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PERFORMANCE EVALUATION OF BARI SOLAR CABINET DRYER FOR RADISH

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Abstract

BARI solar cabinet dryer was tested with the moist radish (about 9 kg) at Hill Agricultural Research Station (BARI), Khagrachari, during 17-18 February 2020. Drying temperature, relative humidity, air velocity, and solar radiation were recorded. After drying, the final weight of the radish was 554 g (93.84% reduction). The inside air temperature of the drying chamber varied from 45.5 to 52.5 °C (first day) and 47.44 to 52.5 °C (second day). Air relative humidity in the drying chamber varied from 13.2 to 20.25% (first day) and 11.5 to 18.5% (second day), whereas the relative humidity in the ambient varied from 30.5 to 67.5 % (first day), and 42.3 to 65.3% (second day). Solar radiation varied from 50 to 900 W/m^2 during the testing period. Moist radish dried in the dryer attained final moisture content of 9.0% from an initial moisture content of 94% after 11 hours of drying period whereas, it took 56 hours to reduce the moisture content to 12% (wb) of a similar sample in the open sun. In the open sun drying method, 9.0 kg of moist radish was dried to 380 g (95.8% reduction). In the open sun drying method, radish losses by 30% during drying because of fungal spoilage. The color of dried slices in the dryer was more bright and the smell was good compared to sun drying of radish slices. The dryer maintained nutrition and made hygienic and safe products of radish slices. Hilly farmers and small-scale traders would be benefitted from using the BARI solar cabinet dryer.

Keywords: Ambient temperature, Fungal spoilage, Hilly Areas, Relative humidity

Introduction

Sun drying is the most commonly used method to dry agricultural products of primary processing. In sun drying, the crop is exposed directly to solar radiation, ambient temperature, wind velocity, relative humidity, etc. Many disadvantages remain in this method. Rain, insects, humans, and animals interfere with this method and as a result of the products are contaminated. In the hilly areas in Bangladesh, various vegetables are produced and the hilly people dry their vegetables by sun drying method and store these to consume in the off-season period. For this reason, a dryer is needed in a hilly area in Bangladesh to produce good-quality dried vegetables. A solar-powered cabinet dryer was developed at Farm Machinery and Post-harvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur for drying vegetables at

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farm levels. Thus, the farmers can produce quality dried vegetables and hence boost vegetable production to attain food and nutrition security. High moisture in vegetables is the major or single factor for the loss of vegetables. To minimize metabolic degradation and control mold growth, moisture content should be less than 12%, whereas to control insect infestation, it should not be over 9% (Gowda, 1997). As the storage condition at the farm level is less favorable, should be dried to 10% moisture content (Copland, 1976). During harvest, radish contains 90-94% moisture. Vegetables should be dried at a constant and optimum temperature to ensure quality. But in sun drying, it is not possible to maintain a constant temperature because of variations in solar radiation. In the sun drying method, vegetables are often dried at low or high temperatures which speeds up the deterioration of quality. Sometimes, continuous rain occurs for a few days or even for a week, spoiling the total amount of vegetables, and restricting traditional sun drying. In this circumstance, a small capacity solar dryer is needed for drying vegetables to reduce the loss of vegetables and produce good quality dried vegetables.

Materials and Methods

Description of BARI solar cabinet dryer

Farm Machinery and Post Harvest Process Engineering Division, BARI has developed BARI solar cabinet dryer. The design of the indirect solar cabinet dryer for drying vegetables was done based on the energy balance and heat and mass balance equations. The dryer comprised a concentrating type of flat plate collector, auxiliary heating unit, and drying chamber. The special feature of the dryer was that it could be operated on a sunny day using solar radiation and on a rainy or cloudy day or at night using auxiliary electric heaters. The length, width, and height of the drying chamber were 0.84 m, 0.81 m, and 1.73 m respectively and the length, width, and height of the collector were 2.30 m, 1.22 m, and 0.33 & 0.14 m respectively. Fig. 1 is a diagram of the BARI solar cabinet dryer.

Drying chamber

The drying chamber comprised a tray, heater, and inlet and outlet fans. Six drying trays were placed in the drying unit. The dimension of the drying tray was 0.08 m × 0.745 m × 0.0488 m. The stainless steel mesh was used and the mesh number was 20. The drying air was passed through the products. Each tray was of metallic frame and a stainless steel net with dimensions of 1040 mm × 780 mm. The drying air was heated in the collector and passed to the drying chamber through a curved pass at the end of the drying unit. and flew over and under all the drying trays and was exhausted from the outlet. For auxiliary heating, two electric heaters each of 2.5 kW capacities were installed at the bottom of the drying chamber. A temperature controller would have to maintain a constant temperature in the dryer. Two small DC fans (each of 5W) were used for air flowing in the dryer operated by a small solar panel (25W) and in the absence of solar energy, it is operated by alternative current (electricity). A 5 W axial flow fan was connected outside the collector to draw the atmospheric air into the collector and to push

out the heated air to the drying chamber with the desired air velocity. Another 5 W axial flow fan was at the top of the drying chamber. A temperature controller was used to maintain the temperature in the dryer.

Collector

The collector was fabricated with a transparent polyethene sheet, corrugated iron sheet, MS flat bar, wood, and MS angle bar, overall dimensions of the flat plant plate concentrating solar collector are 2.30 m long and 1.22 m wide. The transparent cover of the collector was a 2 mm thick clear plastic sheet. About 1 mm black painted corrugated iron sheet is used as an absorber plate. The collector was placed on 4 legs with 140 mm diameter wheels to turn the solar collector horizontally and change its direction according to the change of the sun's angle.

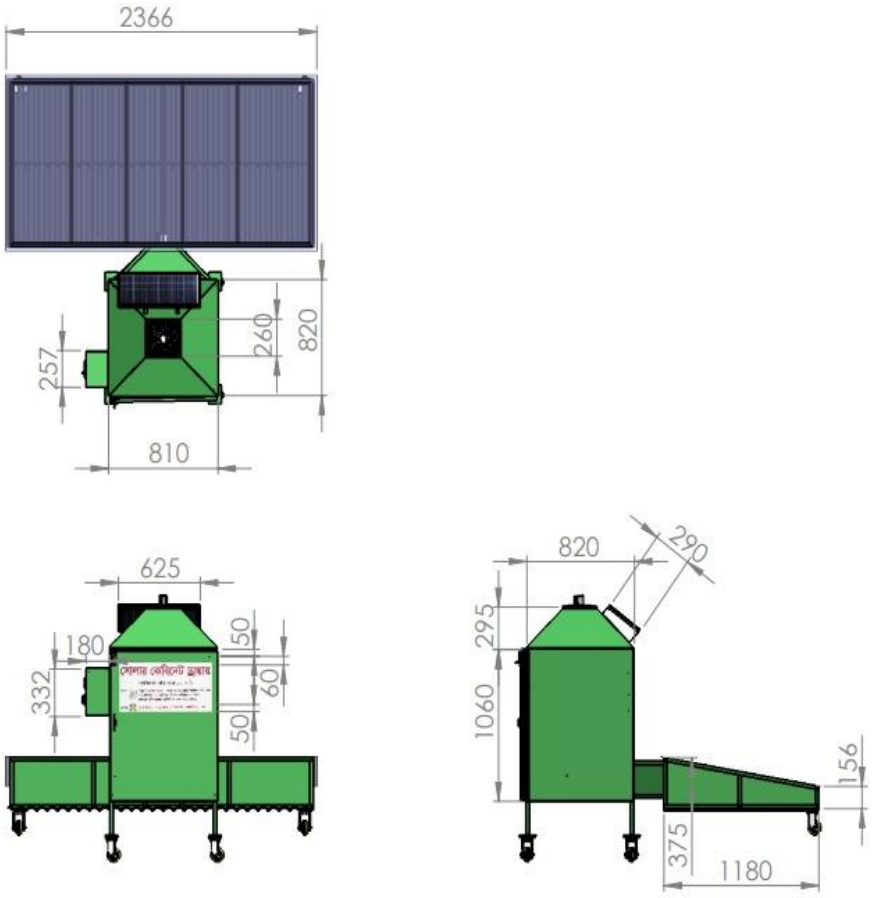

Fig. 1. Diagram of BARI Solar Cabinet Dryer

Testing procedure

The dryer was placed in a sunny place so that it was not affected by shadows. The dryer was tested for drying of radish (Fig. 2) during 17-18 February 2020. Drying in the open sun drying method is shown in Fig. 3. Freshly harvested radish (White Star) was purchased from a farmer in Khagrachari and sliced in 1.8 cm thickness manually. Nine kilograms of sliced radish spread on three trays of the dryer. A similar sample of sliced radish was placed in the open sun for comparison with the solar dryer. Ambient temperature, ambient relative humidity, solar radiation, the temperature at different points in the collector and drying chamber, air velocity at the outlet of the drying chamber, and moisture contents of radish slices were recorded at 1-hour interval. Temperatures were measured at 1-hour interval by a digital temperature meter (model: k 102, accuracy ± 0.3%, Conrad Electronic, Germany). Relative humidity was measured using a digital hygrometer (Model: MY-91HT, accuracy ±0.5%, Conrad Electronic, Germany). A digital solar meter (Model: 776E, accuracy ±3%, Digital Engineering. the USA) was used to measure the solar radiation during daytime drying period. The velocity of drying air was measured by an anemometer (Model TA430, accuracy ± 3% Airflow Ltd., England). The moisture content of radish slices was measured by oven-dry methods. Three layers (i.e., top, middle, and bottom layers) in the drying rack were used in the dryer. The data were recorded at 1-hour intervals from 9.00 am to 5:00 pm. The weights of the samples were measured with an electronic balance. Brand: Shimadzu, model: ELB-3000, made: Japan, capacity and sensitivity 3000g and 0.1g, respectively.

Fig. 2. Photographs showing drying of radish in BARI solar cabinet dryer

Fig. 3. Photographs showing drying of radish in the open sun

Results and Discussion

Dryer performance test with radish

Variations of ambient air temperature and dryer air temperature with solar radiation at different times of a typical day are shown in Fig. 4 during 17-18 February 2020. It was observed that ambient air temperature and solar radiation varied with the time of the day and these were found to reach a peak between 1:00 pm and 12:00 pm. The collector outlet air temperature or inlet air temperature of the drying chamber was found higher than the ambient air temperature.

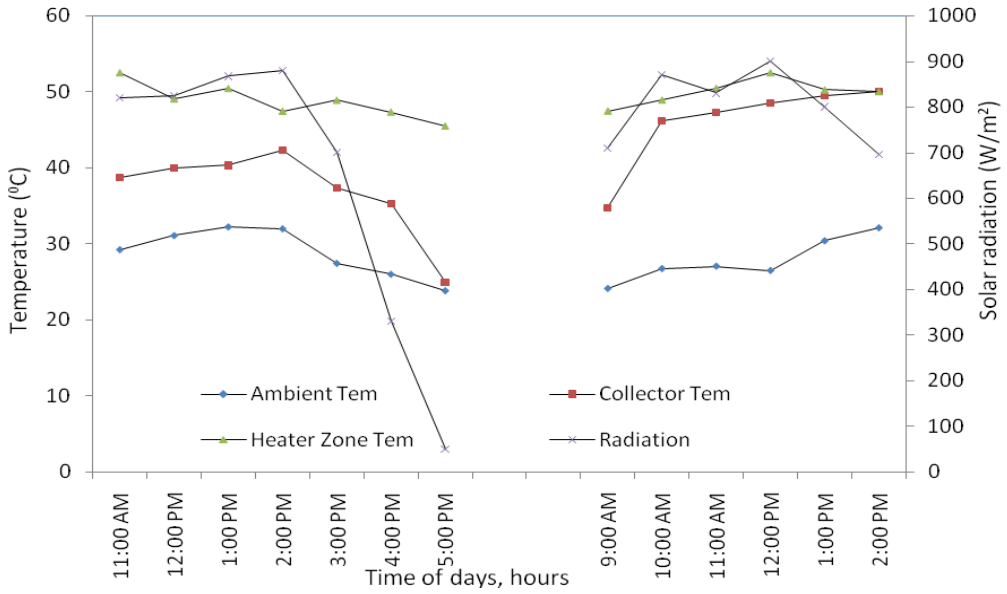

Fig. 4. Variation of an air temperature of ambient, collector, and dryer chamber with solar radiation

The temperature in the collector varied with the ambient temperature and solar radiation. The outlet temperature of the drying chamber was lower than that of the inside temperature of the drying chamber. The inside temperature of the drying chamber varied from 45.5 to 52.5^{0}C (1st day) and 47.4 to 52.5 ^{0}C (2nd day). This temperature was maintained at almost 45-50 ^{0}C using a temperature controller and adjusting air velocity.

Variations of relative humidity of ambient and drying chamber with solar radiation on typical days are given in Fig. 5. Ambient relative humidity on the first and second day varied from 30.5 to 67.5% and 42.3 to 65.3 % respectively, whereas the relative humidity in the drying chamber varied from 13.2 to 20.3% and 11.5 to 18.5%, respectively. Relative humidity in the dryer was reduced due to the increased temperature in the drying chamber. The lower relative humidity is important in drying for higher moisture-carrying capacity of the air (Hossain and Gottschalk, 2009). Collector outlet air relative humidity was found lower than that of the ambient. Air relative humidity in the collector varied with the ambient temperature and solar radiation. The outlet air relative humidity of the drying chamber was higher than that of the inlet of the drying chamber.

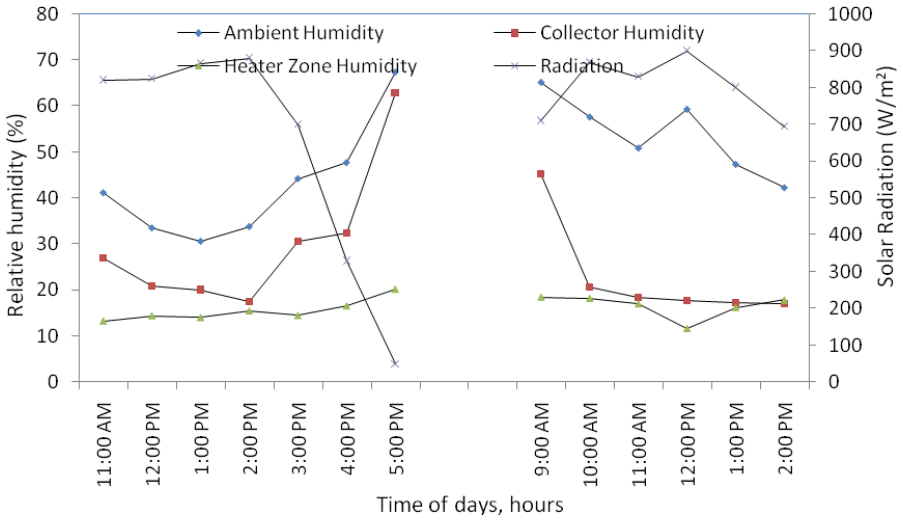

Fig. 5. Variation of ambient and dryer relative humidity with radiation

Air velocity in the drying chamber varied with the time of the days (Fig. 6). Air velocity varied from 2.4 to 3.5 m/s. This variation was because of the variation of voltage in electricity. Two DC fans were operated by a solar panel. Voltage depends on the intensity of global solar radiation. The drying rate increases with the air velocity, but the drying rate becomes independent of a certain air velocity. For drying most of the crops, air velocity should be within the range of 0.50 to 0.75 m/s. The air velocity was higher than the desired range. The temperature in the drying chamber was almost constant although air velocity varied. This was because the air temperature in the dryer was maintained constant by the temperature controller.

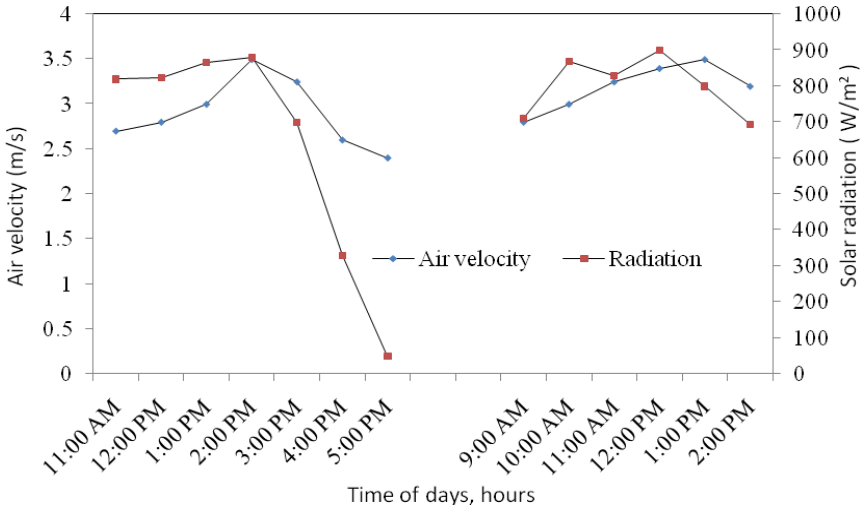

Fig. 6. Variation of air velocity in the dryer with the solar radiation during different times of a day

The drying curves of the radish are shown in Fig. 7. It was observed that the moisture content decreased gradually with drying time. The initial moisture content of radish slices was 94% (wb) and after drying the moisture content was 9.0% (wb) in 11 hours of drying time in the solar cabinet dryer. At the same time, the moisture content of a similar sample of radish slices in the open sun drying method was reduced from 94% to 73% (wb). A total of 11 hours is needed to dry a radish in the solar cabinet dryer to reduce moisture from about 94.0% to 9.0% and 56 hours are needed in open sundry methods to reduce moisture contents from about 94% to 12%. During night, when radish slices were not dried, then the slices absorbed moisture from the air, and as a result, the moisture content of the slices on the second day was higher than at the end of the first day. The moisture content of the radish of the bottom tray was the lowest compared to middle and top trays and the radish of the middle tray was the second lowest. Due to two electric heaters being installed at the bottom of the drying chamber, the drying rate of the bottom tray was the highest, followed by the middle and top trays. After drying 9 kg, raw radish becomes 554 g in the cabinet dryer. During drying in the open sun dry method, some radishes were infected by fungus and needed to sort out after drying 9 kg of raw radish became 390 g. The color was white and the smell was good in the solar cabinet dried radish slices whereas the color was white-dark and the smell was not good in the open sun drying methods (Fig. 8 and 9) respectively.

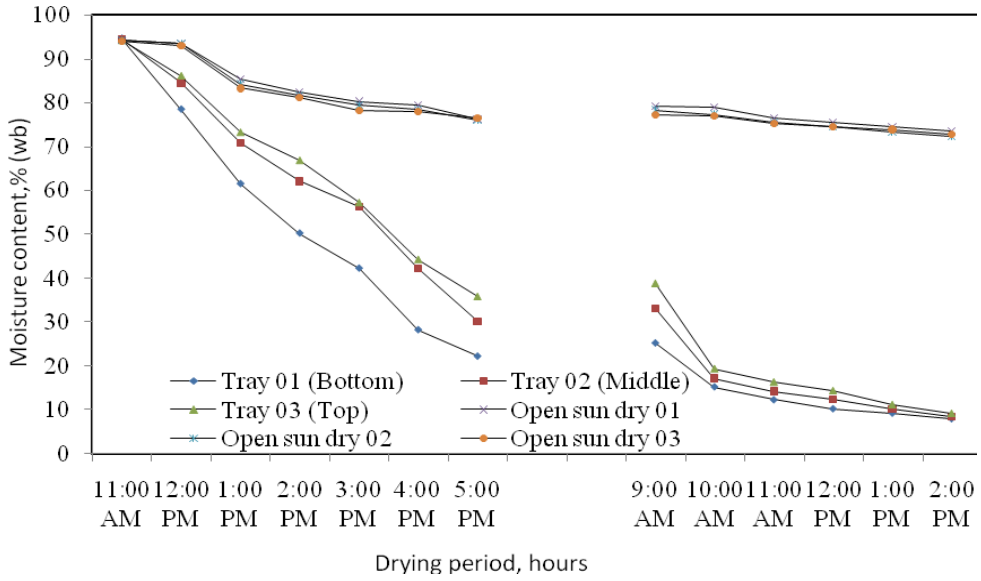

Fig. 7. Variations of moisture content of sliced radish in the dryer and open sun drying methods

Fig. 8. Dried radish slices in the solar cabinet dryer

Fig. 9. Dried radish slices in the open sun

Conclusion

Nine kilograms of moist radish was dried, and it was reduced to 554 g. The drying temperature in the drying chamber was maintained to be 45.5 to 52.5 ^{0}C during the drying period. Relative humidity in the drying chamber varied from 11.53 to 20.5%. The solar radiation varied from 50 to 900 W/m^2 during the testing period. The moisture content of the radish reduced from 94% to 9.0% (wb) in 11 hours of drying whereas, it took fifty-six hours to reduce the moisture content to 12% (wb) of a similar sample in the open sun. In the open sun drying method, 9.0 kg of moist radish was reduced to 380 g after drying. The dryer should be used for drying hygienic, safe, and nutritious radish slices. Hilly farmers and small-scale traders would be benefitted from using the BARI solar cabinet dryer.

Acknowledgement

We gratefully acknowledge the full financial support of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Copland, L. O. 1976. Principles of Seed Science and Technology, Burgess Publication Co, Minnesota.

Gowda, H. G. 1997. Effects of stages of harvesting and drying methods on seed quality in onion. M. Sc. (Agri). Thesis, University of Agricultural Sciences, Dharwad.

Hossain, G. 2009. Effects of moisture content, storage temperature and storage period on colour, ascorbic acid, lycopene and total flavonoids of dried tomato halves, *Inter. J. Food Sci. & Tech.*. 44(6):1245-1253. doi: 10.1111/j.1365-2621.2009.01954.x

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PERFORMANCE OF BARI-RELEASED GLADIOLUS VARIETIES UNDER THE CLIMATIC CONDITIONS OF YOUNG BRAHMAPUTRA AND JAMUNA FLOODPLAIN

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Abstract

The experiment was conducted in the farmers' field at the Farming System Research and Development site (FSRD), Atia, Delduar, Tangail during the Rabi season of 2018-19 and 2019-20 to evaluate the performance of BARI released gladiolus varieties and popularize these varieties among the farmers of Tangail region. BARI developed three varieties of gladiolus, namely BARI Gladiolus-3, BARI Gladiolus-4, and BARI Gladiolus-5. Among the three varieties, BARI Gladiolus-4 performed the best in terms of the spike (191009 piece ha^{-1}) and corm (254322 piece ha^{-1}) production from the average of 2018-19 and 2019-20. Though BARI Gladiolus-4 performed the best in terms of yield, the maximum economic return was obtained from BARI Galdiolus-5 due to a higher spike in demand and market price compared to the other two varieties. The highest gross return (Tk.2406215 ha^{-1}), gross margin (Tk. 1402546 ha^{-1}), as well as BCR (2.40), were also recorded in BARI Gladiolus-5 followed by BARI Gladiolus-4. The lowest gross return (Tk. 1837608 ha^{-1}), gross margin (Tk. 833939 ha^{-1}) as well as BCR (1.83), were obtained from BARI Gladiolus-3. The farmers under the AEZ-8 areas can become economically benefitted by the production of BARI Gladiolus-5 and BARI Gladiolus-4.

Keywords: AEZ-8, Bulbour flower, Corn yield, Cut flower, Gladiolus, Varieties

Introduction

Gladiolus (*Gladiolus* sp.) is one of the most popular commercial flowers in Bangladesh as well as throughout the world. Gladiolus is popularly known as Sword Lily which is an ornamental plant under the monocot family Iridaceae (Sumi *et al.*, 2021). Among bulbous crops, gladiolus occupies an apex position among commercial cut flower crops due to high demand in both domestic and international markets. It is called the queen of bulbous flowers for its excellent aesthetic value and shelf life (Bhattacharjee and De, 2005). It is believed that gladiolus has been originated in South Africa (Sumi *et al*., 2021). Gladiolus is mainly cultivated for cut flowers because of its elegant appearance and prolonged vase life. Gladiolus spikes are most popular in flower arrangements and for preparing attractive bouquets. Its magnificent inflorescence with

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various colors has made it attractive for use in landscaping as an herbaceous border, bedding, rockeries, pots, and cut flowers (Singh *et al.*, 2020). In addition, along with ornamental value, gladiolus has medicinal use to cure headaches, lumbago, diarrhea, rheumatism, and allied pains (Bose *et al*., 2003). Some of the gladiolus varieties of flowers and corms are consumed as food in many countries of the world. The agroecological conditions of Bangladesh, are very suitable for the cultivation of gladiolus. In Bangladesh commercial floriculture is expanding rapidly. Now a days, floriculture has emerged as a lucrative profession with a higher potential for returns than most other fields and horticultural crops in Bangladesh (Sultana, 2003). In a study, conducted by Momin (2006) it was found that gladiolus flower production is six times higher than the returns from rice. Gladiolus production technology is comparatively easy. In Bangladesh, the major growing area of gladiolus is Jessore (Sadar, Sharsha, Chowgacha upazila), Kushtia, Chuadanga, Chattogram, Mymensingh, Dhaka, Savar, and Gazipur. At present, the production area of gladiolus has been started on a small scale. The total production of gladiolus was 4159.54 M. Ton from 382 ha of land (BBS, 2022). It has great economic value as a cut flower and its cultivation is easy. The agroecological conditions of Tangail are conducive to the survival and culture of gladiolus. Bangladesh Agricultural Research Institute has developed some promising, high-yielding gladiolus varieties. There is a great scope to introduce these varieties among the farmers of the Tangail region. Through the cultivation of BARI gladiolus varieties, farmers will be economically benefitted. Considering the popularity of the gladiolus flower, it deserves before the dissemination of BARI gladiolus varieties it is very important to find out a suitable gladiolus variety and popularize that among the farmers of Tangail.

Materials and Methods

The experiment was conducted at the Farming System Research and Development site (FSRD), Atia, Delduar, Tangail under Agroecological Zone-8 during the Rabi seasons of 2018-2019 and 2019-2020. The geographical coordinates of the experimental location were 24.160152 North Latitude and 89.897974 East Longitude at 16 m above sea level. The maximum, minimum temperature (^{o}C), and total rainfall (mm) of the experimental field are presented in Figure 1 (BMD, 2020). The highest (576.1 mm) and the lowest rainfall (0 mm) were observed in January 2018-2019 and 2019-20, respectively. The average maximum temperature (34.79 ^{o}C) was observed in May 2019 whereas the minimum (10.0 ^{o}C) was in January 2018. The experimental plot was prepared 15 days before sowing. Before planting the corms of gladiolus were soaked in 0.2% Diathen M-45 (Mancozeb) for 30 minutes and air-dried in shade. The land was fertilized with 138-75-150-18-2-2 kg NPKSZnB ha^{-1} and 5 t ha^{-1} cowdung. Total amount of cowdung, Triple Superphosphate, Muriate of Potash, Boric acid, Zinc Sulphate, and Gypsum was applied during the final land preparation and mixed with the soil thoroughly.

The total amount of urea was divided into two parts. The first part of urea was applied 25 days after corm sowing and the second part was top-dressed during the spike development (Azad *et al*., 2017). The corms were sown on 7 November and 30 October in 2018-19 and 2019-20, respectively. Two irrigation was provided. Two-hand weeding

was also provided for the proper growth and development of the plant. BARI Gladiolus-3, BARI Gladiolus-4, and BARI Gladiolus-5 were considered planting materials. The spike colors of BARI Gladiolus-3, BARI Galdiolus-4, and BARI Gladiolus-5 were white, pink, and yellow, respectively. The planting materials (corm) of different gladiolus varieties were collected from Horticultural Research Centre, Bangladesh Agricultural Research Institute, Gazipur. Unit plot size was 5 m x 4 m with Randomized Complete Block Design with six replications. The spacing was 25 cm x 15 cm. Harvesting was done starting from the second week of January to the first week of February in both years. The gross economic return was calculated based on the prevailing market price of the commodity. Data on the yield and yield contributing characters were collected and statistically analyzed following the R Project for Statistical Computing Software Version 4.1.1 (R Core Team, 2021). 10 m^2 area was selected and harvested for collecting spike, corm, and corn yield data when lower 1-2 florets started to open. Mean separation was done by the Least Significant Difference (LSD) at 5% level of significance.

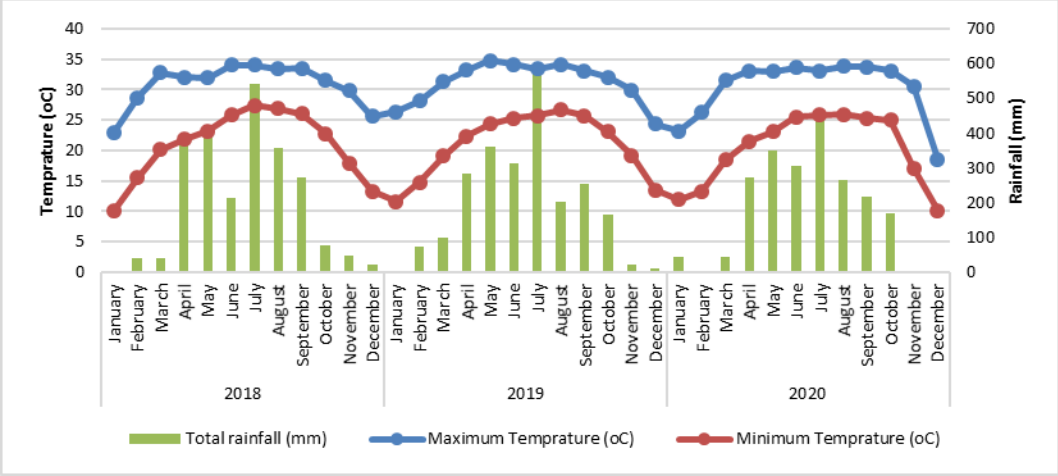

Fig. 1. Monthly record of air maximum, minimum temperature (°C), and total rainfall (mm) of the experimental site during the period from January 2018 to March 2020.

Results and Discussion

Vegetative and floral characteristics of gladiolus varieties

The leaf length of different gladiolus varieties varied significantly. Leaf length was affected by genotypes and varied from 39.8 to 47.1 cm (Table 1). The highest leaf length was observed in BARI Gladiolus-4 (47.14 cm). On the other hand, the lowest is BARI Gladiolus-3 (39.8 cm). These findings are at par with Hossain *et al.*, 2011. Leaf breadth was not varied significantly among the tested varieties of gladiolus. Among the tested varieties, the leaf breadth range was 2.55 to 3.35 cm in the two consecutive years. The highest leaf breadth was observed in BARI Gladiolus-4 (3.35 cm) followed by BARI Gladiolus-5 (3.05 cm) whereas the lowest was in BARI Gladiolus-3 (2.55 cm). Hossain *et*

al., 2011 reported that the leaf breadth of different gladiolus cultivars ranged from 1.65-3.05 cm. The plant height among the different varieties showed no significant difference which varied from 59.21 to 100.05 cm. The highest plant height 100.05 cm was produced by BARI Gladiolus-5 whereas the lowest was 59.2 in BARI Gladiolus-3 (Table 1). Variations in vegetative attributes may be due to their genetic makeup as well as varietal differences and environmental effects. Similar, results were observed by Pragya *et al*.,(2010) and Neha *et al*., (2012) in gladiolus. The number of leaves showed no significant difference among the varieties from the average of two years. The highest number of leaves was produced by BARI Gladiolus-5 (8.38) whereas the lowest was (7.15) in BARI Gladiolus-4 (Table 1). Variation in the number of leaves per plant in gladiolus was also reported by Padma and Kumar (2004). The variation might be due to genotype as well as some known and/ or unknown environmental factors (Hossain *et al.,* 2011).

