The highest value of set diameter differed significantly with the value of transplanting seedlings (28.32mm). Set/bulb size decreased as density increased (Anonymous, 2010; Hamam *et al*., 2012 and Shock *et al*., 2015). The results disagreed with the findings of Ansari (2007) who did not found decreased size of sets with the increase of seeding rate. Seed rate of 2g/m^2 gave the highest individual seed weight (12.03g) followed by transplanted (10.42g) and the lowest set weight in seeding @ 10g/m^2 (3.23g). The results e similar to the findings of (Mohammedali *et al*., 2022 and Mohamed *et al*., 2012) on set/bulb weight. The proportion of small bulbs was increased with the increase in plant density (Shock *et al*., 2015). As plant population increases, onion bulb yield also increases because the leaf canopy intercepts a higher percentage of light (Brewster, 2008).

Transplanting seedlings exhibited the highest dry matter of sets (16.99%) and the lowest dry matter in seeding 2g/m^2 (15.93%). The findings of Ketema *et al*. (2018) and Izadkhan *et al*. (2009) opined that mean dry weight of onion bulb was higher with transplanting seedlings than that of direct seeding. Plants in transplanting method were attributed to stronger photosynthetic efficiency and vigorous vegetative growth due to better establishment which resulted in maximum dry matter content in the bulb of transplant (Ketema *et al*., 2013).

The maximum value of bolting was occurred in transplanting seedling (6.48%) followed by seeding @ 2g/m^2 (3.72%) but the lowest value of bolting in seeding 10g/m^2 (1.07%). Maximum incidence of bolting was found in transplanting as compared to that of direct seeding (Ketema *et al*., 2013).

The greatest shape index was computed in seeding 10g/m^2 (1.38) which was in statistical parity with seeding @ 8g/m^2 (1.36). However, the smallest shape index was calculated in seeding @ 2g/m^2 (1.10). Higher shape index means lower equatorial diameter and higher polar diameter. An increase in plant population leaded to elongated bulbs (Hygrotech, 2010).

The maximum percent of optimum set was obtained from seed rate of 6g/m^2 (65.74%) and seeding 2g/m^2 had the lowest percent of optimum set (42.02%). Sowing seeds @ 2g/m^2 showed the maximum medium set (27.65%) followed by transplanting seedlings (22.74%). However, the lowest percent medium set was recorded from seeding 8g/m^2 (12.52%). Seeding 2g/m^2 demonstrated the maximum oversized set (19.92%) and sowing seeds @ 10g/m^2 had the minimum oversized sets (1.13%). Seeding 10g/m^2 provided the maximum undersized set (33.15%) which was significantly followed by seeding 8g/m^2 (24.36%). Increasing seed rate decreased significantly the percent of large set size as described by Mohammedali *et al*. (2022).

The set yield was increased with the increase in seeding rate up to 8g/m^2 and thereafter the set yield was decreased. Seeding 8g/m^2 gave the maximum set yield

(14.34t/ha) followed by transplanting seedlings (13.50t/ha) while lowest set yield (9.71t/ha) in sowing seeds @ 2g/m^2. Decreased yield from seeding 10g/m^2 might be due to smaller set in seeding 10g/m^2. The present finding also was at par with the results of Mohammedali *et al*. (2022). Yield was positively associated with density of onion plants (Shock *et al*., 2015).

Combined effect of variety and seed rate

The combined effect was found statistically significant variation in all studied traits (Table 5 & 6). The combination of V_4 x S_5 exhibited the maximum number of plants/m^2 (698.26) but V_3 x S_1 had the minimum number of plants/m^2 (140.84). The tallest plant height (56.02cm) was recorded from V_4 x S_6 while V_1 x S_5 showed the shortest plant height (42.49cm). The maximum number of leaves/plant was obtained in the combination of V_1 x S_6 (6.89) while minimum number from V_2 x S_5 (5.01).

The interaction of V_2 x S_6 required the maximum time (156 days) for maturity of sets followed by the combination of V_4 x S_6 (155 days). But the V_3 x S_5 took the minimum time to mature of sets (128 days). The largest equatorial diameter of set was recorded from V_4 x S_1 (31.24mm) and the smallest diameter was obtained under V_1 x S_5 (20.12mm). The interaction of V_4 x S_1 gave the heaviest individual set weight (12.55g) followed by V_2 x S_1 (12.45g) while lightest set in the combination of V_3 x S_5 (2.94g). Similar results were observed by Mohammedali *et al*. (2022) who stated that interaction effect of cultivars and seed rate was statistically significant on single set weight. The V_1 x S_6 (transplanting of seedlings) produced the highest dry matter of set and V_3 x S_1 yielded the lowest dry matter of set (14.41%).

The combination of V_1 x S_6 showed the maximum value of bolting (7.73%) but V_2 x S_5 gave the lowest value of bolting (0.92%). Whereas, V_2 x S_5 expressed the greatest shape index (1.64) and the smallest shape index from the combination of V_1 x S_1 (0.85). The maximum optimum set (78.10%) was recorded from V_1 x S_2 followed by V_1 x S_3 (74.96%). Nonetheless, the V_1 x S_1 produced the lowest percent of optimum set (36.39%). The combination of V_1 x S_6 had the maximum medium set (33.80%) followed by V_4 x S_6 (33.56%). The minimum medium set (5.61%) was counted from the combination of V_2 x S_4. The more percent of oversized set (23.23%) was recorded from the combination of V_4 x S_1 and the smallest oversized set (0.24%) from V_4 x S_5. The interaction of V_4 x S_5 generated the maximum undersized set (45.42%) but the V_2 x S_1 had the lowest undersized set (5.27%). The combination of V_4 x S_4 out yielded (15.16 t/ha) all treatment combinations followed by the combination of V_4 x S_3 (14.49 t/ha). However, the combination of V_1 x S_1 gave the lowest set yield (8.35t/ha). Quality parameters of onion sets are: single set (non-splitting), non-bolter, higher dry matter, well matured, properly cured, without molding, bruising & decaying and optimum size (3.5-6.5g).

Table 5. Combined effect of variety and seed rate on plants/m^2, plant height, leaves/plant, days to maturity, set diameter, individual set weight and dry matter of onion sets (2021-2022)

Variety x seed rate	Plants/m^2 (no.)	Plant height (cm)	Leaves /plant (no.)	Days to maturity	Set diameter (mm)	Individual set weight (g)	Dry matter of set (%)
V_1S_1	144.85	45.96	6.68	135	28.43	11.42	18.82
V_1S_2	371.19	44.15	5.81	135	27.71	8.84	19.20
V_1S_3	402.53	43.69	5.54	133	26.02	6.02	19.30
V_1S_4	623.58	45.95	5.48	132	24.90	4.61	19.44
V_1S_5	535.94	42.49	5.14	129	20.12	3.52	19.62
V_1S_6	245.62	50.42	6.89	153	28.39	10.33	19.95
V_2S_1	158.28	53.08	5.94	137	30.98	12.45	15.77
V_2S_2	387.83	50.55	5.41	136	27.88	8.78	14.83
V_2S_3	551.30	50.55	5.34	135	27.78	6.94	15.11
V_2S_4	563.78	47.55	5.41	132	24.34	5.12	15.35
V_2S_5	641.97	46.69	5.01	131	21.82	3.07	15.63
V_2S_6	238.83	55.95	6.88	156	28.10	10.42	15.84
V_3S_1	140.84	51.48	6.14	134	29.18	11.69	14.41
V_3S_2	349.16	50.62	6.14	132	27.65	8.16	14.88
V_3S_3	389.83	50.02	5.88	133	26.21	6.35	16.16
V_3S_4	501.08	49.55	5.34	129	24.66	5.01	16.28
V_3S_5	606.13	47.28	5.11	128	21.09	2.94	16.30
V_3S_6	236.10	51.88	6.74	153	28.51	10.87	16.340
V_4S_1	196.85	53.68	5.94	136	31.24	12.55	14.75
V_4S_2	391.89	54.48	5.74	135	28.06	9.47	15.08
V_4S_3	561.36	53.55	5.74	134	26.93	7.05	15.22
V_4S_4	607.22	53.55	5.55	132	25.41	5.33	15.60
V_4S_5	698.26	47.82	5.41	131	21.55	3.50	15.53
V_4S_6	242.08	56.02	6.28	155	28.28	10.04	15.84
LSD (0.05)	105.17	3.02	0.57	2.33	1.97	0.95	0.89
CV (%)	27.18	6.46	9.85	1.34	7.49	10.66	4.54

Footnote: V_1 = BARI Piaz-1, V_2 = BARI Piaz-4, V_3 = BARI Piaz-6 and V_4 = LalTeer king and six seeding rate viz. S_1 = 2g seeds/m^2, S_2 = 4g seeds/m^2, S_3 = 6g seeds/m^2, S_4 = 8g seeds/m^2, S_5 = 10g seeds/m^2 and S_6 = transplanting of seedlings densely

Table 6. Combined effect of variety and seed rate on bolting, shape index, optimum set, medium set, oversized set, undersized set and yield of onion sets (2021-2022)

Variety x seed rate	Bolting (%)	Shape index	Optimum set (%)	Medium set (%)	Oversized set (%)	Undersized set (%)	Set yield (t/ha)
V_1S_1	4.37	0.85	36.39	32.93	18.70	11.97	8.35
V_1S_2	2.01	0.91	78.10	9.26	2.24	10.38	10.99
V_1S_3	1.49	1.01	74.96	10.69	1.54	12.81	12.53
V_1S_4	1.13	1.09	62.71	9.69	6.30	21.30	13.75
V_1S_5	1.03	1.10	57.69	18.29	1.41	22.61	12.03
V_1S_6	7.73	0.93	54.03	33.80	3.58	8.59	12.26
V_2S_1	3.86	1.38	42.91	29.82	22.00	5.27	10.19
V_2S_2	2.13	1.42	50.65	19.98	12.18	17.19	12.20
V_2S_3	2.01	1.50	61.73	13.34	2.27	22.66	13.35
V_2S_4	1.12	1.60	64.45	5.61	3.90	26.04	14.43
V_2S_5	0.92	1.64	61.69	11.22	1.88	25.21	12.64
V_2S_6	6.52	1.40	63.78	11.41	15.00	9.81	14.34
V_3S_1	2.87	1.10	52.95	15.28	15.75	16.02	9.55
V_3S_2	1.99	1.27	59.54	20.46	1.65	18.35	11.62
V_3S_3	1.48	1.30	63.12	15.69	5.12	16.07	12.79
V_3S_4	1.13	1.45	52.90	21.46	5.22	20.42	14.03
V_3S_5	1.03	1.47	44.69	14.93	1.02	39.36	12.39
V_3S_6	5.51	1.17	71.82	12.19	8.97	7.02l	13.05
V_4S_1	3.79	1.09	35.84	32.57	23.23	8.36	10.75
V_4S_2	1.94	1.19	56.33	19.00	9.17	15.50	13.19
V_4S_3	1.86	1.28	63.17	15.45	3.11	18.27	14.49
V_4S_4	1.26	1.30	54.14	13.32	2.85	29.69	15.16
V_4S_5	1.32	1.34	44.19	10.15	0.24	45.42	13.40
V_4S_6	6.18	1.17	52.75	33.56	1.91	11.77	14.36
LSD (0.05)	0.96	0.12	3.04	2.81	2.13	2.61	1.21
CV (%)	26.22	8.35	4.17	10.89	19.03	10.26	6.46

Footnote: Footnote: V_1 = BARI Piaz-1, V_2 = BARI Piaz-4, V_3 = BARI Piaz-6 and V_4 = LalTeer king and six seeding rate viz. S_1 = 2g seeds/m^2, S_2 = 4g seeds/m^2, S_3 = 6g seeds/m^2, S_4 = 8g seeds/m^2, S_5 = 10g seeds/m^2 and S_6 = transplanting of seedlings densely, Optimum bulb = 3.5-6.5g, medium bulb = 7-14g, oversized bulb = >14g and undersized bulb = <4g.

Conclusion

The highest optimum sets were obtained from seeding 4-6g/m^2. Transplanting method took long time to mature of onion sets. The set yield was increased with the increase in seeding rate up to 8g/m^2 and thereafter the set yield was decreased. The var. BARI Piaz-1, BARI Piaz-4 and BARI Piaz-6 are also suitable for producing optimum onion sets with good yield of onion at 4-6g/m^2 seed rate. In combined effect, BARI Piaz-1 had the highest optimum set with 4-6g seeds/m^2.

References

Aliyu, U., A. Dikko., M. D. Magaji and A. Singh. 2008. Nitrogen and intra-row spacing effect on growth and yield of onion (*Allium cepa* L.). *J. Plant Sci*. **3(3):**188-193.

Anonymous, 2010. Vegetable Production Guides. Oregon State University, College of Agricultural Science, Department of Horticulture., Oregon, USA.

Ansari, N. A. 2007.Effect of density, cultivars and sowing date on onion set production. *Asian J. Plant Sci*. **6(7):**1147-1150.

Arya, J. S., N. Singh., P. S. Arya and A. Kant. 2017. Morphological variations and relationship among onion germplasm for quantitative and qualitative traits at trans-Himalaya Ladakh, India. *Aus. J. Crop Sci*. **11(3):**319-337.

BBS (Bangladesh Bureau of Statistics). 2022. Yearbook of Agricultural Statistics of Bangladesh-2021. 33rd Series, May 2022. Bangladesh Bureau of Statistics, Statistics & Informatics Division, Ministry of planning, Government of the People's Republic of Bangladesh, p. 138.

Boyhan, G. E., J. C. Diaz-Perez., C. Hopkins., R. L. Torrance and C. R. Hill. 2008. Direct seeding short-day onions in Southeastern Georgia. HortTechnology, **18(3):**349-355.

Brewster, J. L. 2008. Onions and Other Vegetable Alliums. 2nd edition, CAB International, Wallingford, No. 15, 454p.

Gomez, K. A. and A. A. 1984. Statistical Procedures for Agricultural Research (2nd edition). John Wiley and Sons, New York, USA, 680p.

Hamam, M., S. Yacoub., M. Abdalla and R. Gamal. 2012. Yield and quality of onion sets as affected by seeding rate and planting date under Assiut conditions. *Assiut J. Agril. Sci*. **43(1):**24-44.

Hygrotech, 2010. Production guidelines of onions. Hygrotech Sustainable Solutions. Hygrotech, Pretoria, South Africa. www.hygrotech.com.

Izadkhan, M., M. Tajbakhsh., A. Hasnzadeand and S. A. Moosavezade. 2009. Study effects of different planting systems on marketable yield, grading and some bulb quality traits in onion (*Allium cepa* L.). *Online Int. J. Agron. & Bio*. **2(7):**366-369.

Jilani, M. S., P. Ahmed., K. Waseem and M. Kiran. 2010. Effect of plant spacing on growth and yield of two varieties of onion (*Allium cepa* L.), *Pakistan J. Sci*. **62(1):**37- 41.

Ketema, S., L. Dessalegn and B. Tesfaye. 2013. Effect of planting methods on maturity and yield of onion (*Allium cepa* var. *cepa*) in the central rift valley of Ethiopia. *Ethiopia J. Agric. Sci*. **24**:45-55.

Ketema, S., L. Dessalegn and B. Tesfaye. 2018. Effect of planting methods on growth of onion (*Allium cepa* var. *cepa*). *Advances in Applied Physio*. **3(1):**8-13.

Khan, M. A., M. M. Rahman and S. Rinky. 2021. Effects of set size and plant population density on the yield attributes, yield and quality of onion (*Allium cepa* L.). *North American Acad. Res. J*. **4(7):**93-109.

Khan, M. A., M. M. Rahman., S. N. Mozumdar and M. I. Haque. 2020. Strategies for increasing storability of onion (in Bengali). A Folder, Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur. Publication No. SRSC/BARI/Farid.01/2020, p.3-8.

Khan, M. A., M. M. Rahman., S. N. Mozumder and R. Sarker. 2023. Performance of varieties on the yield and quality of onion (*Allium cepa* L.) through set to bulb method. *J. Exp. Agri. Intern*. **45(10):**349-354.

Khan, M. A., M. M. Rahman., S. N. Mozumder., M. A. Alam., M. N. A. Choudhury and M. I. Haque. 2022. Performance of eveluation of short-day onion (*Allium cepa* L.) genotypes. *North American Academic Res*. **5(10):**54-69.

Khokhar, K. M., S. I. Hussain., T. Mahmood., Hidayatullah and M. H. Laghari. 2002. Bulb yield and quality as affected by set size in autuman season onion crop. *Asian J. Plant Sci*. **1**:657-658.

Macias-Duarte, R., R. L. Grijalva-Contreras., M. de J. Valenzuela-Ruiz and F. Robles-Contreras. 2004. Yield and quality of onion varieties under direct seed and transplant seedling. *Hort Science Abstracts*. **39(4):**801.

Mandal, J.; P. Acharyya; W. D. Singh and S. Mohanta. 2018. Studies on set production of onion (Allium cepa L.) cultivars. *J. Allium Res*. **1(1):**28-31.

Mohamed, R. G., M. M. A. Abdalla., M. H. Z. El-Dekashey and S. Y. Attallah. 2012. Yield and quality of onion sets as affected by seeding rate and planting date under Assuit conditions. *Assiut J. Agric. Sci*. **43(1):**27-47.

Mohammedali, A. A., E. E. E. Elshukry., A. M. Alamin and A. Z. Elhag. 2022. Effects of seed bed, cultivars and seed rates on yield and quality of onion sets (*Allium cepa* L.). *J. Agron. Res*. **4(4):**9-16.

Motallebi, A., S. Masshia and F. Shekari. 2001. Effect of different sowing methods on yield and bulb characteristics in onion (*Allium cepa* L.). *Acta Agronomica Hungarica*. **49(2):**169-174.

NHB (National Horticulture Board). 2019. Indian Horticulture Database. National Horticulture Board, Ministry of Agriculture, Government of India, New Delhi.

Shock, C. C., E. B. G. Feibert and L. D. Saunders. 2004. Plant population and nitrogen fertilization for subsurface drip irrigated onion. *Hort Sci.* **39**:1722-1727.

Shock, C. C., E. B. G. Feibert., A. Riveira and L. D. Saunders. 2015. Response of onion yield, grade and financial return to plant population and irrigation system. Amer. Soc. *Hort Sci.* **45(9):**1312-1318.

Walle, T., N. Dechassa and W. T. Kebede. 2018. Yield and yield components of onion cultivars as influenced by population density at Bir Sheleko, North-Western Ethiopia. Academic Res. *J. Agril. Sci. and Res*. **6(3):**172-192.

PERFORMANCE OF ONION GARLIC AND CORIANDER AS INTERCROPPING WITH CHILLI

M. A. H. Khan[1], M. Rahman[2], M. A. Siddiky[3]
M. M. Hossain[4] and S. T. Zannat[5]

Abstract

An experiment was conducted at the research field of regional agricultural research station (RARS), Bangladesh Agricultural Research Institute (BARI), Cumilla during 2020-21 to find out the suitable crop combination of onion, garlic and coriander with chilli for increasing total productivity, economic return and maximizing land utilization through intercropping system. Seven treatments were viz., T_1 = Sole chilli (50 cm × 50 cm) , T_2 = Two rows of onion in between two rows of chilli (15 cm × 10 cm), T_3 = Two rows of garlic in between two rows of chilli (15 cm × 10 cm), T_4 = 100% coriander (leaf) in between two rows of chilli, T_5 = Sole onion (15 cm × 10 cm), T_6 = Sole garlic (15 cm × 10 cm), T_7 = Sole coriander. The trial was set up in a randomized complete block design with three replications. Results showed that different intercrop combination significantly influenced yield and yield contributing characters of chilli. The yield of chilli was comparatively lower in intercropping than sole chilli but total productivity was increased due to additional yield of onion, garlic and coriander. Increased total productivity in terms of chilli equivalent yield (CEY) was 14.05 to 16.88 t/ha in intercrop combination compared to sole chilli 9.13 t/ha (main crop). All the intercrop combinations showed better performance in terms of chilli equivalent yield, gross return and benefit cost ratio (BCR) over sole crops. Among the intercrop combinations two rows of onion (15 cm x 10 cm) in between two rows of chilli (50 cm × 50 cm) was found feasible and profitable intercropping system in respect of chilli equivalent yield (16.88 t/ha), gross return (Tk.675200/ha), gross margin (Tk. 526800/ha) and benefit cost ratio (4.32).

Keywords: Intercropping, Chilli, Onion. Garlic, Coriander.

Introduction

Chilli is one of the major spices crop cultivated round the year in Bangladesh with area of 2, 49,748 acres of land (both winter and summer) with a production of 1,41,177 metric tons (BBS, 2018). It is tall structure, long duration (150 – 200 days) and wide spread (60-80 cm). Chilli is rich in Vitamin-A, Vitamin-C, iron and dietary fiber. Onion, garlic and coriander also an important spices in our daily life. Intercropping is a traditional practice in Bangladesh and it increases total productivity per unit area through maximum utilization of land, labor and growth resources (Ahmed, *et al.* 2013). By judicious choice of compatible crops and

[1&5]Scientific Officer, Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, [2]Scientific Officer, [3]Principal Scientific Officer, Regional Agricultural Research Station, BARI, Cumilla, Bangladesh, [4]Scientific Officer, Planning and Evaluation Wing, BARI, Gazipur, Bangladesh.

adopting appropriate planting geometry, inter/intra specific competition may be minimized resulting higher total productivity (Alom *et al.* 2013). Canopy architecture of tall stature crop regulates the availability of light on under storied crop (Faruque *et al*. 2006). Intercropping is one of the viable technologies to ensure efficient utilization of their resources for increased production and family income. Intercropping offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield in tropical and sub-tropical areas (Nazir *et al*., 2002; Bhatti *et al*., 2005).

So, there is a great scope to cultivate short duration spices like onion, garlic and leafy spices (coriander) in the inter row space of chilli could be introduced as intercrop. Short duration and quick growing spices crops like onion, garlic and leafy spice coriander can be easily intercropped between two rows of chilli at early growth stage for getting higher economic return. However, the literature regarding onion-chilli, garlic-chilli and coriander- chilli intercropping is very scarce. Keeping this view in mind, the experiment was undertaken to find out the most suitable crop combination of onion, garlic and coriander with chilli for increasing total productivity, economic return and maximize land utilization through intercropping system.

Materials and Methods

A field experiment was conducted at research field of Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Cumilla during 2020-21. The treatments were; T_1 = Sole chilli, T_2 =Two rows of onion in between two rows of chilli, T_3 = Two rows of garlic in between two rows of chilli, T_4 = 100% coriander (broadcasting) in between two rows of chilli, T_5 = Sole onion, T_6 = Sole garlic, T_7 = Sole coriander. The trial was set up in a randomized complete block design with three replications. The unit plot size was 3.0 m $\times$ 3.0 m. Chilli (var. BARI Marich-3) was the main crop and onion (var. BARI Piaj-6), garlic (var. BARI Rashun-2) and coriander (var. BARI Dhonia-1) were used as intercrops in the study. Sole chilli and intercrop treatments were fertilized with 120-80-120-20-4 N-P-K-S-Zn kg/ha, respectively where sole onion, sole garlic and sole coriander were fertilized with 90-45-120-30 N-P-K-S kg/ha, respectively (BARC, 2018). For sole chilli and intercrop treatments; half N and all other fertilizers were used as basal. Rest N was applied at 20 and 50 days after transplanting. For sole onion and other sole crop; half of N, K and full dose of P, S were applied at the time of final land preparation and remaining N and K were top dressed at 25 and 50 days after transplanting followed by irrigation. The sole crop of chilli was planted at a spacing of 50 cm $\times$ 50 cm, the sole crop of onion and garlic was planted at a spacing of 15 cm $\times$ 10 cm. As intercropping system two rows of onion and two rows of garlic were planted as per treatment. Coriander seed (100%) was broadcast in between two rows of chilli. Chilli (25 days old seedling) was transplanted on 24 November 2020. Onion seedling, garlic clove and coriander seeds were

planted/sown on 26 November 2020. Irrigation were applied as per necessary. Fipronil was sprayed three times @1 ml per liter of water for controlling the infestation of thrips. One miticide Vertimec was also sprayed three times @ 2 ml per liter of water for controlling mites. The coriander leaf was harvested on 20 December at 24 days after sowing. Onion and garlic were harvested on 1 March and 5 March 2021, respectively. Chilli was harvested at three times i.e. 10 March, 22 March and &10 April 2021. For chilli, onion, garlic, and coriander at harvest the yield data was recorded plot wise. The collected data were analyzed statistically using statistix 10 package and means were adjudged by LSD at 5% level of probability. Chilli equivalent yield (CEY) was converted by converting yield of intercrops on the basis of market price of individual crop following the formula (Bandyopadhyay, 1984):

$$\text{Chilli Equivalent Yield (CEY)} = \text{Yield of intercrop Chilli} + \frac{Yi \times Pi}{\text{Price of chilli}}$$

Where, Yi = Yield of intercrops (onion/garlic/coriander) and Pi = Price of intercrops (onion/garlic/coriander).