Table 1. Average vegetative and flowering parameters of three gladiolus varieties during the Rabi seasons of 2018-19 and 2019-20 at farm level

Variety	Leaf length (cm)	Leaf breadth (cm)	Plant height (cm)	Leaves at flowering (no.)	Spike length (cm)	Rachis length (cm)	Floret spike^{-1} (number)	Weight of single spike (g)	Spike yield (piece ha^{-1})	Vase life (days)
BARI Gladiolus-3	39.75 b	2.55 a	59.21 b	7.73 a	79.25 a	47.05 a	11.82 a	78.65 b	174477 a	8 a
BARI Gladiolus-4	47.14 a	3.35 a	97.95 a	7.15 a	71.25 b	38.85 a	11.13 a	66.7 c	191009 a	9 a
BARI Gladiolus-5	45.85 a	3.05 a	100.05a	8.38 a	83.35 a	56.47 a	9.54 a	93.65 a	181655 a	7 a
Level of significance	*	NS	*	NS	*	NS	NS	*	NS	NS
CV (%)	6.65	11.21	6.83	6.75	8.35	11.62	1.35	9.37	6.58	3.15

In a column, means having similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly as per 0.05 level of probability; *significant at p=0.05; NS = Non Significant

Statistically, a non-significant difference was observed in spike length. The highest spike length was observed in BARI Gladiolus-5 (83.5). On the contrary, the lowest spike length was found in BARI Gladiolus-4 (71.25 cm) (Table 1). In a varietal evaluation conducted by Bhagur (1989), it was recorded that spike length ranged from 50-120 cm in gladiolus. The variation in spike length in different varieties may be due to the influence of genetic and environmental factors. Similar observations were reported by Singh *et al*., (2017) and Mushtaq *et al.,* (2018). Considering the rachis length, it was observed that there was no significant difference among the varieties. The longest rachis (56.5 cm) was found in BARI Gladiolus-5 whereas the shortest rachis length in BARI Gladiolus-4 (38.9 cm) (Table 1). Anuradha and Gowda (1994) found the highest rachis length in gladiolus about 50 cm. The variation in rachis and spike lengths might be attributed to the inherent genetic characteristics associated with genotypes. Similar observations were recorded by Krishan *et al*., (2005); Manjunath and Jankiram (2006), and Neha *et al.,* (2012).

A non-significant difference was observed among the varieties for the number of florets in the spike. The highest number of florets spike^{-1} was observed in BARI Gladiolus-3 (11.82) followed by BARI Gladiolus-4 (11.1) whereas the lowest in BARI Gladiolus-5 (9.54) (Table 1). The number of florets per spike varied from 7-17 as reported by Negi *et al*., (1982) and Lal and Plant (1989). Producing spike with more florets happens because of less competitiveness among plants to obtain water, minerals, nutrients, and light (Azimi and Banijamali, 2019). A significant difference was observed in spike weight among the gladiolus varieties. The highest single spike weight 93.65 g was observed in BARI Gladiolus-5 followed by BARI Gladiolus-3 (78.65 g) whereas the lowest was in BARI Gladiolus-4 (66.7 g) (Table 1). In a previous trial conducted in Tista Meander Floodplain the spike weights of the BARI-released gladiolus ranged from 94.67-160 (Islam *et al*., 2017). There was a non-significant difference observed for spike yield among the varieties of gladiolus. Though the yield of tested gladiolus varieties was high yielding, the maximum spike yield was found in BARI Gladiolus-4 (191009 piece spike ha^{-1}) whereas the minimum spike yield from BARI Gladiolus-3 (174477 piece spike ha^{-1}) (Table 1). The yield of different BARI gladiolus varieties varied from 175000-200000 sticks ha^{-1} (Azad *et al*., 2020). Ornamental plants show considerable diversity in their growth habits, colors, blooming structure, flower shape, and size (Pasha *et al*., 2016).

Among the varieties, vase life varied from 7 to 9 days which was statistically non-significant. The maximum vase life (9 days) was observed in BARI Gladiolus-4 whereas the minimum vase life of 7 days was observed in BARI Gladiolus-5 during the growing period of 2018-19 and 2019-20 (Table 1). The results are in conformity with the findings of Singh *et al*., (2018) and Azad *et al*., (2020). The variation in vase life might be due to senescing behavior by producing higher amounts of ACC, ethylene-forming enzymes, and ethylene along with the genetic makeup of different varieties (Singh *et al.*, 2020).

Corm and cormel characteristics in gladiolus genotype

The average data of the year 2018-19 and 2019-20 on corm production of three BARI-released gladiolus varieties are presented in Table 2. A statistically significant difference was observed in corm production. The number of corms produced per plant was the highest in BARI Gladiolus-4 (1.33). The lowest number of corms per plant 1.11 was found in BARI Gladiolus-5 (Table 2). The variation observed in corm production among the varieties might be due to differences in genetic construction as well as environmental variation (1.1-2.5 corm plant^{-1}) was observed by Hossain *et al*., 2011 in some genotypes. The breadth of corm showed significant differences among the gladiolus varieties which ranged from 18.33 to 23.21 cm. The highest corm diameter was observed in BARI Gladiolus-5 (23.31 cm) whereas the lowest was in BARI Gladiolus-4 (18.33) (Table 2). Similar findings were also reported by Kumar (2009) and Nalage *et al*., 2019, who reported significant varietal differences in corm diameter in different genotypes of gladiolus.

Table 2. Average corm and cormel production as influenced by three gladiolus varieties (average of 2018-19 and 2019-20) at farm level

Variety	Corm plant^{-1} (No.)	Breadth of corm (cm)	Wt. of corm (g)	Cormel plant^{-1} (No.)	Wt. of single Cormel plant^{-1} (g)	Corm yield (No. ha^{-1})
BARI Gladiolus-3	1.12 b	19.47 ab	69.44 c	76.83 a	15.01 b	205423 b
BARI Gladiolus-4	1.33 a	18.33 b	72.95 b	60.01 b	22.74 b	254322 a
BARI Gladiolu-5	1.11 b	23.31 a	81.71 a	78.75 a	45.35 a	211693 b
Level of significance	*	*	*	*	*	*
CV (%)	3.61	6.05	3.35	8.13	17.02	6.61

In a column, means having similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly as per 0.05 level of probability; *significant at p=0.05; NS = Non Significant

A statistically significant difference was observed among the gladiolus varieties in corm weight. The highest corm weight was found in BARI Gladiolus-5 (81.7 g) which was followed by BARI Gladiolus-4 (72.9 g) whereas the lowest in BARI Gladiolus-3 (69.44 g) (Table 2). The corm weight varied from 30-60 g in a varietal trail of gladiolus conducted in India (Sharma and Sharma, 1984) in consonance with the present investigation. The number of cormels plant^{-1} showed a wide range (60.0 to 78.8) of variability. The highest number of cormels per plant was obtained from BARI Gladiolus-5 (78.8) which was closely followed by BARI Gladiolus-3 (76.8) whereas the lowest in BARI Gladiolus-4 (60.0). Difference in the number of cormels plant^{-1} in gladiolus. A statistically significant difference was observed among the gladiolus varieties in the weight of a single cormel which ranged from (15.0 to 45.4 g). The maximum weight of a single cormel was observed in BARI Gladiolus-5 (45.4 g) (Table 2). Negi *et al.*, (1982) reported that cormel weight in gladiolus genotypes ranged from 5.2 to 17.0 g. A significant difference was observed among the gladiolus varieties for corm yield. The highest average corm yield of 2018-19 and 2019-20 was observed from BARI Gladiolus-4 (254322 piece ha^{-1}) whereas the lowest (205423 piece ha^{-1}) was in BARI Galdiolus-3 (Table 2). In an investigation, Khan *et al*., 2012 mentioned that the corm yield of BARI Gladiolus-1 was 75000-120000 ha^{-1}.

Cost and return analysis

The cost and return of BARI-released gladiolus varieties were estimated from the average of two years' spike and corm yield considering the market values (Table 3). The highest total gross return (Tk. 2406215 ha^{-1}), gross margin (Tk. 1402546 ha^{-1}), as well as BCR (2.40), were observed in BARI Gladiolus-5 and the lowest gross return (Tk. 1837608 ha^{-1}), gross margin (Tk. 833939 ha^{-1}) as well as BCR (1.83) in BARI Gladiolus-3. Though the yield of BARI Gladiolus-5 was statistically similar to BARI Gladiolus-4, a higher gross return was found in BARI Gladiolus-5 due to the higher demand and market price of the flowering spike. Gross margin Tk. 216844-1005144 ha^{-1} was found by Islam *et al*., (2017) in a performance trial of different BARI-released gladiolus varieties.

Table 3. Cost and return analysis for cultivation of BARI Gladiolus varieties (average of 2018-19 and 2019-20) at farm level

Variety	Average spike yield (no. ha^{-1})	Average corm yield (no. ha^{-1})	Return (Tk. ha^{-1})		Total gross return (Tk. ha^{-1})	Variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
			Spike	Corm				
BARI Gladiolus-3	174477	205423	1221339	616269	1837608	1003669	833939	1.83
BARI Gladiolus-4	191009	254322	1623576	762966	2386542	1003669	1382873	2.38
BARI Gladiolus-5	181655	211693	1771136	635079	2406215	1003669	1402546	2.40

Market price: BARI Gladiolus-3 @ Tk. 7 spike^{-1}, BARI Gladiolus-4 @ Tk .8.5 spike^{-1}, and BARI Gladiolus-5 @ Tk. 9.75 spike^{-1}, corm @ 3 Tk. piece^{-1} (Islam *et al*., 2017 reported the price of gladiolus varied from 2-6 Tk. spike^{-1}).

Conclusion

The results of the study over two years showed that BARI Gladiolus-4 provided the best spike and corm yield but the highest gross return and gross margin was observed in BARI Gladiolus-5 due to higher market price of spikes compared to other gladiolus varieties. The farmers of the Young Brahmaputra and Jamuna Floodplain in Bangladesh can be socio-economically benefited through the production of BARI Galdiolus-5 and BARI Galdiolus-4.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Anuradha, S. and Gowdha, J. V. 1994. Correlation studies in Gladiolus. [In: Floriculture Technology, Trades and Trends. (Eds.) Prakash, J. and K. R. Bhandry.] Oxford and IBH Publishing Co. Pvt. Ltd. Calcutta. pp. 285-287.

Azad, A. K., Goshami, B. K., Rahman, M. L., Malaker, P. K., Hasan, M. S. and Rahman, M. H. H. 2017. Krishi Projukti Hatboi (Handbook on Agro-technology), 7th Edition, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh. pp. 321-324.

Azad, A. K., Miaruddin, M., Wahub, M. A., Sheikh, M. H. R., Nag, B. L. and Rahman, H. F. 2020. Krishi Projukti Hatboi (Handbook on Agro-Technology), 9th Edition, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh. pp. 311-312.

Azimi, M. H. and Banijamali, S. M. 2019. Introducing superior cultivars of Gladiolus by important quality and quantity indexes. *J. Ornam. Hortic*. 9(1):33-40.

BMD (Bangladesh Meteorological Department), Dhaka, Bangladesh. 2020. Available: http://www.bmd.gov.bd/

BBS (Bangladesh Bureau of Statistics). 2022. Year Book of Agricultural Statistics of Bangladesh Statistical Yearbook of Bangladesh. 2021. Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Dhaka. p.391.

Bhagaur, H. S. 1989. Studies on variability and genetical component of flowering in exotic varieties of gladiolus. Ph.D. thesis, Kanpur University, Kanpur.

Bhattacharjee, S. and L. C. De. 2005. Postharvest technology of flowers and ornamental plants. Aavishakar Publishers, Jaipur, India. pp.11-19.

Bose, T. K., Yadav, L. P., Pal. P., Das, P. and Parthasarathy, V. A. 2003. Commercial Flowers. 2nd Rev. ed. Nayaprokash, Calcutta, India.

Hossain, M. D., Talukder, K. H., Asaduzzaman, M., Mahmud, F., Amin, N. and Sayed, M. A. 2011. Study on morphological characteristics of different genotypes of gladiolus flower. *J. Sci. Found.* 9(1&2):01-08.

Islam, M. K., Anwar, M., Alam, A. U., Khatun, U. K. and K. A. Ara. 2017. Performance of different Gladiolus varieties under the climatic condition of Tista Meander Flood. *Progress. Agric.* 28(3):198-203.

Kamble, B. S., Reddy, B. S., Gangadharappa, P. M. and Kulkarni, B. S. 2004. Evaluation of gladiolus varieties for quality parameters, flower and corm yields. *Haryana J. Hort. Sci.* 33(1/2):74-75.

Khan, F. N., Rahman, M. M., Karim, A. J. M. S. and Hossain, K. M. 2012. Effects of nitrogen and potassium growth and yield of gladiolus corms. *Bangladesh J. Agric. Res.* 37(4):607-616.

Kishan S., Krishan, P. S. and P. S. Kanwar. 2005. Performance of gladiolus under Delhi conditions. *J. Ornam. Horticul.* 8:32-35.

Kumar, R. 2009. Evation of exotic gladiolus under sub-tropical mid-hills of Meghalaya. *Indian J. Agric. Sci.* 79 (2):115-117.

Lal, S. D. and C. C. Plant. 1989. Some newly developed hybrids of gladiolus. *Progressive Horti*. 21:189-93.

Manjunath Rao, T. and Janakiram, T. 2006. Performance of exotic orchidiolas and IIHR gladiolus cultivars. *Progressive Horticul*. 9:61-62.

Momin, M. A. 2006. Floriculture Survey in Bangladesh. A Consultancy Report. FAO/UNDO (IHNDP/BGD/97/06).

Mushtaq, S., Hafiz, I. A., Arif, M. and Anwar, A. 2018. Performance evaluation of elite gladiolus cultivars under agro climate conditions of Rawalpindi. *Asian J. Agric. Res.* 5(3):1-6.

Nalage, N. A., Haldankar, P. M., Gawankar, M. S. and Rathod, N. G. 2019. Evaluation of different gladiolus varieties (*Gladiolus hybridus* Hort.) under Konkan conditions of Maharashtra. 7(2):2018-2021.

Negi, S. S., Raghava, S. P. S. and Sharma, T. V. R. S. 1982. New cultivars of Gladiolus. *Indian Horti.* 26(4):19-20.

Neha Chopde, R. P., Gawali and T. Seema. 2012. Evaluation of gladiolus varieties for flower and corm production under Vidarbha conditions. *Plant Arch.* 12: 911-913.

Chopde, N., Gawali, R. P. and Seema, T. 2012. Evaluation of gladiolus varieties for flower and corm production under Vidarbha conditions. *Plant Arch.* 12:911-913.

Padma, M. and Kumar, M. R. 2004. Evaluation of gladiolus varieties in high altitude tribal zone of Andhra Pradesh. *Orissa J. Horti.* 32(2):95-98.

Pasha, M. F. K., Ahmad, H. M., Qasim, M. and Javed, I. 2015. Performance evaluation of zinnia cultivars for morphological traits under the agro-climatic conditions of Faisalabad. *European J. Biotechnol. Biosci*. 3(1):35-38.

Pragya, J., Ranjan, K., Attri, B. L., Das, B., Krishna, H. and Ahmed, N. 2010. Performance of gladiolus genotypes for cut flower and corm production under high altitude of Uttarakhand. *Indian J. Hortic*. 67:389-90.

R Core Team, 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Sharma, A. N. and Sharma, S. C. 1984. Some promising Gladiolus hybrids. NAGC Bull., No. 157. pp. 51-52.

Singh, A. K., Sisodia, A., Sisodia, V. and Ray, P. 2017. Performance of Indian and exotic varieties of gladiolus under Eastern UP conditions. *J. Ornam. Hortic.* 20 (3&4):153-157.

Singh, A. K., Kumar, D., Sisodia, A. and Padhi, M. 2018. Varietal Evaluation of Gladiolus for Flowering Attributes Under Indo-Gangetic Plains. *Int. J. Curr. Microbiol. App. Sci.* 7(07):3728-3735.

Singh, A. K., Rakesh Kumar, K. S., Tomar, H. K., Sanjeev, K. and Amit, K. 2020. Evaluation of Gladiolus (*Gladiolus hybridus* Hort.) Varieties for Vegetative and Floral Characters under Bundelkhand Conditions. *Int. J. Curr. Microbiol. App. Sci.* 9(5):2612-2619. doi: https://doi.org/10.20546/ijcmas.2020.905.299

Sultana, N. 2003. Floriculture exports from Bangladesh. A paper presented in international floriculture conference on 6th November, 2003, BARC, Farmgate, Dhaka.

Sumi, M. A., Habib, M. A., Uddin, M. S., Hossain, M. A. and Sharifuzzaman, S. M. 2021. Evaluation of gladiolus genotypes at Akbarpur, Moulvbazar. *Bangladesh J. Agric. Res.* 46(3):321-329.

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PRODUCTION OF DISEASE FREE SEED POTATO TUBER THROUGH OPTIMIZATION OF PLANTING AND HAULM PULLING TIME

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Abstract

The time for planting and haulm pulling is very crucial for production of quality of seed potato tuber. Thus, the different planting times i.e., 15th October, 4th November, 24th November, and 14th December, and haulm pulling (HP) at 68, 75, 82, and 89 days after planting (DAP) were evaluated to find out the suitable planting time and haulm pulling time for disease-free potato seed production. This study was conducted in the research field of the Plant Pathology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during 2016-2017. The maximum seed potato tuber yield (23.9 ton/ha) was recorded from 4th November planting time with haulm pulling at 82 days after planting. The findings also exhibited that the minimum disease infestation was observed in the same treatment combinations which enhanced the maximum photosynthesis and growth for the plants resulting in higher seed potato yield. Farmers of subtropical regions would be benefitted if they practice these methods.

Keywords: Canker, Diseases incidence, Heat injury, Leaf blight, Tuber yield

Introduction

Potato (*Solanum tuberosum*) is one of the most important food crops grown in more than 100 countries in the world. It is the second most important food crop in Bangladesh next to rice; and is mainly used as vegetables that cover 468626 ha of land where total potato production was 9887 million tons (BBS, 2021). It is also a world-leading crop that furnishes an appreciable amount of Vitamin-B and Vitamin-C as well as some minerals. The average yield of potatoes is 20.8 metric tons per hectare which is very low compared to the potato growing countries. Several factors are responsible for such low yield of potatoes in Bangladesh, where quality potato seed tuber is a crucial one and that is dependable on the optimum planting and haulm pulling time. However, the different planting time in various parts of Bangladesh are practiced, consequently showed

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variable yield potentiality of seed potato. Thus, it should be needed to fix the optimum planting time for higher seed potato yield. The planting time affected tuber quality (Haile *et al*., 2015; Alam *et al.*, 2017), and influenced the emergence percentage, vegetative growth, tuber number, and also the yield of potato (Thongam *et al.*, 2017). Likewise, farmers of Bangladesh harvested seed potato at different times which also influence the quality of seed potato. In addition, the key hinders to potato production have been identified as the unavailability of quality and healthy seed potatoes, complexities of disease-free seeds production and distribution, a wide range of pests and diseases, insufficient cold storage facilities for large-scale seeds, resulting in rotting and sprouting and violent price fluctuation (Hoque and Sultana, 2012). So, it is essential to ensure quality seed potato within the farmer's ability. The main reason for the low yield of potato is the use of poor-quality seeds. Only 10% quality seed potato of the total requirement is being supplied by different governments and other private organizations, and the remaining 90% seed requirement is being mitigated by the farmers' retained seed which is usually of poor quality (Siddique *et al.*, 2015). On the contrary, the quality of seed potato is considered to improve farmers' potato yields and income (Eshetu *et al*., 2005; Hirpa *et al.*, 2005). The haulm pulling time regulates tuber size and quality of seed potato/disease pressure (Virtanen and Seppanen, 2014). Early harvesting can be done by haulm pulling which ensures expected tuber size and tuber skins strengthened as to avoids plant pathogens to spread the vegetative and reproductive organs.The haulm pulling is practiced for seed potato production to protect the seed-borne or soil-borne pathogens, such as; viruses, bacteria, and fungi black scurf (*Rhizoctonia solani*), late blight (*Phytophthora infestans)*, gangrene (*Phoma foveata)*, Verticillium wilt (*Verticillium dahliae)* (Kempenaar and Struik, 2008). Moreover, haulm pulling increases the quality of tubers as after haulm pulling, the skin of the tubers becomes hardened (Hoque *et al.,* 2010).

In addition, various diseases are strongly correlated with planting time and haulm pulling time which is responsible for the quality of seed production in Bangladesh with existing climatic factors (Lutfunnahar *et al*., 2020). But the time of planting and haulm pulling can interact with the plant development and tuber size, quality, and yield of potato (Alam *et al.*, 2017). Hence, the most important factors affecting of growth, yield, and quality of tubers are the planting and harvesting time (Nedunchezhihan and Byju, 2005). As such, the management practice like proper planting time and haulm pulling time of potato can ensure good quality seed by escaping different diseases.The planting and haulm pulling time influence the different soil or seed-borne viral, fungal as well as bacterial diseases. Thus, the study was undertaken to determine the optimum planting time and haulm pilling time for quality seed potato production.

Materials and Methods

Experimental site

The experiment was conducted in the research field of the Plant Pathology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during 2016-2017. The experimental site was under AEZ-1 (Old Himalayan

Piedmont plain) under the latitude of 25.7^{0}N and longitude 88.65^0 E with an altitude of 37 m from the sea level. The chemical properties of the initial soil of the study field along with metrological data during the crop growing period have been presented in Table 1 and Fig. 1.

Table 1. Chemical properties of the experimental soil (initial) at the experimental field, HSTU, Dinajpur

	P^H	OM (%)	N (%)	P (µg g^{-1})	K (meq100^{-1} g soil)	S (µg g^{-1})	Zn (µg g^{-1})	B (µg g^{-1})
Field Status	5.19	0.65	0.04	13.69	0.21	13.75	1.12	0.17
Critical level			0.12	10.0	0.12	10.0	0.60	0.20

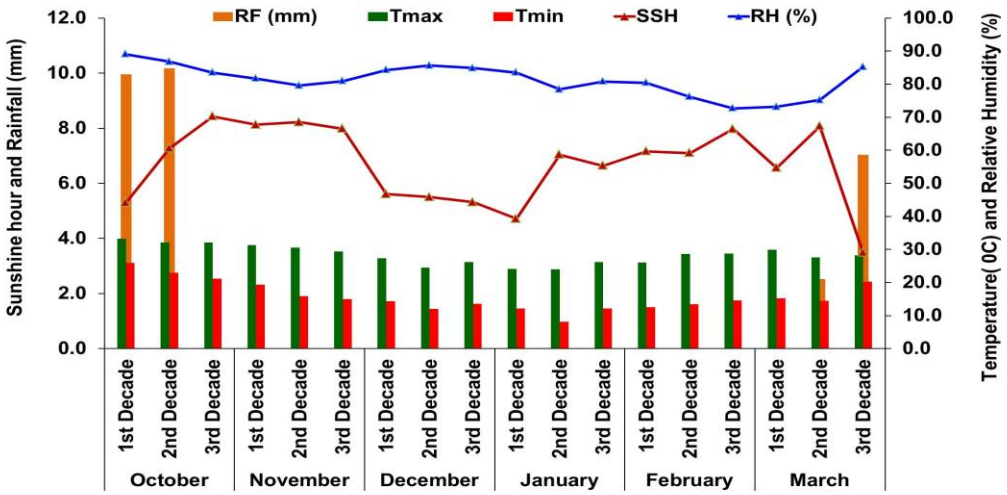

Fig. 1. Decade-wise average maximum temperature, minimum temperature, sunshine hour and rainfall during the cropping period from 2016-2017 at HSTU, Dinajpur

Treatment and design

The experimental design was RCB with two factors (factorial) where the first factor consists of different planting times i.e., i). 15th October, ii). 4th November, iii) 24th November, and iv) 14th December, and the second factor consists of different haulm pulling time i.e., at 68, 75, 82 and 89 DAP. The plant spacing was maintained at 60 cm× 25 cm. The unit plot size was 2.4 m × 3.5 m.

Planting material

The most popular potato variety "Cardinal" was used as a test crop. The saline feature of the test crop are given in below

Developed by	:	Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
Origin	:	The Netherlands
Year of release	:	1993
Main characteristics	:	Tuber: red, oval, medium size, skin smooth, flesh yellow and shallow eye, stem color reddish violet, plant hard and rapidly growing, number of stem lower but wave-like, seed dormancy 50-60 days in general temperature, crop duration 90-95 days, at first sprout initiation round shape, later it will taller, color bright reddish violet and slightly hairy. This variety is cultivated throughout Bangladesh. Farmers themselves can grow seeds.
Planting season	:	Rabi (November).
Yield potentiality	:	25-30 t/ha

Crop management

Fertilizers were applied @ N-P-K-S-Mg-Zn-B as of 90-20-90-10-5-2-0.5 kg ha^{-1} and cowdung @ 5 t ha^{-1}. Half of N and the full dose of other fertilizers were applied as basal doses before final land preparation (BARC, 2012). The rest half of N was side-dressed at 35 DAP. The seed tubers were taken out from the cold storage 10 days before planting and were spread over the floor under diffused light for sprouting. The good-looking, healthy, and well-sprouted whole tubers were used for planting. Planting was done at the depth of 5-7 cm apart with time. Earthing up was done two times, the first was just after planting and the second was at 35 DAP. One weeding was done at 35 DAP. Irrigation was provided thrice times at 10, 35, and 50 DAP. For controlling insect pest (cutworm and aphid), Dursban @ 5 ml per liter of water and Metasystox @ 1 ml per liter of water was applied respectively. The fungicide Mencozeb @ 2.0 mg per liter was sprayed at every 10 days interval from 20 DAP as a routine spray to keep the potato plants free from late blight infection. After taking the aforementioned protection, if the symptoms of late blight diseases were observed, Acrobate HZ 72 @ 2.0 mg per liter and Melody due @ 2.0 mg per liter were used two times at 3 days intervals to control the late blight. The planting and haulm pulling times of the crop were maintained according to the treatments. Ten plants were harvested for the first time from each plot for data collection. The yield was measured on a whole plot basis. The emergence of potato per plot was recorded by eye observation at 20 DAP and 30 DAP. Yield-contributing traits were recorded from five representative plants in each plot. Data were recorded as follows-

i. The leaf area coverage was estimated using the method outlined by Burstall and Harris (1983).

ii. The percent disease incidence of different diseases was recorded by the following formula-

$$\textit{Percent disease incidence of plants} = \frac{Number\ of\ plants\ infected\ by\ disease}{Total\ number\ of\ plants\ observed} \times 100$$

iii. Foliage infection by the late blight (LB) disease was measured according to disease severity 1-9 scale (Rahman *et al.*, 2008) as follows:

Score	% foliage affected	Description
1	0	No disease observed
2	0 .1	0.1% blighted (a few scattered plants are blighted: no more than 1 or spots in a 10-meter radius)
3	1	1% blighted (upto to spots per plant or general light infection)
4	5	5% blighted (about 50 spots per plant: up to 1 in 10 leaflets infected). More than 5% but less than 25%.
5	25	25% blighted (nearly every plant affected, but plants looking normal form) More than 25% but less than 50%.
6	50	50% blighted (every plant affected and about 50% of the leaf area is destroyed) More than 50% but less than 75%.
7	75	75% blighted (every plant affected and about 75% of the leaf area is destroyed) More than 75% but less than 90%.
8	95	95% blighted (only a few leaves on the plant, but stems are green). Only very few green areas leaf (much less 10%)
9	100	100% blighted (all leaves dead, stems dead or drying. Foliage is destroyed.

iv. Present disease index (PDI) was estimated from 16 randomly selected plants from each plot (Rahman *et al.*, 2008):

$$PDI = \frac{Class\ frequency}{No.plants\ assessed \times Highest\ score\ of\ scale} \times 100$$

v. ELISA test

Seed collected from the virus-infected plants were kept separately for ELISA test. DAS-ELISA test was done following the fundamental protocol outlined by Clark and Adams (1977) and modified by Akanda *et al.*, (1991) in the laboratory of Tuber Crop Research Centre (TCRC), BARI, Gazipur. Tubers were graded into four categories

namely oversize (> 55 mm), "B" grade (40-55 mm), "A" grade (28-40 mm), and small size (10-28 mm). The number of infected tubers by Common scab, *Rhizoctonia* canker, or deformed tuber was counted by eye inspection of the tubers at room storage condition.

Disease index and incidence of common scab

The treatments were categorized into different disease reactions according to the disease scale described earlier (Patel, 1991) as given below. The disease rating scale for the common scab of potato was done according to Manthan *et al.*, 2016.

Rating	Description of symptoms
0.0	Healthy tubers
1.0	1-10 percent tuber surface was affected
2.0	11-25 percent tuber surface was affected
3.0	26-50 percent tuber surface was affected
4.0	Above 50 percent tuber surface was affected

The disease index and disease incidence (%) were calculated according to the equations given below

$$\textit{Disease index} = \frac{\textit{Total number of infected tubers} \times \times \textit{Disease rating}}{\textit{Total number of tubers}} \times 100$$

$$\textit{\% Disease incidence} = \frac{\textit{Total number of infected tubers}}{\textit{Total number of tubers}} \times 100$$

Disease index and incidence of *Rhizoctonia* canker of potato

The treatments were categorized into different disease reactions according to the disease scale described earlier (Kulkarni and Chavhan, 2017) as given below.

Disease Rating Scale (*Rhizoctonia* canker): Observations were done by using a 0 – 4 scale and Percent Disease Incidence was calculated (Kulkarni and Chavhan**,** 2017).

0 - Healthy

1 – Up to 25% tuber area affected

2 – 26-50% tuber area affected

3 – 51-75% tuber area affected

4 – More than 75% tuber area affected

The disease index and disease incidence (%) were calculated according to the equations given below.

$$\textit{Disease index of Rhizoctonia canker} = \frac{\textit{Total number of infected tubers} \times \textit{Disease rating}}{\textit{Total number of tubers}}$$

$$\textit{\% Disease incidence of Rhizoctonia canker} = \frac{\textit{Total number of infected tubers}}{\textit{Total number of tubers}} \times 100$$

Estimation of deformed tuber

The percentage of deformed tuber was calculated using the following formula: Deformed tuber (%) = (Number of deformed tubers/Total tuber) x 100.

Statistical analysis

Data were analyzed by using the statistical computer package program, MSTAT-C (Russell, 1986) to find out the levels of significance of the experimental results. Duncan's Multiple Range Test (DMRT) at a 5% level of probability was used for the mean comparison.

Results and Discussion

Effects of planting time on the emergence of potato

Percent seed potato emergence at different dates of data collection differed significantly (Table 2). At 20 DAP, the maximum 88.02% emergence was recorded when the seed potato was planted on 14th December, which was similar to 4th November. The seed potato emergence percentage was increased at 30 DAP. The maximum 100% emergence was recorded at potato planting time of 4th November, 24 November and 14 December, and the minimum 74.48% seed emergence was observed when the potato was planted on 15 October. This happened due to high temperatures along with high soil moisture because of rainfall, which enhanced the rot of seed tubers. These results indicate that the emergence of seed potato had no effect at the planting time of early November to mid-December. Similar results were also reported by Afsana (2018) who recorded a maximum of 99.7% seed emergence at the planting time of 1st November and a minimum of 88.5% at the planting time of 2nd October. Comparatively soil moisture and temperature in November are congenial to potato cultivation in Bangladesh which enhances the emergence and better plant growth. Jamro *et al.,* (2015) establish the maximum of 84.95% emergence of potato at the planting time of 30th October. The earliest planting date of 30th September in Maharastra, India recorded the maximum emergence of potato at 15 and 30 DAP reported by Thongam *et al.,* (2017). Alternatively, the early planting of potato on October 20 delayed emergences was reported by Bewuketun *et al.,* (2015). Alam *et al.,* (2017) stated that from 31 October to 30 November, planting time is suitable for the emergence of seed potato in Bangladesh due to favorable agro-climatic conditions.

Influence of planting time on plant height and stem number per hill

The plant height varied significantly at haulm pulling time (Table 2). The maximum plant height (56.9 cm) was recorded at the planting time of 15th October which was statistically similar to 4th November (52.3 cm) and 24th November (53.5 cm). On the other hand, the minimum plant height (47.3 cm) was observed when data was recorded on 14th December. These differences in plant height might be due to attribute different prevailing weather conditions at various planting times. The most favorable environment remained on 15th October, a long period of high temperature for plant growth during the cropping season. But, the planting time of 14th December gave the lowest plant height (47.2 cm) due to faced lower temperature along with a short growth period which reduced the allocation of assimilates for growth, practiced compared to

other planting dates by the plants after emergence than three planting dates. After mid-February or 50-55 DAP the plants experienced higher temperatures than on other planting dates due to climatic conditions. The results are in line with the findings of Sandhu *et al.*, (2012), Ezekiel and Bhargava (1992), Alam *et al.*, (2017), Afsana (2018), and Monsor (2014).

Table 2. Effect of planting time on vegetative growth of seed potato

Planting time	Emergence at 20 DAP (%)	Emergence at 30 DAP (%)	Plant height (cm) at HP time	Stem per hill (No.) at 30 DAP	Leaf Area Coverage (%) at 60 DAP	Canopy wt/pl (g) at HP
15th October	61.5 (4.33)	74.5 (4.77)	56.9	2.77	61.1 (49.84)	103.7
04th November	79.7 (4.94)	100.0 (5.54)	52.3	5.40	89.5 (69.19)	209.7
24th November	65.1 (4.40)	100.0 (5.54)	53.45	4.67	88.7 (68.22)	164.4
14th December	88.02 (5.19)	100.00 (5.54)	47.25	5.47	83.67 (64.18)	68.9
$LSD_{0.5}$	0.41	0.12	4.9	0.72	5.8	31.2
CV%	10.4	2.82	11.16	18.93	11.08	27.4
LS	**	**	**	**	**	**

LS= Level of significance; *=significant at p=0.05; **significant at p=0.01; Parenthesis indicate the transformed value (1st and 5th column Arcsine, 2nd column Square root).

Effects of planting time on stem number per hill

The results showed that the stem number per hill was influenced by different planting times (Table 2). At 30 DAP the maximum number (5.47) of stem per hill was observed when the seed was sown on 14th December which was similar to seed planting on 4th November. The minimum number (2.77) of stems per hill was counted when the seed was sown on 15th October. The cumulative age of seed tubers was higher at late planting and more desprouting was needed before planting which was responsible for more sprouting and more stem per plant. As per the results of Alam *et al.*, (2017), there was no significant influence on stem per hill by the early to late November dates of planting of potato. The stem number per plant differed based on very early planting time (Mid-October) with other planting times (November to Mid. December), according to Afsana (2018) and Bewuketun *et al.*, (2015).

Effects of planting time on leaf area coverage and canopy weight

Percent leaf area coverage (LAC) varied significantly with different planting times of potato. Regarding 60 DAP, the highest LAC (89.5 %) was found at the planting time of 04th November which was similar to 24th November (88.7%) and 14th December (83.7%). But, the lowest LAC (61.1 %) was found at the planting time of 15th October (Table 2). Comparatively highest plant height with maximum stems per plant is responsible for higher canopy coverage. The different planting times on canopy weight per plant also varied significantly (Table 3). The highest canopy weight (209.7 g) per

plant was recorded from the planting time of 4th November. The lowest canopy weight (68.9 g) per plant was recorded at the planting time of 14th December. The winter season in Bangladesh, mainly from November to early February, was the best environmental condition for proper growth and development of potato, so early November planting time performed better in canopy weight per plant due to finding a longer winter life cycle and can synthesize and accumulate more carbohydrates in the canopy. The result is supported by the finding of Alam *et al*., (2017) and Bahram *et al.*, (2012), who stated that early planting is most suitable for vegetative development and yield of potato.

Effects of different haulm pulling time on leaf area coverage and canopy weight

The different haulm pulling (HP) time on the leaf area coverage (LAC) was significant (Fig. 2). The highest LAC (79.7%) was found in the haulm pulling of 68 DAP which was similar to the haulm pulling of 75 DAP and followed the haulm pulling of 82 DAP. The lowest LAC (40.8 %) was found in the haulm pulling of 89 DAP. Delaying haulm pulling time decreases the LAC of potato after the vegetative stage or from the maturity stage the plants are dried and weathered day by day. Moreover, the effect of haulm pulling times on the canopy weight per plant also varied significantly (Fig. 2). The highest weight (181.8 g) of canopy per plant was counted from the haulm pulling time of 75 DAP which was similar to 68 DAP and followed 82 DAP. The lowest weight (60.3 g) of canopy per plant was found from the haulm pulling of 89 DAP. Higher leaf area coverage may cause higher canopy weight, which is regulated by plant height and branch number per plant. Delaying haulm pulling time reduces the water content, defoliates the leaves and stems, and may transfer the starch contents to tubers and decrease the canopy weight. This result is supported by the findings of Thongam *et al.*, (2017), Alam *et al.*, (2017), and Jamro *et al.*, (2015), who stated that ground coverage is related to the plant height and leaves number per plant.

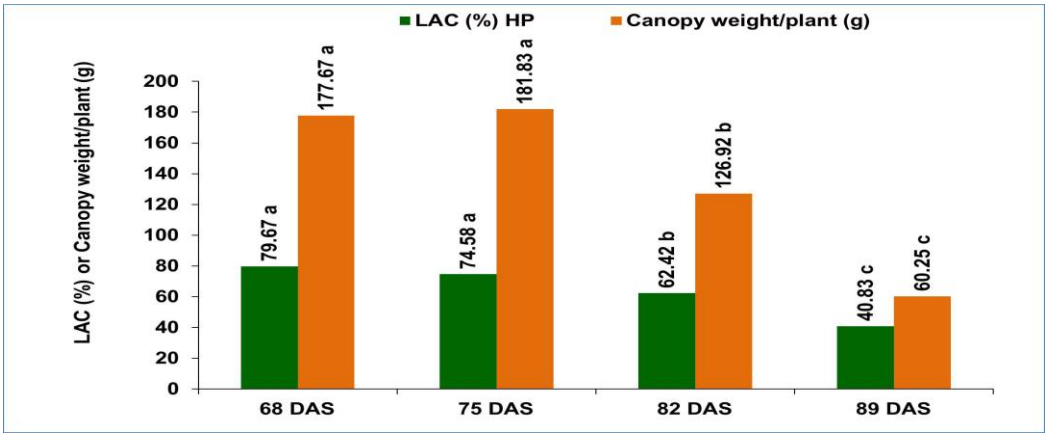

Fig. 2. Effects of different haulm pulling (HP) time on LAC and canopy weight of the potato

Effects of planting time on late blight of potato

Late blight (LB) of potatoes was observed in 1st week of January 2017 due to the presence of low temperatures and foggy weather (Table 3). The data revealed that different planting times on natural LB development on 05 January 2017 varied significantly among the observations. Maximum late blight infestation (2.90%) and LB severity i.e. PDI (21.81) was recorded in the planting time of 24th November while planting time of 14th December had significantly less amount of late blight infestation (0.29%) and LB severity or PDI (13.09). The highest (21.81) PDI was recorded at the planting time on 24th November. On 5th January, plants were at the growth stage of 82, 62, 42, and 22 days in respect of chronological different planting times. The highest infection percent and PDI of late blight were found at the planting time of 24th November which was followed by 4th November and 14th December. The lowest infection percent and PDI of late blight were recorded at the planting time of 15th October. On 18th January 2017, the highest LB infestation and PDI were also recorded at planting time of 24th November. On the other hand, the lowest LB infestation and PDI were also recorded at the planting time of 15th October (Table 3). The late planting showed the first appearance of late blight and rapid progress of late blight. The results conform to the findings of Afsana (2018) and Singh and Pundhir (2012) who stated that different planting times influence the late blight development of potato.

Effects of planting time on disease and heat injury

The effect of different planting times on the naturally occurring potato leaf roll virus (PRLV) was significant at only haulm pulling time. The maximum percentage (4.17%) of PLRV was identified at the 4th of November planting time which was similar to the 15th of October. The minimum percentage (0.52 %) of PLRV was identified on 14th December. In the case of potato mosaic virus (PMV) at 45 DAP, there were significant variations. The maximum percentage (2.60%) of PMV was identified on the 24th of November planting time which was followed by the 4th of November. At haulm pulling time, the highest percentage (9.38%) of PMV-affected plants was counted from 24th November which was followed by 14th December. In the case of potato virus Y (PVY), at 60 DAP, the maximum infected plants (2.08%) of PVY were identified from 24th November planting time which was followed by 4th November. But, at haulm pulling time, the highest percentage (1.04%) of PVY-affected plants was counted from 4th November (Fig. 3). Delaying the planting time of potato in Bangladesh, ensure climate warmth in the vegetative stage of potato and increase the potato virus disease due to vector (aphid) spread in the field. These results are in agreement with the finding of Monsor (2014), Rahman and Akanda (2010), Halim (1999), and Afsana (2018).

Table 3. Effect of different planting times on late blight (LB) development

Planting time	05 January 2017		11 January 2017		18 January 2017	
	% LB	PDI	% LB	PDI	% Disease	PDI
15th October	0.46 (1.07)	13.74	0.42 (1.04)	13.41	0.00 (0.84)	12.50
04th November	1.29 (1.40)	17.25	1.74 (1.52)	17.97	1.54(1.39)	17.58
24th November	2.90 (1.88)	21.81	3.08 (1.94)	25.13	6.25 (2.63)	30.47
14th December	0.29 (0.99)	13.09	1.68 (1.53)	16.60	1.87(1.58)	17.64
$LSD_{0.5}$	0.15	1.30	0.28	2.01	0.39	4.59
CV%	13.58	9.43	11.18	13.19	14.58	14.1
LS	***	***	***	***	***	***

LS= Level of significance; ***significant at p=0.001; parenthesis indicate transformed value

The incidence of bacterial wilt of potato plants varied significantly in different planting times observed (Fig. 3). The 14th December planting time performed the highest (47.92%) bacterial wilt-infected plant at Haulm pulling time. But the minimum (4.17%) wilt incidence was observed when the seed was sown on 15th October. The effect of different planting times on the Heat injury varied significantly. Only at the planting time of 14th December showed heat injury (Fig. 3). Daley planting time, mid-December, increase the wilt and heat injury due to warmed weather from the 2nd week of February when the plants were at the vegetative stage (55 DAP). Struik (2007) stated that temperatures higher than 25°C can enhance stem growth and branching, and increase the leaf number, but cause a reduction in leaf size and total leaf area. These results are also supported by the findings of Wahid *et al.,* (2007) and Rykaczewska, (2013).

Effects of haulm pulling time on disease and heat injury

The effect of different haulm pulling times on the naturally occurring PRLV, PMV, and PVY was significant (Fig. 4). The maximum infected plants ((PRLV 3.13%, PMV 4.69%, and PVY 2.6 %) were recorded from late haulm pulling (89/82 DAP) and the minimum infected plants (PRLV 1.56%, and PVY 0 %) were recorded from early haulm pulling (68 DAP). Increasing haulm pulling time, the vectors ensure more time for spreading which increases the viral diseases. These results are in agreement with the finding of Monsor (2014).

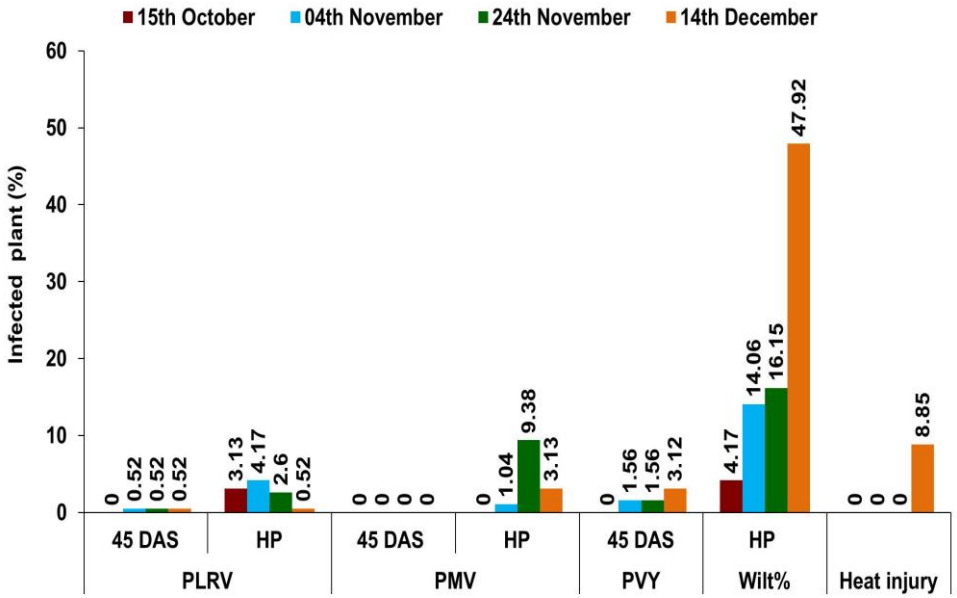

Fig. 3. Effects of different planting times on PLRV, PMV, PVY, wilt and Heat Injury

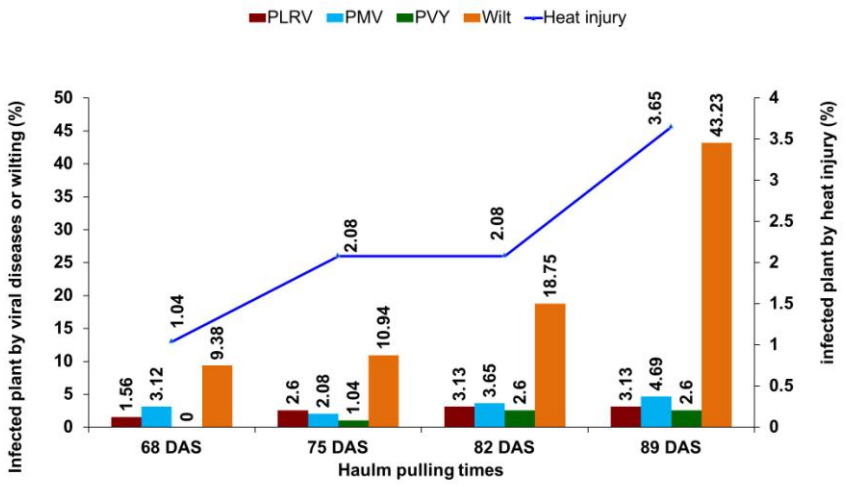

Fig. 4. Effects of haulm pulling time on PLRV, PMV, PVY, wilt, and heat injury of potato

The incidence of bacterial wilt of potato plants varied significantly in different Haulm pulling times (Fig.4). The highest (43.23 %) bacterial wilt infected plant was found in late Haulm pulling at 89 DAP, which is similar to at haulm pulling time 82 DAP. Minimum (9.38%) plants were wilted when haulm pulling early (68 DAP or 75 DAP). If haulm pulling is delayed, the temperature is increased which enhances microbial activities. So the incidence of wilting is enhanced. The result is supported by the finding

of Karan YB (2021) and Anonymous (2017) where it was stated that moist and warm environments are encouraging the development of bacterial wilt disease, which depends on species, age, and resistance of the host and environmental conditions. According to Anonymous (2017), Bacterial wilt disease development is favored by warm temperatures (25°C-30°C) and low temperatures (10°C), and the bacterium cannot survive in dry soil conditions.

Different haulm pulling times significantly varied the heat injury of potato specially planted on 14th December. The maximum (3.65%) plants were injured by heat at the time of haulm pulling 89 DAP which was similar to 82, 75 DAP. The minimum (1.04%) plants were injured by heat at the time of haulm pulling 68 DAP (Fig. 4). From the last week of January, the temperature increased rapidly which directly affect the development of crops of mid-December planting time. These results are corroborated by the finding of Wahid *et al.,* (2007) and Rykaczewska, (2013). According to Wahid *et al.,* (2007), an array of morpho-anatomical, physiological, and biochemical changes in plants are caused by transitory or constant a high temperatures, which affects the plant growth and development reducing the economic yield. According to Rykaczewska (2013), the response of potato plants to high temperatures during the growing season is related to the growth stage. For the growth and yield of potato, the impact of high temperatures of 32˚C/25˚C on potato plants was more negative.

Effects of planting times on yield and yield component of potato

The different planting times significantly affected the total tuber number and weight per plant, seed-tuber number and weight per plant, potato yield, and seed-potato yield (Table 4). The maximum tuber number (11.07) was counted from the late planting time i.e. 14th December which was followed by 4th November and the minimum number (7.33) of tuber was found on 24th November. The highest number of seed tubers per plant (7.65) was recorded from the planting time of 14th December which was similar to 4th November (6.92) and followed by 24th November (5.93). The lowest number of seed tubers per plant (4.63) was collected on the 15th of October. In the case of the planting on 14th December, the seed tubers were collected 20 days before planting time. So the collected seeds were de-sprouted one time before final sprouting. For this reason, the stem number per plant and the tuber number per hill were increased. The maximum weights (400.23 g) of total tuber per plant were recorded from the planting time of 4th November which was similar to the planting time of 24th November. The minimum weight (332.07 g) of the tuber was observed during the planting time of 15th October which was similar to the planting time of 14th December. A similar trend of results also counted at potato yield. The maximum potato yield (24.28 ton/ha) was recorded from 4th November which was identical to 24th November. The lowest yield (15.31 ton /ha) was recorded from the planting time of 15th October. Considering seed (28-55 mm size tuber) potato per plant, significant variation was also found in different planting times. The highest weight (342.77 g) per plant was recorded from 4th November which was similar to 24th November. The minimum weight (217.77 g) was counted from 15th October (Table 4). These results are consistence with many workers (Thongam *et al.,* (2017),

Alam *et al.,* (2017), Monsor (2014), Sajeda *et al.,* (2013), Bahram *et al.,* (2012), Hasanpanah *et al.,* (2009), Kawakami *et al.,* (2005) and Iritani *et al.,* (1983)) reported that different planting dates influenced tuber number and yield of potato.

Effects of haulm pulling times on yield and yield component of potato

In the case of the total number of tuber per plant, the highest number (9.78) was found in 82 DAP which was similar to 75 and 89 DAP. The minimum number (8.15) of total seed tuber was recorded from the haulm pulling time of 68 DAP due to less formation of tubers (Table 4). The results are corroborated by Alam *et al.,* (2017), Monsur (2014), and Bahram *et al.,* (2012), who found that harvesting dates influenced tuber number per plant significantly. The maximum weight (385.20 g) of total tuber was recorded from the haulm pulling time at 82 DAP which was statistically similar to 75 and 89 DAP. The minimum weight (285.80 g) of the tuber was observed from the haulm pulling at 68 DAP. The maximum potato yield (22.02 ton ha^{-1}) was recorded from the haulm pulling at 89 DAP which was similar to haulm pulling at 82 and 75 DAP. The lowest yield (17.45 tons/ha) was recorded from haulm pulling at 68 DAP. The maximum seed yield (18.41 ton ha^{-1}) was recorded from haulm pulling at 82 DAP which was similar to haulm pulling at 89 and 75 DAP. The lowest yield (15.94 ton ha^{-1}) was recorded from haulm pulling at 68 DAP (Table 4). The potato plants matured at 75 DAP after that the carbohydrate accumulation rate decreased. The earlier study reported that harvesting dates influenced the yield of potato (Alam *et al.,* 2017; Jamro *et al.,* 2015; Monsor 2014; Sandhu *et al.,* 2012; Bahram *et al.,* 2012; Virtanen and Seppanen 2014 and Hussain 1992.

Effects of different planting times on the grading of potato

The smallest-sized (10 - 28 mm) tuber weight was not varied significantly, but the tuber number was different among the treatments of different planting times (Table 5). The maximum smallest tuber number per plant (3.42) was produced from the planting time of 14th December which was statistically different from the other three dates of planting times. Considering 28 - 40 mm or A grade tuber per plant, it was statistically significant among different treatments both weight and number basis. The highest weight (201.55 g) and number 5.95 of "A" grade tuber were counted from 14th December which was followed by the planting time of 4th November and 24th November. The lowest weight (73.82 g) and number (2.25) of "A" grade tubers were recorded from the planting time of 15th October. Regarding "B" grade (40 -55 mm) tuber production, maximum weight (218.5 g) and number (2.82) of "B" grade tubers were produced from the planting time of 4th November which was statistically similar to the planting time of 15th October and 24th November. In the case of size (> 55 mm) tuber, the largest weight (45.7) and number (0.30) of tubers were recorded from the planting time of 15th October and no sized tubers were found in the planting time of 14th December (Table 5). The grades of potato depend on the duration of their life span, which is influenced by different planting times (Monsur, 2014).

Table 4. Effect of planting and haulm pulling times on yield and yield component of potato

Treatment	Tubers /plant	Seeds/ plant	Tuber wt/plant	Seed weight/plant (g)	Yield (ton ha^{-1})	Seed Yield(ton ha^{-1})
Planting time						
15th October	7.33	4.63	332.07	271.77	15.31	12.32
04th November	9.70	6.92	400.23	342.77	24.28	20.85
24th November	8.27	5.93	358.10	315.58	24.28	21.51
14th December	11.07	7.65	332.88	303.23	17.38	15.85
$LSD_{0.5}$	1.15	NS	44.78	39.80	3.92	1.99
CV(%)	15.21	16.9	15.09	15.48	11.56	13.52
LS	***		**	**	***	***
Haulm pulling time						
68 DAP	8.15	4.63	285.80	260.87	17.45	15.94
75 DAP	9.13	6.92	376.27	337.18	20.19	18.11
82 DAP	9.78	5.93	385.20	325.85	21.59	18.41
89 DAP	9.30	7.65	376.02	309.45	22.02	18.07
$LSD_{0.5}$	1.15	0.89	44.78	39.80	3.92	1.99
CV(%)	15.21	16.9	15.09	15.48	11.56	13.52
LS	*		***	**	***	*
Planting times × Haulm pulling Time						
$LSD_{0.05}$	4.21	NS	163.45	NS	7.15	7.25
CV%	15.21	16.9	15.09	15.48	11.56	13.52
LS	-	NS	-	NS	**	-

LS= Level of significance; NS= Non significant; *significant at p=0.05; **significant at p=0.01; ***significant at p=0.001

Effects of different haulm pulling time on the grading of potato

The effect of different haulm pulling times on "B" grade (40 - 55 mm) tuber and oversize (< 55mm) tuber per plant varied significantly (Table 5). Haulm pulling at 75, 82, and 89 DAP produced the higher weight (205.3, 208.6, 182.3 g) and number (2.65, 2.60, and 2.50) of "B" grade tuber respectively. The lowest weight (192.6 g) and number (1.72) of "B" grade tubers were recorded from the haulm pulling time of 68 DAP. Moreover, maximum weight (45.65 g) and number (0.32) of size tubers were recorded from the haulm pulling time of 89 DAP. The lowest tuber weight (4.10 g) and number (0.03) per plant of size seed tubers were collected from the haulm pulling time of 68 DAP. The grades of potato are influenced by different haulm pulling time, which affects the tuber formation (Alam *et al.,* 2017 Monsor 2014).

Table 5. Effects of different planting time and haulm pulling time on the grading of potato

Treatments	10-28 mm (below size) tuber plant^{-1}		28-40 mm (A grade) tuber plant^{-1}		40-55 mm (B grade) tuber plant^{-1}		> 55mm (Oversize) tuber plant^{-1}	
	Wt.(g)	Number	Wt.(g)	Number	Wt.(g)	Number	Wt.(g)	Number
Planting times								
15th October	14.6	2.40	73.8	2.25	198.0	2.38	45.7	0.30
04th November	40.2	2.65	124.3	4.10	218.5	2.82	17.2	0.13
24th November	19.1	2.18	107.8	3.37	207.8	2.57	23.5	0.15
14th December	29.7	3.42	201.6	5.95	101.7	1.70	0.0	0.00
$LSD_{0.5}$	37.83	0.88	27.21	0.89	36.31	0.46	23.74	0.14
CV (%)	101.20	39.49	25.72	27.4	24.00	23.19	131.82	112.56
LS	NS	*	**	**	***	***	**	***
Haulm pulling Time								
68 DAP	20.8	2.37	131.3	4.03	129.6	1.72	4.1	0.03
75 DAP	34.3	2.55	131.9	3.90	205.3	2.65	4.8	0.03
82 DAP	27.5	3.17	117.2	3.82	208.6	2.60	31.8	0.20
89 DAP	20.9	2.57	127.2	3.92	182.3	2.50	45.7	0.32
LSD.5	37.83	0.88	NS	NS	36.31	0.46	23.74	0.14
CV(%)	101.20	39.49	25.72	27.4	24.00	23.19	131.82	112.56
LS	NS	NS	NS	NS	***	***	****	***
Planting times × Haulm pulling Time								
$LSD_{0.05}$	43.69	1.75	99.30	3.27	132.533	1.6702	86.64	0.50
CV%	101.20	39.49	25.72	27.4	24.00	23.19	131.82	112.56
LS	NS	NS	NS	NS	NS	NS	NS	NS

LS= Level of significance; NS= Non significant; *significant at p=0.05; **significant at p=0.01; ***significant at p=0.001

Effects of planting times on tuber's common scab and *Rhizoctonia* canker

A significant effect on the common scab of potato was found at different planting times (Table 6). The disease incidence (25.16%) and PDI (Percent Disease Index) (42.55) of common scabs were highest in the field of planting time 15th October and the lowest incidence percentage (10.06) and PDI (13.03) of common scabs was in planting time 14th December (Table 6). From the result, it was revealed that delayed planting time decreases the common scab of potato. Delayed planting time faced comparatively low temperatures from seedling to vegetative stage and got high temperatures from mid-February to onward (tuber development stage) than early planting, which may cause a low infestation of common scab. The results are just altering the results of Waterer (2002), who noticed that the yields and grade-out of potato tuber were influenced by the planting and haulm

pulling times due to tuber damage by common scab (*Streptomyces* spp.). The relatively high temperature (25-30°C) is suitable for the growth of *S. scabies*is, and more severe losses are done by a scab in warm regions or growing seasons (Hooker 1981; Loria *et al.,* 1997). Appropriate planting of potato reduces the crop's exposure to temperatures suited to the growth of the scab lesions and may decrease crop losses, which does not excessively hamper crop productivity.

Table 6. Effect of planting time and haulm pulling time on common scab and *Rhizoctonia* canker of potato

Treatments	Common scab		*Rhizoctonia* canker	
	% Disease incidence	PDI (% Disease Index)	% Disease incidence	PDI (%Disease Index)
Planting time				
15th October	25.16(4.97)	42.55(6.41)	21.11(4.46)	0.49
04th November	19.24(4.22)	32.98(5.24)	9.17(2.95)	0.13
24th November	14.37(3.84)	22.36(4.63)	9.73(3.10)	0.17
14th December	10.06(3.15)	13.03(3.46)	5.21(2.29)	0.06
$LSD_{0.5}$	0.87	1.51	0.7643	0.3139
CV(%)	25.65	36.71	28.66	88.15
LS	**	**	***	***
Haulm pulling time				
68 DAP	14.76	20.82	7.81(2.66)	0.11
75 DAP	15.88	27.88	7.96(2.83)	0.09
82 DAP	20.42	30.35	13.56(3.62)	0.25
89 DAP	17.77	31.86	15.88(3.69)	0.41
LSD.5	0.87	1.51	0.7643	0.3139
CV(%)	25.65	36.71	28.66	88.15
LS	NS	NS	NS	*
Planting time× Haulm pulling time				
$LSD_{0.05}$	3.1574	3.02	2.7898	0.5729
CV%	25.65	36.71	28.66	88.15
LS	NS	NS	NS	***

LS= Level of significance; NS= Non significant; *significant at p=0.05; **significant at p=0.01; ***significant at p=0.00

The statistical difference was found in the effect of different planting times on *Rhizoctonia* canker on tubers. The maximum disease incidence (21.11) percentage and PDI (0.49) of *Rhizoctonia* canker potato was in the planting time 15th of October and the minimum disease incidence (5.21) percentage and PDI (0.06) of *Rhizoctonia* canker of potato was in planting time 14th December (Table 6). Early planting increases the *Rhizoctonia* canker on tubers. The suitable temperature for *Rhizoctonia* canker is below 10˚C and above 24˚C (Mulder and Turkensteen, 2005). Moreover, the Expansion of

these diseases is favored by soil temperatures between 16 to 23°C, while the severity of canker is reduced by soil temperatures above 25°C reported by Anderson (1982).

Effects of different haulm pulling time on common scab and *Rhizoctonia* canker

There was no significant effect among the treatments of different haulm pulling times on the case of common scab, but *Rhizoctonia* canker of potato (Table 6). The maximum % disease incidence (20.42) and PDI (30.35) of common scab on tubers were counted from the seeds of the haulm pulling at 82 DAP. The minimum % disease incidence (7.81) and PDI (0.11) of Rhizoctonia canker on tubers were counted from the seeds of the haulm pulling at 68 DAP. Delay haulm pulling increases the *Rhizoctonia* canker incidence of the tuber. These results are supported by Mulder *et al.,* (1992); Lootsma and Scholte, (1996), and Kumar *et al.*, (2017), who opined that Green-crop-harvesting and immature-crop-harvesting, i.e., early haulm pulling often result in low levels of infection of *Rhizoctonia* canker.

Conclusion

From the above results, it may be concluded that for quality seed potato cultivation, planting and haulm pulling time is very important for seed tuber and tuber production of potato. The 1st week of November is the best planting time and 75 - 82 days after planting is the best haulm pulling time for seed potato production in Bangladesh due to the lowest disease infestation and the maximum yield of potato.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Afsana. 2018. Disease free potato production through cultural management. MS Thesis, Plant Patho. Dept., HSTU, Dinajpur, p. 36.

Akanda, M. A. M., Tsuno, K. and Wakimoto, S. 1991. Serological detection of four plant viruses in cucurvitaceous crops from Bangladesh. *Phytopath. Soc. Japan.* 57:499-505.

Alam, M. S., N. Islam, M. J. and Hossain, M. S. R. Bhuiyan, M. I. Hossain. 2017. Effect of varied planting time and dehaulming on the yield potential, processing quality and economic benefit in potato. *Bangladesh J. Agril. Res.* 42(2):273-288.

Anderson, N. A. 1982. The genetics and pathology of *Rhizoctonia-solani*. *Ann. Rev. of Phytopath.* 20:329-347.

Bahram, D., A., Ahani, J. Y. and Ghasemi, K. 2012. The effect of planting and harvesting dates on yield and vegetative growth of two potato cultivars in Ardabil region. *Int. J. Agron. Plant Prod.* 3(S):675-678.

BARC. 2012. Fertilizer recommendation guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka,-1215. p. 110.

BBS (Bangladesh Bureau of Statistics). 2021. Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of the Peoples Republic of Bangladesh, Dhaka. p. 143.

Bewuketun, H., Ali, M. and W. Gebremedhin. 2015. Effect of planting date on growth and tuber yield of potato (*Solanum tuberosum* L.) varieties at Anderacha district, Southwestern Ethiopia. *Int. J. Res. Agril. Sci.* 2(6):272-280.

Burstall, L. and Harris, P. M. 1983. Estimation of percentage light interception from leaf area index and percentage ground cover in potatoes. *J. Agril. Sci. Cambridge*. 100:241-244.

Clark, M. F. and Adams, A. N. 1977. Characteristics of the Microplate Method of ELISA for the detection of Plant viruses. *J. Gen. Virol.* 34(3):475-483.

Eshetu, M., Ibrahim, O. E. and B. Etenesh. 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. *J. New Seeds*. 7(3):31–56.

Ezekiel, E. and Bhargava, S. C. 1992. Physiological analysis of growth of potato in relation to planting date. *Indian J. Plant Physiol.* 35(1):56-63.

Getachew, T. and Mela, A. 2000. The role of SHDI in potato seed production in Ethiopia: Experience from Alemaya integrated rural development project. *In*: Adipala E, Nampala P, Osiru, M (eds) Proceedings of the 5th Triennial Congress of the African Potato Association, Kampala, Uganda. pp. 415-419.

Haile, B., Mohammed, A. and G. Woldegiorgis. 2015. Effect of planting date on growth and tuber yield of potato (*Solanum tuberosum* L.) varieties at Anderacha district, Southwestern Ethiopia. *Int. J. Agril. Sci*. 2(6):272-280.

Halim, M. A. 1999. Serodiagnosis of PLRV and PVY from certified potato seed and their impact on yield. M. S. Thesis, Department of plant pathology, Bangladesh Sheikh Mujibur Rahman Agril. Univ., Gazipur, p.6.

Hassanpanah, D., Hosienzadeh, A. A. and N. Allahyari. 2009. Evaluation of planting date effects on yield and yield components of Savalan and Agria cultivars in Ardabil region. *J. Food, Agri. & Environ.* 7(3&4):525-528.

Hipra, T. 2005. Effect of plant population and harvesting time on growth and dry matter production of potato (*Solanum tuberosum* L.), *Ethiopion J. Bio. Sci.* 4(1):1-9.

Hoque, M. A. and Sultana, M. S. 2012. Disease free seed potato production through seed plot technique at famers' level in Bangladesh. *J. Plant Protect. Sci*. 4(2):5l-56.

Hoque, M. A., Mahmud, A. A., M. S., Hossain, M. and Bhuyan, M. A. J. 2010. Home Storage of Potato in Natural Condition (In Bengali). Tuber Crops Research Sub Centre, BARI, Munshiganj and KGF, Dhaka. pp.1-14.

Hooker, W. J. 1981. Compendium of potato diseases.American Phytopathological Society, St. Paul, Minnesota, United State of America.

Hussain, M. M. 1992. Studies on production of seed potatoes in relation to variety and production practices, PhD Thesis. Department of Horticulture, Bangladesh Agricultural University, Mymensingh. pp. 150-152.

Iritani, W. M., Weller, L. D. and Knowles, M. R. 1983. Relationship between stem numbers, tuber set and yield of Russet Burbank Potatoes. *Am. Potato J.* 60:423-431.

Jamro, M. M. R., Tunio, S. D., Buriro, U. A. and Chachar, Q. D. 2015. Effect of planting dates on growth and yield of true potato seed (TPS) in Nursery Raising Approach, *J. Basic & Appl. Sci.*11:318-322.

Karan, Y. B. 2021. The impact of haulm killing on yield and quality of potato (*Solanum tuberosum* L.). *PLOS ONE*. 16(8):e0255536.