Land equivalent ratio (LER) values were determined from the yield data of the crops according to Mian (2008).

$$\text{LER} = \frac{YiC}{Y\,syc} + \frac{Yicc}{Ysycc}$$

Where,

Yic= Intercrop yield of chilli

Ysyc = Sole yield of chilli

Yicc = Intercrop yield of component crops

Ysycc = Sole yield of component crops

Results and Discussion

Yield and yield attributing characters of chilli

Number of branch/plant, number of fruits /plant, single fruit weight, fruit length and green chilli yield were significantly influenced due to intercropping onion, garlic and coriander with chilli (Table 1). The maximum number of branch/ plant (7.53) was obtained from sole chilli (T_1) which was statistically similar to T_4 (7.13) and the lowest in T_3 treatment. The maximum number of fruits/plant (174.73) was recorded in sole chilli which was statistically identical to T_4 (167.80). The maximum single fruit weight (1.92 g) was obtained from sole chilli which was statistically similar with T_2 treatment. Higher fruit length (5.5 cm) and green chilli fruit yield (9.13 t/ha) was obtained from sole chilli which was statistically similar with T_4 treatment and the lowest fruit length (5.13 cm) and green chilli fruit yield (6.68 t/ha) in T_3 treatment. The maximum fruit yield was obtained in sole chilli treatment might be due to the combined effect of yield contributing characters like

number of fruits per plant and single fruit weight. Islam *et al.* (2012) also reported similar result.

Table 1. Fruit yield and yield attributes of chilli under sole and intercropping situation (2020-2021)

Treatment	Plant height (cm)	Branch/ plant (no.)	Fruits/ plant (no.)	Single fruit wt. (g)	Fruit length (cm)	Green chilli yield (t/ha)
T_1	56.80	7.53	174.73	1.92	5.50	9.13
T_2	58.93	6.47	163.47	1.88	5.17	7.52
T_3	59.73	6.20	165.60	1.55	5.13	6.68
T_4	59.63	7.13	167.80	1.71	5.30	8.3
LSD $_{(0.05)}$	NS	0.80	8.1	0.18	0.32	0.34
CV (%)	11.2	8.9	5.5	6.3	5.1	10.5

T_1 = Sole chilli, T_2 =Two rows of onion in between two rows of chilli, T_3 = Two rows of garlic in between two rows of chilli, T_4 = 100% coriander (leaf) in between two rows of chilli.

Yield of component crops

The yield of onion, garlic and coriander was significantly influenced by intercrop onion, garlic and coriander with chilli (Table 2). The maximum bulb yield was recorded in onion (14.99 t/ha) in sole treatment followed by (12.49 t/ha) T_2 treatment (Two rows of onion in between two rows of chilli) and the lowest yield (4.6 t/ha) in T_4 treatment 100% coriander (leaf) in between two rows of chilli. In case of garlic and coriander the similar trend was also observed. These results were obtained might be due to the no harmful effect of onion in between chilli. Faruque *et al. (*2006*)* also reported the similar result.

Table 2. Yield of onion, garlic and coriander under sole and intercropping situation (2020-2021)

Treatment	Yield (t/ha)
T_2 =Two rows of onion in between two rows of chilli	12.49
T_3 = Two rows of garlic in between two rows of chilli	6.44
T_4 = 100% coriander (leaf) in between two rows of chilli	4.60
T_5 = Sole onion	14.99
T_6 = Sole garlic	9.37
T_7 = Sole coriander	6.46
LSD $_{(0.05)}$	1.92
CV (%)	7.2

Chilli equivalent yield (CEY)

Chilli equivalent yield is expressed in total productivity. Chilli equivalent yield were higher (14.05-16.88 t/ha) in all the intercrops than the sole crop of chilli (9.13 t/ha), onion (11.24 t/ha), garlic (11.71 t/ha) and coriander (8.07 t/ha). In intercrop combination the maximum chilli equivalent yield (16.88 t/ha) was recorded in T_2 treatment (Two rows of onion in between two rows of chilli) which was followed by T_3 treatment (Two rows of garlic in between two rows of chilli) (14.73 t/ha) and the lowest chilli equivalent yield (8.07 t/ha) from T_7 treatment (Sole coriander). Ahmed *et al.* (2013) also reported that intercrop combination increase the equivalent yield.

Land equivalent ratio (LER)

Land equivalent ratio is the most common index adopted in intercropping to measure the land productivity. It is often used as an indicator to determine the efficacy of intercropping. The highest land equivalent ratio (1.65) was recorded in T_2 treatment (Two rows of onion in between two rows of chilli) followed by T_4 treatment (100% coriander in between two rows of chilli) (1.60) and the lowest Land equivalent ratio (1.41) in T_3 treatment (Two rows of garlic in between two rows of chilli). LER of different crop combinations ranged from 1.41 to 1.65% indicating land utilization 41-65% increased by intercropping. The mean values of LER (more than one) in all intercropping treatments indicated that land was more efficiently utilized under intercropping than sole cropping of chilli, onion, garlic and coriander.

Cost benefit analysis

Intercropping combination of onion, garlic and coriander with chilli showed higher monetary return than sole crop (Table 3). The maximum gross return (Tk. 6,75,200/ha) was recorded from T_2 treatment (Two rows of onion in between two rows of chilli) which was 84% higher than the sole chilli. This treatment intercropping combination also gave the higher gross margin (Tk.5,26,800/ha) and benefit cost ratio (4.32) followed by T_4 treatment (100% coriander in between two rows of chilli) with BCR (3.81). The results of increased productivity and returns were consistent with the earlier reports of yield advantages of crop mixture compared to monoculture (Islam *et al.* 2012 and Ahmed *et al.* 2013). Though higher benefit from treatment T_2 but second highest cost of production among the treatments. All sole crops showed much lower cost of production than intercrops but lower CEY as well gross return, gross margin and BCR respectively.

Table 3. Chilli equivalent yield (CEY), land equivalent ratio (LER) and cost and return analysis of intercropping (2020-2021)

Treatment	CEY (t/ha)	LER	Gross return (Tk./ha)	Cost of production (Tk./ha)	Gross margin (Tk./ha)	BCR
T_1	9.13	1.00	365200	135250	229950	2.70
T_2	16.88	1.65	675200	156200	526800	4.32
T_3	14.73	1.41	589200	158500	448700	3.71
T_4	14.05	1.60	562000	147250	463550	3.81
T_5	11.24	1.00	449600	132100	444500	3.40
T_6	11.71	1.00	468400	135100	259700	3.46
T_7	8.07	1.00	322800	102500	186800	3.14

CEY= Chilli equivalent yield; LER= Land equivalent ratio, BCR= Benefit cost ratio.

T_1 = Sole chilli, T_2 =Two rows of onion in between two rows of chilli, T_3 = Two rows of garlic in between two rows of chilli, T_4 = 100% coriander (leaf) in between two rows of chilli, T_5 = Sole onion, T_6 = Sole garlic, T_7 = Sole coriander.

Market price (Tk./kg): Onion=30, Garlic=50, Chilli=40, Coriander leaf=50

Conclusion

The result revealed that, all intercropping were found relatively better in respect of productive and profitable than that of sole cropping. Among the treatments, two rows of onion (15 cm x 10 cm) in between two rows of chilli (50 cm x 50 cm) were more productive and profitable in respect of chilli equivalent yield and monetary return.

References

Ahmed, F., M.N. Islam, M.S. Alom, M.A I. Sarker and M.A. Mannaf. 2013. Study on intercropping leafy vegetables with okra (*Abelmoschus esculentus* L.). *Bangladesh J. Agril. Res.* **38(1):** 137-143.

Alom, M.S., B.L. Nag, M.N. Islam, F. Ahmed and S. Akter. 2013. Performance of different crop species with pointed gourd (*Trichosanthes dioica* Roxb.). *Bangladesh J. Agril. Res*. **38(3):** 523-529.

Bandyopadhyay, S.N. 1984. Nitrogen and water relations in grain sorghum-legume intercropping systems. Ph. D. Dissertation, *Indian Agricultural Research Institute*, New Delhi.

BBS (Bangladesh Bureau of Statistics) 2018. Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning. Govt. of the Peoples' Republic of Bangladesh.

Bhatti, I.H. 2005. Agro-Physiological studies on sesame legume intercropping system in different geometric arrangements. Ph.D. Thesis, Department of Agronomy, University of Agriculture. Faisalabad, Pakistan.

Faruque, A., M.A. Rahman, M.A.H.S. Jahan, M. Ahmed and M.A. Khayer. 2006. Effect of different planting systems in Maize/spinach-red amaranth intercropping. *Bangladesh J. Agric. And Environ.* **2(2):** 69-76.

BARC (Bangladesh Agricultural Research Council). 2018., Farmgate, Dhaka 1215. 223p.

Islam, M.R., M.A.K. Mian and M.T. Rahman. 2012. Suitability of intercropping sesame with mukhikachu. *Bangladesh J. Agril. Res.* **37(4):** 625-*634.*

Mian, M.A.K. 2008. Performance of maize oriented cropping patterns under different nutrient management. Ph.D. Dissertation. Dept. Agron. Bangladesh Agril. Univ., Mymensingh. Pp. 31-137.

Nazir, M.S., A. Jabbar, I. Ahmad, S. Nawaz and I.H. Bhatti. 2002. Production potential and economics of intercropping in autumn-planted sugarcane. *Int. J. Agric. Biol*. **4:**140-142.

MANAGEMENT OPTIONS FOR CROP PRODUCTION UNDER UNFAVORABLE ECOSYSTEMS: A REVIEW IN BANGLADESH

M. N. Yousuf[1], M. A. A. Khan[2] and S. Brahma[3]

Abstract

The agriculture regarded as a major economic activity in Bangladesh, facing the great challenges of ensuring food security and other basic needs to a vast population. There are many obstacles in Bangladesh: decreasing land resources & climatic vulnerabilities, water & salinity stress, drought, heat, high temperature, disease & insect pests' outbreak, unexpected & uneven rainfalls, floods, cyclones, tidal surges, water logging, land sliding, soil erosion, declining soil fertility and productivity etc. In every year about 1% (76,000 to 80,000 ha) of premium agricultural land is being lost for accommodation, infrastructure, industrialization, urbanization etc. in the country. For ensuring food and nutritional security, the highest priority to production of crop. The enormous pressure has been exerted on the natural resources like land, irrigation water, air etc. to produce more foods. There is limited scope for horizontal expansion of food production, vertical expansion with adaptation of technologies under unfavorable ecosystems in Bangladesh. Crop production under unfavorable ecosystems: coastal lands, char lands, hills, *haors*, *baors*, *beels*, *jheel*, piedmonts, Barind Tract and peats areas of Bangladesh should be properly improved & strengthened immediately for ensuring food security to large populations. HYV, hybrid crop varieties and modern appropriate as well as sustainable technologies for crop production should be adapted of the adverse ecosystems of the country. Developed of alternative and improved cropping pattern against traditional cropping pattern which upscaling crop productivity and cropping intensity in those ecosystems. Long term strategy, policy and infrastructure development by government should be generated for improving crop production, increment of income and reduction of poverty of the area. Therefore, this review paper has been designed and discussed adaptation of technologies and diagnosis the unfavorable ecosystems of Bangladesh for crop production.

Keywords: unfavorable ecosystems, diagnosis, management technique and crop production.

Introduction

Bangladesh (lies between $20^0 34^/$ & $26^0 38^/$ North latitude and $88^0 01^/$ & $92^0 41^/$ East longitude) is the largest deltaic floodplain in the world (BBS, 2023; Sarker *et al.*, 2022). It has a various but tropical climate characterized by wide seasonal rainfall, high humidity and high rainfall (Reza *et al.*, 2015). The total area of 1,47,570 km^2 of which 88,892 km^2 is occupied by rivers, hills and estuaries (BBS, 2023). The

---

[1]Senior Scientific Officer, [2]Scientific Officer, [3]Principal Scientific Officer, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

great delta is flat throughout and sketches from near foothills of the Himalayas in the north to a southern irregular deltaic coastline is 710 km that faces the Bay of Bengal (BBS, 2023; GED, 2018; MEFCC, 2018). There are three categories of lands: floodplains (80%), terraces (8%) and hills (12%) which only 69% of total area is suitable for crop cultivation and intense in floodplains (Banglapedia, 2021). On the basis of origin and properties, the soils were broadly categorized into seven tracts (Table 1) consisting 30 Agro-ecological zones (AEZ), based on land form, parent materials, land types, soil characteristics and agro-climatology. Mica is the predominant clay mineral followed by smectite, chlorite, vermiculite and kaolinite (BARC, 2018). The major crops produced in the country are rice, vegetables, wheat, tuber crops, spices, oilseeds, pulses, jute, cotton, sugarcane, maize and tobacco (BBS, 2023, Chaki *et al.*, 2023). The cropping pattern is mainly rice based and covered 76% areas of cultivable lands (Shil *et al.,* 2016; Hasan *et al.*, 2013). Cropping intensity (212%) has increased remarkably, accompanied with use of high yielding verity (HYV) & hybrid crop varieties and agricultural inputs (fertilizers & pesticides) has impacted deterioration of soil health (BBS, 2023, Chowdhury *et al.*, 2018). The top most priority in Bangladesh is to produce food for feed its vast and over increasing population (Aziz *et al.*, 2016). For getting solution, to extend agriculture to the fullest volume the unfavorable ecosystem should be effective through proper management and selection of crops (Bokhtiar *et al.*, 2023; Khan *et al.*, 2008). The unfavorable ecosystems of Bangladesh are coastal lands, char lands, hills, *haors*, *baors*, *beels*, *jheel*, piedmonts, Barind Tract and peats areas (Bokhtiar *et al.*, 2023, GED, 2018, Saha *et al.*, 2016, Karim, 2015). The major crop production constraints are land availability, urbanization, top soil removal, social forestry, land & soil degradation, infrastructural developments, drainage impedance and water logging, fisheries and climatic vulnerability (Xu *et al.*, 2020, Hossain *et al.*, 2019, Miah *et al.*, 2018). To extend crop production under adverse ecosystems such as coast lands, char lands, hills, piedmonts, Barind tract, *haors*, *beels* and peats proper management approaches are advisable.

Table 1. Distribution of different soil Tract in Bangladesh

Soil Tract with area	Physiography units	General Soil type
Madhupur Tract (10,000 km²)	Madhupur Tract	Red-brown terrace soil
Barind Tract (13,000 km²)	Barind Tract	Grey terrace soil, Deep red-brown terrace soil
Gangetic Alluvium (27,000 km²)	Ganges river floodplain, Arial Beel, Gopalganj-Khulna peat basins, Ganges tidal floodplain (non-saline part)	Calcareous dark grey floodplain soil, Acid basin clay, Peat, Grey floodplain soil

Soil Tract with area	Physiography units	General Soil type
Tista Tract (16,000 km^2)	Old Himalayan piedmont plain, Tista floodplain	Black terai soil, non-calcareous brown floodplain and grey floodplain soil, grey floodplain and non-calcareous brown floodplain soil, non-calcareous dark grey floodplain soil, non-calcareous alluvium, non-calcareous grey floodplain soil (non-saline phase), non-calcareous alluvium
Brahmaputra Alluvium (40,000 km^2)	Jamuna floodplain, Old Brahmaputra floodplain, Haor Basin, Surma-Kushiyara floodplain, Middle Meghna floodplain, Old Meghna estuarine floodplain, Young Meghna estuarine floodplain (northern part), Chittagong coastal plain, Northern and eastern piedmont plain	Non-calcareous brown floodplain and grey, floodplain soil, grey floodplain and non-calcareous brown floodplain soil, non-calcareous dark grey floodplain soil, grey floodplain soil, Acid basin clay, Surma-Kushiyara floodplain soil, Comilla basin soil, grey floodplain and non-calcareous dark grey floodplain soil, Calcareous alluvium (non-saline part), non-calcareous alluvium, Floodplain soil, Old Piedmont plain soil
Coastal Saline Tract (20,000 km^2)	Young Meghna estuarine floodplain, Ganges tidal floodplain (saline part), Sundarban, Chittagong coastal plain (partly)	Calcareous alluvium (saline phase), Acid sulphate soil, grey floodplain soil (saline phase), Grey Piedmont Soils (saline part)
Hill Tract (17,000 km^2)	Northern and eastern hills	Brown hill soil

Source: Banglapedia, 2021 and BARC, 2018

Coastal Ecosystems

The coastal lands (47,201 km^2) of Bangladesh, consists of 19 districts, covers 32% of the country: Jessore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirozpur, Jhalakati, Barguna, Barisal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chittagong and Cox's Bazar (Islam and Sarkar, 2021; Ahmad, 2019). About 53% land of this region is saline (Haque *et al.*, 2018, Haque *et al.*, 2008). The coastal and offshore areas are about 2.85 million hectares include tidal, estuarine and meander floodplains (Hasan and Kumar, 2022, Uddin *et al.*, 2020). The tidal floodplain occurs mainly in the south of the Ganges floodplain (49%) and also on large parts of Chittagong coastal plains (6%), Estuarine floodplains (18%) of the coastal area located in greater Noakhali, Barisal,

Patuakhali and a smaller area of Chittagong districts (Ahmed *et al*., 2021, Aziz *et al*., 2016b; Ahsan and Sattar, 2010). About 30% of coastal lands are suitable for crop production. Soils of Jessore, Magura, Narail, Faridpur, Gopalgonj, Barisal, Jhalokhati and Patuakhali have been newly salinized and reaches its pick in April - May (Hossain *et al*., 2019; Haque *et al*., 2018; Islam, 2015). This area is relatively flat and suffers from saline soil-water to different degrees. The degree of salinity goes down in rainy season could possible to crop production (Ahmed *et al*., 2021, Islam, 2020). Increasing salinity is the major concerning issue to the people of the coastal region of Bangladesh (Rashid, 2019, Salehin *et al*., 2018). Due to increasing salinity in the water and soil, the people of the region are suffering from scarcity of safe drinking water, irrigation, agriculture and other uses (Buisson *et al*., 2021, Ahsan, 2010). For that 20-40% crop production is reduced in coastal saline belts (Rahman *et al*., 2021; Miah *et al.,* 2020). Many natural and man-made calamities: tidal surge, cyclone, acid sulphate soils, waterlogging in polder areas, salinity intrusion, land erosion & unstable atolls, sedimentation in riverbeds, sea level rise, shortage of rainfall, late draining, heavy soil consistency, poor nutrient status, brackish shrimp cultivation and making dam & barrages (Hossain *et al.,* 2019, Toufique and Yunus, 2013).

Management for crop production

The opportunity of crop intensification to increase crop production in unfavorable and underutilized coastal ecosystem could be achieved by manipulation of soil, desalinization, improved irrigation and drainage system and modern soil & water management practices. Cultivation of salt tolerant shallow rotted crops like wheat, barley, groundnut, chilli, fenugreek etc., could bring substantial changes in agricultural practices in the salt affected soils. The extent of non-saline to very slightly saline and very slightly saline to slightly saline area covers about 8,45,910 ha of coastal districts which are very potential for crop production. Different *Rabi* crops such as mung bean, lentil, grass pea, chickpea, cowpea, mustard, linseed, chilli, wheat, sweet potato, aroids, watermelon, *Rabi* vegetables and HYV and local *Boro* rice could be grown there. Similarly, about 2,40,220 ha of land fall under slightly saline to moderately saline and another 1,98,890 ha lands are moderate to strong saline. Adoption of some soil and crop management practices make those area cultivable for winter (*Rabi*) crops. Cropping system should be improved and developed. There are some technological options for crop production in saline areas-

- Cultivation of released salt tolerant rice varieties of Bangladesh Rice Research Institute (BRRI) as BRRI dhan 47, BRRI dhan, 53, BRRI dhan 54, BRRI dhan 61, BRRI dhan 76, BRRI dhan 78, BRRI dhan 82, BRRI dhan 97, BRRI dhan 99 and Bangladesh Institute of Nuclear Agriculture (BINA): BINA Dhan 8 and BINA Dhan 10.

- Bangladesh Agricultural Research Institute (BARI), Bangladesh Wheat and Maize Research Institute (BWMRI) and BINA released crop varieties:

Wheat (BARI Gom 25, BARI Gom 33, WMRI Gom 2, WMRI Gom 3, BINA Wheat 1, BAW-1147 and BAW-1290), Barley (BARI Barley 4, BARI Barley 8, BARI Barley 10), Sorghum (BARI Sorghum-2), Finger millet (BARI Raghi 1), Mustard (BARI Sarisha 16, BARI Sarisha 18, BINA Sharisha 5, BINA Sharisha 6), Potato (BARI Alu 72, BARI Alu 73, BARI Alu 78, BARI Alu 104), Sweet potato (BARI Mishti Alu 6 and BARI Misthi Alu 7), Taro (BARI Pani kachu 8, BARI Pani kachu 9), Sesame (BARI Til 4 and BARI Til 6), Mungbean (BARI Mung 6, BINA Moog 7) and Soybean (BARI Soybean 5, BINA Soybean 5, BINA Soybean 6) could be grown during *rabi* season.

- Introduction and replacement of local cultivars with high yielding variety (HYV) varieties of mung bean, lentil, grass pea and cowpea.

- Application of organic manure, brown manure with extra 20-25% nitrogenous fertilizers recommended dose.

- Replacing Na^+ in the soil with Ca^{2+} by applying gypsum.

- Application of plant growth promoting bacteria (PGPR).

- Practicing rain water harvest in rainy season for irrigation during dry season.

- Cultivation of salt tolerant crops sugar beet, sorghum, watermelon, groundnut, sunflower and fenugreek.

- Raised bed with mulch followed by drip irrigation is the most suitable technique to reduce soil salinity, save water and to increase production of high value horticultural crops.

- Soybean-T. Aus-T. Aman, Groundnut-T.Aus-T. Aman, Watermelon-T. Aus-T. Aman, Watermelon-Indian spinach-T. Aman, Sunflower-T. Aus-T. Aman, Mustard-Mung bean-T. Aus-T. Aman, Potato-Mung bean-T. Aus-T. Aman, Sunflower-Jute-T. Aman, Potato-T. Aus-T. Aman, Linseed-T. Aus-T. Aman, Mustard-T. Aus-T. Aman, Mustard-Boro-T. Aman, Boro-Jute-T. Aman, Wheat-Mung bean-T. Aman, Chilli-Fallow-T. Aman an alternate and improved cropping pattern

Char land Ecosystems

Char lands can be considered as a 'by-product' of the hydro-morphological dynamics of accretion in the rivers are newly emerged through the erosional and depositional process of fluvial system with sedimentation of huge amount of sand, silt and clay over time (Sarker *et al*., 2024; Khatun *et al*., 2022). It includes all types of bars including both lateral (point-bars) and medial (braid-bars). The sand bars emerging as islands within the river channel (island chars) or as attached land to the riverbanks (attached chars), once vegetated such lands are commonly called

chars in Bangladesh (Tasnim *et al.*, 2022, Sarker *et al.*, 2022). This area occurs along the major river systems of the Padma, the Meghna, the Jamuna and the Brahmaputra with their numerous tributaries which have a complex topography (Haque and Jakariya, 2023, Sultana *et al.*, 2011). Bangladesh has about 0.83 million hectares char lands of which about 0.52 to 0.79 million hectares are cultivable (Chowdhury *et al.*, 2018; Karim *et al.*, 2017). Crops are often lost through active changes in river alignment and complete alteration of landscape at a local level (Ahmed *et al.*, 2021). The active floodplain and char lands occur in the districts of Kurigram, Lalmonirhat, Sirajgonj, Pabna, Jamalpur, Tangil, Manikgonj, Faridpur, Shariatpur, Madaripur, Mymenshingh, Kishorgonj, Narshingdi, Dhaka, Munshigonj, Brahmanbaria, Cumilla, Chandpur, Noakhali, Lakshmepur and Bhola (Table 2) (Sattar and Islam, 2010; Khan, 2010). Burial of standing crops and good agricultural lands pose serious constraints to crop production by fresh sediment of sandy deposits, land instability, coarse textured soils, low water holding capacity, low nutrient capacity, river bank erosion, seasonal drought, flooding and poor communication are major problems related to crop production (Alam *et al.*, 2018, Aziz *et al.*, 2016, Naher *et al.*, 2016).