Kawakami, J., Iwama, K. and Jitsuyama, Y. 2005. Effect of planting date on the growth and yield of two potato cultivars grown from micro-tubers and conventional seed tubers. *Plant Prod. Sci.* 8(1):74-78.

Kempenaar, C. and Struik, P. C. 2008. Haulm killing. *Potato Res.* 50:341-345.

Kulkarni, S. and Chavhan, T. 2017. Management of black scurf disease caused by Rhizoctonia solani kuhn through research and farmers participatory trials in major potato growing regions of Northern Karnataka. *Int. J. Agril. Innov. Res.* 6 (1):138-142.

Kumar, M., Singh, J. K., Kumar, S. and Kumar, A. 2017. A comprehensive overview on black scurf of potato. *Int. J. Curr. Microbiol. App. Sci*. 6(10):4981-4994.

Lootsma, M. and Scholte, K. 1996. Effects of soil disinfection and potato harvesting methods on stem infection by Rhizoctonia solani Kühn in the following year. *Potato Res*.39:15-22.

Loria, R., Bukhalid, R. A., Fry, B. A. and King, R. R. 1997. Plant pathogenicity in the genus Streptomyces. *Plant Dis.* 81: 836–846.

Lutfunnahar, M. F., Hossain, M. A., Malek, R. and Kamrunnahar, J. H. 2020. Planting time effect on quality seed production of three varieties of carrot (Daucus carota L.). *Bangladesh Agron. J.* 23(2):23-34

Manthan, K., Darshan, D., Tarun, K., Hitesh, J., Chaudhari, S. M. and Chauhan, R. M. 2016. Evaluation of Indian potato (Solanum tuberosum L.) germplasms against common scab caused by *Streptomycess cabbies. Int. J. Agri. Sci.* 8(19):1336-1338.

Monsor, A. B. M. G. 2014. Integrated management practices for quality seed potato production of variety diamond and their effect on storage. A Thesis of PhD. Department of seed science and technology. Bangladesh Agricultural University. Mymensingh, Bangladesh

Mulder, A., Turkensteen, L. J. and A. Bouman. 1992. Perspectives of green-crop harvesting to control soil-borne and storage diseases of seed potatoes. *Netherlands J. Plant Path.* 98 (2):103-114.

Nedunchezhihan, M. and Byju, G. 2005. Effect of planting season on growth and yield of sweet potato (*Ipomoea batatas* I.). *J. root crops.* 31(2):111-114.

Rahman, M. S. and Akanda, A. M. 2010. Effect of PLRV infected seed tuber on disease incidence, plant growth and yield parameters of potato. *Bangladesh J. Agril. Res.* 35(3):359-366.

Rahman, M. M., Dey, T. K., Ali, M. A., Khalequzzaman, K. M. and Hussain, M. A. 2008. Control of late blight disease of potato by using new fungicides. *Int. J. Sustain. Crop Prod*. 3(2):10-15.

Russell, D. F. 1986. MSTAT-C Pakage Programme. Crop and Soil Science Department, Michigan University, USA.

Rykaczewska, K. 2013.The Impact of High Temperature during Growing Season on Potato Cultivars with Different Response to Environmental Stresses. *Am. J. Pl. Sci.* 4:2386-2393.

Sandhu, K. S., Chinna, G. S., Marwaha, R. S., Pandey, S. K., Kumar, P. and Singh, R. K. 2012. Effect of staggered planting and dehaulming schedule on yield and processing quality of potato cultivars in Punjab. *Potato J.* 39(1):39-47.

Sajeda, A., Islam, M. M., Azad, M. A. K., Hakim, M. A., Alam, M. S. and Rahman, M.W. 2013. Effect of planting time and variety on the yield and processing quality of potato. *J. Food Agric. & Environ.* 11(1):461-465.

Siddique, M. N. A., Sultana, J., Huda, M. S., Abdullah, M. R. and Chowdury, M. A. 2015. Potato production and management with preference to seed potato supplychain, Certification and Actors Involve in Bangladesh. *J. Busin. Manage. Soci. Res.* 1(1):01-13.

Singh, V. K. and Pundhir, V. S. 2012. Effect of date of planting on potato late blight development and tuber yield. *Pantnagar J. Res*. 10(1):31-34.

Struik, P. C. 2007. Responses of the potato plant to temperature. In: Vreugdenhil D, ed. Potato biology and biotechnology: Advances and Perspectives. Oxford, Amsterdam. Elsevier pp. 367-393.

Tindimubona, S., Kakuhenzire, R., Hakiza, J. J., Wagoire, W. W. and Beinamaryo, J. 2000. Informal production and dissemination of quality seed potato in Uganda. In: Adipala E, Nampala P, Osiru, M (Eds) Proceedings of the 5th Triennial Congress of the African Potato Association, Kampala, Uganda. pp. 99-104.

Thongam, B., Kadam, A. S., Singh, A. A. and Singh, Y. H. 2017. Influence of planting dates on growth and yield of potato (Solanum tuberosum L.). *J. Pharmacognosy and Phytochem.* 6(6):1243-1246.

Virtanen, E., M. Seppänen. 2014. Effects of haulm killing on seed potato quality. *J. Agril. Sci.* 6(3):168-175.

Wahid, A., S. Gelani, M. Ashraf, M. R. Foolad. 2007. “Heat Tolerance in Plants: An Overview. *Envir and Exp Bot.* 61(3):199-223.

Waterer, D. 2002. Management of common scab of potato using planting and harvest dates. *Can. J. Plant Sci.* 82:185-189.

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EVALUATION OF DIFFERENT FIELD TREATMENTS ON SEED AND SEEDLING QUALITY OF ONION AGAINST PURPLE BLOTCH DISEASE

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Abstract

An investigation was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to evaluate the effect of some field treatments' on seed and seedling quality of onion. From the 16 treatment integrations, the harvested seeds were significantly varied in terms of seed germination, seedling vigor, Zinc & Boron content, and the presence of pathogenic microorganism in onion seed. Treatment T_{11} (Score 250 EC+Poultry waste) and T_8 (Rovral+Poultry waste) showed significantly the highest seed germination of 99.50%, 99% and vigor index of 1592 & 1438; respectively. The Zn and B contents in seed were found to be increased in the seed produced from the integrated treatment where micronutrient was applied. The T_9 treatment (Rovral + Zn+B) and T_{12} (Score 250 EC + Zn+B) showed the best result in respect of Zn and B contents. No pathogenic microorganisms were found in treatment T_{11} (Score 250 EC+Poultry waste) and T_8 (Rovral+Poultry waste) which was statistically significant over T_1 (Rovral 50 WP), T_2 (Score 250 EC), T_3 (Alamanda), T_7 (Rovral + Bioagent) and T_9 (Rovral + Zn+B).

Keywords: Boron**,** Chemical fungicides, Seed health, Vigor index, Zinc

Introduction

Among the main spice crops, onion (*Allium cepa*) is one of the most essential spiecs in Bangladesh. It is used as a salad while it's stalk becomes green as well. The leaves of an onion and it's stem are full of Vitamin C and Calcium. Onion is mainly grown in Rabi (winter) season and harvested in the spring or early summer. China is the largest onion producer in the world with 26% and India produces 21% while Bangladesh produces 2% of world production yearly (Quaiyum, 2020). Bangladesh made a place on the list of top ten onion-producing countries in the world four years ago. Farmers use their own produced seed, local quality seeds, improved seed, and HYV and Hybrid seeds returning the different size of the onion bulb. Seeds were required about 1245 MT to cultivate 4,40,000 acres of land in 2018-19 (Quaiyum, 2020). It is known that 90% seeds are produced by the farmers and the rest by BADC along with other Private

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Companies (Quaiyum, 2020). Thus, a deficit of onion bulbs for consumption and a huge amount of onion seed for bulb production per annum creates a market crisis among onion farmers in the growing season in Bangladesh. Practically, onion plants raised from the bulb for seed production need to be kept in the field for a month-long period as a standing crop compared to bulb crops. Lower seed production makes the seed market vulnerable and affects the onion growers and overall onion production in the country. Application of Zn and B is required for achieving a higher bulb yield of onion. Zinc (Zn) and Boron (B) can positively influence the yield and quality of onion seeds (Sarker, 2011; Rafique *et al.*, 2011). Zinc-enriched seeds can perform better with respect to seed germination, seedling health, crop growth, and finally yield advantage (Cakmak *et al.*, 1996; Alam *et al.*, 2010). For the formation of plant auxin, zinc has a significant role. During water absorption, the necessity of zinc is indispensable. Boron is necessary for cell division, nitrogen and carbohydrate metabolism, salt absorption, and water relation in the plant. Studies demonstrated that boron application had remarkable effects on the production of leaf, plant height, root numbers, seed yield, the weight of 1000 seeds, germination percentage, and quality of onion seed (Quddus *et al*., 2014). Usually, dicots have higher boron requirements than monocots. Micronutrients are also important for seed formation and seed quality (Jahiruddin *et al*., 1992; Yilmaz *et al*., 1998, Ahmed *et al*., 2007). Baktear *et al*., (2001); reported that there was a significant positive effect of micronutrients on the yield of T. aman rice. Boron deficiency may induce grain sterility in crops. Onion also suffers from different diseases by various pathogens causing substantial losses every year in Bangladesh. Among the diseases, a purple blotch of onion caused by *Alternaria porri* and white blotch of onion caused by *Stemphylium vesicarium* is presently considered the most damaging diseases. This disease is most devastating affecting both bulb yield and seed production all over the world including Bangladesh (Mishra and Gupta, 2012; Rahman *et al.*, 1988). Lower seed production makes the seed market vulnerable and affects the onion growers as well as onion production in the country. Based on the facts the present investigation was undertaken to evaluate the different treatments that affect seed germination, seed vigor, the presence of pathogenic microorganisms (*Alternaria porri* and *Stemphylium vesicarium*), and Zn+B contents in onion seed production in the field.

Materials and Methods

The experiments were conducted at the Seed Health Laboratory of the Department of Plant Pathology and Genetics and Plant Breeding Lab of Sher-e-Bangla Agricultural University (SAU), Dhaka. Test for the presence of Zn and B was done at Soil Resource Development Institute (SRDI), Khamarbari, Dhaka. The experiments were conducted during 2012-13 by using a Completely Randomized Design (CRD) with 4 replications for Laboratory experiments and a Randomized Complete Block Design (RCBD) with 4 replications for field experiments. Duncan's Multiple Range Test (DMRT) was explored for comparison of means (Gomez and Gomez, 1983). The complete package program MSTAT-C was used for the analysis of the experimental data.

Treatments

In the field, the following IDM Components were used as a treatment for the management of the purple blotch complex disease of onion. The treatments were T_0 = Control (Bulb treatment + foliar spraying with plain water); T_1 = Bulb treatment + Foliar spraying with Rovral 50 WP (Ipridione) @ 0.2%; T_2 = Bulb treatment + Foliar spraying with Score 250 EC (Difenoconazole) @ 0.1%; T_3 = Bulb treatment and Foliar spraying with Alamanda leaf extract (*Allamanda cathartica*) @ 1:2 (w/v); T_4= Soil amendment with Trico-compost (*Trichoderma sp*.) @ 5 t/ha; T_5 = Soil amendment by fully decomposed Poultry waste @ 5 t/ha; T_6 = Soil amendment by $ZnSO_4$ (Zn) @ 5 kg/ha and Borax (B) @ 5 kg/ha; T_7= T_1+T_4; T_8= T_1+T_5; T_9= T_1+T_6; T_{10}= T_2+T_4; T_{11}= T_2+T_5; T_{12}= T_2+T_6; T_{13}= T_3+T_4; T_{14}= T_3+T_5; and T_{15}= T_3+T_6. Seeds were collected from each treatment and later seed health study was conducted to evaluate the treatment effect on seed germination, seed vigor, and the presence of the pathogenic organism, *Alternaria porri,* and *Stemphylium vesicarium* in germinating seedlings.

Field study

The selected IDM components were integrated for their combined performance in controlling the purple blotch complex of onion for seed production. The popular and widely cultivated local variety of onion 'Taherpuri' was used in this experiment. Before plantation, the onion bulbs were treated with the respective solutions of plant extracts and fungicides by dipping the bulbs for 15 minutes. The treated bulbs were then shade dried and sown in the field without delay. For the control treatment, the bulbs were treated with plain water. Inoculation was done with a spore suspension of *A. porri* and *S. vesicarium* 21 days after planting (DAP). Spraying of fungicides, plant extracts, and tri-compost was started 36 days after bulb planting and 10 sprayings were done at 7 days intervals by a hand sprayer. One liter suspension of each fungicide and plant extract was used to spray the plants under each treatment. To avoid the drifting of the fungicides during the application, temporary fencing was made with a polyethylene sheet surrounding the unit plot. A control treatment was maintained in each block where spraying was done with plain water only. Irrigation, weeding, and mulching were done as per requirement of the plots at regular intervals.

Seed health study

For the seed health study, 400 seeds from each treatment were tested by following the standard procedure of the blotter method of seed health testing (ISTA, 2000). Sixteen petridishes were used for each treatment and 25 seeds were placed in each petridish in equidistance. All the plates with seeds were kept at room temperature for germination. After 12 days, seed germination was counted and expressed in percentage for each treatment (Plate 1-A, B). For detecting the incidence of *A. porri* and *S. vasicarium*, all the plates with seeds were incubated at room temperature ($25^0 \pm 2^0$C). After 14 days of incubation, each seed was observed under the stereo-binocular microscope to detect the presence of *A. porri* and/or *S. vasicarium* (Fig. 1-E, F).

Seedling vigor test

For the seedling vigor test, 400 seeds from each treatment were tested in a tray filled with soil so that the root and shoot can develop in a natural situation. Four trays were used for each treatment and 100 seeds were placed in each tray randomly. On the 15^{th} day of seed plating, 10 normal seedlings were selected randomly in each treatment from all the replications (Plate 1-C, D). The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and the mean shoot length was expressed in cm. The root length was measured from the tip of the primary root to the base of hypocotyls and the mean root length was expressed in cm. The vigor index (VI) was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed in numbers.

Vigor index = Germination (%) × (Shoot length+ Root length) cm

The harvested seed samples were tested for the presence of micronutrients (% Zn and % B) by the help of Soil Resource Development Institute (SRDI), Khamarbari, Dhaka.

Zinc content of seed

The seed sample was oven dried and analyzed for Zn by using an Absorption Spectrophotometer (AAS) according to Rahayu *et al*., (2001).

Boron content of seed

Boron content was determined by the Curcumin method (Hunter, 1980). A 0.25 ml seed filtrate was taken in a plastic bottle; 2.0 ml of curcumin in HOAC was added and thoroughly mixed. A 0.5 ml of conc. H_2SO_4 was added and thoroughly mixed and was allowed to stand for at least 35 minutes for cooling. Then, 15 ml of methanol solution (3: 2) was added, and mixed thoroughly. After 15 minutes, the spectrophotometer reading was recorded at 555 nm. The boron value (ppm) was determined by the following equation:

Boron (ppm) = Y x Abs (X) x f

Where, Y = df = 100/0.25 x (1) x ml /0.5 = 800

Where, 100 = Sample volume up to 100 ml

F = 6.25 (From standard curve)

0.25 ml = filtrate taken

0.5 g = seed sample

Results and Discussion

Seed germination

The effect of different integrated treatments was recorded in respect of seed germination percent (Table 1). Treatments showed significant variation in respect of seed germination. At 15 days of incubation treatment T_{11} (Score 250 EC + Poultry waste) showed 99.5% germination followed by T_8 (Rovral+Poultry waste) 99%, T_7 (Rovral + Bioagent) 97%, and T_1 (Control) 96%, however their performances were statistically

indifferent. Most of the treatments showed above 80% germination except T_4 (Soil amendment with Bioagent) 63.3% and control (56.8%).

Table 1. Effect of different integrated treatments on seed health against purple blotch complex of onion

Treatments		% Germination	Seeding Vigor Index
T_0	Control	56.8 g	438.5 g
T_1	Rovral 50 WP	96.5 a	1274.0 b
T_2	Score 250 EC	92.0 bc	1170.0 bc
T_3	Alamanda	83.3 de	976.8 de
T_4	Soil amendment with Bioagent	63.3 f	669.0 f
T_5	Soil amendment with Poultry waste	80.0 e	846.4 e
T_6	Micronutrient (Zinc+Boron)	56.8 g	438.5 g
T_7	Rovral + Bioagent	97.0 a	1312.0 b
T_8	Rovral + Poultry waste	99.0 a	1438.0 a
T_9	Rovral + Micronutrient	92.3 bc	1173.0 bc
T_{10}	Score 250 EC + Bioagent	96.0 b	1270.0 b
T_{11}	Score 250 EC + Poultry waste	99.5 a	1592.0 a
T_{12}	Score 250 EC + Micronutrient	84.5 d	981.1 de
T_{13}	Alamanda + Bioagent	89.0 c	1092.0 cd
T_{14}	Alamanda + Poultry waste	89.5 c	1098.0 cd
T_{15}	Alamanda + Micronutrient	83.5 de	982.3 de
CV (%)		2.51%	8.11%

Values in a column with the same letter (s) do not differ significantly (p=0.01)

Seed vigor

Seedling vigor was evaluated by a seed germination test in a plastic tray (Table 1). On the 15th day of seed plating the highest vigor index was estimated on treatment T_{11} (Score 250 EC + Poultry waste) 1592 which was statistically similar to treatment T_8 (Rovral+Poultry waste) 1438. Statistically, the 2nd highest vigor index was estimated in T_7 (Rovral + Bioagent) 1312 which was statistically indifferent with T_{10} (Score 250 EC + Bioagent) 1270 and T_1 (Rovral 50 WP) 1274. The lowest vigor index was recorded on treatment T_0 (Control) at 438.50.

Zinc content of seed

The seeds produced from integrated treatment were subjected to estimate the micronutrient (% Zn and % B) shown in table 2. The amount of Zn differed significantly among the treatments. The seed content of Zn was found to be higher in the treatments where Zn is applied as a micronutrient during soil amendment. The treatments where poultry waste is used for soil amendment also enrich the Zn content of the seed. Statistically, the highest Zn content was found in T_9 (Rovral + Micronutrient) 37.78 ppm which is statistically similar to T_{12} (Score 250 EC + Micronutrient) 36.46 ppm followed

by T_{15} (Alamanda + Micronutrient) 33.15 ppm, T_6 (Micronutrient) 31.96 ppm, T_8 (Rovral + Poultry waste) 28.89 ppm and T_{11} (Score 250 EC + Poultry waste) 27.36 ppm. The lowest Zn content was estimated at 8.36 ppm in control treatment T_0.

Table 2. Zinc and Boron content of the harvested onion seeds from different treatments applied plots for the management of purple blotch disease

Treatment		Zn (ppm)	B (ppm)
T_0	Control	8.36 m	10.60 hi
T_1	Rovral 50 WP	13.79 jk	18.64 ef
T_2	Score 250 EC	13.36 kl	14.27 gh
T_3	Alamanda	9.57 lm	8.80 i
T_4	Soil amendment with Bioagent	11.79 k-m	15.69 fg
T_5	Soil amendment with Poultry waste	24.73 fg	22.23 de
T_6	Micronutrient (Zinc+Boran)	31.96 cd	39.71 a
T_7	Rovral + Bioagent	17.35 ij	16.32 fg
T_8	Rovral + Poultry waste	28.89 de	23.40 d
T_9	Rovral + Micronutrient	37.78 a	41.63 a
T_{10}	Score 250 EC + Bioagent	20.36 hi	17.02 fg
T_{11}	Score 250 EC + Poultry waste	27.36 ef	29.06 c
T_{12}	Score 250 EC + Micronutrient	36.46 ab	32.56 bc
T_{13}	Alamanda + Bioagent	18.18 i	16.55 fg
T_{14}	Alamanda + Poultry waste	22.40 gh	21.48 de
T_{15}	Alamanda + Micronutrient	33.15 bc	35.46 b
CV (%)		8.71	8.74

Source: Test done at Soil Resource Development Institute (SRDI), Khamarbari, Dhaka

Boron content of seed

The amount of Boron differed significantly between the treatments (Table 2). The seed content of Boron was found to be higher in the treatments where Boron is applied as a micronutrient during soil amendment. The treatments where poultry waste was used for soil amendment also enrich the Boron content of the seed. Statistically, the highest Boron content was found in T_9 (Rovral + Micronutrient) 41.6 ppm which is statistically similar to T_6 (Micronutrient) 39.7 ppm followed by T_{15} (Alamanda + Micronutrient) 35.46 ppm, T_{12} (Score 250 EC + Micronutrient) 32.6 ppm and T_{11} (Score 250 EC + Poultry waste) 29.1 ppm. The lowest Boron content was estimated in treatment T_3 (Alamanda) at 8.80 ppm which is statistically similar to control treatment T_0 (10.6 ppm).

Incidence of pathogenic organism

In the present studies, different integrated treatments showed significant variation in respect of the percent of pathogenic organism presence in germinating seedlings. On the 18th day of seed plating the highest incidence of *A. porri* and *S. vesicarium* was recorded on treatment T_0 (Control) 2.75% which was statistically similar to treatment T_6 (Micronutrient)) 2.25%, T_{13} (Alamanda + Bioagent) 2.25%, T_{14} (Alamanda + Poultry waste) 2.25% and T_{15} (Alamanda + Micronutrient) 2.25%. No pathogenic incidence was noticed on treatment T_8 (Rovral + Poultry waste) and T_{11}(Score 250 EC + Poultry waste). The treatments T_1 (Rovral 50 WP), T_2 (Score 250 EC), T_3 (Alamanda), T_7 (Rovral + Bioagent), and T_9 (Rovral + Micronutrient) showed a statistically indifferent effect with respect to pathogenic incidence (Fig.1).

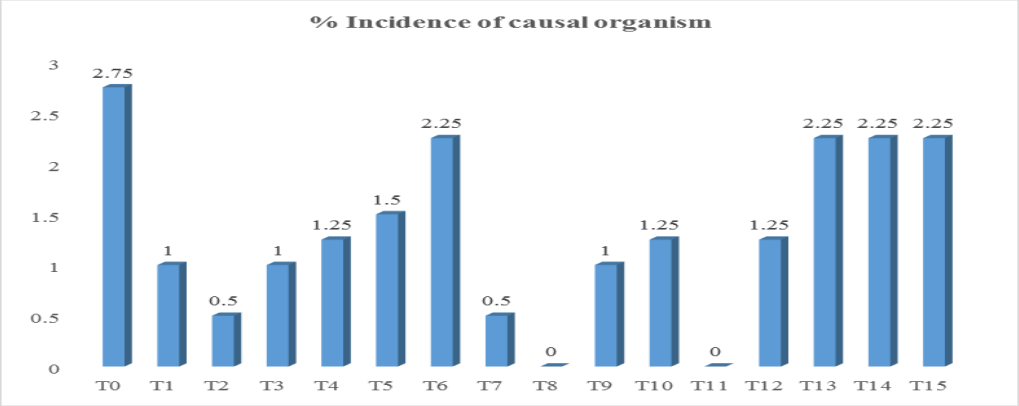

Fig. 1. Percentage of Incidence for *Alternaria porri* & *Stemphylium vesicarium* of purple blotch disease in onion seeds harvested from different integrated treatment applied plots.

Pathogens *A. porri* and *S. vesicarium* were isolated and identified by observing the key characteristics under a stereo and compound microscope. The quality of onion seed produced from the 15 integrated treatments was analyzed based on seed germination, seed vigor, presence of pathogenic microorganisms, micronutrient (Zinc+Boron) contents, and BCR. All the parameters significantly varied as per the treatments applied. The seed germination varied from 56.8% -99.5% where control scored the lowest germination and the treatment that comprised poultry waste for soil amendment and fungicide Score 250EC for bulb treatment and foliar spraying. The use of Rovral 50 WP in the place of Score 250EC in combination with poultry waste for soil amendment also scored statistically similar seed germination (99.0%). The seedling vigor ranged from 438.50-1592.00 owing to the application of different treatments. The vigor index was found to be higher where Rovral 50WP or Score 250EC were integrated with soil amendment with poultry waste or bioagent or micronutrient (Zn+B). The incidence of microorganisms on seed also varied statistically in response to the variation of treatments applied and the highest incidence (2.75%) was noticed in the case of control while no incidence of pathogenic microorganisms was found in the case of application of

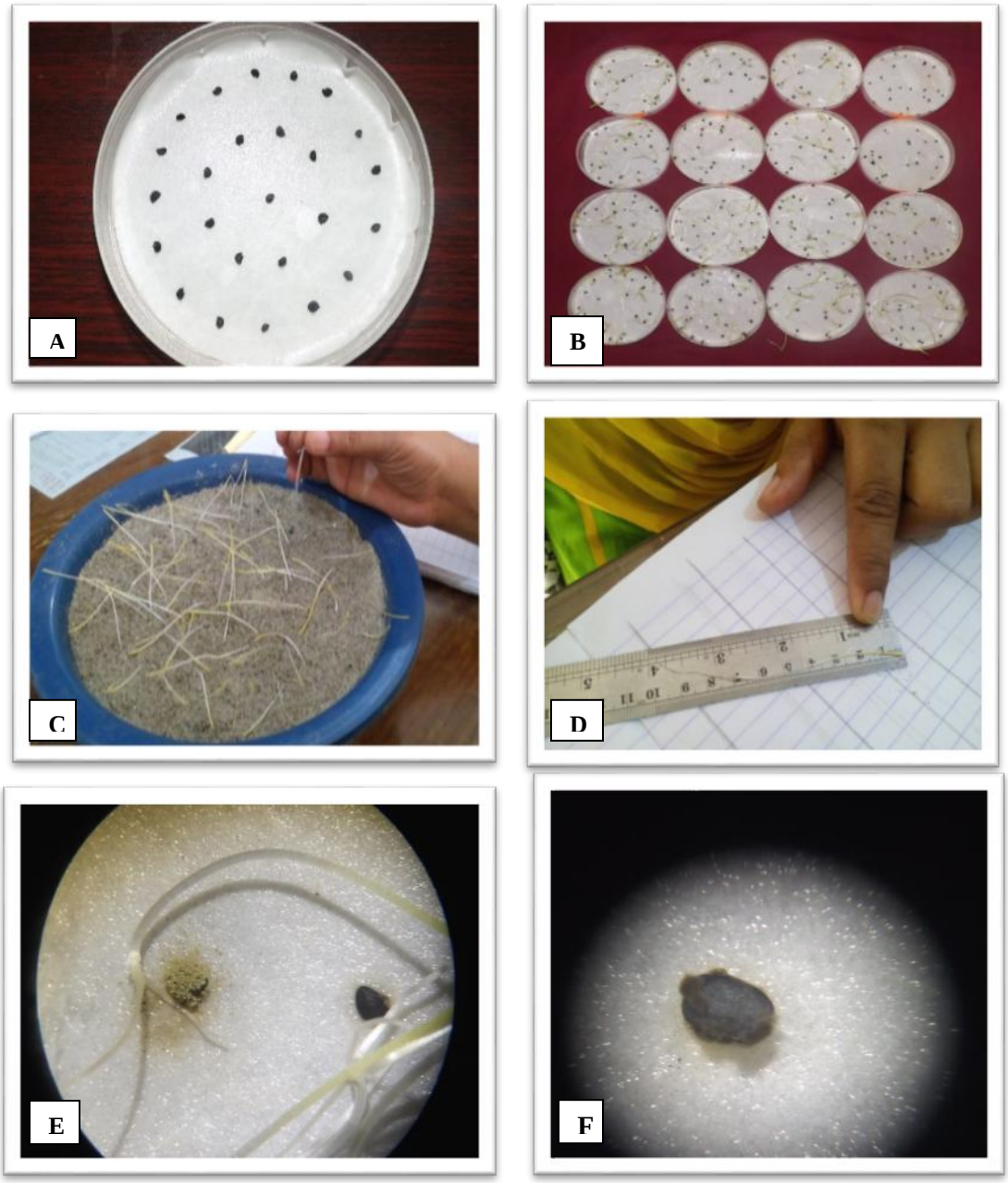

Fig. 2. Testing of seed quality of harvested seed of onion; A). Plotting of Onion Seed on blotter paper; B). Germinating seedlings at 7 DAS; C). Seed sowing on sand media; D) Measuring of shoot and root length; E). Observing seedlings under Compound Microscope; F). Non-germinated infected seed.

Score 250EC with poultry waste and Rovral 50WP with poultry waste. Among the other treatments, the pathogenic incidence was lower where Rovral 50WP or Score

250EC was applied either alone or in combination with other soil amendment options. For the case of micronutrient (Zn+B) analysis it was observed that the Zn and Boron contents of the seed varied significantly. The higher amount of Zn and B content were recorded where micronutrient was provided as a component of integrated treatments. The highest content of Zn (37.8 ppm) and B (41.6 ppm) was recorded in the treatment where micronutrient was applied in combination with Rovral 50WP.

The lowest content of Zn (8.26 ppm) was recorded in the control while the B (8.80 ppm) was noted in the seed sample harvested from Alamanda treated plot. The health quality of the seed regarding seed germination, seedling vigor, and the absence of pathogenic microorganisms was found to be improved significantly due to the application of different treatment combinations. The treatment combinations that had remarkable contributions in reducing the disease incidence and severity of the purple blotch complex of onion in field conditions had contributed the lowest incidence of pathogenic microorganisms in the corresponding seeds which subsequently improved the seed quality regarding seed germination and seed vigor. Patil *et al.,* (2006) reported that Zn had a favorable effect on seed formation and subsequent seed development which might be the reason for increasing the seedling vigor. Sarker (2011) also reported that there have positive effects of zinc and boron on the highest seed yield and germination quality of onion. Rafique *et al*., (2011) stated that Zn concentration in mature onion seeds also appeared to be a good indicator of soil Zn availability status. Haque *et al*., (2014) reported that Zinc (Zn) and boron (B) positively influence the yield and quality of onion seed, the response is genotype dependent and the interaction of both elements is rarely studied. A similar result was reported by Begum *et al*., (2015).

Conclusion

The quality of onion seed produced due to the integrated treatments was evaluated in terms of seed germination, seed vigor, presence of pathogenic microorganisms, and micronutrient (Zn+B). The treatment T_{11} (Score 250 EC + Poultry waste) and T_8 (Rovral + Poultry waste) showed significantly the highest seed germination (99.50%, 99.00%) and vigor index (1592, 1438) and the lowest (0.0%) presence of pathogenic microorganisms, respectively. The micronutrient (Zn+B) contents of the seed were found to be increased in the seed produced from the integrated treatment where micronutrient was combined which influenced the seedlings' vigor. A significant amount of Zn and B was found in T_{11} and T_8 where poultry waste was combined. Results showed that the presence of Zn and B in seed influence of the highest seed germination, vigor index, and the lowest presence of pathogenic microorganisms.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

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

Ahmed, M., Jahiruddin, M. and Mian, M. H. 2007. Screening of wheat genotypes for boron efficiency. *J. Plant Nutri.* 30:1127-1138.

Alam, M. N., Abedin, J. and Azad, M. A. K. 2010. Effect of micronutrients on growth and yield of onion under calcareous soil environment. *International Research J. Plant Sci.* 1(3):56-61.

Hossain, M. B., Kumar, T. N. and Ahmed, S. 2001. Effect of Zinc, Boron and Molybdenum Application on the Yield and Nutrient Uptake by BRRI Dhan 30. *J. Bio. Sci.* 1:698-700.

Begum, R., Jahiruddin, M., Kader, M. A., Haque, M. A. and Hoque, A. B. M. A. 2015. Effects of zinc and boron application on onion and their residual effects on Mungbean. *Progressive Agri*. 26:90-96.

Cakmak, I. B., Torun, B., Erenoglu, M., Kalayci, A., Yilmaz, H. and Ekij & Braun, H. J. 1996. Zinc deficiency in soils and plants in Turkey and plant mechanism involved in Zinc deficiency. *Turkish J. Agric. Forest.* 20 (Special issue):13-23.

Gomez, K. A. and Gomez, A. A. 1983. Statistical Procedures for Agril. Res. 2nd End. Intl. Res. Inst. Manila, Philippines. pp. 139-207.

Haque, M. R., Robbani, M., Hasan, M. M., Asaduzzaman, M., Hasan, M. M. and Jaime, A. Teixeira da Silva. 2014. Zinc and Boron Effect on Yield and Quality of Onion *(Allium cepa L.)* Seed. *Inter. J. Vegetable Sci*. 20(2):131-140. doi: 10.1080/19315260. 2013.780197

Hunter, A. H. 1980. Soil Fertility Analytical Service in Bangladesh. Consultancy Report, BJRI project phase II, Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh. p.53.

ISTA, 2000. International Rules of Seed Testing Association. Proc. Int. Seed Test Assoc. p. 180.

Jahiruddin, M., Hoque, M. S., Haque, A. K. M. M. and Roy, P. K. 1992. Influence of Boron, Copper and Molybdenum on grain formation in wheat. Health & Environmental Research Online (HERO). HERO ID 4842020.Technical Report. 5(1):35-42.

Mishra, R. K. and Gupta, R. P. 2012. *In vitro* evaluation of plant extracts, bio-agents and fungicides against Purple blotch and *Stemphylium* blight of onion. *J. Med. Plants Res.* 6(45):5658-5661.

Patil, S. B., Vyakaranahal, B. S., Deshpande, V. K. and Shekhargouda, M. 2006. Effect of Boron and Zinc application on seed yield and quality of Sunflower Restorer Line, Rha-857. *Karnataka J. Agric. Sci*. 19(3):708-710.

Quaiyum, A. 2020. Demand and supply of onion in Bangladesh. The Daily Observer. Thursday, 29 October, 2020.

Quddus, M. A., Naser, H. M., Hossain, M. A. and Hossain, M. A. 2014. Effect of Zinc and Boron on yield and yield contributing characters of Lentil in low Ganges River floodplain soil at Madaripur, Bangladesh. *Bangladesh J. Agril. Res.* 39(4):591-603.

Rafique, E., Mahmood-ul-Hassan, M., Ishaq, M. and Khokhar, K. M. 2011. Determining the Zinc requirement of onion by seed analysis. *J. Plant Nutrition*. 4(4):492-503.

Rahayu, Y. S. V., Romheld, F., Bangerth, D., Neilsen, B., Fallahi, G. and Neilsen & Peryea. F. 2001. Does zinc nutrition affect calcium disorder of fruit? *Acta. Hort*. 564:135-143.

Rahman, M. L., Ahamed, H. U. and Mian, I. H. 1988. Efficacy of fungicides in controlling purple blotch of onion. *Bangladesh J. Plant Path.* 4(1&2):71-76.

Sarker, S. M. 2011, Effects of zinc and boron on seed production of onion cv. Bari piaz-1. MS Thesis. Department of Horticulture Bangladesh Agricultural University Mymensingh. p. 49.

Yilmaz, A., Ekiz, H., Gültekin, I., Torun, B., Barut, H., Karanlik, S. and Cakmak, I. 1998. Effect of seed zinc content on grain yield and zinc concentration of wheat grown in zinc-deficient calcareous soils. *J. of Plant Nutri*. 21(10):2257-2264.

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A COMPARATIVE MACROMORPHOLOGICAL AND ETHNOMEDICINAL ANALYSIS OF FIVE *Kalanchoe* Adans. TAXA FROM BANGLADESH

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Abstract

The best-known species of the succulents family Crassulaceae in Bangladesh are *Kalanchoe blossfeldiana, Kalanchoe daigremonitnum, Kalanchoe heterophylla, Kalanchoe laciniata* and *Kalanchoe pinnata* during the period January, 2019 to March, 2020. But this is the first time that two new species named *K. delagoensis* and *K. gastonis-bonnieri* were reported from Bangladesh in this study.Viviparous plantlets formation along the leaf margin is the remarkable feature of these new two species along with formerly reported species *K. pinnata*. The abundance of *K. pinnata* among the five species of this genus was the highest (53%), while *K. gastonis-bonnieri* was the lowest (3%). The experimented five species were used to treat 9 human ailments named cough and cold, cuts and wounds, stomach disorder, kidney and gall bladder stones, jaundice, high blood pressure, skin burning, headache, and eye pain. The citation frequency of all the species except *K. laciniata* ranged from 2% to 100% in contrast to any ailment, while *K. blossfeldiana* and *K. pinnata* were frequently cited. Alike citation frequency the species *K. blossfeldiana* and *K. pinnata* along *K. gastonis-bonnieri* had the highest fidelity level, but *K. delagoensis* had the lowest fidelity level among the five species analyzed. Leaf juice and baked leaf are the common modes of administration. The most cited and high-fidelity species *K. blossfeldiana* and *K. pinnata* were top-ranked in DMR analysis. These two top-ranked species are under threat for several factors and need conservation strategies.

Keywords: Baked leaf, Ethnomedicinal, Kalanchoe, Leaf juice, Macrscopical

Introduction

The Crassulaceae commonly known as succulents consist of approximately 1500 species belonging to 33 genera and distributed worldwide except in Australia, and Pacific Island (Allorge-Boiteau, 1996). Southern Africa is the suspected place of origin and the centers of diversification are Mexico, Micronesia, and the Mediterranean region along with the Himalayas (Ham and Hart, 1998).

This family raises the interest of research globally because it is the only family where Crassulacean acid metabolism (CAM) occurs in both aquatic and terrestrial

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representatives (Keeley, 1998; Keeley and Philip, 2003). They are known as wonders of nature due to their medicinal value. The best-known genus of this family is *Kalanchoe* Adans. comprising 144 species (Kubitzki, 2007) for they may have ethnomedicinal and beautification importance. For natural history, karyology, bioactive phytochemicals, eco-physiology, molecular biology and horticultural study of the genus *Kalanchoe* are suitable among crassulents (Osmond, 1978). Although Hooker (1886) documented eight genera including 40 species from the Indian subcontinent of which two species were explored from Bangladesh territory from the family Crassulaceae (Rahman and Rashid, 2012). Ahmed *et al*., (2008) reported five species named *K. blossfeldiana, K. daigremonitnum, K. heterophylla, K. laciniata* and *K. pinnata* from Bangladesh already.

Succulent and fleshy leaves, pendulous or erect flowers, and eight stamens inserted in the middle or at the base of the tubular corolla (Baldwin, 1938) are the typical features of all the members of this genus. But the taxonomical status of *Bryophyllum* and *Kitchingia* was not clear when the genus *Kalanchoe* was first published by Michel Adanson (1727-1806) (Dyer, 1952; Isley, 1994and Staples, 2013). But in recent years with progress in molecular technology, the taxonomical status of *Kalanchoe* has been reanalyzed, and advancement has been made (Ham and Hart, 1998; Gehrig *et al*., 2001; Gontcharova and Gontcharov, 2009; Laskar *et al*., 2022; Smith and Figueiredo, 2018). However, *Kalanchoe* has diverged into three groups, i.e., *Kalanchoe, Bryophyllum,* and *Kitchingia* based on a few evolutionary studies (Gehrig *et al*., 2001). The three-section (sect. *Kalanchoe*, sect.*Bryophyllum*, and sect. *Kitchingia*) view of *Kalanchoe* (Boiteau and Allorge-Boiteau, 1995) is instead famous and well-prevalent, participants of the species from those sections exhibit variations in flower morphology and geographical distribution. While the species of the sect. *Kalanchoe* generally tends to have erect flowers and connate stamens at the center of the tubular corolla, contributors of the sect. *Bryophyllum* usually bears bulbils along their leaf margins, pendent flowers, and inflated tube of fused sepals with basal position of stamens at the corolla tube. On the other hand, species of the sect. *Kitchingia* shares the constant flower morphology with the sect. *Bryophyllum* and therefore the same stamen position as the sect. *Kalanchoe,* with distinct spreading carpels of floral structure. A study of the comparative morphology may be enough in setting those species into proper taxonomical ranks because of the presence of similarities and variations both within and across sections.

The Indian subcontinent has nine species (Singh *et al*., 2011) of which six are introduced and naturalized, while three are endemic and poorly documented. As no recent complete monograph is available for the genus *Kalanchoe*, reliable species determination in the genus is confused and greatly in need of revision (Descoings, 2003). Moreover, uncertainty remains, and more work needs to be done to fully elucidate the taxonomical properties and the phylogenetic history of *Kalanchoe*. No comparative morphological and ethnobotanical study among these five *Kalanchoe* found in Bangladesh has been conducted. So the present study intends to explore the comparative habitat, macroscopic

morphological profiling, and ethnobotanical information about different ailments. So that the disputed taxonomic status of species and disputed interspecific relationships can be resolved.

Materials and Methods

Plant specimen collection, preservation and conservation

Plant specimens of five *Kalanchoe* Adans. species viz., *K. blossfeldiana, K. delagoensis, K. gastonis-bonnieri, K. laciniata,* and *K. pinnata* were collected from different districts of Bangladesh (Table 1 and Fig. 1A-E) and critically studied along with identification with the help of a comprehensive literature review on the genus from January, 2019. A number of different samples were selected for this investigation. *Kalanchoe* species were collected from home gardens, nurseries, and abandoned areas of Barishal and Khulna divisions. Identifications were confirmed by consulting standard relevant literature (Hooker, 1886 and Eggli, 2003) and experts. Specimens belonging to these five species are housed at the net house of the University of Barishal. The updated nomenclature of the species is confirmed by consulting the Encyclopedia of Flora and Fauna of Bangladesh (Ahmed *et al.*, 2008), and the nomenclatural databases of The Plant List (2013), TROPICOS (2017) and Flora of Bangladesh (2020). A voucher specimen has been preserved at the Department of Botany and germplasms have been conserved at the net house of the University of Barishal respectively. Several additional localities for all of the five species examined have been identified in different regions of Bangladesh, where collections were made and photographs were taken with the digital camera.

Ethnomedicinal data collection

The ethnomedicinal information was gathered through semi-structured interviews, key informant discussions, and informal conversations with all social classes of people from the Barishal and Bagerhat of Khulna division from both sexes including traditional herbal medicinal practitioners, farmers, small shopkeepers, street hawkers, students from Department of Botany of the University of Barishal. A total of 72 informants were interviewed among which 56 were male and the remaining 16 were female. The voucher specimen was shown to every informant and they were asked about the ethnobotanical information, availability, and mode of administration regarding each species. Then the data collected from the survey was compiled through an Excel spreadsheet (2007) and summarized following graphical and statistical analysis.

Citation frequency of the medicinal plants (Cf%)

Citation frequency values are useful to conclude the most common medicinal plants. Citation frequency values of medicinal plants were estimated (Friedman *et al*., 1986) using the formula:

Citation frequency (Cf %) = $\frac{n}{N}$×100

Where n refers to the number of people interviewed citing species, N refers to the total number of people interviewed.

Table 1. List of collected *Kalanchoe* species

Sl. No.	Scientific name	Common name
1.	*Kalanchoeblossfeldiana* V. Poelln.	Florist's Kalanchoe
2.	*Kalanchoedelagoensis* Eckl. and Zeyh.	Chandelier plant
3.	*Kalanchoegastonis-bonnieri* Raym.-Hamet and H. Perrier	Donkey ear plant
4.	*Kalanchoelaciniata* (L.) DC.	Christmas tree plant
5.	*Kalanchoepinnata* (Lamk.) Pers.	Life plant

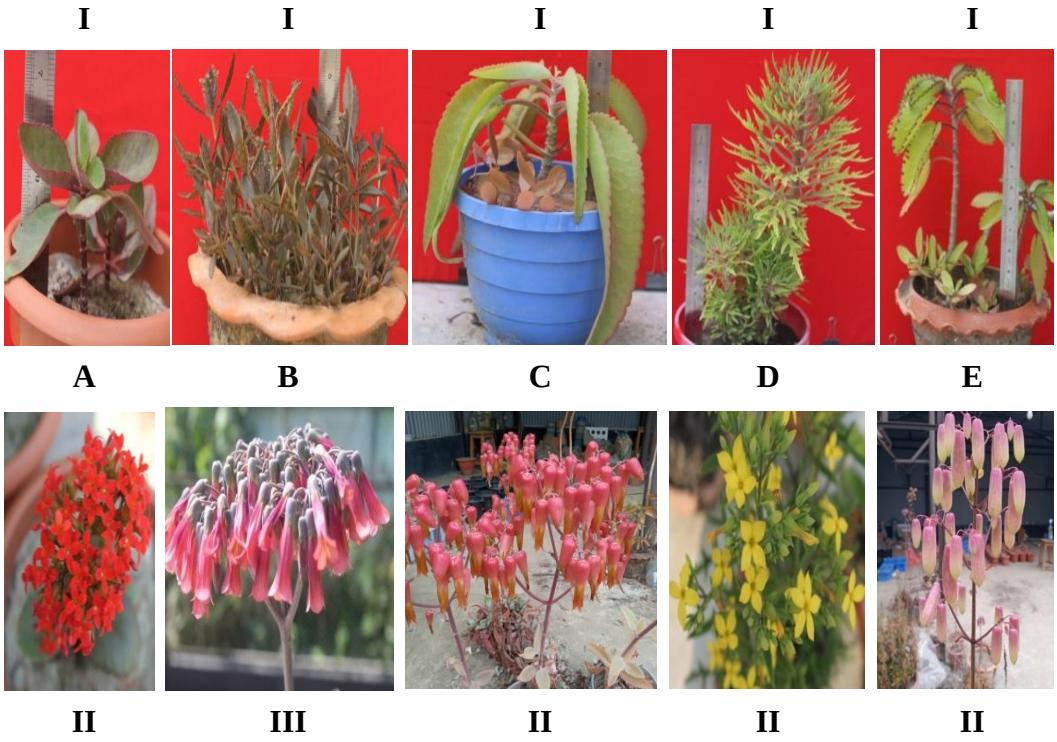

Fig. 1. Comparative vegetative (I) and inflorescence (II) morphology of five species of Kalanchoe taxa. A). *K. blossfeldiana*; B). *K. delagoensis*; C). *K. gastonis-bonnieri*; D). *K. laciniata* and E). *K. pinnata*.

Fidelity level (Fl %)

The Fidelity level value is useful for identifying the informants' most claimed species in use for treating certain ailments (Friedman *et al*., 1986). The Fidelity level index was determined by the following formula:

$$\text{Fidelity level (Fl \%)} = \frac{Np}{N} x100$$

Where Np is the number of informants who claimed one species to treat a certain disease, and N is the number of informants who uses the species to treat any disease (Alexiades, 1996).

Data matrix ranking (DMR)

Data collected from the respondents were used for DMR analysis to compare the use diversity of given plant species. Selected informants were asked to assign use values in the following categories 5, 4, 3, 2, 1, and 0 for best, very good, good, less used, least used, and not used classes respectively for each species. The round value of average scores given to each species was summed up and ranked.

Results and Discussion

Morphological investigation of *Kalanchoe* Adans.

The members of the genus Kalanchoe are mostly succulent, fleshy, erect, and herbs. Phyllotaxy is the opposite decussate type, leaf simple. Inflorescence cymose, flowers paniculate, erect/pendent tetramerous, bisexual. Sepals and petals are united at the base to form calyx and corolla tubes respectively. Stamens were four/eight arranged in two series and carpel four. Fruit is many seeded follicles.

Kalanchoe blossfeldiana V. Poelln.

Vernacular Name: Lalpathorkuchi

A succulent, erect, perennial herb. Stem round, glabrous, reddish-green. Leaves simple, opposites-decussate, petiolate, exstipulate, ovate, crenate, apex round. Inflorescence is a paniculate cyme. Flowers erect, pedicellate, bracteates, actinomorphic, bisexual, hypogynous. Calyx of four sepals, free reddish-green, persistent. Corolla of four, united at base to form a long tube, lobes four, spreading, red. Stamens eight in two series of four each.Carpels four, apocarpous, green, glabrous, each carpel with long style.Fruit follicle, seeds small (Fig. 1A). The partial persistent result was reported by Klein *et al*., 2021. Flowering and fruiting-December-April. Habitat: Gardens under direct sunlight. Propagation: Stem and leaf cuttings.

Kalanchoe delagoensis Eckl. and Zeyh.

Vernacular Name: Hazaripathorkuchi

Succulent herbs, robust biennials or perennials, completely glabrous. Stems simple, erect, terete; Leaf ternate to apparently opposite or alternate, sessile, usually straight, erect to spreading, sub-cylindrical, grooved, reddish-green to grey-green with reddish-brown spots, tip with small teeth with numerous bulbils, base attenuate; Inflorescence compact many-flowered rounded thyrsus, Pedicel slender; Flower pendent

bisexual, hypogynous, actinomorphic; calyx campanulate, reddish to green striped with red, tube, lobes triangular-lanceolate, very acute; corolla red, violet, pale orange to yellow suffused with red, tube funnel-shaped, lobes oblong-obovate, obtuse or truncate, spreading; Stamen inserted below the middle of the Corolla tube; Anther ovate; Carpel ovate-oblong; Style long; Fruits dry, indehiscent, papery follicles (Fig. 1B). Similar morphology was reported by Tian *et al*., 2021. Flowering and fruiting: November-March. Habitat: Arid regions, grows on concrete as a weed. propagation: viviparous plantlet leaf margin.

Kalanchoe gastonis-bonnieri Raym.-Hamet and H. Perrier

Vernacular Name: Boro Pathorkuchi

Perennials or sometimes biennials with basal Rosette; stems usually very short, glabrous; Leaf petiolate, very thick, fleshy, whitish-pruinose above, green with numerous irregular brownish-green spots, glabrous, petiole broad, amplexicaul, lamina ovate-Ianceolate, folded lengthwise like a gutter, tip long-acute with bulbils, base cuneate, margins coarsely crenate; Inflorescence many-flowered corymb pedicellate; FIower pendent or spreading, actinomorphic, hypogynous, bisexual; Calyx glabrous, green with red or violet lines, tube cylindrical, lobes deltoid, acute; Corolla yellow-green with red or violet lines, finely glandular-hairy, tube cylindrical, lobes orbicular, acuminate; Stamens inserted towards the base of the Corolla tube, upper stamens slightly exerted; Anther reniform; Carpel long. Fruit follicles and seeds are small (Fig. 1C). These morphologies were partially supportive with results reported by Smith *et al*., 2020. Flowering and fruiting-November-March Habitat: Arid regions, planted in gardens that receive direct sunshine. Propagation, viviparous plantlet in leaf margin at maturity.

Kalanchoe laciniata (L.) DC.

Vernacular Name: Himasagar

An erect, rather robust herb. Stem round, glabrous, green. Leaves opposites-decussate, petiolate, exstipulate, twice/thrice forked, laciniate. Inflorescence is a paniculate cyme. Flowers erect, pedicellate, actinomorphic, bisexual, tetramerous.Calyx of 4 sepals, free, lanceolate, persistent. Corolla of four petals united to form a long tube, lobes four, spreading, yellow, and cruciform. Stamens four in two series of two each.Carpel four, apocarpous, green, glabrous, each carpel with moderately long style and capitates stigma. Fruit follicle, seeds small (Fig. 1D). The partially similar result was found in Deb and Dash, 2013. Flowering and fruiting: January-May Habitat: Gardens in arid condition as ornamental Propagation: Stem and petioles cuttings.

Kalanchoe pinnata (Lamk.) Pers.

Vernacular Name: Pathorkuchi

A tall, erect, perennial herb. Stem round, glabrous, reddish. Leaves simple, opposites-decussate, foliate, fleshy, petiolate, ovate, elliptic, crenate, apex rounded to acute. Inflorescence is a very long paniculate cyme. Flowers are pendulous, pedicellate, actinomorphic, bisexual, and hypogynous. Calyx of 4 sepals, united at the base to form a tube, reddish, lobes four. The Corolla of four petals, united at the base to form a long tube exceeding the calyx tube, lobes four, red. Stamens eight in two series of four each.

Carpels four, apocarpous, each carpel with a short style and stigma.Fruit follicle, seeds small (Fig. 1E). This macroscopical finding is partially consistent with Shruti *et al*., (2018); Fernandes *et al.,* 2019. Flowering and fruiting: December-April. Habitat: Dry regions, also planted in gardens Propagation: New plantlet from leaf margin. From the observations, it can be demonstrated that all these species have a strong interrelationship among them with respect to leaf and floral morphology. However, there were some significant differences too. Chernetskyy (2012) also reported that leaves of *Kalanchoe* sp. exhibit permanent species-specific macro-morphological traits.

Table 2. Macroscopic morphology of leaf and flower of five *Kalanchoe spp*.

Part	Character	*Kalanchoe blossfeldiana*	*Kalanchoe delagoensis*	*K. gastonis-bonnieri*	*Kalanchoe laciniata*	*Kalanchoe pinnata*
Leaf	Petiole	Visible	Mixed with leaf blade	Short, stout	Mixed with leaf blade	Long, violet
	Leaf blade	Ovate	Narrowly oblong	Ovate-lanceolate	Lanceolate	Ovate
	Phyllotaxy	Decussate	Decussate, whorled in sets	Opposite decussate	Opposite decussate	Opposite decussate
	Leaflets	No	No	No	No	Yes
	Leaflet margin	Crenate	Dentate	Tooth-like jagged at young, serrate at aged	Coarsely dentate	Dentate-crenate
	Leaf apex	Round	Tapered	Blunt	Blunt	Obtuse
	Leaf-borne plantlets	No	Yes	Yes	No	Yes
	Leaf color	Deep green	Reddish green with reddish brown spots	Light to bronze green, waxy white powder at young	Light green	Medium green
	Midrib	Obscure	Obscure	Prominent lower part	Obscure	Prominent lower part
	Inflorescence	Compact corymbose cyme	Corymbose cyme	Compact corymbose cyme	Corymbose cyme	Loose corymbose cyme
	Inflorescence position	Terminal, axillary at apex	Terminal	Terminal	Terminal, axillary at apex	Terminal
Flower	Flower	Erect	Hanging	Hanging	Erect	Hanging
	Calyx color	Dark green/ red green	Pale green	Bright peach colored	Pale green	Reddish green
	Corolla color	Bright red	Orange to scarlet	Yellowish green, reddish yellow	Bright yellow	Yellowish green

But many members of this genus possess polymorphism, which made it essential to conduct micro-morphological analysis for better identification of *Kalanchoe* sp. Nevertheless, all the findings of our observations are compatible with the previous literature (Ahmed *et al.*, 2008; Eggli, 2003). So it can be concluded that all these five *Kalanchoe* sp. possess distinct vegetative and reproductive characteristics.

Based on Morphological characters a taxonomic key to the investigated species of *Kalanchoe* Adans.is depicted below:

A. Leaf viviparous, large hanging flowers;

I). Leaf blade narrow, short petiole, small calyx, long corolla tube → *K.delagoensis;*

II). Broadleaf blade, long petiole, large calyx, short corolla tube;

a). Leaf simple, lanceolate; Calyx bright peach colored→ *K. gastonis-bonnieri;*

b). Leaf pinnate, ovate; Calyx reddish green colored→ *K. pinnata;*

B). Leaf non-viviparous, small erect flowers;

I). Leaf blade coarsely dentate, corolla bright yellow→ *K. laciniata;*

II). Leaf blade simple, ovate, corolla scarlet red→ *K. blossfeldiana*.

The taxonomic key based on macroscopic characteristics is supportive of the taxonomic key morpho-anatomy-based systematic key proposed by Laskar *et al*., 2022.

Availability

Alike other plant species each species of *Kalanchoe* spp. has required a specific environmental condition. From the result, it was observed that *K. pinnata* has highest availability (53%) following *K. blossfeldiana, K. delagoensis, K.laciniata* (Fig. 2) respectively. The reason for this distributional variation of these *Kalanchoe* taxa may be habit and/or habitual variation among them. The availability of particular taxa in a specific region may affect ethnobotanical information among informants. In addition, sometimes due to consumption of specific taxa having medicinal potentiality may reduce the availability of that taxa. Moreover, urbanization, deforestation, exotic species plantation, and other anthropogenic practices may affect the availability of particular specimens. Moreover, both biotic and abiotic factors of an environment may affect the availability of a particular species.

Ethnobotanical data analysis

Ethnomedicinal information

Ethnomedicinal information is respected by local people and students from the district Barishal and Bagerhat districts of the Khulna division. The documented five *Kalanchoe* Adans. species viz., *K. blossfeldiana, K. delagoensis, K. gastonis-bonnieri, K. laciniata,* and *K. pinnata* were used to treat 9 human ailments named cough and cold, cut and wounds, stomach disorder, kidney and gall bladder stone, jaundice, high blood pressure, skin burning, headache and eye pain. The collected ethnomedicinal information

regarding this genus was cross-checked with already published available literature and was found supportive of Costa *et al*., (2008); Fernandes *et al*., 2019; Shruti *et al*., (2018); Ahmed *et al*., (2008) and Khan *et al*., (2015). The quantitative method was implemented to evaluate the relative importance of each species against each ailment. The results of the ethnomedicinal data supported that the alternative uses of different species against the same ailment depend on the availability of the species from locality to locality.

Citation frequency

The citation frequency of each species except *K. laciniata* ranges from 0 to 100% in contrast to any ailment (Fig. 3). The species *K. blossfeldiana* and *K. pinnata* had highest citation frequency among the five species against all ailments. All the species except *K. laciniata* of *Kalanchoe* taxa had the highest citation frequency against kidney and gall bladder stone ailments among all other ailments. It was recorded that the rare species *K. gastonis-bonnieri* had citation frequency against all ailments categories though the value was more runt. The reason for this least citation frequency was suspected that the scarcity has limited their popularity among local people. The species *K. laciniata* had no citation frequency against all ailments and informants answered that though the species has been used for indoor ornamentation it is systematic

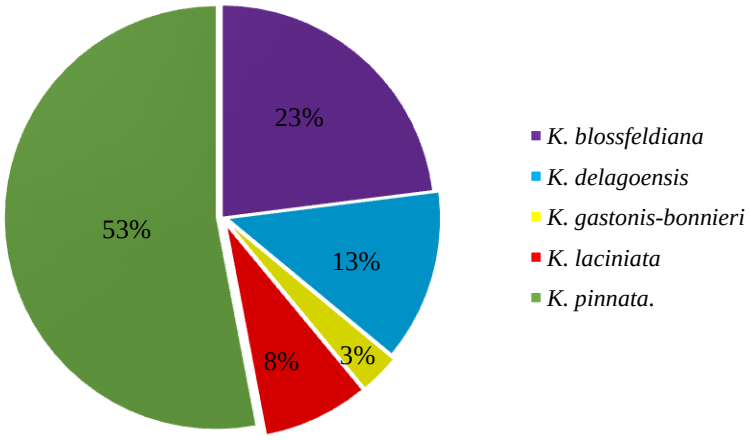

Fig. 2. Comparative availability of five species of *Kalanchoe* taxa.

Information is not well known to them. In the category of cough and cold *K. blossfeldiana* had the highest citation frequency (80%) but *K. gastonis-bonnieri* had the lowest citation frequency (8%). In addition, in the ailment category cut and wound citation frequency rangedfrom 2% to 60% in which *K. pinnata* had the highest citation frequency (60%) but *K. delagoensis* has the lowest citation frequency. In the case of stomach disorder ailment citation frequency ranged from 10% to 45%in which *K. pinnata* and *K. blossfeldiana* had about 4 and 4.5 times citation frequency respectively than *K.*

delagoensis (10%). The highest citation frequency was found for kidney andgall bladder stone ailments (100%) which were five and ten times of *K. delagoensis* and *K. gastonis-bonnieri* respectively (Fig. 3). Moreover in the case of jaundice, 2% to 40% citation frequency had been found, in which *K. pinnata* had highest (40%) but *K. gastonis-bonnieri* had lowest (40%). In the ailment, High blood pressure *K. blossfeldiana* and *K. pinnata* had the same but highest frequency (20%) while *K. delagoensis* has the lowest (2%) citation frequency.

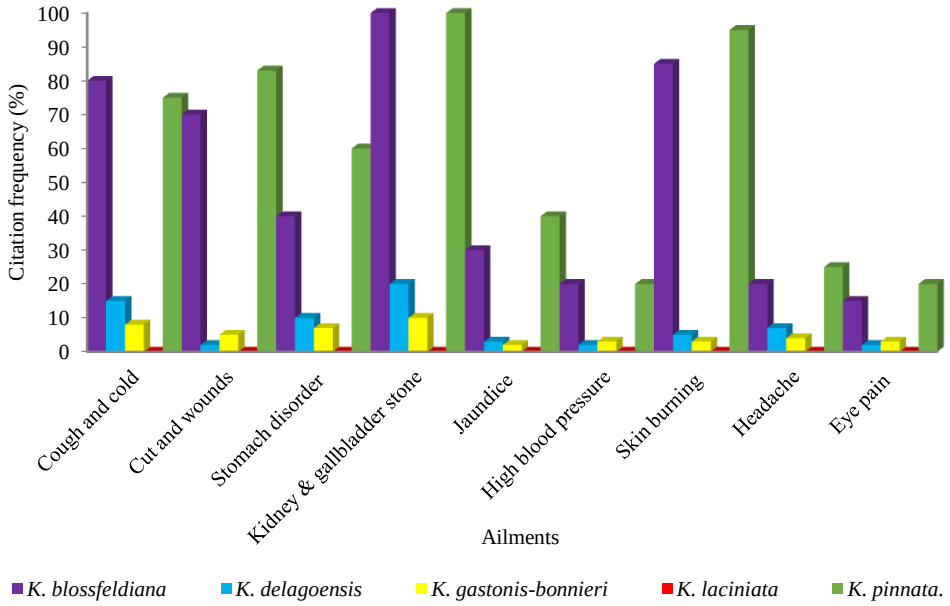

Fig. 3. Comparative citation frequency (%) with respect to ailments and five species of *Kalanchoe*.

The citation frequency for skin burning ranged from 3 to 85% with which *K. pinnata* had the highest (85%) value. In addition, in the case of skin burning *K. pinnata* and *K. blossfeldiana* had the highest (85% and 80% citation frequency respectively) but *K. gastonis-bonnieri* had the lowest (3%) citation frequency. In the ailment named headache, *K. pinnata* had 25% and *K. blossfeldiana* had 20% citation frequency which was about six times and five times greater than *K. gastonis-bonnieri* respectively. Moreover, in the category of eye pain *K. pinnata* had the highest (20%) and *K. blossfeldiana* had 15% citation frequency while *K. delagoensis* had the lowest (2%) (Fig. 3).

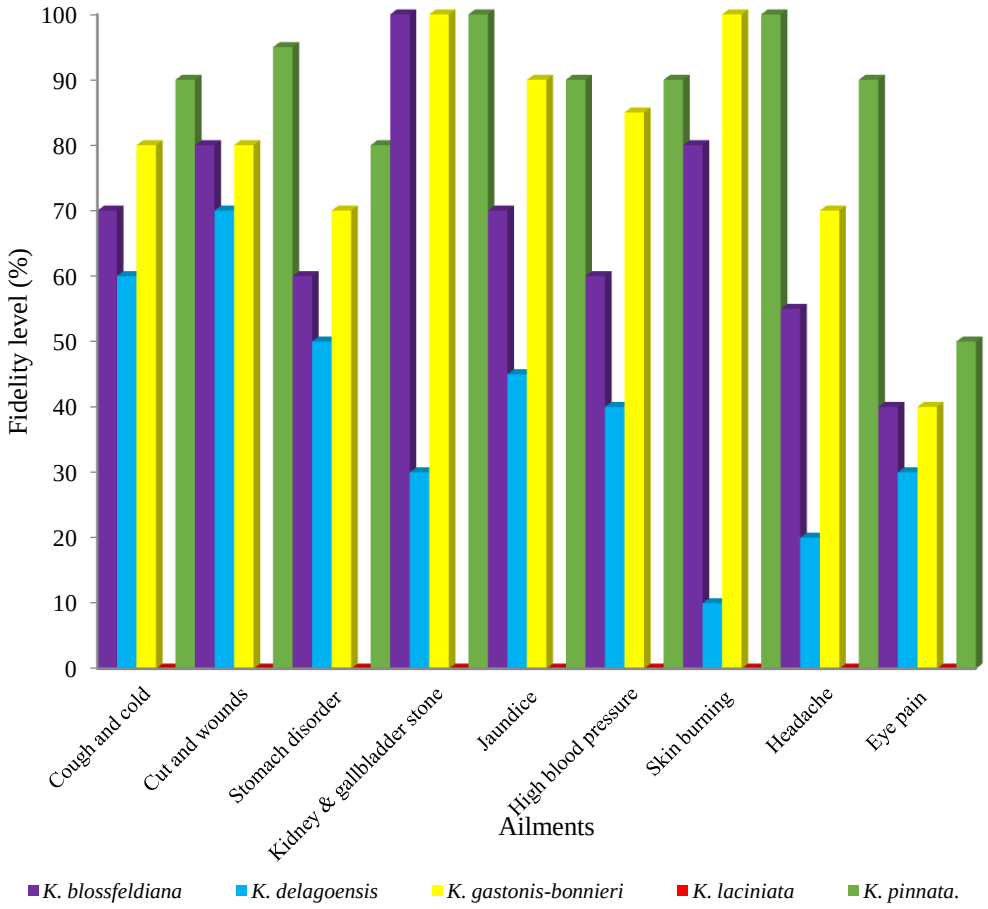

Fig. 4. Comparative fidelity level (%) with respect to ailments and five species of *Kalanchoe*.