Table 2. Distribution of char lands in Bangladesh

Region	Area (thousand ha)	% of total char lands
Dhaka	74.6	9.7
Jamalpur- Tangil	116.0	14.2
Comilla- Noakhali	129.9	15.9
Pabna- Rajshahi	125.8	15.4
Bogra-Pabna-Rangpur	321.5	39.3
Faridpur-Kushtia	17.3	2.1
Faridpur	29.8	3.6
Mymenshingh-Kishorgonj	1.8	0.2
Patuakhali	2.0	0.2
Total	818.7	100

Source: Sattar and Islam, 2010.

Management for crop production

Generally, farmers in char lands grow local variety of different crops such as sweet potato, groundnut, sweet gourd, lentil, grass pea, mungbean, chilli, cheena, watermelon, mustard, onion, sweet corn millets etc. which are usually grown by the farmers during *rabi* season. Farmers usually follow their traditional crop cultivation practices. Therefore, yield of crops is unsatisfactory compared to other ecosystems. To increase crop productivity following options could be suggested:

- Mega varieties (MV) and hybrid varieties (HV) of rice (BRRI dhan 48, BRRI dhan 49, BRRI dhan 50, BRRI dhan 67, BRRI dhan 74, BRRI dhan 81, BRRI dhan 84, BRRI dhan 87, BRRI dhan 89, and BRRI dhan 92),

wheat, maize, oil seeds, pulses, potatoes, sweet potatoes, millets, spices and vegetables should be introduced by replacing local or traditional crops and varieties.

- The crop varieties performed well under char land condition could be introduced: Chickpea (BARI Chola 4, BARI Chola 9), Lentil (BARI Masur 6, BARI Masur 7), Mungbean (BARI Mung 6), Sesame (BARI TIl 5 and BARI Til 6), Mustard (BARI Sharisha 14, BARI Sharisha 18, BARI Sharisha 20, BINA Sharisha-9), Groundnut (BARI Chinabadam-9), Proso millet (BARI Cheena-1), Foxtail millet (BARI Kaon-2), Maize (BARI Hybrid Maize 9, WMRI Hybrid Maize 1, WMRI Hybrid Baby Corn), Sweet pea (BARI Motorshuti 2), Soybean (BARI Soybean 5, BINA Soybean 3), Onion (BARI Piaz 4, BARI Onion 6), Chilli (BARI Morich 4), Fennel (BARI Mouri 2) and Black cumin (BARI Kalozira 1) have been identified as better performer in char land areas.

- Modern and recommended crop production technologies along with IPNS should be practiced for higher yield, income and improvement of soil fertility.

- Intercropping of different crops like potato, leafy vegetables and legume with hybrid maize and sugarcane is another good option to increase production and income generating.

- Organic and synthetic mulch should be used for conserving soil moisture.

- Polythene mulch should be used for conserving soil moisture and controlling weeds.

- Conservation or zero tillage should be practices.

- Crop diversification with legumes such as BARI Kheshari 3 and BARI Masur 8 should be cultivated.

- Sandbar cropping technology should be introduced

- Potato-Groundnut-T. Aman, Mustard-Boro-Jute-T. Aman, Potato-Jute-T. Aman, Wheat-Jute-T. Aman, Mustard-Boro-T. Aman, Garlic/Maize-Fallow-T. Aman, Maize-Jute-T. Aman, Chilli- Fallow-T. Aman, Potato-Foxtail millet-T. Aman, Linseed-Groundnut-T. Aman, Mustard-T. Aus-T. Aman, Potato-Boro-T. Aman, Onion-Sesame-T. Aman an alternate and improved cropping pattern

Hill Ecosystems

Hills are part of the Hindu Kush Himalayas Mountain ecosystem, located in the south-east and north-eastern regions of Bangladesh in Table 3. Maximum hills of the country are situated above 60^0 slopes (Azia *et al.,* 2016a; Chowdhury and

Mallik, 2010). The major constraints for crop cultivation in Hilly regions are soil erosion (by heavy downpours in July-August), inadequate irrigation facility, landslides (causes due to sloppy land and jhum cultivation), heavy rainfall, flash flood in valley, afforestation, depleting ground water table, soil acidity, low nutrient status (except K, Fe and Mn), limited volume of soil for root anchorage, nutrient leaching and low soil organic matter content (Alam *et al.*, 2022, Quais *et al.*, 2017). Poor communication & marketing facilities, Bengali-Tribal people conflict and land ownership or tenure issues are the further constraints to the food security of the hilly people. Continuous depletion of soil fertility is the major constraint to crop production (Marma and Islam, 2018). Jhum cultivation (shifting cultivation) and deforestation are the predominant form of land degradation (Faisal and Hayakawa, 2022; Islam *et al.*, 2020). Jhum cultivation is a traditional farming system, difficult to discard it. Rapid loss of soil fertility and toxicity of Al^{3+}, Fe^{3+} and Mn^{4+} are the two major problems for achieving satisfactory yield of jhum crops (Gafur *et al.*, 2003). Soil fertility is in declining trend due to loss of nutrients and organic matter (Zakaria and Majumder, 2019). Jhum cultivation causes gully erosion and losses of soil ranging from 10-120 t $ha^{-1}yr^{-1}$ (Aziz *et al.*, 2016a).

Table 3. Distribution of hill areas in Bangladesh

Hills	Area (km²)	% of total hills
Chittagong Hill Tract (Khagrachari, Rangamati and Bandarban)	13069	76.38
Chittagong and Cox's Bazar	2317	13.54
Sylhet Division (Sunamgonj, Sylhet, Habigonj and Moulavibazar)	1587	9.28
Others (Comilla, Netrokona, Brahmanbaria, Jamalpur, Sherpur, Mymensingh and Feni)	137	0.80
Total	**17110**	**100**

 Source: Hossain *et al.*, 2019.

Management for crop production

The prospect of increased crop production through proper utilization of soil and water conserving technologies in high in Hills. A number of crops can be grown throughout the year provided crops and soil are well managed. The region is especially suitable for horticultural and plantation crops. In Hilly areas BARI is established settled farming, decrease shifting cultivation and to minimize land degradation. Some sustainable technologies have been developed for hills.

- Year round and multi strata crop combination.
- Rain water harvesting in rainy season and used in dry season.
- Practicing settles farming instead of Jhum cultivation.
- Better performing crop varieties like mung bean var. BINA Mug 2, BARI Mug 6, BARI Mug 4, mustard var. BARI Sharisha 20, chickpea var.

BARI Chola 3, BARI Chola 11, Lentil var. BARI Masur 6, Chilli var. BARI Morich 2 and BARI Morich 6, ginger var. BARI Ada 2, BARI Afda 3, turmeric var. BARI Holud 4 and BARI Holud 5, eryngium var. BARI Bilatidhonia 1, sweet potato var. BARI Sweet potato 7, maize var. BARI Maize 5, BARI hybrid Maize 7 and field pea var. BARI Motorshuti 2 should be cultivated.

- Sac culture method for application of ginger should be disseminated.

- Mustard-Seasame-T. Aman, Mustard-Fallow-T. Aman, Potato- T. Aus-T. Aman, Potato-Boro, T. Aman, Potato-Maize- T. Aman, Boro- Fallow-T. Aman an improved cropping pattern.

Piedmonts ecosystem

Piedmont areas, comprises of the feet of some coalesced alluvial fan formed by the rivers, washing the adjacent Himalayan slope, the north-west part of Bangladesh, occur in: Old Himalayan Piedmont Plains (AEZ 1), and Northern and Eastern Piedmont Plains (AEZ 22). The Old Himalayan Piedmont Plains (3982 km^2) covers most of Thakurgaon and Panchagor districts, and north-western part of Dinajpur district (Ratul *et al.*, 2021, Sarker *et al.*, 2020, Uddin *et al.*, 2012). The Northern and Eastern Piedmont Plains (4038 km^2) covers Netrokona, Sunamganj, Sherpur, Sylhet, Habiganj, Mymensingh, Moulvibazar, Comilla and Brahmanbaria districts. Constraints of crop production related to soil management include sandy loams and sandy clay loams soils, high permeability, nutrient leaching, low organic matter content, low pH (very strongly acidic to slightly acidic), Al^{3+}, Fe^{3+} & Mn^{2+} toxicity, macro & micro-nutrient deficiencies, stone lifting in Tetulia upazila (causes degradation of soil), very low to low P availability, deficiencies of N, K, S, Ca, Mg, Zn, B and flash flood (Kamal *et al.*, 2019, Yousuf *et al.*, 2013). Some technologies should be practices for crop productions under piedmont soil:

Management for crop production

- Use of organic matter for conserving soil moisture

- Balanced utilization of nutrient elements

- Application of lime for reclamation of soil acidity

- Mg and B fertilizers are applied for cultivation of *Rabi* crops

- Seed priming, mulching and conservation agriculture techniques are practiced.

- Cultivation of rice var. BRRI dhan 72, BRRI dhan 88, BINA dhan 11, wheat var. BARI Gom 26, mustard var. BARI Sharisha 14, BARI Sharisha 18, BARI Sharisha 20, chilli var. BARI Morich-2 and potato var. BARI Alu 41, BARI Alu 78, BARI Alu 79, BARI Alu 90, BARI Alu 104.

- Potato-Mungbean-T. Aman, Mustard-Boro-T. Aman, Mungbean-T. Aus-T. Aman, Potato- T. Aus-T. Aman, Chickpea-T. Aus-T. Aman, Potato-Maize-T. Aman, Mustard-T. Aus-T. Aman, Wheat-Mungbean-T. Aman, Chilli-Fallow-T. Aman, Potato-Jute-T. Aman an improved cropping pattern

Peat land Ecosystems

The peat lands of Bangladesh occupy about 4010 km^2 (Uddin and Mohiuddin, 2019; Khan, 2010). Peat is an unconsolidated deposit of semi-carbonized plant matter in a water-saturated environment, certainly high moisture content, Structure less has low bearing capacity (when wet). The rate of decomposition depends on anaerobic conditions (Rashid, 2021, Masud *et al.*, 2011). The peat soil contains higher amount of organic matter (Ali *et al.*, 2020, Saha *et al.*, 2016). The soils are highly permeable, deeply flooded during rainy season, bulk density 0.01-0.4g cm^{-3}, C: O ratio 2:1 and organic matter content more than 30% (Lennartz and Liu, 2019; Liu and Lennartz, 2019). The concentration of carbon in peat soils ranges 30–70 kg m^{-3}, easily burns when dried & also very hard (Clarke and Rieley, 2019; Agus *et al.*, 2011). The peat was also used as an energy source in ancient time (Ali *et al.*, 2020, Hossain, 2014). There are three categories of peat soils: Sapric (immature) peat, Hemic (medium mature) peat and Fibric (mature) peat (Deru, 2021). The major peat lands are situated in low-lying areas of Gopalgonj, Madaripur, Khulna, Jessore, Bagerhat, Narail, Barishal, Pirojpur (AEZ 14) and minor scale in the Sylhet, Maulavibazar, Netrokona, Kishoreganj and Brahmanbaria districts (Uddin and Mohiuddin, 2019). The soils are strongly acidic, having medium K and low in S, P, B, Zn and Cu contents, brownish black to black, fibrous (Ali *et al.,* 2020, BARC, 2018).