Fidelity level

Alike the citation frequency all the species of *Kalanchoe* had fidelity levels except *K.laciniata* in contrast to any ailment (Fig. 4). The species *K. blossfeldiana* and *K. pinnata* along with *K. gastonis-bonnieri* represented the highest fidelity (100%) with regards to kidney and gall bladder stone ailment. The species *K.delagoensis* had the lowest fidelity among all species of *Kalanchoe* having fidelity level in all ailments categories. The reason for this may be a variation in leaf morphology that creates a dispute about the systematic position. In addition, leaf juice, and baked leaves were used as a mode of administration, so that a colorful appearance restrained people from using. But experienced local people/healers found mentionable results. In the case of cough and cold, *K. pinnata* has highest fidelity level (90%) followed by *K. gastonis-bonnieri* (80%), *K. blossfeldiana* (70%), *K.delagoensis* (60%) respectively. In the ailment category cut and wounds *K. pinnata* was reported to have the highest fidelity level (95%) followed by

K. blossfeldiana (80%), *K. delagoensis* (70%) respectively (Fig. 4). In addition, *K. pinnata* was recorded for having highest fidelity level (80%) followed by *K. gastonis-bonnieri* (70%), *K. blossfeldiana* (60%) and *K. delagoensis* (50%) respectively in the ailment category of stomach disorder. The species *K. blossfeldiana*, *K. gastonis-bonnieri*, and *K. pinnata* independently had the highest fidelity level (100%) followed by *K. delagoensis* (30%) with regards to kidney and gall bladder stone ailment. In the ailment category of Jaundice, the fidelity level ranged from 45-90% in which *K. gastonis-bonnieri*(90%) and *K. pinnata* (90%) had two times the fidelity level than *K. delagoensis* (45%). Moreover, in the high blood pressure ailments, fidelity levels ranged from 40-90% in which *K. pinnata* (90%) had over two times the fidelity level than *K. delagoensis*(40%). In addition, in the ailment category of skin burning, *K. gastonis-bonnieri*(100%) and *K. pinnata* (100%) independently had ten times the fidelity level value than *K. delagoensis* (10%). Moreover, for the headache category *K. delagoensis*had about one-fifth fidelity level of *K. pinnata* (90%) while *K. pinnata* had the highest fidelity level (50%) followed by *K. blossfeldiana* (40%), *K. gastonis-bonnieri* (40%), *K .delagoensis* (30%) respectively (Fig. 4) for the eye pain ailment.

Table 3. Data matrix ranking of five species of *Kalanchoe* Adans

Use parameter	*K. blossfeldiana*	*K. delagoensis*	*K. gastonis-bonnieri*	*K. laciniata*	*K. pinnata.*	Total	Rank
Indoor ornamentation	4	5	2	5	4	20	**3**
Outdoor gardening	5	5	4	5	5	24	**1**
Medicinal	5	2	4	0	5	16	**5**
Irrelevant daily study	5	2	5	1	5	18	**4**
Personal cares	4	2	3	0	5	14	**6**
Botanical study	5	5	4	3	5	22	**2**
Total	28	21	17	15	29		
Rank	**2**	**3**	**4**	**5**	**1**		

The presence of a wide range of secondary metabolites in the *Kalanchoe* taxa is related to ethnomedicinal applications (Stefanowicz-Hajduk, 2020). Bufadienolides have been postulated as responsible for many pharmacological activities (Kolodziejczyk-Czepas and Stochmal, 2017) despite the presence of other secondary metabolites viz. alkaloids (Biswas *et al*., 2012), phenolic acid (Singab *et al*., 2011), flavonoids (Nielsen *et al*., 2005), saponins and tannins (Pattewar, 2012). Bufadienolide compounds have antiviral, anticancer, antimicrobial, cardiotonic, and antioxidant effects (Supratman *et al*., 2001; Cunha Filho *et al*., 2005; Wu *et al*., 2006). But the reason for the difference in

citation frequency and fidelity level among the species documented may be the availability and popularity of particular species.

Data matrix ranking

The results of the DMR analysis on multipurpose uses enabled us to detect which of the five species is/ are under stress and the reasons that are threat to the plant species (Table 3). According to DMR analysis, *K. pinnata* was ranked first followed by *K. blossfeldiana, K. delagoensis, K. gastonis-bonnieri, and K. laciniata.* The multipurpose uses of *K. pinnata* and *K. blossfeldiana* tend to these two species are under great pressure as excessive harvesting by local people for a variety of purposes. Six factors are responsible for the decline of *K. pinnata* abundance in the area among which five factors were major while four factors were minor for reducing the availability of *K. blossfeldiana* that result from over-harvesting. On the other hand, *K. laciniata* is the lowest ranked and this may be due to a lack of proper knowledge regarding the systematic position, abundance, popularity, and lack of medicinal information. Sometimes traditional people mostly used whole plants or roots for ethnomedicinal recipes, as well as for other diverse uses.

Conclusion

Kalanchoe is one of the most important medicinal plants in most countries of the world including Bangladesh. *K. pinnata* has the highest availability among the five species found in Bangladesh followed by *K. blossfeldiana, K. delagoensis, K. gastonis-bonnieri*, and *K. laciniata* respectively. All five species were used to treat 9 human ailments named cough and cold, cuts and wounds, stomach disorder, kidney and gall bladder stones, jaundice, high blood pressure, skin burning, headache, and eye pain. The diversified uses of the different species rely on the availability, ethnomedicinal knowledge, popularity, locality, and perceptions of local people against particular species. It can be concluded after completion of compiling the availability with respect to citation frequency that the higher the percentage of availability, the higher the rate of usage frequency except for *K. gastonis-bonnieri*, and *K. laciniata* against all kinds of ailments. The compilation of fidelity level (%) value reflects that *K. pinnata* possess the highest fidelity value followed by *K. gastonis-bonnieri, K. blossfeldiana, K. delagoensis,* and *K. laciniata* against all ailments. Compilation availability, citation frequency, fidelity level, and data matrix data reflect a dire need for conservation strategy to save the declining population of the top-ranked purpose plant species *K. pinnata* and *K. blossfeldiana* and extension strategy for middle and lower ranked species *K. gastonis-bonnieri, K. delagoensis* and *K. laciniata*.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Ahmed, Z. U., Z. N. T. Begum, M. A. Hassan, M. Khondker, S. M. H. Kabir, M. Ahmad, A. T. A. Ahmed, A. K. A. Rahman and E. U. Haque (Eds.). 2008. *Encyclopedia of Flora and Fauna of Bangladesh*. Asiatic Soc. of Bangladesh, Dhaka, Bangladesh. 7:286-289.

Alexiades, M. N. (Eds.). 1996. Selected Guidelines for Ethnobotanical Research: A Field Manual. The New York Botanical Garden, New York. p. 305.

Allorge-Boiteau, L. 1996. Madagascar centre de speciation etd' origine du genre *Kalanchoe* (Crassulaceae). ORSTOM, Paris, France. pp. 137-145.

Baldwin, J. T. 1938. *Kalanchoe*: the genus and its chromosomes. *Am. J. Bot*. 25(8):572-579.

Biswas, S. K. A., S. Z. Chowdhury, M. A. Raihan, M. A. Muhit, Akbar and R. Mowla. 2012. Phytochemical investigation with assessment of cytotoxicity and antibacterial activities of chloroform extract of the leaves of *Kalanchoe pinnata*. *Am. J. Plant Physiol*. 7:41-46.

Boiteau, P. and L. Allorge-Boiteau. 1995. *Kalanchoe* (Crassulacées) de Madagascar: systématique, écophysiologieetphytochimie. Paris: Karthala. pp. 223-224.

Chernetskyy, M. 2012. The role of morpho-anatomical traits of the leaves in the taxonomy of Kalanchoideae Berg.subfamily (Crassulaceae DC.). *Modern Phytomorph*. 1:15-18.

Costa, S. S., M. F. Muzitano, L. M. M. Camargo and M. A. S. Coutinho. 2008. Therapeutic Potential of *Kalanchoe* Species: Flavonoids and other Secondary Metabolites. *Natu. Product Commu*. 3(12):2151-2164.

Cunha Filho, G.A., C.A. Schwartz, I.S. Resck, N.M. Murta., S.S. Lemos, M.S. Castro, C. Kyaw, O. R. Pires, J. R. Leite and C. Blochl. 2005. Antimicrobial activity of the bufadienolides marinobufagin and telocinobufagin isolated as major components from skin secretion of the toad *Bufo rubescens*. *Toxicon*. 45:777-782.

Deb, J. and G. K. Dash. 2013. *Kalanchoe lacinata* (L.) DC: A lesser known Indian medicinal plant. *Int. J. of science invention today*. 2(2):158-162.

Descoings, B. (Eds.). 2003. *Kalanchoe*. *Springe*r-Verlag, New York, USA. pp. 143-181.

Eggli, U. 2003. Illustrated Handbook of Succulent Plants: Crassulaceae. *Springer*, Berlin, Germany. pp. 413-481.

Fernandes, J. M., L. M. Cunha, E. P. Azevedo, E. M. G. Lourenc, M. F. Fernandes-Pedrosa and S. M. Zucolotto. 2019. *Kalanchoe laciniata* and *Bryophyllum pinnatum*: an updated review about ethnopharmacology, phytochemistry, pharmacology and toxicology. *Brazilian J. pharmacognosy*. 29:529-558.

Flora of Bangladesh. 2020. Survey of Vascular Flora of Chittagong and Chittagong Hill Tracts projects. Ministry of Environment and Forest. Bangladesh National Herbarium.http://bnh-flora.gov.bd/Accessed on 16 June 2020.

Friedman, J., Z.Yaniv, A. Dafni and D. Palewitch. 1986. A preliminary classification of healing potential plants, based on a rational analysis of an ethno pharmacological field survey among Bedouins in the Negev Desert, Israel. *J. Ethnopharmacology*.16:275-287.

Gehrig, H., O. Gaussmann, H. Marx, D. Schwarzott and M. Kluge. 2001. Molecular phylogeny of the genus *Kalanchoe* (Crassulaceae) inferred from nucleotide sequences of the ITS-1 and ITS-2 regions. *Plant Sci*. 160:827–835.

Gideon, F., E. Smith, Wolff and L. Thoumin. 2020. The taxonomy and nomenclature *of Kalanchoe gastonis-bonnieri* Raym.-Hamet & H.Perrier (Crassulaceae sub fam.

Kalanchooideae), with biographical notes on Gaston Eugène Marie Bonnier (1853–1922). *Bradleya*. 38:94-103.

Gontcharova, S. B. and A. A. Gontcharov. 2009. Molecular phylogeny and systematics of flowering plants of the family Crassulaceae, D. C. *Mol. Biol*. 43:794-803.

Ham, R. C. H. J. and H. Hart. 1998. Phylogenetic relationships in the Crassulaceae inferred from chloroplast DNA restriction-site variation. *Am. J. Bot*. 85:123-134.

Hooker, J. D. 1886. The Flora of British India. L. Reeve & Co., London, UK. 2:414-416.

Isley, D. 1994. One Hundred and One Botanist. pp. 97-100.

Keeley, J. E. and W. R. Philip. 2003. Evolution of CAM and C_4 carbon-concentrating mechanisms. *Int. J. Plant Sci*.164:55-77.

Keeley, J. E. 1998. Photosynthetic pathway diversity in a seasonal pool community.*Funct. Ecol*.13:106-118.

Klein, D. P., R. Shtein, L. Nusbaumer and M.W. Callmander. 2021. *Kalanchoe darainensis* (Crassulaceae), a new species from northeastern Madagascar. *Candollea.* 76:117-123.

Kolodziejczyk-Czepas, J. and A. Stochmal. 2017. Bufadienolides of *Kalanchoe* species: an overview of chemical structure, biological activity and prospects for pharmacological use. *Phytochem Rev*. 16:115-1171.

Kubitzki, K. 2007. Flowering Plants.Eudicots.Asterales. *Springer*. 8:83-118.

Laskar, M. A. R., M. T. Islam, M. M. Hasan, S. K. Das and M. U. Hossain. 2022. Comparative Morpho-Anatomical Analysis of *Kalanchoe* Adans. Species from Bangladesh. *Bangladesh J. Bot.* 51(2):229-235.

Nielsen, A. H., C. E. Olsen and B. L. Moller. 2005. Flavonoids in flowers of 16 *Kalanchoë blossfeldiana* varieties. *Phytochemistry*. 66(24):2829-2835.

Osmond, C. B. 1978. Crassulacean acid metabolism: a curiosity in context. Ann. Rev. *Plant Physiol*. 29:379-414.

Pattewar, S. V. 2012. *Kalanchoe pinnata*: phytochemical and pharmacological profile. *Int. J. Phytopharm*. 2:1-8.

Rahman, M. A. and M. E. Rashid. 2012. Updated nomenclature and taxonomic status of the plants of Bangladesh included in Hook F. The flora of British India. *Bangladesh J. Plant Taxon*. 19(2):173-190.

Shruti, B., D. Bhayita., Z, Maitreyi and C. Divya. 2018. A comparative pharmacognostical and phytochemical analysis of *Kalanchoe pinnata* (Lam.) Pers. leaf extracts. *J. of Pharmacognosy and Phytochemistry*. 7(5):1519-1527.

Singab, A. N. B., S. H. El-Ahmady, R. M. Labib and S. S. Fekry. 2011. Phenolics from *Kalanchoe marmorata* Baker, family Crassulaceae. *Bull Fac Pharm Cairo Univ*. 49:1-5.

Singh, N. B., U. C. Bhattacharyya and B. P. Uniyal. 2011. Crassualaceae of India.Dehradun. pp. 54.

Smith, G. F. and E. Figueiredo. 2020. The infrageneric classification and nomenclature of *Kalanchoe* Adans. (Crassulaceae), with special reference to the southern African *Spe. Bradleya*. 36(36):162-172.

Staples, C. J. 2013. A Historical Authors of C&S Plant Names and Books for the Amateur Hobbyist. 2:151-203.

Stefanowicz-Hajduk, J., A. Hering, M. Gucwa, R. Hałasa, A. Soluch, M. Kowalczyk, A. Stochmal and R. Ochocka. 2020. Biological activities of leaf extracts from selected *Kalanchoe* species and their relationship with bufadienolides content. *Pharm Biol*. 58(1):732-740.

Supratman, U., T. Fujita, K. Akiyama, H. Hayashi, A. Murakami, H. Sakai, K. Koshimizu and H. Ohigashi. 2001. Anti-tumor promoting activity of bufadienolides from *Kalanchoe pinnata* and *K. daigremontiana x tubiflora*. *Biosci. Biotechnol. Biochem*. 65:947-949.

The Plant List. 2013. The Plant List, a working list of all plant species. http://www.theplantlist.org. Accessed on 16 June 2020.

Tian X., J. Guo, X. Zhou, K. Ma, Y. Ma, T. Shi and Y. Shi. 2021. Comparative and Evolutionary Analyses on the Complete Plastomes of Five *Kalanchoe* Horticultural Plants. *Front Plant Sci*. 12:705874.

TROPICOS. 2017. Tropicos.org. <www.tropicos.org>. Missouri Botanical Garden, Saint Louis, Missouri, USA.Accessed on 16 June 2020.

Wu, P. L., Y. L. Hsu, T. S. Wu, K.F. Bastow and K. H. Lee. 2006. Kalanchosides A-C, new cytotoxic bufadienolides from the aerial parts of *Kalanchoe gracilis*. *Org Lett*. 8:5207-5210.

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AN ASSESSMENT OF PRIVATE WOODLOT AT KALIGONJ UPAZILLA OF JHENAIDAH DISTRICT, BANGLADESH

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Abstract

The study presents an assessment of the species selection, management technique, and socio-economic benefits of raising private woodlot plantations in Kaligonja upazila, Jhenaidah district of Bangladesh during 2016-2017. A total of 80 woodlot owners were surveyed randomly to assess the status of woodlot plantations. Major growers (55%) were middle-aged (41-55 years) and dominated by males (95%). About 90% of woodlots were rectangular in size and monoculture in species composition (70%) of which about 75% was *Swietenia macrophylla*. A total of 77.5% of owners has single ownership, whereas about 97.5% of the respondents practice woodlot on their landowner. The majority of the land (85%) was previously used as agricultural landowner. The socioeconomic benefit was timber production, utilization of fallow land, income generation, fuel wood production, etc. The owners manage their woodlots by following traditional and silvicultural techniques. Most of the respondents are conscious and have general knowledge of thinning (80%) and pruning (97.5%). Selection felling systems (60%) and clear felling (40%) were the two types of harvesting systems found in this area. About 90% of respondents fixed the rotation period ranging from 10 to 20 years depending on the species and market value. They still need proper guidance and training to increase their knowledge and efficiency for the maximum productivity of woodlots in the study area.

Keywords: Harvest, Monoculture, Ownership, Rotation, Woodlot shape,Woodlot size

Introduction

The area of forestland in Bangladesh is 2.6 million ha (17.62% of the country's entire area) (FD, 2016). Bangladesh Forest Department (BFD) manages 1.6 million hectares of forestland (FD, 2016). Only 6.7% of the total area of Bangladesh is forested and that area is being exhausted at the distressing rate of 3.1% per annum (FAO, 2009). Forests in tropical countries like Bangladesh are fading at a frightening frequency because of various socio-economic extortions, biotic forces, and competing land uses. Additional causes of forest degradation include encroachment, grazing, fire, uncontrolled and wasteful commercial logging, illegal felling, fuel wood collection, and official transfer of forestland to another sector, i.e., for settlement, agriculture, and other industries (Anon, 2011).

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The area of Bangladesh is very small and incomparable to the population. The increasing number of people creates new pressure on the various inadequate resources like forest and land resources (FAO, 2015). Humans also transfigure forestland into agricultural land and for other purposes that cause the annihilation of forests and the degradation of the environment. There is no scope to increase the forestland and agricultural land, but the production will be increased by converting the traditional land use pattern into sustainable land uses like agroforestry and woodlot plantation (Nair, 2006). The number of private woodlots should be increased to reduce the pressure on a natural forest to fulfill forest-related needs. It provides a notable contribution to sustainable agricultural production because of its potential to meet economic, social, ecological, and institutional conditions for sustainable livelihoods (Nair, 2006). It also provides alternative sustainable sources of fresh resources for woody industries (Aggangan, 2003) and recovers the microclimate circumstance of the area, and lessens soil erosion and siltation of rivers and streams.

At present, woodlot is an accepted sustainable enlargement prototype throughout the world. In Bangladesh, it is defined as the deliberate growing and tending of fast-growing tree species on state/privately owned land for locally used fuel wood, poles, posts, and small wood for local consumption and cottage industries (BBS, 2014). Woodlot has been raised as a benefit-sharing program with the involvement of land encroachers and other economically disadvantaged people (Muhammed *et al*., 2008). Kaligonj Upazila in Jhenaidah district is an important area of Bangladesh, where the practice of agroforestry and woodlots are more extensive and the area is suitable for these practices. But, the status of a woodlot (like woodlot's size and shape, cost and benefits, management technique, land ownership, etc.) is still unknown in this area. Bangladesh needs to increase the number of private woodlots to conserve the environment as well as uplift the livelihood of marginal. At the same time, the appropriate management technique is the primary provider for economic paybacks. Considering all of these, this study aims to obtain the present management status and socio-economic benefits of a private woodlot.

Materials and Methods

Study area

Kaliganj Upazila of Jhenaidah district, located in southwestern Bangladesh, with an area of 303.53 sq. km, is located between 23°16´ and 23°28´ north latitudes and in between 89°02´ and 89°16´ east longitudes (Fig-1). It is bounded by Jhenaidah Sadar Upazila on the north, Jessore Sadar and Chaugachha Upazila on the south, Salikha and Bagherpara Upazilas on the east, Kotchandpur and Chaugachha Upazila on the west. About 63.46% are landowners and 36.54% are landless. The main crops are paddy, jute, sugarcane, betel leaf, wheat, pulse, and vegetables. The main rivers are Chitra, Bhairab, and Begabati. The main baors are Morjat, Sarjat, Sako, Barfa and Simla Baor. Noted beels are Uttar (Magura - Tattipur), Dighar, Arua Salva and Tentul Beel. The duration of the rainy season is June to

October followed by winter (November to February) and the dry season (March to May) (BES. 2020). The annual average temperature varies from a maximum of 36.6°C to a minimum of 12.8°C and the average annual rainfall is 1492 mm (BES. 2020).

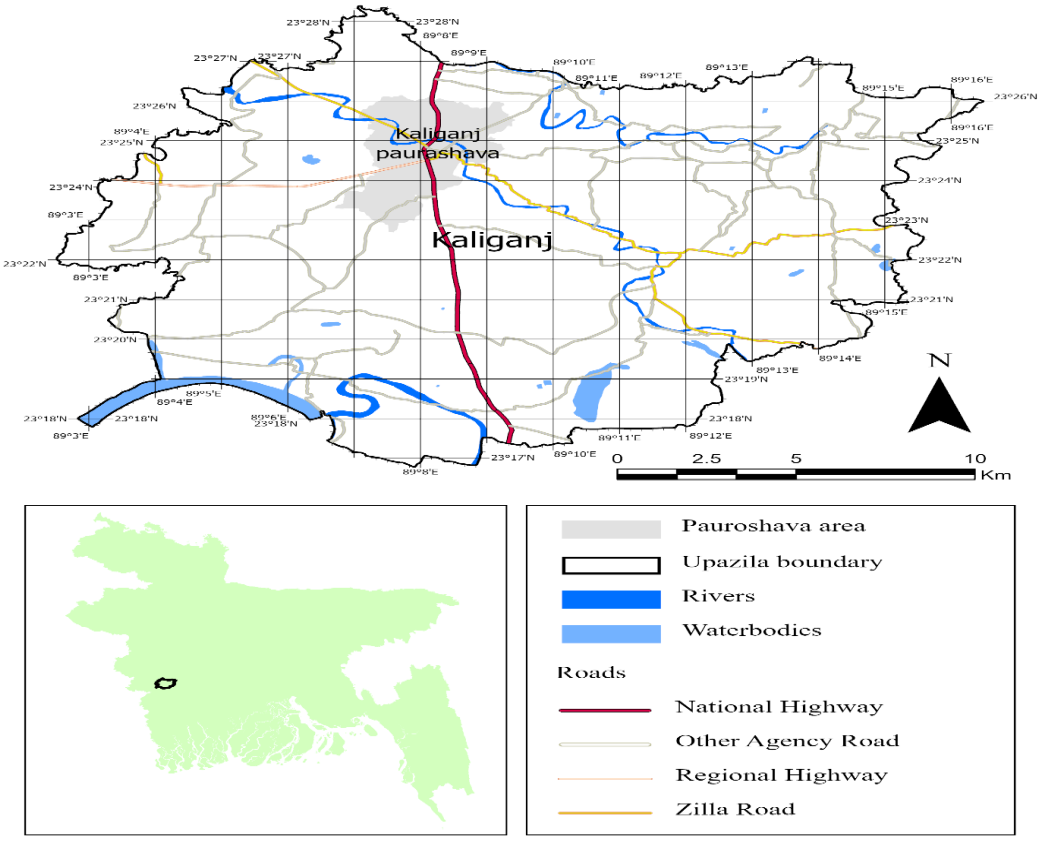

Fig 1. Map of Kaligonj Upazila, Jhenaidah

Methodology

An exploratory survey was conducted by a multistage random sampling technique in Kaliganj upazila, Jhenaidah purposively during 2016-2017. The criterion for selecting the site was the availability and diversity of private woodlot plantations. At first, a reconnaissance survey was carried out to select the potential village. Ten potential villages were selected purposively where many woodlots were located. After that, eight respondents from each village were selected randomly and a total of 80 respondents were contacted to participate in the face-to-face interview. Demographic (such as age, gender, income, land ownership, occupation, etc.) and management data on this aspect were collected by interviewing the respondents by questionnaire and by the author's observation. All data were compiled and the descriptive analysis was done by Microsoft Office Excel 2019.

Results

Socio-economic characteristics of the respondents

In the study area, during 2016-2017, most of the woodlot owners were educated (89%), economically podded, and had another source of income other than agriculture. About 32% of woodlot owners completed Secondary School Certificate (SSC) followed by below SSC (15%), Higher Secondary School Certificate (HSC) (28%), graduation (14%), and illiterate (11%) (Table 1). The age of the respondents in the study area was divided into three categories. Major respondents (55%) were middle-aged (41-55 years old) followed by 25% were 25-40 years and 20% were 56-70 years (Table 1). About 95% were male and only 5% were female. Professionally they were farmers (49%), businessmen (31%), and service holders (20%) (Table 1). They were categorized into five groups based on their income. The highest (35%) woodlot owner earned (yearly) between 80001.-130000 taka followed by 30000 -80000 taka (5%), 130001 - 180000 taka (30%), 180001 -230000 taka (22%) and 8% earn more than 230000 taka (Table 1).

Table 1. Demographic status (age, gender, education, occupation, and income) of the respondents (N=80)

Age		**Occupation**	
Categories	Percentage %	Categories	Percentage %
25-40 years	25	Farmer	49
41-55 years	55	Business	31
56-70 years	20	Service Holder	20
Gender		**Yearly Income**	
Categories	Percentage %	Earnings	Percentage %
Male	95	30000-80000 taka	5
Female	5	80001-130000 taka	35
Education		130001-180000 taka	30
Categories	Percentage %	180001-230000 taka	22
Below SSC	15	More than 230000 taka	8
SSC	32		
HSC	28		
Graduate	14		
Illiterate	11		

A complete portrayal of the woodlot in the study area

About 90% of the woodlots were rectangular, and 10% were irregular where 77.5% of woodlots had single ownership and the rest 22.5% had joint ownership. About 97.5% of woodlots were on their land and only 2.5% practiced on leased land (Table 2). Most of the

Table 2. Shape, land used pattern, type of species and plantation, landholdings and ownership, and benefits of woodlot in the study area.

Shape of the woodlot		**Woodlot land used previously**	
Categories	Percentage	Categories	Percentage
Rectangular	90%	Fallow	10%
Irregular	10%	Agriculture	85%
		Others	5%
Types of species			
Categories		**Type of the plantation**	
	Percentage	Categories	Percentage
Mahagony	75%	Mono-plantation	70%
Other	25%	Mixed-plantation	30%
Landholdings		**Ownership**	
Categories	Percentage	Categories	Percentage
Own	97.50%	Jointly	22.50%
Leased	2.50%	Single	77.50%
Sources of the planting materials		**Types of the seedlings**	
Categories	Percentage	Categories	Percentage
Purchase	92.50%	Taproot	80%
Own raised	5%	Polybag	18.75%
Others	2.50%	Seed sowing	1.25%
Age of the seedlings		**Purposes**	
Categories	Percentage	Categories	Percentage
1 year	46.25%	Easily manageable	20%
2 years	42.75%	Economically Profitable	40%
above 2 years	10%	Safe investment	5%
Benefits		Security	2.50%
Categories	Percentage	Unfit for agriculture	32.50%
Cash	75%		
Timber	10%		
Others	15%		

land was previously used as agricultural land (85%) where 10% of fallow land and the rest was other uses (5%). Within 5%, the lands were used as a brickfield, poultry farm, homestead land, and woodlot also. The increased price of agricultural inputs like fertilizer, seed, etc., was the leading cause of raising woodlots in agricultural land. Most

of the respondents converted their agricultural land into woodlot when the land lost its fertility and suitability for agricultural crop production. The shortage of time for care and protection of agricultural fields was also a cause of raising woodlots in agricultural land. Planting materials used by the respondents were mostly purchased from nurseries (92.5%). About 5% used their seedlings and only 2.5% took free from the government or NGOs (Table 2). Most of the respondents (80%) used coppice followed by polybag seedlings (18.75%) and sown seeds (1.25%) in the woodlot areas. It was found that 46.25% of the respondents used 1-year-old seedlings whereas 43.75% and 10% of respondents used 2 years old and more than 2 years old seedlings respectively (Table 2). All respondents planted the seedlings in the rainy season (June-August). About 40% of respondents raised woodlot for economic profit (i.e. low investment, low maintenance cost, more profit at a time, etc.) while 32.5% for the utilization of fallow agricultural land. Another 20% practiced woodlot for easy management technique and require less time and manpower, 5% for a safe investment, and 2.5% for security for the solvency of the new generation and to keep possessions of the land (Table 2). Maximum respondents (75%) thought that income generation was the most important benefit obtained by selling timber, fuel wood, and fruits. Some respondents (10%) used timber for household construction, furniture, etc., and the other 15% of respondents mentioned other benefits of woodlot.

Maximum (70%) woodlots in the study area were mono plantations and only 30% were mixed plantations (Table 2). Within the monoculture, about 75% was comprised of *Swietenia macrophylla*. Other 25% of plantations were comprised of *Samanea saman*, *Leucaena leucocephala*, *Dalbergia sissoo*, etc. (Table 3). In a mixed plantation, a number of species used such as *Swietenia macrophylla*, *Samanea saman*, *Leucaena leucocephala*, *Dalbergia sissoo*, *Azadirachta indica*, *Gmelina arborea*, *Bombax ceiba*, *Syzygium cumini*, *Albizia procera*, *Artocarpus heterophyllus*, *Acacia nilotica*, etc., (Table 3). It was found that most of the private woodlot comprised *Swietenia macrophylla* because of its good growth, timber quality, and demand. Now, respondents disagreed to raise *Leucaena leucocephala* plantation because of its light timber and because it was easily damaged by the storm. So, *Leucaena leucocephala* was found in some old woodlots of the study area but no new plantation was established with *Leucaena leucocephala*. Next to *Swietenia macrophylla*, respondents' prefers to plant *Dalbergia sissoo*, *Samanea saman*, and *Albizia procera* and few choose to plant *Acacia nilotica*, *Syzygium cumini*, *Neolamarckia cadamba*, *Azadirachta indica*, etc., (Table 3). It was also found that some respondents practiced agricultural crops simultaneously like *Curcuma longa*, *Zingiber officinale*, *Solanum melongena*, *Colocasia esculenta*, *Citrus aurantifolia*, etc. They practiced these crops, mostly in the initial years of the establishment of the woodlots.

Table 3. Tree species found in the woodlot at Kaliganj Upazilla of Jhenaidah district

	Tree species		
Local name	Scientific name	Local name	Scientific name
Mahogoni	*Swietenia macrophylla*	Kathal	*Artocarpus heterophyllus*
Raintree	*Samanea saman*	Jam	*Syzygium cumini*
Koroi	*Albizia procera*	Aam	*Mangifera indica*
Ipil-ipil	*Leucaena leucocephala*	**Agricultural crops**	
Sissoo	*Dalbergia sissoo*	Halud	*Curcuma longa*
Kadam	*Neolamarckia cadamba*	Kachu	*Colocasia esculenta*
Neem	*Azadirachta indica*	Ginger	*Zingiber officinale*
Babla	*Acacia nilotica*	Lebu	*Citrus aurantifolia*
Simul	*Bombax ceiba*	Brinjal	*Solanum melongena*
Gamari	*Gmelina arborea*		

Other benefits

Species like *Leucana leucocephala*, *Anthocephalus chinensis*, *Acacia nilotica* etc. were raised mainly for producing and selling fuel wood. Branches pruned from trees, dry leaves, dry branches, and trees that were removed by thinning or other cutting were also used as good fuel. *Syzygium cumini*, *Citrus aurantifolia*, *Artocarpus heterophyllus*, *Mangifera indica*, etc., were very nutritious fruits that fulfilled the demand of local people. These types of fruit-producing trees were grown purposively. Some woodlot plantations were considered a money-saving account for present and future generations. They thought that woodlots will provide a handsome amount of money at a time. Some tree species had medicinal value and varieties of products were made from a grown tree on the woodlot. Palatable and nutritious fodder was also grown in woodlots like *Acacia nilotica*, *Leucana leucocephala*, etc. The wasteland and degraded land were properly utilized by planting trees. Most of the forestry activities are labor-intensive so woodlot plantations increased the employment opportunity. In the middle of the agricultural land sometimes woodlots were made to break the wind flow. Woodlots helped to improve the environmental condition by giving oxygen and taking CO_2. It reduced soil erosion, increased nutrients of soil through litter fall, reduced temperature, etc.

Management technique of the woodlot

Site preparation

The total respondents (100%) reported that they took extra care of soil like plowing, digging, etc. but no burning was done at all just before planting the seedlings. Soil work was done for minimizing soil loss. Spacing is very essential for tree growth,

especially for tree diameter and height. In the study area, the maximum number of respondents (70%) planted trees with 1.83m × 1.83m distance followed by 1.98m × 1.98m (16.25%) and 2.13m × 2.13m (13.75%) distance (Table 4).

Tending operation

Weeding was generally done in the seedling stage of the plantation. In the study area, 100% of the respondents practiced weeding to ensure rapid growth and reduce competition for light and nutrition. Most respondents said that they practiced weeding in the early years of the establishment of the woodlot. About 80% of respondents practiced 2 times weeding per annum and the other 20% practiced 1 time per annum (Table 4). Cleaning was done to free the best trees from undesirable individuals of the same age that overtop them or are likely to do so. In the study area, 95% of the respondents have practiced cleaning and the other 5% of respondents did not practice (Table 4). Most of the respondents (about 80%) were conscious and practiced thinning and the rest of the respondents (20%) did not practice thinning at all (Table 4). Some respondents felled the vigorous trees during thinning for giving better opportunities to the trees of slower growth. The majority (97.5%) of the respondents in the study area practiced pruning and only 2.5% were not practiced. The wrong pruning operation may produce a defect in the tree and reduce timber quality.

Improvement of the site

About 98.75% of the respondents used various types of fertilizers (Triple Super Phosphate, potash, urea, cow dung, etc.) in their woodlot to improve the growing conditions before planting trees. They usually used 50 kg TSP or potash or urea per bigha (1 bigha = 33 decimals). Other 1.25 % of respondents did not use fertilizers. Only 15% of the respondents watered the woodlot whereas 85% were not practiced. It was done during the dry season when the soil became very dry due to excessive water evaporation of water from the soil by shallow and deep tube-well.

Woodlot maintenance

A total of the respondents (100%) took special protection to save their woodlot in the initial stage from cattle, human beings, insects, etc. They built bamboo and *Acacia nilotica* live fences to protect their woodlot from grazing animals and human interference. They sprayed pesticides such as Malathion, Thiovit, Karati, etc. protect their woodlot from different pests and insects. They used different types of sticks to provide support to the young seedlings. About 52.5% of the respondents have filled the vacant area produced by the death of seedlings (Table 4). Most of them followed vacancy filling after one year of plantation. The rest respondents (47.5%) did not practice vacancy filling.

Harvesting and rotation

About 60% of the respondents harvested their woodlot by selection system. Another 40% used a clear-felling system. In the case of rotation, most of the respondents (90%) did not fix the rotation and only 10% fixed the rotation year 10-20 years which varied with species. For *Leucana leucocephala* and *Neolamarckia cadamba* they fixed 10 years but for *Swietenia macrophylla*, *Acacia nilotica*, *Dalbergia sissoo*, *Samanea saman*,

Azadirachta indica, *Albizia procera*, *Albizia lebbeck*, etc. they fixed 20 years or more. Because *Leucana leucocephala* and *Anthocephalus chinensis plantations* were raised for fuelwood purposes but others were planted for timber production. In the case of fruit species, rotation age was not fixed.

Table 4. Respondents' attitude on spacing, site preparation, site improvement, rotation, protection, tending, and harvesting of woodlot in the study area.

					Yes	No
Spacing	Categories	Percentage	Site preparation	Soil Working	100%	0%
	1.83m x 1.83m	70%		Burning	0%	100%
	1.98 m x 1.98 m	16.25%	Tending operation	Weeding	100%	0%
	2.13 m x 2.13 m	13.75%		Cleaning	95%	5%
Harvesting	Categories	Percentage		Thinning	80%	20%
	Clear felling	40%		Pruning	97.5%	2.5%
	Selection system	60%	Improvement of the site	Fertilizing	98.5%	1.25%
Rotation age	Categories	Percentage		Watering	15%	85%
	10-20 years	10%	Woodlot maintenance	Protection	100%	0%
	Not Fixed	90%		Vacancy filling	52.5%	47.5%

Problems of woodlot

The major problem in the study area was grazing because of having pet animals. Respondents said that seedlings and trees were damaged by cattle with insect and pest attacks. All owners did not practice thinning, pruning, salvage cutting, sanitation cutting, etc., at the right time. Some people did not use accurate techniques and tools for pruning at the correct time as a result timber quality had been damaged. Besides this, the lack of a proper supply of planting material at a reasonable price locally and the unconsciousness of respondents about rotation reduced the production also. In some cases, owners did not agree to use fast-growing locally suitable species. Successful woodlot plantations were affected by the unwillingness to vacancy filling caused by the lack of proper training and guideline of the respondents.

Discussion

The biographical characteristics (age, education, and source of income) and the socio-economic characteristics had much influence on the adoption behavior regarding new practices (Amacher *et al*., 2004; Hansen *et al*., 2005; Salam *et al*., 2000). Mostly middle-aged (55%) and male (95%) people in the study area were practicing woodlot more because they decide for their families. One of the major demographic characteristics was the age that influences the adoption of agroforestry (Buyinza and Wambede, 2008, Gebreegziabher *et al*., 2008, Kabwe *et al*., 2009, Neupane *et al*., 2002). Traditionally middle-aged males are responsible for agricultural and forestry works that

retard females to join such activities in Bangladesh (Azad *et al*., 2020; Bichitra *et al*., 2022; Dey *et al*., 2020; Islam *et al*., 2020; Nurunnahar *et al*., 2020; Ripon *et al*., 2021). In the study area, the educated people (about 89%) who had another source of income and had available land for woodlot plantations practiced woodlots as an extra income source. Besides, educated people were more conscious of the importance of woodlots. It was found that the people who had economic solvency raised woodlot because woodlot is a long-term investment. Economic factors were more important than ecological factors in shaping farmers' decisions (Salam et al., 2000). In contrast to the outcomes of Emtage and Suh (2004) from the Philippines, where decisions were driven by the household needs for timber and building materials. However, the main purpose of raising woodlots in the study area was economic profit (40%). Most of the owners said that the practice of woodlot was not their main occupation. But they established it because they had not enough time to cultivate crops. It seemed that about 85% of agricultural land was converted into woodlot in this area. Larger-income households accepted new technologies more and a similar result was found in many studies around the world (Patel *et al*., 1995; Hyde *et al*., 2000; Pattanayak *et al*., 2003).

Moreover, it was found that 77.5% had single ownership, and the rest 22.5% had joint ownership where 97.5% practiced woodlot on their land and only 2.5% practiced on leased land. Joint ownership means a single woodlot has more than one owner. The major reason for ownership jointly of the woodlot was joint ownership of land acquired hereditarily in Bangladesh. Most owners practiced woodlot on their land because the tree has long rotation than crops and in the case of own lands it is secured, but in the case of leased land, it is not secured. (Nyadzi *et al*., 2003) reasoned that farmers with land deficiencies did not have sufficient land to exercise agroforestry like woodlot. Maximum (70%) woodlots in the study area were mono plantations and only 30% were mixed plantations. Rahaman *et al*., (2020) stated that mono-culture adjacent to natural forests declines the diversity with having high carbon accumulation value (Pitol and Mian, 2022; Pitol *et al*., 2019), but the study area was far from the natural forest land. Most of the activities were labor-intensive and increased employment opportunities. Besides, many authors (Dev *et al*., 2006; Appiah and Pappinen, 2010; Stewart *et al*., 2011) informed that woodlots offer both environmental and social benefits like give oxygen (O_2) and taking CO_2, used as a windbreak, reducing soil erosion, increased nutrients of soil through litterfall, reduced temperature, etc. About 75% comprised of *Swietenia macrophylla* and Pitol *et al*., (2019) stated that the woodlot plantation of *Swietenia macrophylla* at Kaliganj Upazila absorbed a huge amount of carbon (168.99 Mg ha-1). While *Swietenia macrophylla* woodlot uptook 125.5-1004.5 Mg/ha (mean 436.3 Mg/ha) of CO_2 and released 91.25-730.26 Mg/ha (mean 317.2 Mg/ha) of oxygen (O_2) that may earn 4,285-34,470 BDT/ha (mean 14,900 BDT/ha) and 3.2-25.5 million BDT/ha (average 11.1million BDT/ha) respectively (Pitol and Mian, 2022). Woodlot in the study area was maintained and advancement work was done by the owner. It seemed that 100% took special protection for their woodlot whereas 98.5% applied fertilizer. They knew weeding (100%), cleaning (95%), thinning (80%), and pruning (97.5%), but only 52.50% filled the vacant area caused by the death of trees. They still need proper guidance and training that will increase their knowledge and provide aid for the advancement of woodlots in the study area.

Recommendation

Protection against cattle should be taken properly and it will reduce the causes of seedlings and tree damage. The planting materials should be raised locally and potentially near the woodlots which will ensure a good supply of planting materials at a reasonable price. Proper pest management should be done at the right time and it will reduce the risk of total tree attack. After any natural disaster removal of uprooted and pruning of damaged branches should be carried out as soon as possible. The first growing species which has a desirable value should be selected for the woodlot. Pruning should be done in time, which helps to produce the knot-free and desirable height of timber. Accurate tools and techniques should be used in pruning. The vacancy filling should be done in the second year of the planting during the onset of the rainy season. Healthy and a little higher than existing seedlings should be planted during vacancy filling. Special training about the management technique of woodlot should be provided by the Agricultural department and Forest department. Farmers need to be conscious of market information. The actual rotation at which the tree produces maximum wood should be known by the owner. After the rotation age, the woodlot should be harvested.

Conclusion

To fulfill the demand for food, fuel, housing, and transportation of this increased population, greater pressure has been put on the forest resource of the country. The pressure on natural forests can reduce and also increase the area of the forest land by raising private woodlots. First, growing species can raise in woodlots to fulfill our demand within a short time. Also, the owner should follow proper management techniques to get more benefits from it. Some important operations which are required to get success, such as proper planting time, site preparation, spacing, weeding, thinning, pruning, etc. should be ensured by the owners. Protection against grazing animals, fire, human interference, diseases, and pests also should be taken by the owners. However, they lack modern technology and insufficient organizational support. Proper guidance can improve existing practices. Government and responsible organizations should take initiative for assisting them and ensuring strong extension work.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aggangan, R. T. 2001. Tree farming in the Philippines: some issues and recommendations. Socio-economic evaluation of the potential for Australian tree species in the Philippines. pp.33-43.

Amacher, G. S., Ersado, L., Hyde, W. F. and Osorio. 2004. Tree planting in Tigray, Ethiopia: The importance of human disease and water microdams. *Agroforestry Systems*. doi:10.1023/B:AGFO.0000024411.22604.0a

Anon. 2011. http://en.wikipedia.org/wiki/Agroforestry, Date Accessed: 2014-05-13

Appiah, M. and Pappinen, A. 2010. Farm Forestry Prospects among Some Local Communities in Rachuonyo District, Kenya. *Small-Scale Forestry*. 9(3):297-316. https://doi.org/10.1007/s11842-010-9117-z

Azad, A. K., Pitol, M. N. S. and Rakkibu M. G. 2020. Livelihood status of Sundarbans dependent people at Shymnagar Upazila of Satkhira, Bangladesh. *Asian J.* 5:28-35. https://doi.org/10.13057/asianjfor/r050104

BES. 2020. Bangladesh Environment Statistics-2020, Statistics & Informatics Division (SID), Ministry of Planning; Government of the People's Republic of Bangladesh. pp. 29-40.

BBS. 2014. Report on Household based forestry survey 2011-12. Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning.

Bichitra, K. B., Dey, T., Islam, M. A. and Pitol, M. N. S. 2022. Management of Nurseries to Produce Quality Planting Stocks: A Case Study at Phultala Upazila of Khulna District, Bangladesh. *Food and Agri Economics Revi.* 2(1):01-06. doi:10.26480/faer.01.2022.01.06

Buyinza, M. and Wambede, N. 2008. Extension for agroforestry technology adoption: mixed intercropping of crotalaria (Crotalaria grahamiana) and maize (Zea mays L.) in Kabale District, Uganda. *Environ Res J*. 2(3):131-137.

Dev, I., Misri, B. and Pathania, M. S. 2006. Forage demand and supply in western Himalaya: A balance sheet for Himachal Pradesh. *Indian J. Animal Sci*. 76 (9):720-726.

Dey, T., Kamruzzaman, M., Islam, M. A., Bachar, B. K. and Pitol, M. N. S. 2020. Attitudes of local people towards community based eco-tourism in the Sundarbans. *International J. Business Management and Social Res.* 9(2):528-535. https://doi.org/10.18801/ijbmsr.090220.55

Emtage, N. and Suh, J. 2004. Socio-economic factors affecting smallholder tree planting and management intentions in Leyte Province, Philippines. *Small-Scale Forest Economics, Management and Policy*. https://doi.org/10.1007/s11842-004-0018-x

FAO. 2009. The State of World Forests 2009. Food and Agriculture Organization of the United Nations Rome, Italy.

FAO. 2010. Global Forest Resources Assessment 2010. Main Report. Food and Agriculture Organization of the United Nations, Rome, FAO Forestry Paper163.

FAO. 2015. Global Forest Resources Assessment 2015. Desk reference. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/publications

FD. 2016. Tathya Kanika: National Tree Planting Campaign and Tree Fair. Forest Department, Ministry of Environment and Forests.Gebreegziabher, Z., Oskam, A. and Demeke, B. 2011. Urban fuel demand in Ethiopia: an almost ideal demand system approach. *Ethiopian J. Economics*. https://doi.org/10.4314/eje.v19i1.71414

Hansen, J. D., Luckert, M. K., Minae, S. and Place F. 2005. Tree planting under customary tenure systems in malawi: Impacts of marriage and inheritance patterns. *Agri. Systems*. https://doi.org/10.1016/j.agsy.2004.05.003

Hyde, W. F., Kohlin, G. and Amacher. G. S. 2000. Social forestry reconsidered. In: Hyde WF, Amacher GS (eds) Economics of forestry and rural development: an empirical introduction from Asia. University of Michigan Press, Ann Arbor.

Islam, A., Sharmin, A., Biswas, R., Dey, T., Bachar, B. K. and Pitol, M. N. S. 2020. Utilization of Minor Forest Products of the Sundarbans in Bangladesh. *Adv. in Agri. Horti. and Entomology*: AAHE-126. ISSN 2690-1900. 2020(04):1-8. https://kosmospublishers.com/utilization-of-minor-forest-products-of-the-sundarbans-in-bangladesh/

Islam, M. T. 2013. People's participation in Protected Areas of Bangladesh. First Asia Park Congress, Sendai City, Japan, 13-17 November 2013. http://www.env.go.jp/nature/asia-parks/

Kabwe, G., Bigsby, H. and Cullen, R. 2009. Factors influencing adoption of agroforestry among smallholder farmers in Zambia. Paper Presented at the 2009 NZARES Conference, Tahuna Conference Centre, Nelson.

Muhammed, N., Koike, M., Haque, F. and Miah, M. D. 2008. Quantitative assessment of people-oriented forestry in Bangladesh: A case study in the Tangail forest division. *J. of Envir.Management*. https://doi.org/10.1016/j.jenvman.2007.01.029

Nair, P. K. R. 2006. Whither home gardens? In: Kumar B. M. and Nair P. K. R. (eds.), Tropical Homegardens: A time tested example of sustainable agroforestry. *Springer*, Netherlands, 3:355-370.

Neupane, R. P., Sharma, K. R. and Thapa, G. B. 2002. Adoption of agroforestry in the hills of Nepal: A logistic regression analysis. *Agri. Systems*. https://doi.org/10.1016/S0308-521X(01)00066-X

Nurunnahar, Pitol, M. N. S. and Sharmin, A. 2020. Status and Prospects of Agroforestry at Kaligonj Upazila in Satkhira District. *European J. Agri. and Food Sci.* 2(6). https://doi.org/10.24018/ejfood.2020.2.6.186

Nyadzi, G. I., Otsyina, R. M., Banzi, F. M., Bakengesa, S. S., Gama, B. M., Mbwambo, L. and Asenga D. 2003. Rotational woodlot technology in northwestern Tanzania: Tree species and crop performance. *Agroforestry Systems*. https://doi.org/10.1023/B:AGFO.0000005226.62766.05

Patel, S. H., Pinckney, T. C. and Jaeger, W. K. 1995. Smallholder wood production and population pressure in East Africa: evidence of an environmental Kuznets curve? *Land Economics*. https://doi.org/10.2307/3146715

Pattanayak, S. K., Mercer, D. E., Sills, E. and Yang, J. C. 2003. Taking stock of agroforestry adoption studies. *Agroforestry Systems*. https://doi.org/10.1023/A:1024809108210

Pitol, M. N. S. and Mian, M. B. 2022. High carbon storage and oxygen (O_2) release potential of Mahagony (*Swietenia macrophylla*) woodlot plantations in Bangladesh. Saudi *J. Bio. Sci.* doi: https://doi.org/10.1016/j.sjbs.2022.103498

Pitol, M. N. S., Khan, M. Z. and Khatun, R. 2019. Assessment of Total Carbon Stock in Swietenia macrophylla Woodlot at Jhenaidah District in Bangladesh. *Asian J. Res. Agri. and Forestry*. 2(3):1-10. https://doi.org/10.9734/ajraf/2018/46922

Rahaman, M. T., Gurung, D. B. and Pitol, M. N. S. 2020. Comparative Study of Understory between Exotic Monoculture Plantation (Acacia Sp.) and Adjacent Natural Sal (Shorea Robusta) Forest. *European J. Agri. and Food Sci*. 2(6). https://doi.org/https://doi.org/10.24018/ejfood.2020.2.6.204

Ripon, S., Islam, M. A., Sharmin, A., Biswas, R. and Kumar, J. 2021. Sustainable Agroforestry Practice in Jessore District of Bangladesh. *European J. Agri. and Food Sci*. 3(1):1-10. https://doi.org/10.24018/ejfood.2021.3.1.150

Roy, R. C. 2004. Land rights of the indigenous peoples of the Chittagong Hill Tracts, Bangladesh. International Work Group for Indigenous Affairs (IWGIA), Copenhagen, Denmark.

Salam, M. A., Noguchi, T. and Koike, M. 2000. Understanding why farmers plant trees in the homestead agroforestry in Bangladesh. *Agrofo. Systems*. https://doi.org/10.1023/A:1006403101782

Stewart, H. T. L., Race, D. H., Curtis, A. L. and Stewart, A. J. K. 2011. A case study of socio-economic returns from farm forestry and agriculture in south-east Australia during 1993–2007. *Forest Policy and Eco*. 13(5):390-395. https://doi.org/10.1016/j.forpol.2011.03.004

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PREVALENCE OF ZOONOTIC DISEASES OF SMALL RUMINANTS AT SAVAR UPAZILA OF DHAKA DISTRICT

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Abstract

The objective of this study was to assess the prevalence of zoonotic diseases of small ruminants (SR) at Savar upazila of Dhaka district. A questionnaire-based survey was conducted in small and middle-scale goat and sheep farms at Savar Upazila with a total number of 1981 SR (1438 goats and 543 sheep). We found a total of 468 diseased SR (281 goats and 187 sheep), of which 206 cases were zoonotic (41.37%) (124 / 60% goats; 82/40% sheep). Prevalence of bacterial zoonoses (Salmonellosis, Tetanus Dermatophilosis, Brucellosis, Listeriosis and Campylobacteriosis) was higher (23.78% in goat and 15.53% in sheep) followed by that of parasitic zoonoses (Hydatidosis, Fascioliasis, Amphistomiasis and Cryptosporidiosis) (17.48% in goat and 11.65% in sheep), viral zoonoses (Contagious Ecthyma, Foot and Mouth Disease and Rabies) (12.14% in goat and 7.77% in sheep), rickettsial zoonoses (Q Fever) (2.91% in goat and 1.94% in sheep). The age-wise, sex-wise and breed-wise prevalence of zoonotic diseases in goats and sheep were also determined. The study provided an epidemiological forecast showing the prevalence of zoonotic diseases of SR, which can be helpful for the clinician in the diagnosis of such infections. The present study revealed that the SR at Savar Upazila is susceptible and also infected with various zoonotic diseases. So, prevention and control of these zoonotic diseases are essential.

Keywords: Bacterial zoonoses, Parasitic zoonoses, Prevalence, Small ruminants

Introduction

Small ruminants (SR), particularly goats and sheep constitute the major portion of livestock in Bangladesh; about 80% of rural people are involved with livestock farming (Siddiki *et al.,* 2009). Goats and sheep are important livestock resources that give more production per unit of investment, have younger slaughter age, and have a well-established market (Prasad, 2007). They also contribute to earnings of a significant amount of foreign currency by exporting skins and other by-products (Kamaruddin,

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2003). Bangladesh has the third highest population of goats among the Asian countries which accounts for about 34.5 million heads representing 57% of total ruminant livestock (FAO, 2003) Maximum numbers of SR are raised under small holder old style management system in rural zones in Bangladesh.

The term "Zoonoses" is derived from the Greek word "Zoon", which means animal, and "nosos", which means illness. Zoonotic diseases are infectious diseases that spread naturally between species (sometimes by a vector) from animals to humans or from humans to animals. According to the World Health Organization (WHO), any disease or infection that is naturally transmissible from vertebrate animals to humans or from humans to animals is classified as zoonosis (WHO, 2020). Zoonotic diseases are common throughout the world and the public health threat of emerging, reemerging, and neglected zoonoses in the industrial world has been reported (Cutler *et al.*, 2010; Weese *et al.*, 2002) but it constitutes an important threat to human health in developing countries like Bangladesh. Among the human pathogens, about 61% are zoonotic in nature (Taylor et al., 2001). Most of the zoonoses diagnosed SR are transmitted by close contact with humans and some others are airborne, vector-borne, and foodborne diseases. Most of these diseases affect animal health and decrease livestock production (Grace *et al.*, 2012). These diseases constitute a public health problem throughout the world, particularly in the tropics where their control is restricted by inadequate infrastructure and financial resources. A strong database on the prevalence of zoonotic diseases in any area might contribute to the provision of appropriate veterinary practice and effective zoonotic disease control programs and SR production systems considering the different geographical locations, it is an important issue to have a baseline database on zoonotic diseases prevalence of small ruminants.

Savar is an upazila of Dhaka district in the division of Dhaka, Bangladesh. Savar is located at 23.8583 °N 90.2667 °E. It has 66,956 households and a total area of 280.13 km². The main economic sectors in Savar are agriculture (23.6%), industry (59.6%), and service (16.8%) (Wikipedia, 2019). The total number of goats in Savar Upazila is about 266,397 and sheep about 5,382 (Data source-Upazila Livestock Office and Veterinary Hospital, Savar, Dhaka). The present study was conducted to estimate the prevalence of zoonotic diseases in SR; the comparative prevalence of bacterial, parasitic, viral, fungal, and rickettsial zoonoses along with age-wise, sex-wise, and breed-wise distribution of zoonotic diseases affecting SR.

Materials and Methods

Study area and period

The study was conducted at Savar Upazila in Dhaka district by visiting small and middle-scale goat and sheep farms and also from Upazila Livestock Office and Veterinary Hospital during the period between 15 March 2021 and 21 August 2021.

Data collection

The data was collected and evaluated from a total number of 1981 SR (1438 goats and 543 sheep). A total of 150 questionnaires were prepared for the study.

Information was collected using a structured questionnaire by face to face interview of farmer and veterinary surgeon. The data was characterized according to the basic information about the farmer and farm such as the number of animals, age, sex, breed, body weight, vaccination, deworming, disease condition, rearing system, problems in rearing, and suggestions or comments.

Study design

The study was a cross-sectional study. During the study period, different ages, breeds, and sex of diseased SR were received at Upazila Livestock Office and Veterinary Hospital and also at different small and middle-scale goat and sheep farms in Savar Upazila. The zoonotic diseases were diagnosed on the basis of clinical history (e.g. deworming, vaccination, feeding etc.), clinical signs (e.g. nasal discharge, lacrimation, fever, salivation etc.) and post mortem lesions (e.g. necrosis, haemorrhage etc.).

Data analysis

Data that were collected had been stored in an MS Excel spreadsheet and descriptive statistics (percentage) were computed.

Results and Discussion

Overall prevalence of zoonotic diseases of SR

The study found a total number of 206 cases of zoonotic diseases at Savar Upazila where 124 cases were in goats and 82 cases were in sheep (Table 1). Here about 60% of cases in goats and about 40% of cases in sheep were zoonotic (Fig. 1). Among 124 zoonotic cases in goats; 49/23.78%), 36/17.48%), 25/12.14%), 8/3.88%, and 6/2.91% were recorded as bacterial zoonoses, parasitic zoonoses, viral zoonoses, fungal zoonoses, and rickettsial zoonoses, respectively, and another 82 zoonotic cases in sheep; 32/15.53%, 24/11.65%, 16/7.77%, 6/2.91%, and 4/1.94% were recorded as bacterial zoonoses, parasitic zoonoses, viral zoonoses, fungal zoonoses, and rickettsial zoonoses, respectively (Fig. 2).

Table 1. Total Number of Cases of Zoonotic Diseases of Small Ruminants at Savar Upazila

Species	Total No. of Diseased Animals	Total No. of Animals with Zoonoses
Goat	281	124
Sheep	187	82
Total Cases	468	206

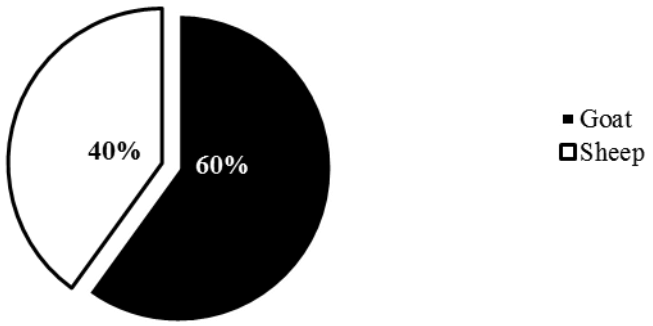

Fig. 1. Percentage of Zoonotic Diseases of Small Ruminants at Savar Upazila

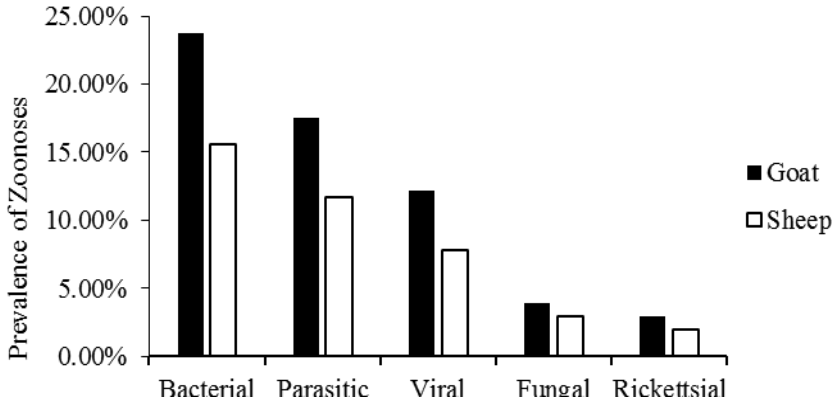

Fig. 2. Etiology of Zoonoses of Small Ruminants at Savar Upazila

Prevalence of bacterial zoonoses of SR

The bacterial zoonoses that were found in both goats and sheep were Salmonellosis, Tetanus Dermatophilosis, Brucellosis, Listeriosis, and Campylobacteriosis (Fig. 3). The prevalence of these bacterial zoonoses was higher in goats (23.78%) than in sheep (15.53%). The prevalence of Salmonellosis in goats was 10.19% and in sheep was 6.79%. Similarly, Tetanus 5.34% in goats and 3.88% in sheep; Dermatophilosis 2.91% in goats and 1.94% in sheep; Brucellosis 2.43% in goats and 1.46% in sheep; Listeriosis 1.94% in goat, 0.97% in sheep and Campylobacteriosis 0.97% in goat and 0.49% in sheep. Infection of Salmonellosis in animals is maintained by recycling slaughterhouse waste as animal feed, fecal-oral spread, and fecal contamination of hatching eggs (Borhanuddin *et al.,* 1986). The prevalence of Brucellosis was observed in small ruminants in the Tangail district (8.4%) followed by the small ruminants at Savar upazila (8.0%) (Gani *et al.,* 2016).

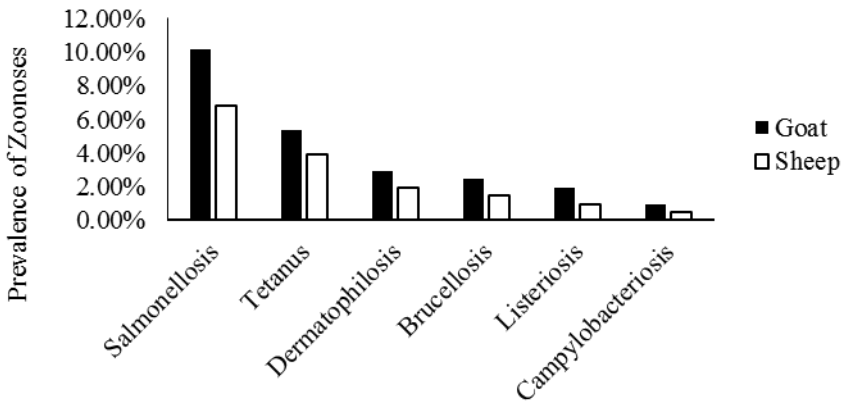

Fig. 3. Prevalence of Bacterial Zoonoses of Small Ruminants at Savar Upazila

Prevalence of parasitic zoonoses of SR

The parasitic zoonoses that were found in both goat and sheep were Hydatidosis, Fascioliasis, Amphistomiasis, and Cryptosporidiosis (Fig. 4). The prevalence of parasitic zoonoses were higher in goat (17.48%) than in sheep (11.65%). The prevalence of Hydatidosis in goats was 7.76% and in sheep was 5.34%. Similarly, Fascioliasis 5.83% in goats and 3.40% in sheep; Amphistomiasis 2.43% in goats and 1.94% in sheep and Cryptosporidiosis 1.46% in goats and 0.97% in sheep. Similar findings were also found by Kabir et al., (2009). Hydatidosis is an important parasitic zoonosis and the disease has been recorded in almost all parts of the world during the execution of veterinary inspection in slaughterhouses (E1-Badawi et al., 1980, Chermette, 1983, Petkov et al., 1987, Ashraf et al., 1987; Anwar et al., 1993). The highest case fatality of Fascioliasis (33) per ten thousand animals was recorded in goats by Rahman et al. (2017).

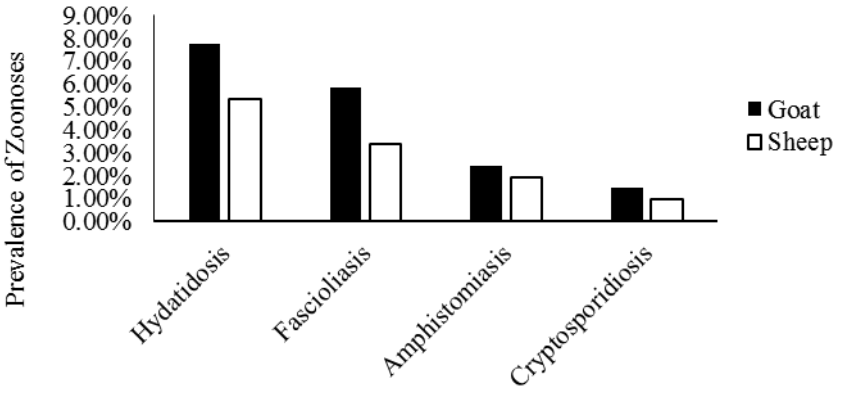

Fig. 4. Prevalence of parasitic zoonoses of small ruminants at savar upazila

Prevalence of viral zoonoses of SR

The viral zoonoses that were found in both goats and sheep were Contagious Ecthyma, Foot, and Mouth Disease (FMD), and Rabies (Fig. 5). The prevalence of these viral zoonoses was higher in goats (12.14%) than in sheep (7.77%). The prevalence of Contagious Ecthyma in goats was 9.22% and in sheep was 6.13%. Similarly, FMD is 1.94% in goats and 0.97% in sheep, and Rabies is 0.98% in goats and 0.94% in sheep. Contagious ecthyma is a zoonotic disease that primarily affects sheep and goats worldwide. Although the clinical occurrence of this disease in goats has been reported in Bangladesh (Samad, 2000a), its transmission from animals to humans has not yet been documented locally. Foot-and-mouth disease is an endemic disease mainly affecting ruminants in Bangladesh and severe outbreaks are mostly recorded in cattle (Islam and Samad, 1998). Almost all human deaths caused by Rabies originated in Asia and Africa (Samad, 2008). Epidemiological studies of Rabies in Bangladesh are very limited (Ali *et al.*, 1982; Biswas *et al.*, 1996) to formulate an effective control program.