Management for crop production

Considering physical and chemical properties it shows the management of peat soils are very difficult due to lack of mineral matter in the profile. There are some development possibilities in small area having mineral horizon either at the top or in the horizon close to top soil, still it depends on thickness of mineral horizon. The thicker one will perform better management: tillage, sowing, transplanting etc. There are some possibilities to improve the soils by allowing sediments settling down on these peat basins from the adjoining tidal rivers. This process of sedimentation should be continued for several years to make the land high and make potential for agriculture. Consequently at least two crops should be grown in a year. *Boro* followed by transplanted or broadcast Aman could be grown by irrigation through fresh water. There are several procedures of management of peat soils practiced in this area. Two of them are described below:

a) *Sarjan* **procedure:** Generally, this procedure is practiced in medium high to medium lowland having late draining phase. In this case land is divided into several subplots. Between two subplots there is a ditch for keeping water permanently. Every subplot is raised by taking the soil from the adjoining side. Optimum size of the plot is 8.0 m X 1.5 m, which may be changed depending on the presence of mineral matter at the surface and size of the plot. The present crops on the raised bed are mainly vegetables, spices and *dhaincha*. Local fishes are grown in the ditches between the two beds.

b) *Gher* **procedure:** It is one type of fish culture area where both crops and fishes are grown alternatively at the same time. The dyke/ail is raised along the boundary of the plot by taking soil from inside of the plot. The digging part will be turned into a ditch to keep water for long time (dry season). The soils of the ditch are kept by the side of a raised dyke having a certain length, breadth and height. The present land use patterns are Boro-Shrimp (Lobster) and Boro- mixed Shrimp and T. Aman. Vegetables are grown on the raised dyke.

Haors and *Baors* Ecosystem

Haors with their unique hydro-ecological characteristics are large bowl or saucer-shaped floodplain depressions lies between low lying areas of Surma-Kushiyara floodplain and Sylhet basin, covers the upper Meghna River basin in North-Eastern regions of Bangladesh, are most complex of seasonal inundated wetlands (Islam, 2020, Kamruzzaman and Uddin, 2020). The total area of 8,600 km^2 of which around 43% area is *Haor* districts and classified as Acid Basin Clays (Saha *et al.*, 2016, Kamruzzaman and Shaw, 2018). It extends in Sylhet, Maulvibazar, Sunamgonj, Habigonj, Netrakona, Kishoregonj and Brahmanbaria districts (AEZ 21). The *Baor* is an oxbow lake, found mostly in the moribund delta as in greater Comilla, Faridpur, Dhaka and Pabna districts (Mohiuddin, 2022, Yousuf, 2022). The *Haor* soils are peat and muck occurred in top of the soil profile. Due to containing decomposed organic matter and sulphur produced H_2S gas, which injured roots (Masud *et al.*, 2011). The major problems related to crop production are: strongly acids soils, heavy soil texture, nutrient deficiency (N, S and Zn), flash flood, excess rainfall in the upstream hilly areas & subsequent runoff, sedimentation in the rivers, deforestation, hill cuts, landslide, improper drainage and unplanned road and water management infrastructure (Rahaman *et al.*, 2020, Islam *et al.*, 2015). It's also suffering from wave erosion and eutrophication (BHWDB, 2012). Total cropped area is about 1.93 million ha, of which rice is 1.74 million ha (90.2%) and the rest 0.19 million ha (9.8%) is non-rice crops. Around 66% of Haor areas under cultivation (Alam *et al.*, 2010). The total rice area of Bangladesh is 11.35 million hectares of which 15.3% falls in the *Haor* area. About 5.25 million metric tons of rice is produced in *Haors* which is 16.5% of the total rice production of Bangladesh (Aziz *et al.*, 2016a). The contribution of *Boro* 60%,

Aman 33% and *Aus* 7% of rice production in *Haor* areas (Hassan *et al.*, 2019.. In *Haor* areas the application of fertilizers is the minimum for crop production than other areas of the country (Aziz *et al.*, 2016a and Khan, 2010).

Table 2. Distribution of *Haor* and their area

District	Upazila	Total area (ha)	*Haor* area (ha)	Number of *Haor*
Sylhet	Jaintiapur, Beanibazar, Fenchuganj, Balagonj, Biswanath	349000	189909	105
Maulvibazar	Maulivibazar Sadar, Kulaura, Rajnagar, Sreemangal	279900	47602	3
Sunamgonj	Sunamganj Sadar, Jagannathpur, Dharmapasha, Jamalganj, Chhatak, Derai, Salla, Tahirpur, Bishambarpur	367000	268531	95
Habigonj	Ajmerigonj, Hobiganj Sadar, Bahubal	263700	109514	14
Netrakona	Atpara, Barhatta, khaliajuri, Mohongonj, Madan, Kandua	274400	79345	52
Kishoregonj	Mithamain, Karimgonj, Austragram, Itna, Nikli, Bazitpur, Kuliarchar, Tarail, Bhairab, Katiadi	273100	133943	97
Brahmanbaria	Bhramanbaria Sadar, Nasirnagar	192700	29616	7
Total		1999800	858460	373

Source: Kamruzzaman and Shaw, 2018, BHWDB, 2012.

Management for crop production

A large area in the country suffers occasional or more frequent waterlogging. The low-lying ecology of the country make this a wide spread natural phenomenon and many areas remain fallow . Waterlogging also limits the nutrient uptake by reducing plant transpiration and restrict root function. Therefore, crop production in waterlogged soils is very difficult. Some options for increasing crop production in waterlogging and flood prone areas:

- Cultivation of flood prone and waterlogging tolerant MV and hybrid rice varieties like BRRI dhan 51, BRRI dhan 78, BRRI dhan 79, BRRI Hybrid dhan1, BRRI Hybrid dhan2, BRRI Hybrid dhan 3, BRRI Hybrid dhan 5, BRRI dhan 92, BRRI dhan 101, BRRI dhan 102, BRRI dhan 107, BRRI dhan 108, Swarna, BINA Dhan 11 and BINA Dhan 12 Short duration crop varieties should be adopted.

- Adoption of short duration crop varieties.

- Floating bed agriculture plays an important role for vegetable and Spices cultivation in waterlogging area.

- Cultivation of different aroids var. BARI Panikachu 5. BARI Panikachu 6 and BARI Panikachu 7.

- Cultivation of mustard varieties like BARI Sharisha 14, BARI Sharisha 15, BARI Sharisha 16, BARI Sharisha 18, wheat var. BARI Gom 25, BARI Gom 26, field pea var. BARI Motorshuti 2, lentil var. BARI Masur 6, BARI Masur 8, mungbean var. BARI Mung 6, chickpea var. BARI Chola 8, chilli var. BARI Morich-3, BARI Morich 6 and maize var. BARI Hybrid maize 9 in high and medium highland area of haor.

- Cultivation of traditional deep water rice cultivars in low lying flood prone area.

- Fallow-Boro-Fallow, Potato-Groundnut-Fallow, Sunflower-Kenaf-Fallow, Sweet potato-Kenaf-Fallow, Wheat-Fallow-Fallow, Boro-Fallow-T. Aman, Fallow-B. Aus-T. Aman, Groundnut-Fallow-Fallow cropping pattern

Beel and *Jheel* Ecosystem

Beels are countless shallow lakes or ponds, surrounded by flooding fields. A *Beel* is usually a depression or topographic low generally produced by erosion or other geographical process (Yousuf, 2022; Kakon *et al*., 2020, Khondoker *et al.,* 2014). These are marshy in character. Sometimes beels are remains of a river that has changed its course. Many of the *Beels* dry up in the winter but during the rains expand into broad and shallow sheets of water, which may be described as fresh water lagoons (GED, 2018, CIAT, 2017). There is 6300 *Beels*, and 3,500 of them are permanent and 2,800 of them are seasonal (BHWDB, 2020). The riverbanks of the Jamuna and the Padma make the region basin-shaped; the *Chalan Beel* is an extensive low land area at the lower Atrai basin, spread across the districts of Natore, Pabna and Sirajganj. The *Aril Beel* a basin like shape of the riverbanks of the Padma and Dhaleshwari rivers in Dhaka and Munshiganj districts. *Jheels* as an oxbow lake of an old river channel bed clogged with silt, in the south western Ganges deltaic flood plain. The area of *Beels* and *Jheels* have been reduced and land use has been changing. The soils have high organic matter content above 2%, high CEC, N, S, Zn, B, K and P content is low to medium and low moisture holding capacity (BARC, 2018; Khan *et al.*, 2008).

Management for crop production

- Cultivation of rice var. BRRI dhan 33, BRRI dhan 51, BRRI dhan 78, BRRI dhan 79, BRRI dhan 103, BINA Dhan 11, BINA Dhan 12, BINA Dhan 25, sesame var. BARI Til 4, mustard var. BARI Sharisha 14, BARI Sharisha 18, onion var. BARI Piaz-1, BARI Piaz-4, BARI Piaz-6, BARI Piaz-7, Garlic var. BARI Rasun-3, BARI Rasun-4, BARI Rasun-5, BAU Rasun 1, BAU Rasun 2, chilli var. BARI Morich-3, coriander var. BARI

Dhonia-2, patato var. BARI Alu 79 and ground nut var. BARI Cheenabadam-7, BARI Cheenabadam-8 and other *rabi* crops

- Mulching practices for moisture conservation
- Use conservation tillage practices
- Intercropping for increasing total productivity
- Application of Zn and B fertilizers for *Rabi* crops
- Traditional deep water rice cultivars should be cultivated in low land areas.
- Popularized Mustard-Boro-Fallow cropping pattern instead of Fallow-Boro-Fallow pattern.

Barind Tract Ecosystem

The Barind Tract (7,770 km^2) is developed over Madhupur clay in old alluvial formation, covering AEZ-25 (Level Barind Tract), AEZ-26 (High Barind Tract) and AEZ-27 (North Eastern Barind Tract) most parts of the Noagaon, Bogura, Dinajpur, Joypurhat, Siarjgonj, Natore, Rajshahi, Gaibandha, Chapai Nawabganj districts (Banglapedia, 2021, Salam *et al*., 2017). The greater part of the Barind Tract is almost plain and is crisscrossed by only a few minor rivers. This tract is considered as an ecologically fragile ecosystem with extremely low vegetation coverage (Aziz *et al*.,2016c, Ali, 2018). High temperature, low and erratic rainfall, heavy dependency on ground water for irrigation causes lowering of ground water table, prolonged dry season, fluctuation in diurnal temperature and land degradation which could be the major problems for crop production (Saifullah *et al.*, 2024, Islam *et al.*, 2019). The soil characteristics is silty loam to silty clay loam in texture, very low to low pH, low water holding capacity, very low to low status of N, P, K, Zn & B and low to medium organic matter content (Sarker *et al.*, 2022, Riches *et al.*, 2008, Khan *et al.*, 2008).

Management for crop production

- Cultivation of drought tolerant rice varieties: BINA Dhan 7, BINA Dhan 25, BRRI dhan 39, BRRI dhan 56, BRRI dhan 57, BRRI Dhan 66, BRRI dhan 71, BRRI dhan 75, BRRI dhan 103 and BRRI dhan 107. Barley (BARI Barley 8), Proso millet (BARI Cheena-2), Mustard (BARI Sharisa-14, BARI Sharisa-18, BARI Sharisa-20), Chickpea (BINA Chola-4, BARI Chola-10, BARI Chola-11), Grass pea (BARI Kheshari-3), Garlic (BARI Rasun-4, BARI Rasun-5, BAU Rasun-1), Garden pea (BARI Motorshuti-3), Lentil (BARI Masur-7, BARI Masur-9), wheat (BARI Gom-28), Onion (BARI Piaz-1)
- Minimum or zero tillage for conservation of soil moisture
- Relay cropping T. *Aman* with pulses
- Alternate wetting and drying technique used for rice production

- Harvesting rain water during rainy season
- Used balance fertilizers, lime, organic matter and brown manuring should be practiced.
- Practicing mulching and conservation agriculture technique.
- Potato-Onion-T. Aman, Potato-Maize-T. Aman, Potato-Mungbean-T. Aman, Wheat-Mungbean-T. Aman, Potato-Boro-T. Aman, Black gram-Boro-T. Aus, Mustard-Fallow-T. Aman, Lentil-Sweetcorn-T. Aman, Sorghum-Maize-T. Aman

Conclusion

Assuring future growth in agriculture will be a difficult endeavor; though, it is not possible. In order to fed the ever-increasing population from a very limited land resource. Future thrust should be given to increase crop production in adverse ecosystems like, coastal, hills, *haor*, *beels*, *jheel*, peats, piedmonts, Barind Tract and char lands. Adoption of modern with climate resilient crop varieties in cropping system and appropriate as well as sustainable technologies could increase crop production in these unfavorable ecosystems. Government should take initiatives to implement unfavorable ecosystem management technologies for upliftment of these socio-economic status of the areas for making a hunger free, happy and prosperous Bangladesh.

Reference

Agus, F., K. Hairiah and A. Mulyani. 2011. Measuring carbon stock in peat soils: practical guidelines. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Indonesian Centre for Agricultural Land Resources Research and Development.

Ahmad, H. 2019. Bangladesh coastal zone management status and future trends. *J. Coast Zone Manag.* **22:** 3-7.

Ahmed, K.U., M.A. Salam, A.S.M.M.R. Khan and S.C. Sarker. 2021. Improvement of Farm Productivity through Intervention with Improved Agricultural Technologies in Char land Eco-System. Sub- project Completion Report, pp. 1-158

Ahmed, K.U., M.A. Salam, A.S.M.M.R. Khan and S.C. Sarker. 2021. Climate Resilient Farming Systems Research and Development for the Coastal Ecosystem, Sub- project Completion Report, pp.1-206.

Ahsan, M. and M.A. Sattar. 2010. Coastal areas and saline soils of Bangladesh: their extent, salinity status, management practices and future research needs. Paper presented in the Workshop on Soil Fertility, fertilizer Management and Future research Strategy, held at Bangladesh Agricultural Research Council, during 18-19 January, 2010.

Ahsan, M. 2010. Saline Soils of Bangladesh. Soil Resource Development Institute, SRMAF Project, Ministry of Agriculture, Mrittika Bhaban, Krishikhamar Sarak, Farmgate, Dhaka.

Alam, M.R., M.A. Malak and M.A. Quader. 2018. Livelihood vulnerability of char land people in Brahmaputra-Jamuna River system. *Jagannath Uni. J. Life Earth Sci.* **4(1):** 54–64.

Alam, M.S., M.A. Quayum and M.A. Islam. 2010. Crop Production in the Haor Areas of Bangladesh: Insights from Farm Level Survey. *The Agriculturists*, **8(2):** 88-97.

Alam, M.R., T. Zahan, Z. Ferdous, M.S. Hossain, M.M. Islam, M.T. Islam, M. Islam, M. Maniruzzaman, B.C. Sarker, Q. Naher, M.A. Hossain, M.F. Hossain, S. Ishtiaque, A.K. Chaki, M.M. Anwar, M. Shahiduzzaman and M.A. Ali. 2022. Adaptation and Scaling up Agroforestry for Livelihood Improvement of farmers in Agricultural Ecosystem of Bangladesh. Sub-Project Completion Report, pp. 1-102.

Ali, Y.M. 2018. Evolution of Agriculture in the high Barind tract of Bangladesh. Arik Prokasona, Dkhaka. Bangladesh.

Ali, M.R., M.R. Islam, M.H. Islam, K. Osamu and M. Kosuke. 2020. Potential of peatlands in Bangladesh and sustainable management strategy. *Agril. Eng. Intl. CIGR J.* **22(4):** 65-74.

Aziz, M.A., M.R.I. Mondal and M.H.H. Rahman. 2016. Unfavorable eco-system: crop production under Char land ecosystem. Agronomy Division, Bangladesh Agricultural Research Institute. Gazipur.

Aziz, M.A., M.R.I. Mondal, B.R. Banik and M.H.H. Rahman. 2016a. Unfavorable eco-system: crop production under hill and haor eco-system. Agronomy Division, Bangladesh Agricultural Research Institute. Gazipur.

Aziz, M.A., M.R.I. Mondal, B.R. Banik and M.H.H. Rahman. 2016b. Unfavorable eco-system: crop production under salinity stress. Agronomy Division, Bangladesh Agricultural Research Institute. Gazipur.

Aziz, M.A., M.R.I. Mondal, B.R. Banik and M.H.H. Rahman. 2016c. Unfavorable eco-system: crop production under high temperature and drought stress. Agronomy Division, Bangladesh Agricultural Research Institute. Gazipur

BARC (Bangladesh Agricultural Research Council). 2018. Fertilizer recommendation guide. BARC Soils Pub. No. 45. Bangladesh Agricultural Research Council. Dhaka, Bangladesh.

Banglapedia: National Encyclopedia of Bangladesh. 2021. Seven Tracts of Bangladesh. The Asiatic society of Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2023. Year book of Agricultural statistics-2022. Ministry of Planning. Bangladesh.

BHWDB (Bangladesh Haor and Water Development Board). 2020. Master plan of haor area. Center for Environmental and Geographic information services. Ministry of water Resources. Dhaka. Bangladesh.

BHWDB (Bangladesh Haor and Water Development Board). 2012. Master plan of haor area. Center for Environmental and Geographic information services. Ministry of water Resources. Dhaka. Bangladesh.

Bokhtiar, S.M., S. Samsuzzaman, M. Jahiruddin and G.M. Panaullah. 2023. Agricultural Development for Fragile Ecosystems in Bangladesh. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Buisson, M.C., P. Saikia and S. Maitra. 2020. Community water management and agricultural extension services: effects, impacts and perceptions in the coastal zone of Bangladesh. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). pp. 48.

Chaki, A.K., T. Zahan, M.S. Hossain, Z. Ferdous, M.A. Islam, M.T. Islam, M.M. Islam, M. Mohiuddin, M.F. Hossain, M.R. Alam, J.C. Barman, M.S.I. Khan, M.A.H. Talukder, K. Gyeltshen, M.R. Islam, M.B. Hossain and M.M. Anwar. 2023. Climate-smart agriculture technologies and practices in Bangladesh. SAARC Agriculture Centre, SAARC, Dhaka, Bangladesh, 111p

Chowdhury, J.A., A.A. Begum and M.R. Karim. 2018. Training manual on agronomic research and technology development of major crops. Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur.

Chowdhury, M.M.U. and S.A. Mallik. 2010. Hill soils of Bangladesh: their management practices and future research needs. Presented in the Workshop on Soil Fertility, fertilizer Management and Future research Strategy, held at BARC, during 18-19 January, 2010. Dhaka.

Clarke, D. and J.O. Rieley. 2019. Strategy for Responsible Peatland Management. 6 Edition, International Peatland Society, Jyväskyl, Finland.

Deru, J.G.C. 2021. Soil quality and ecosystem services of peat grasslands. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Faisa, B.M.R. and Y.S. Hayakawa. 2022. Geomorphological processes and their connectivity in hillslope, fluvial, and coastal areas in Bangladesh: A review. *Prog. Earth Planet. Sci*. **9(41):**1-22.

GED (General Economics Division), 2018. Bangladesh delta plan 2100. Bangladesh Planning Commission, Government of the People's Republic of Bangladesh.

Gafur, A., J.R. Jensen, O.K. Borggaard and L. Petersen. 2003. Runoff and losses of soil and nutrients from small watersheds under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh. *J. Hydro*. **279:** 293–309.

Haque, M.A., D.E. Jharna, M.N. Uddin, and M.A. Saleque. 2008. Soil solution electrical conductivity and basic cations composition in the rhizosphere of lowland rice in coastal soils. *Bangladesh J. Agril. Res*. **33(2):** 243–250.

Haque, M.A., M. Jahiruddin and D. Clarke. 2018. Effect of plastic mulch on crop yield and land degradation in south coastal saline soils of Bangladesh. *Intl. Soil Water Conser. Res*. 317-327.

Haque, C.E. and M. Jakariya. 2023. Bengal Delta, Charland Formation, and Riparian Hazards: Why Is a Flexible Planning Approach Needed for Deltaic Systems? *Water*. **15(2373):** 1-23.

Hasan, M.N., M.S. Hossain, M.A. Bari and M.R. Islam. 2013. Agricultural land availability in Bangladesh. SRDI, Dhaka, Bangladesh. pp. 42.

Hasan, M. and L. Kumar. 2022. Changes in coastal farming systems in a changing climate in Bangladesh. *Reg. Environ. Change.* 22(113):1-15.

Hossain, M.A., N.C. Shill, S. Akther and H.M. Nasir. 2019. Training manual on soil fertility and nutrient management for major crops. Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur.

Hossain, M.A. 2014. Floating Cultivation: an indigenous technology for adapting to water logging situation towards sustainable livelihood security in the low lying areas of Bangladesh. *J. Biosci. Agric. Res*. **01(01):** 54-58.

Hassan, A.W.R., F.R.S. Ahmed, M.R.A. Siddiqui and A. Barma. 2019. Climate Resilient Agriculture in Coastal and Flood-plain Regions of BangladeshManusher Jonno Foundation (MJF). Dhaka.pp83

International Center for Tropical Agriculture (CIAT); World Bank. 2017. Climate-Smart Agriculture in Bangladesh. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); World Bank. Washington, D.C. 28 p.

Islam, M.A., M. Kamruzzaman, A. Akter and P.C. Roy. 2015. Perception of haor farmers about the innovative features of floating farming. *Intl. J. Nat. Social. Sci.* **2(4):** 52-58.

Islam, M.M. 2020. Adoption of floating vegetable cultivation by the farmers. MS Thesis. Department of Agricultural Extension & Information System. Sher-e-Bangla Agricultural University, Dhaka

Islam, M.R., M.R. Ahmad, M.N. Alam, M.S. Marma and A. Gafur. 2020. Micro-watershed delineation and potential site selection for runoff water harvesting using remote sensing and GIS in a Hilly areas of Bangladesh. *American J. Water Resour.* **8(3):** 134-144.

Islam, M.R. 2020. Land-use and land-cover monitoring in the haor region over the last 40 years using historical Landsat satellite imagery. MS thesis. Dept. of Agroforestry and Environmental Science. Sher-e-Bangla Agricultural University.

Islam, S.M. 2015. A critical analysis of integrated coastal and ocean management in Bangladesh with lessons from global practices. Mater thesis. World Maritime University. Sweden.

Islam, M.S., M.Z. Hossain and M.B. Sikder. 2019. Drought adaptation measures and their effectiveness at Barind Tract in northwest Bangladesh: a perception study. *Nat Hazards.* **97:** 1253–1276.

Islam, M.W. and T. Sarker. 2021. Sustainable coastal and maritime tourism: A potential blue economy avenue for Bangladesh. ADBI Working Paper 1293. Asian Development Bank Institute. Tokyo.

Kakon, S.S., J.A. Chowdhury, A.A. Begum, M.Z. Ali and M.R. Karim. 2020. Improvement of existing cropping pattern through short duration mustard variety in Chalan beel area. Bangladesh Agricultural Research Institute, Gazipur.

Kamal, M.Z.U., M.N. Yousuf and M.Y. Miah. 2019. Piedmont and flood plain soil nutritional status appraisal by CND norm. Lambert Academic Publishing.

Kamruzzaman, M. and M.T. Uddin. 2020. Economic viability of boro rice production in haor ecosystem of Kishoreganj district. *Bangladesh J. Agril. Econ*. **41(2):** 45-62.

Kamruzzaman, M. and R. Shaw. 2018. Flood and sustainable agriculture in the haor basin of Bangladesh: A review paper. *Universal J. Agril. Res*. **6(1):** 40-49.

Karim, M.A. 2015. The challenges of increasing climate variability to climate smart agriculture in Bangladesh. Key note paper presented at 14th Conference of Bangladesh Society of Agronomy. Bangladesh Agricultural Research Council, Dhaka.

Karim, M.A., M.A. Quayyum, S. Samsuzzaman, H. Higuchi and E. Nawata. 2017. Challenges and opportunities in crop production in different types of char lands of Bangladesh: diversity in crops and cropping. *Trop. Agril. Develop*. **61(2):** 77-93.

Khan, M.S. 2010. Problem soils of Bangladesh and their management practices for crop production. Paper presented in the Workshop on Soil Fertility, fertilizer Management and Future research Strategy, held at BARC, during 18-19 January, 2010.

Khan, M.S., M.M. Rahman, R.A. Begum, M.K. Alam, A.T.M.A.I. Mondol, M.S. Islam and N. Salahin. 2008. Research experiences with problem soils of Bangladesh. Soil Science Division, Bangladesh Agricultural Research Institute. Gazipur.

Khatun, M.A., M.A. Baten, M.A. Farukh and M.O. Faruk. 2022. The impact of climate change on ecosystem services and socio-economic conditions of Char Dwellers in Northern Regions of Bangladesh. *J. Govern. Account. Stu.* **2(1):** 29-48.

Khondoker, S., M.L. Hossain and K.A.H. Moni. 2014. Wetland management in Bangladesh: a study on Beel Bakar. *Agric. Forest. Fisher.* **3(4):** 320-328.

Lennartz, B. and H. Liu. 2019. Hydraulic functions of peat and ecosystem service. *Fornt. Environ. Sci.* **7:** 1–5.

Liu, H. and B. Lennartz. 2019. Hydraulic properties of peat soils along a bulk density gradient-A meta study. *Hydrol. Process.* **33:** 101–114.

Marma, M.S. and M.M. Islam. 2018. Development of agroforestry model for conversion of rice- cotton based hill farming system in the Chittagong hill tracts. A report of Competitive Research Grant Sub-Project under National Agricultural Technology Program-Phase II Project (NATP-2), Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka, Bangladesh.

Masud, M.M., M. Moniruzzaman and M.M. Rashid. 2011. Management and conservation of organic peat soils for sustainable crop production in Bangladesh. Bulletin of the Institution of Tropical Agriculture. **34:** 93-101.

MEFCC (Ministry of Environment, Forest and Climate Change). 2018. Third national communication of Bangladesh to the United Nations framework convention on climate change. Government of the People's Republic of Bangladesh.

Miah, M.G., M.M. Rahman, M.A. Rahman and H.M. Abdullah. 2018. Land use functions assessment for sustainable land management: a case study in Barind tract of Bangladesh. *Ann. Bangladesh Agric*. **22(1):** 1-16.

Miah, M.Y., M.Z.U. Kamal, M.A. Salam and M.S. Islam. 2020. Impact of salinity intrusion on agriculture of Southwest Bangladesh - A review. *Intl. J. Agril. Policy Res*. **8(2):** 40-47.

Mohiuddin, M. 2022. Socioeconomic study of floating agriculture in *Haor* area of Bangladesh. Annual Research Report. OFRD, BARI, Kishoreganj. pp 23-29

Naher, Q., M.R. Islam, M.A. Ali, A.K. Choudhury, M.K. Hasan and A.S.M.M.R. Khan. 2016. Location specific climate resilient agricultural technologies in Bangladesh. On-Farm Research Division. Bangladesh Agricultural Research Institute, Gazipur.

Quais, M.K., M.H. Rashid, S.M. Shahidullah and M. Nasim. 2017. Crops and cropping sequences in Chittagong Hill Tracts. *Bangladesh Rice J.* **21(2):** 173-184.

Rahaman, M.A., M.M. Rahman and M.S. Hossain. 2020. Climate-Resilient Agricultural Practices in Different Agro-ecological Zones of Bangladesh. In: Leal Filho, W. (eds) Hand book of Climate Change Resilience. Springer, Cham.

Rahman, M., H. Rashid, M.K. Shahadat, A.A. Topu, A. Hossain and S.A.I. Nihad. 2021. Field performance of some potato varieties under different saline conditions of Bangladesh. *African J. Agril. Res.* **17(11):** 1480-1487.

Rashid, S.M.A. 2019. Coastal Biodiversity – A Review. Report prepared for Long Term Monitoring Research and Analysis of Bangladesh Coastal Zone. Pp.30.

Rashid, M.H. 2021. Project completion workshop on livelihood improvement of farmers through farming system research and development in floating agriculture eco-system. Krishi Gobeshona Foundation (KGF). Bangladesh Agricultural research Institute. Gazipur

Ratul, A.A., T.S. Hoque, M.R. Islam and M. A. Hoque. 2021. Physico-chemical properties of acid soils from Madhupur Tract and Northern & Eastern Piedmont Plains of Bangladesh. Asian J. Med. Biol. Res. **7(1):** 12-20.

Reza, M.K.H., M.M. Alam and M.A. Hossain. 2015. Climatic condition of the northwestern part of Bangladesh. *J. Eng. Sci.* **6(1&2):** 49-56.

Riches, C.R., D. Harris, D.E. Johnson and B. Hardy. 2008. Improving agricultural productivity in rice-based systems of the High Barind Tract of Bangladesh. Los Baños (Philippines): International Rice Research Institute.

Saha, P.K., S. Islam, M.N. Islam, J.C. Biswas and M.M. Haque. 2016. Soil plant nutrient status under intensive rice-farming systems in Unfavorable Eco-systems of Bangladesh. *Intl. J. Chem. Pharma.* **2(2):** 1-13.

Saha, U., S.R. Chowdhury, M. Shabauddin, K.R. Ahmed and N.C. Ghosh. 2016. A geotechnical profile of haor area of Bangladesh. *Tech. J. River Res. Inst.* **13(1):** 125-135.

Saifullah, M., M.G. Mahboob and K.N.A. Jewel. 2024. Climate smart agriculture for adaptation and mitigation: Training manual 2024. Forestry unit, Natural Resources Management Division, Bangladesh Agricultural Research Council. Dhaka.

Salam, M.A., K.U. Ahmed, A.S.M.R Khan and S.C. Sarker. 2021: Integrated Farming Research and Development for Livelihood Improvement in the Plainland Ecosystem. Sub-Project Completion Report, pp 1-224.

Salehin, M., M. M.A. Chowdhury, D. Clarke, S. Mondal, S. Nowreen, M. Jahiruddin, and A. Haque. 2018. Mechanisms and Drivers of Soil Salinity in Coastal Bangladesh. R. J. Nicholls *et al*. (eds.), Ecosystem Services for Well-Being in Deltas. 333-346.

Sarker, D., F. Islam, M.A.Y. Akhand, M.A.H.S. Jahan, H.M. Naser, M. Moniruzzaman, M.M. Rahman and M.H.H. Rahman. 2024. Udbabito Krishi projukti-2022-2023. Bangladesh Agricultural Research Institute. Gazipur.

Sarker, U.K., M.S. Kaysar, M.R. Uddin, M.A. Hossain, S. Hassan and M.M. Hassan. 2022. Exploring farmers' insight on cropping pattern for sustainable crop production in char area of Bangladesh. *Sustainability*. **14:** 1-17.

Sarker, M.M.H. M. Jahiruddin, A.Z.M. Moslehuddin and M.R. Islam. 2020. Changing dynamics of micronutrients in piedmont soil of Bangladesh. *Eurasian J. Soil Sci.* **9(1):** 43 – 51.

Sattar, S.A. and M.N. Islam. 2010. Char lands of Bangladesh: their extent, management practices and future research needs. Presented in the Workshop on Soil Fertility, fertilizer Management and Future research Strategy, held at BARC, during 18-19 January, 2010.

Shil, N.C., M.A. Saleque, M.R. Islam and M. Jahiruddin. 2016. Soil fertility status of some of the intensive crop growing areas under major agro-ecological zones of Bangladesh. *Bangladesh J. Agril. Res.* **41(4):** 735-757.

Sultana, N., I. Kosuke and W. Akira. 2011. Partial oxidation of char to enhance potential interaction with soil. Soil Sci. **176:** 495-501.

Tasnim, N., M.A. Sultana, K. Tabassum, M.J. Islam and M. Kunda. 2022. A review of the water quality indices of riverine ecosystem, Bangladesh. *Archives Agric. Environ. Sci.*, **7(1):** 104-113.

Toufique, K.A. and M. Yunus. 2013. Vulnerability of livelihoods in the coastal districts of Bangladesh. Bangladesh Development Studies. **XXXVI (1):** 95-120.

Uddin, K., N. Khanal, S. Chaudhary, S. Maharjan and R.B. Thapa. 2020. Coastal morphological changes: Assessing long-term ecological transformations across the Northern Bay of Bengal. *Environ. Challen.* **1(100001):** 1-11.

Uddin, M.J. and A.S.M. Mohiuddin, 2019: Estimation of carbon stock in the peat soils of Bangladesh. *J. Asiatic Soc.* Bangladesh. **45(1):** 127-136.

Uddin, M.J., M.K. Hasan, A.S.M. Mohiuddin, S.U. Ahmed and M.M. Hassan. 2012. Study on some soils of the Himalayan Piedmont Plain of Bangladesh. *J. Asiat. Soc. Bangladesh Sci.* **38(2):** 199-206.

Xu, X., S. Shrestha, H. Gilani, M.K. Gumma, B.N. Siddiqui and A.K. Jain. 2020. Dynamics and drivers of land use and land cover changes in Bangladesh. *Regional Environ. Change.* **20(54):** 3-11.

Yousuf, M.N., S. Akter, M.I. Haque, N. Mohammad and M.S. Zaman. 2013. Compositional Nutrient Diagnosis (CND) of onion (*Allium cepa* L.). *Bangladesh J. Agril. Res.* **38(2):** 271–287.

Yousuf, M.N. 2022. Unfavorable ecosystem: a potential economic avenue for Bangladesh. 1st International Conference on Business and Tourism (ICBT 2022). Primeasia University School of Business School, Dhaka, Bangladesh.

Zakaria, A.F.M. and N.M. Majumder. 2019. Are Khasis of Bangladesh Eco-Friendly Agro anager? Reflections on Hill Farming Practices and Forest Conservation. *J. Sci. Tech. Environ. Inform.* **8(1):** 574-582.

Guidelines for Contributors

Bangladesh Journal of Agricultural Research (BJAR) is a quarterly Journal highlighting original contributions on all disciplines of crop agricultural research conducted in any part of the globe. The full text of the Journal is visible in www.banglajol.info and www.bari.gov.bd websites. Contributors are requested to note the following points while preparing paper for the Journal.

* Paper submitted for publication must contain original unpublished material.

* Papers in the Journal are published on the entire responsibility of the contributors.

* Paper must be in English and type-written in Times New Roman (font size 12) with double space on one side of A4 size 80g paper.

* Margin should be 2.50 cm (1 inch) in all sides.

* Manuscript should be submitted in duplicate along with a soft copy.

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

* **Title:** It should be brief and specific and typed in capital letters. The manuscript will have a separate title page giving title of the paper, author(s) name and address.

* **Abstract:** It should not exceed 150 words containing the highlights of the study, but in case of short communication if should not exceed 70 words.

* **Key words: S**hould not exceed 6 words and it should be below the Abstract.

* **Text:** The text of the article should be clear and precise. Introduction should be precise and relevant to the study. Methods already published should be indicated by references. In case of modification of a method it needs explicit description. Results should be stated concisely and presented referring to Tables and Figures. Data of Tables and Figures should not be repeated in the text. Each result should be followed by discussion or interpretation with appropriate reference(s).

* **Tables and Figures:** Number of Tables and Figures should be minimum. The figures and graphs should be properly drawn with bold and solid lines. The photographs should be submitted on glossy paper or in JPG format. Black and white and colored photographs are acceptable.

* All quantitative data must be in metric units.

* Abbreviations should be as per style "Manual for Biological Editors".

✱ **References:** The references and scientific names are important. The authors must be sure about the correctness of citations and spellings. In the text, references should be cited within brackets quoting author's surname and the year of publication in the appropriate place e.g. (Bhuiyan, 1964), Khan and Rahman (1970). Two or more references when put within the same bracket should be separated by a semicolon.

For more than two authors the reference should be cited with the surname of the first author and then *et al.* (year), for example Ahmed *et al.* (1999).

References should be arranged alphabetically according to author's surname, to be followed by year of publication and full title of the paper. Name of the Journal and Book should be in italics, to be followed by volume, number and page range.

Ahmed, F. and M. Z. Alam. 1993. Mango leaf consumption by *Cricula trifenestrata* Heifer   (Lepidoptera: Saturnide) larvae under field conditions. *Bangladesh J. Entomol.* **31:** 9-17.

Cano, H., N. Gabas and J. P. Canselier. 2001. Experimental study on the ibuprofen crystal growth morphology in solution. *J. Crystal Growth* **224:** 335.

De Beer, G. R.1940. Embryology and Taxonomy. *In: The New Systematics.* (Ed. Huxely, J.). Oxford Univ. Press, London. pp. 365-393.

Dockery, D. J. and C. A. Pope, 1994. Acute respiratory effects of particulate air pollution. *Ann. Rev. Public Health* **15:** 107-110.

Edmonds, J. and K. M. Karp. 1997. Theoretical improvements in Algorithmic Efficiency for network flow problems. *J. Assoc. Comput. Mach.* **19:** 248-264.

✱ A full paper exceeding 12 typed pages and a short communication exceeding six typed pages will not be entertained.

✱ Principal author should take consent of the co-author(s) while including the name(s) in the article.

✱ The article prepared from M.S/Ph.D. thesis should be mentioned in the foot note of the article.

✱ Authors get no complimentary copy of the Journal. Twenty copies of reprints are supplied free of cost to the author(s).