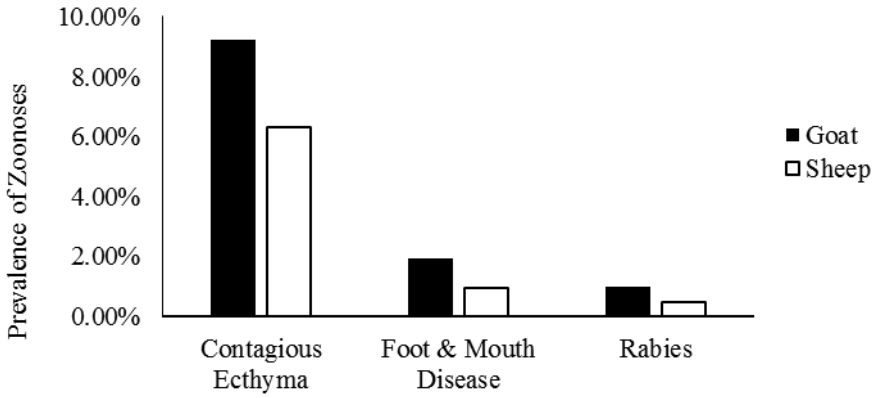

Fig. 5. Prevalence of viral zoonoses of small ruminants at savar upazila

Prevalence of fungal and rickettsial zoonoses of SR

Prevalence of dermatomycosis was found its prevalence was higher in goats (3.88%) than in sheep (2.91%) (Fig. 6), which conforms to the findings of Gupta *et al.*, (1970). Similarly, the prevalence of Q fever was higher in goats (2.91%) than in sheep (1.94%) (Fig. 6). The seroprevalence of Q fever varied according to sex, pregnancy status, and study areas but none was significant statistically (Rahman *et al.*, 2016).

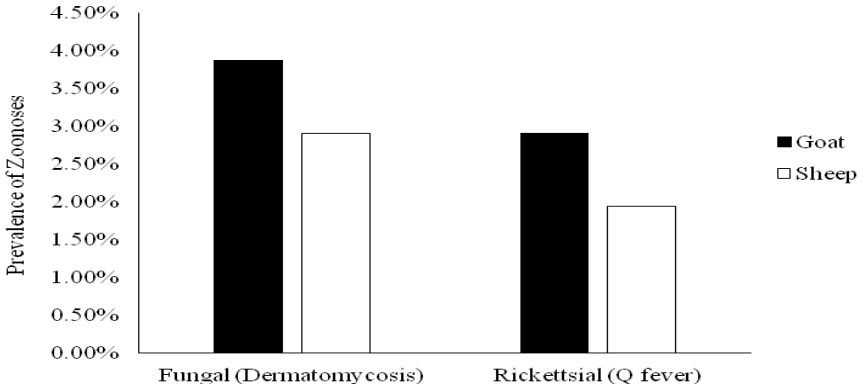

Fig. 6. Prevalence of fungal & Rickettsial Zoonoses of Small Ruminants at Savar Upazila

Age-wise prevalence of zoonotic diseases of SR

In age-wise prevalence, this study found the highest prevalence of zoonotic diseases in young animals (12 to 24 months) both goats (42.74%) and sheep (45.12%) than older animals (more than 24 months) in goats (32.26%) and sheep (29.27%) and growing animals (6 to12 months) in goats (25%) and sheep (25.61%) (Fig. 7). The reason in the prevalence of infection of zoonotic diseases in different age groups in sheep and goat is difficult to explain but it might be due to an immunological phenomenon (Okafor *et al.*, 1988). Besides, higher prevalence in older groups may be due to more exposure to the source of infection (Mohiuddin *et al.*, 1982).

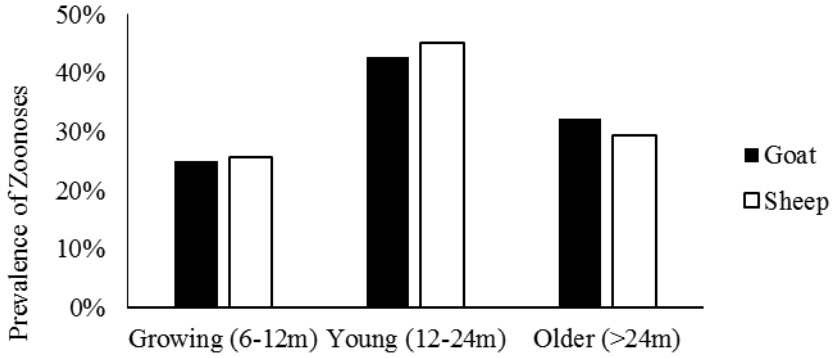

Fig. 7. Age-wise Prevalence of Zoonoses of Small Ruminants at Savar Upazila

Sex-wise prevalence of zoonotic diseases of SR

In sex-wise prevalence, this study revealed that a higher prevalence was observed in females (55.65%) than in males (44.35%) in goats. Similarly in sheep, the higher prevalence was observed in females (54.88%) than in males (45.12%) (Fig. 8). The

higher percentage of infection of zoonotic diseases in the female may be due to alteration in the physiological condition of the animals during pregnancy and lactation (production activity) and also the lack of feed supplement for production, which may lead to the lowering of body resistance of the female (Uddin *et al.*, 2006).

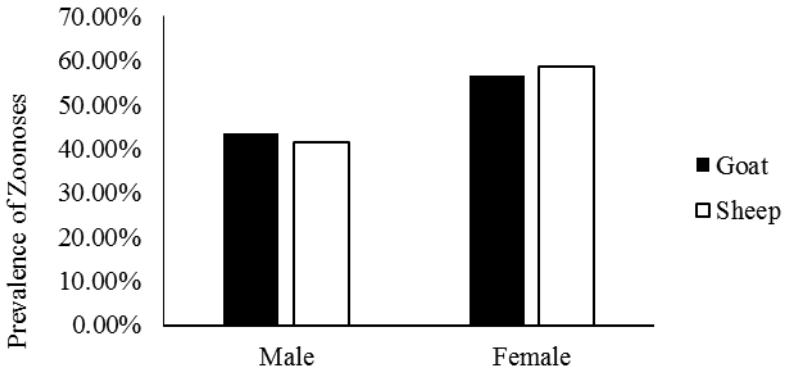

Fig. 8. Sex-wise prevalence of zoonoses of small ruminants at savar upazila

Breed-wise prevalence of zoonotic diseases of SR

In breed-wise prevalence, this study revealed that the highest prevalence in goats was observed in the Black Bengal (45.16%) than in Jamunapari (33.87%) and Cross (20.97%) (Fig. 9). On the other hand, the highest number of prevalence in sheep was observed in the Indigenous (64.63%) than the Garole (35.37%) (Fig. 10). Chakrabartty et al. (2016) found more zoonotic disease prevalence in Black Bengal goat breed.

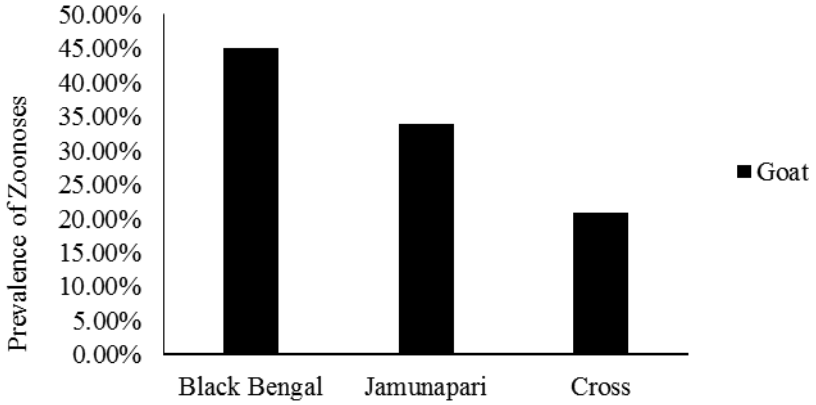

Fig. 9. Breed-wise prevalence of zoonoses of goat at savar upazila

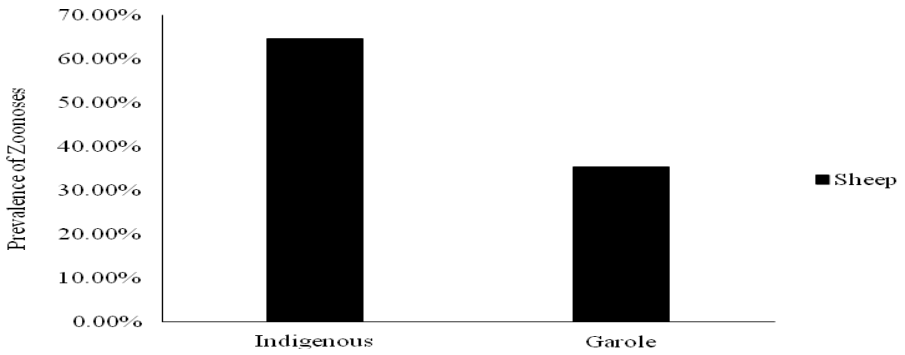

Fig. 10. Breed-wise prevalence of zoonoses of sheep at savar upazila

Conclusion

This study revealed the overall prevalence of zoonoses of SR at Savar Upazila in Dhaka district which might be given a transparent perception about their distribution to the forthcoming researchers or veterinarians to carry on further investigations for finding the problems and solutions.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Ali, M. W., Majumder, M. J., Huq, F., Latif, M. A., Bari, I. F. and Alam, S. A. 1982. Studies of the presence of rabies virus among stray dogs in Dhaka City. *Bangladesh Medical Res. Council Bulletin*. *8*(2):59-62.

Anwar, A. H., Haq, A. U., Gill, S. A. and Chaudhry, A. H. 1993. Prevalence and fertility ratio of hydatid cyst in slaughtered sheep and goats at Faisalabad. *Pakistan Veterinary J*. *13:* 79-79.

Ashraf, M., Khan, M. Z. and Chishti, M. A. 1986. Incidence and pathology of lungs affected with tuberculosis and hydatidoses in sheep and goats. *Pakistan Veterinary J. 6:119-121.*

Biswas, H. R., Hoque, M. M., Samad, M. A. and Rahman, A. 1996. Prevalence of inapparent rabies infection in street dogs. *Bangladesh Veterinarian*. *13*(1-2):29-31.

Borhanuddin, M., Ali, R. and Rahman, M. M. 1986. Microbial contamination level of market shell eggs. *Bangladesh Veterinary J.* 20:95-99.

Chakrabartty, A., Bhattacharjee, P. K., Sarker, R. R., Rahman, A. K. M. A., Henning, K., Neubauer, H. and Rahman, M. S. 2016. Prevalence of Coxiella burnetii infection in cattle, black bengal goats and ticks in Bangladesh. *Bangladesh J. Veterinary Medicine*. *14*(1):65-68.

Chermette, R. 1983. Importance and current position of hydatid disease in France. I. Practical aspects in. *Veterinary Medicine. Point Veterinaire*. 14:15-24.

Cutler, S. J., Fooks, A. R. and Van der Poel, W. H. 2010. Public health threat of new, reemerging, and neglected zoonoses in the industrialized world. *Emerging infectious diseases*. 16(1):1-7.

El-Badawi, E. K., Eisa, A. M., Slepenev, N. K. and Saad, M. B. A. 1979. Hydatidosis of domestic animals in the central region of the Sudan. *Bulletin of Animal Health and Production in Africa*. *27*(4):249-251.

FAO. 2003. Production Year Book, Food and Agricultural Organization, Rome, Italy.

Gani, M. O., Munsi, M. N., Ershaduzzaman, M., Rahman, A. A., Sultana, S. and Alam, M. S. 2016. Seroprevalence of ovine brucellosis in Bangladesh. *Asian J. Medical and Bio. Res.* 2(1):13-18.

Grace, D., Mutua, F., Ochungo, P., Kruska, R. L., Jones, K., Brierley, L., Lapar, M., Said, M. Y., Herrero, M. T., Phuc, P. M., Thao, N. B. and Ogutu, F. 2012. Mapping of poverty and likely zoonoses hotspots.

Gupta, P. K., Singh, R. P. and Singh, I. P. 1970. A study of dermatomycoses (ringworm) in domestic animals and fowls. *Indian J. Animal Health*. 9:85-89.

Islam, M. S. and Samad, M. A. 1998. Clinical observation and management of Foot-and-mouth disease outbreaks in cattle in Tangail Milk-shed area. *Bangladesh Veterinary J*. 32:47-52.

Kabir, M. H. B., Eliyas, M., Hashem, M. A., Mohiuddin, M. and Miazi, O. F. 2009. Prevalence of zoonotic parasitic diseases of domestic animals in different abattoir of Comilla and Brahman Baria region in Bangladesh. *University J. Zoology, Rajshahi University*. 28:21-25.

Kamaruddin, K. M. 2003. Goat farming as a means of poverty alleviation. In Proceeding of the BSVER symposium, BAU. Bangladesh Society for Veterinary Education & Res. BSVER Publications. 25:26-34.

Mohiuddin, A., Khan, M. M., Mughal, F. A. and Sheikh, M. A. 1982. Incidence of amphistomiasis in sheep and goats of different ages in Sind, Pakistan. *Pakistan Veterinary J*. 2:17-18.

Okafor, F. C., Mbata, G. and Anosike, J. 1988. Studies on Paramphistomum cervi infections of ruminants in Imo State, Nigeria with special reference to the role-played by Bulinus b. forskalii (Ehrenberg) in their transmission. *Bulletin of Animal Health and production in Africa*. 36:142-146.

Petkov, A., Tsolov, B., Denev, I., Kostov, R., Rusev, I., Zurliski, P., Stoimenov, K, Azpryanov, M. and Spasov, M. 1987. Distriution of Echinococcus among Animals in Balgaria. *Veterinarnomeditsinski Nauki*. 24:51-55.

Prasad, J. 2007. *Goat, sheep and pig production and management*. Kalyani Publisher, Delhi-India.

Rahman, A. K. M., Islam, S. K., Talukder, M., Hassan, M., Dhand, N. K. and Ward, M. P. 2017. Fascioliasis risk factors and space-time clusters in domestic ruminants in Bangladesh. *Parasites & Vectors*. 10(1):1-12.

Rahman, M., Alam, M., Islam, M., Bhuiyan, A. K. and Rahman, A. K. M. 2016. Serological and molecular evidence of Q fever in domestic ruminants in Bangladesh. *Veterinary medicine international*.

Samad, M. A. 2000. Clinico-therapeutic management of severe complicated cases of contagious ecthyma in Black Bengal goats. *Bangladesh Veterinary J*. 34:39-42.

Samad, M. A. 2008. Animal husbandry and veterinary science. 1st Pub., LEP No. 11, BAU Campus, Mymensingh, Bangladesh.

Siddiki, A. Z., Uddin, M. B., Hasan, M. B., Hossain, M. F., Rahman, M. M., Das, B. C., Sarker, M. S. and Hossain, M. A. 2010. Coproscopic and Haematological Approaches to Determine the Prevalence of Helminthiasis and Protozoan Diseases of Red Chittagong Cattle (RCC) Breed in Bangladesh. *Pakistan Veterinary J*. 30(1):1-6.

Taylor, L. H., Latham, S. M. and Woolhouse, M. E. 2001. Risk factors for human disease emergence. *Philosophical Transactions Royal Soc. London. Series B: Biological Sci.* 356(1411):983-989.

Uddin, M. Z., Farjana, T., Begum, N. and Mondal, M. M. H. 2006. Prevalence of amphistomes in Black Bengal goats in Mymensingh district. *Bangladesh J. Veterinary Medicine*. 4(2):103-106.

Weese, J. S., Peregrine, A. S. and Armstrong, J. 2002. Occupational health and safety in small animal veterinary practice: Part I-Nonparasitic zoonotic diseases. *The Canadian veterinary J*. 43(8):631-636.

World Health Organization. 2020. WHO Health Topic Page: Zoonoses. Available online: https://www.who.int/topics/zoonoses/en/ .

Wikipedia, 2019. Geography of Bangladesh, http: //en.wikipedia.org./wiki/ Geography of Bangladesh.

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INFLUENCE OF NITROGEN SOURCES AND RATES ON YIELD AND NITROGEN USE EFFICIENCY OF TOMATO

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Abstract

A study was carried out with tomato at the research field of Regional Agricultural Research Station of BARI, Cumilla during two consecutive years 2019-20 and 2020-21. The objective was to evaluate the yield response and nitrogen use efficiency (NUE) of tomato (variety BARI Tomato-15) and to suggest the source and the rate of N fertilizer recommendation for tomato. The experiment was laid out in a RCBD design with three N sources (PU, NCU and DAP) and two N rates (100% and 125% of recommendation as per FRG-2018) replicated three times. In the first year, prilled urea (PU), neem coated urea (NCU) and DAP were used but in the second year DAP was replaced by urea super granule (USG). The recommended dose of N for tomato was 120 kg ha^{-1}. Results revealed that between two rates of N application the yield was the maximum (77.4 t ha^{-1} and 60.3 t ha^{-1} in two years, respectively with 125% of RD. The highest agronomic use efficiency of nitrogen (N_{AUE}) was obtained from 100% RD of N as DAP (150.0 kg kg^{-1}) and 125% RD of N as NCU (133.3 kg kg^{-1}). The lowest N use efficiency was observed in 100% PU (84.2 kg kg^{-1}) and 100% NCU (40.8 kg kg^{-1}) treated plots. Due to optimal plant growth, the neem-coated urea treatment yielded little higher than PU treatment.

Keywords: Cowdung, DAP, DMRT, Neem coated urea, USG

Introduction

Tomato (*Lycopersicon esculentum* Mill) is a vitamin (A, B & C) and mineral-rich vegetable crop (Olaniyi and Ajibola, 2008). It belongs to the family Solanaceae, sub family *Solanoideae* and can be grown thoughout the year. It is widely cultivated in tropical, subtropical and temperate climates and ranks second next to potato in terms of world vegetable production with a total production of 186 million metric tons which were harvested from 5.05 million hectares of land (FAOSTAT, 2020). In Bangladesh, the total area and production of tomato was about 29 thousand hactares and 4.15 lac metric tons, respectively (BBS, 2020).

Nitrogen is an essential macro nutrient element for the growth and development of plants because of its role in cell division and expansion. Nitrogen plays a major role in crop production. A non-judicial methods and sources can lead to reduced plant quality,

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economic loss and environmental pollution (Liu *et al*., 2014). Most farmers incorrectly apply excessive amounts of fertilizers as insurance against yield losses without being aware of the cost and environmental consequences (Umar *et al*., 2007). When inorganic fertilizers are applied to soils, N is rapidly released and absorbed by plants. In contrast to inorganic fertilizers, however, organic fertilizers have better efficiency of nutrient use since the nutrients they contain are delivered gradually over a longer period of time. The rate of mineralization in organic fertilizer is affected by several factors including soil properties, temperature, available water, and type of organic fertilizer (Nardi *et al*., 2018). Akanbi *et al.* (2003) reported that N fertilizer influences leaf number per plant, plant height, fruit number per plant, fruit mean weight, and total yield per plant in tomato crops.

To improve fertilizer use efficiency judicious application of different forms of N like prilled urea (PU), urea super granule (USG) and organic N sources is important. In Bangladesh, prilled urea is mostly used as nitrogenous fertilizer and farmers are widely applying it to vegetable crops. Organic manure is a valuable fertilizer for integrated nutrient management systems. Organic manure not only supplies plant nutrients but also improves physical and microbial properties of the soil. Vermicompost is an important high valued organic manure that can contribute to plants and soil. Various studies have been done on the use of nitrogenous fertilizer but, less attention has been given to NUE-based INM for tomato cultivation. Tomato is very responsive to nitrogenous fertilizers and a significant amount of supplemental N is required to maximize fruit yields. Considering all of these issues, a study was undertaken to know the yield response and NUE of tomato (variety BARI tomato-15) and to recommend the N rate and source for tomato in the Cumilla region (AEZ 16).

Materials and Methods

Experimental site and soil

The experiment was conducted at the research field of Regional Agricultural Research Station, BARI, Cumilla for two consecutive years 2019-20 and 2020-21. The experimental site is located at 23°28' 14.3" North latitude 91°09'20.5" East longitude with an elevation of 12 meters (39.4 ft) above sea level. This location belongs to AEZ-16 (Middle Meghna River Floodplain) having non-calcareous grey floodplain soil. The top soils are strongly acidic and sub-soils are slightly acidic to slightly alkaline. The general fertility level was medium with low N and organic matter content. The annual temperature of the area is 25.5 °C and about 2,295 mm of precipitation falls annually. The soil of the experimental field contained 6.1 pH, 1.1% organic matter, 0.19 cmol kg^{-1} K, 15 mg kg^{-1} P & also S, 0.19 mg kg^{-1} Zn and 0.2 mg kg^{-1} B.

Treatments and design

The experiment was laid out in a randomized complete block design (RCBD) with 7 treatments replicated 3 times. In the first year, the treatments were T_0: Native fertility, T_1: 100% Recommended dose (RD) of N as prilled urea (PU), T_2: 100% RD of N as neem coated urea (NCU), T_3: 100% RD of N as di-ammonium phosphate (DAP), T_4: 125% RD of N as PU, T_5: 125% RD of N as NCU, and T_6: 125% RD of N as DAP. But

in the second year, USG was used instead of DAP. Excess amount of phosphorus supplied from DAP treatment was adjusted by TSP for PU and NCU treatments. Each plot was 5.2m in length and 1.2m in width. The spacing between the blocks and plots was 1m and 0.5m, respectively. Two rows per plot were used with 60cm and 40cm between the row and plant, respectively was used. Each row had 13 plants making a total of 26 per plot. Except for DAP, which had 20% N, all other sources had 46% N. The three sources varied in physical forms even though their nitrogen contents were identical. The NCU was prilled urea covered with neem oil extract. Before final land preparation, decomposed cowdung @ 5 t/ha was used as a blanket dosage. The recommended doses of P, K, S, Zn, and B were applied at 30, 40, 15, 2, and 1 kg ha^{-1} in the forms of TSP, MoP, gypsum, chelated zinc and solubor, respectively, based on the FRG 2018.

Crop management

Decomposed cowdung and all the chemical fertilizers except nitrogenous fertilizer were applied as a blanket dose following Fertilizer Recommendation Guide-2018. BARI tomato-15, a high-yielding tomato variety was used as a test crop. The seeds were sown on 25 October, 2019 and 11 November, 2020. Twenty-five days old seedlings were transplanted in the main plot on 19 November, 2019 and 05 December 2020 when the seedlings were 10-15 cm in height. Every seedling was irrigated individually after transplanting and continued upto 5 days until the establishment of the root in soil. Three splits of nitrogenous fertilizers were applied in equal splits as per treatment at 15, 30, and 45 days after transplanting. Gap filling, plant protection, irrigation, and other intercultural operations were done as and when necessary.

Data collection and analysis

Data on the yield and yield attributing parameters were recorded. Five representative plants from 2 rows of each plot were randomly taken and tagged for data collection. Data on 50% flowering, plant height, number of fruits/plants, the weight of fruit/plant, individual fruit weight, yield/plant, and fruit yield per hectare were collected. The date of 50% flowering was 19 December, 2019 and 30 December 2020. The data were subjected to "STATISTIX 10" software, a statistical tool for analysis of variance (ANOVA) and and Duncan's multiple range test (DMRT) (Gomez and Gomez, 1984) was used to assess significant differences between the means.

Calculation of nitrogen use efficiency (NUE)

The N use efficiency (NUE) was estimated in terms of relative agronomic efficiency of N (AE_N). The AE_N refers to the increase in grain yield from addition of nitrogen, expressed as kg grain increase kg^{-1} N applied (modified after Dobermann, 2005):

$$AE_N = (GY_{NA} - GY_{NC})/N_{RN}$$

where GY_{NA} represents grain yield (kg ha^{-1}) obtained from N addition, GY_{NC} represents grain yield (kg ha^{-1}) from N control (N_0) and N_{RN} indicates rate of N added.

Results and Discussion

Growth and yield contributing characters

The effect of N-sources with doses on plant height are presented in Tables 1 and 2. In the first year, the results showed that N amount supplied from different N-sources had a significant effect on the plant height of tomato at the final harvest. The tallest plant (119.0 cm) was observed with T_6 treatment (125% RD of N as DAP) while the shortest plant (90.7 cm) was noted in T_0 treatment (N-control). But in the second year, the tallest plant (109.07 cm) was observed with T_5 treatment (125% RD of N as NCU) while the shortest plant (95.53 cm) was noted in T_0 treatment (N-control). Plant height increased with an increasing amount of N from native fertility to 125% of RD of N (Table 1). Barraclough *et al*. (2014) defined that plant height is highly influenced by 'N-rate' followed by 'growth stage' and then 'genotype'. However, the fruit number per plant varied from 47.6 to 68.3, while the maximum number of fruits per plant (68.3) was counted in the T_6 treatment (125% RD of N as DAP) which was statistically identical to the T_4 (125% RD of N as PU) and T_5 (125% RD of N as NCU) treatments and the lowest number of fruit/plant (47.6) was counted in T_0 (N-control). In the case of average fruit weight, the heaviest fruit (93.3 g) was harvested from the T_6 treatment (125% RD of N as DAP) which was statistically par with T_2 (100% RD of N as NCU), T_3 (100% RD of N as DAP), T_4, (125% RD of N as PU) and T_5 (125% RD of N as NCU) treatments, and the lightest average fruit weight (78.3 g) was noted in T_0 treatment (N-control).

Table 1. Yield and yield complements of tomato as influenced by different nitrogen sources and rates in 2019-20

Treatments	Plant height at final harvest (cm)	No. of fruits/ plant	Fruit wt./plant (kg)	Average fruit wt. (g)	Fruit yield (t/ha)
T_0: N-control	90.7 e	47.6 d	1.77 e	78.3 c	55.2 c
T_1: 100% RD of N as PU	94.0 de	57.3 c	2.26 d	84.7bc	65.3bc
T_2: 100% RD of N as NCU	95.7cde	57.0 c	2.61 c	86.0 ab	68.9 ab
T_3: 100% RD of N as DAP	103.0bc	62.3bc	2.70 c	87.7 ab	73.2 ab
T_4: 125% RD of N as PU	101.6bcd	65.6 ab	2.84bc	88.7 ab	74.3 ab
T_5: 125% RD of N as NCU	110.0 b	67.3 ab	2.97 b	92.0 ab	74.6 ab
T_6: 125% RD of N as DAP	119.0 a	68.3 ab	3.35 a	93.3 a	77.4 a
F-Test	**	**	**	**	**
CV (%)	4.73	5.40	5.58	4.80	8.99

** $P<0.01$

In a column for each character, the mean values followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

The fruit yield per plant and per plot revealed that the treatment T_6 (125% RD of N as NCU) produced the highest yield (3.35 kg and 53.7 kg) whereas the lowest yield (1.77 kg and 38.4 kg) was obtained from treatment T_0 (N-control). However, the yield per

hectare ranged from 55.2 to 77.4 ton. The maximum average per hectare yield (77.4 t/ha) was recorded in T_6 (125% RD of N as NCU) treatment which was statistically similar to the T_2 (100% RD of N as USG), T_3 (100% RD of N as NCU), T_4 (125% RD of N as PU) and T_5 (125% RD of N as USG) treatments while the minimum yield (55.2 t/ha) was noted in T_0 (N-control) treatment. Fageria and Carvalho (2014) stated that yield of crop is affected by N rate applied to it. Another study by Bufogle *et al*. (1997) reported that the response of crop to ammonium sulfate and urea depends on soil or climatic conditions.

Table 2. Yield and yield complements of tomato as influenced by different nitrogen sources and rates in 2020-21

Treatments	Plant height at final harvest (cm)	No. of fruits/ plant	Fruit wt./ plant (kg)	Average fruit wt. (g)	Fruit yield (t/ha)
T_0: N-control	95.5 c	44.2 d	1.87 c	87.0 d	40.3 d
T_1: 100% RD of N as PU	101.0 bc	59.4 b	2.30 b	99.0 abc	48.4 bcd
T_2: 100% RD of N as USG	105.7 ab	51.4 bcd	2.07 bc	95.3 bc	46.9 cd
T_3: 100% RD of N as NCU	105.2 ab	51.9 bcd	2.04 bc	93.0 cd	45.2 cd
T_4: 125% RD of N as PU	107.1 ab	50.8 cd	2.23 b	100.7 abc	54.9 abc
T_5: 125% RD of N as USG	109.07 a	70.0 a	3.08 a	104.3 a	58.6 ab
T_6: 125% RD of N as NCU	109.0 a	54.7 bc	2.19 b	102.8 ab	60.3 a
CV (%)	4.18	8.56	7.18	4.62	12.3
F-Test	*	**	**	**	*

*, $P<0.05$; **, $P<0.01$. In a column for each character, the mean values followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

In 2020-21, the fruit number per plant varied from 44.2 to 70.0, while the maximum number of fruits per plant (70.0) was counted in the T_5 treatment (125% RD of N as USG) which was statistically significant compared to other treatments (Table 2). Average fruit weight showed a similar trend in the second year. The fruit yield per plot revealed that treatment T_6 (125% RD of N as NCU) produced the highest yield (37.63 kg) whereas the lowest yield (25.16 kg) was obtained from T_0 treatment (N-control). The maximum average per hectare yield (60.3 t/ha) was recorded in the T_6 treatment (125% RD of N as NCU) which is statistically similar to the T_4 (125% RD of N as PU) and T_5 (125% RD of N as USG) treatments while the minimum yield (40.3 t/ha) was noted in the T_0 treatment (N-control). Treatments T_4 (125% RD of N as PU), T_5 (125% RD of N as USG), and T_6 (125% RD of N as NCU) resulted in 34.6-36.2%, 35.1-45.4% and 40.2-49.6% increased yield over control in two years, respectively (Fig. 1).

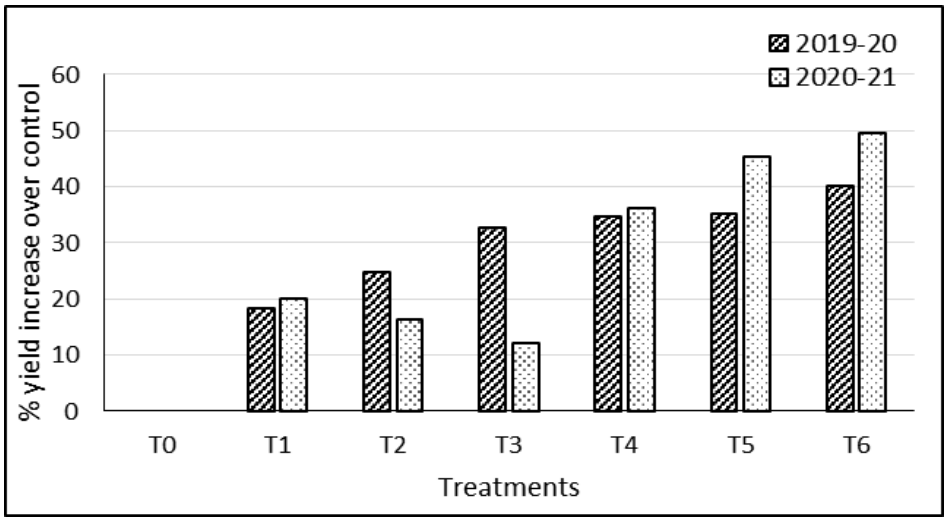

Fig. 1: Increase in percent yield of tomato over control as influenced by the application of PU, NCU, and DAP

Agronomic use efficiency of nitrogen

Agronomic use efficiency of nitrogen (N_{AUE}) refers to the increase in fruit yield of tomato per kg of nitrogen applied (Tables 3 and 4).

Table 3. Agronomic use efficiency (N_{AUE}) of different forms of nitrogen in 2019-20

Treatments	Quantity of N applied	Increase in Nitrogen over N-control (T_0 treatment)	Quantity of fruit yield obtained	Increase in fruit yield over N control (T_0 treatment)	Agronomic use efficiency of N (N_{AUE})
	(kg ha^{-1})				(kg kg^{-1})
T_0: N-control	0	-	55200	-	-
T_1: 100% RD of N as PU	120	120	65300	10100	84.2
T_2: 100% RD of N as NCU	120	120	68900	13700	114.2
T_3: 100% RD of N as DAP	120	120	73200	18000	150.0
T_4: 125% RD of N as PU	150	150	74300	19100	127.3
T_5: 125% RD of N as NCU	150	150	74600	19400	129.3
T_6: 125% RD of N as DAP	150	150	77400	22200	148.0

Table 3 presents the agronomic use efficiency of different forms of nitrogen (N_{AUE}) in 2019-20 ranging from 84.2 to 150.0 kg kg^{-1}. The highest N_{AUE} (150.0 kg kg^{-1}) was obtained from 100% RD of N as DAP treated plot (T_3 treatment). Among the three sources, N_{AUE} was the highest in DAP treated plot followed by the neem coated urea (NCU) treated plot. The lowest agronomic use efficiency (N_{AUE}) was obtained from the

prilled urea (PU) treated plot (T_1 treatment, N_{AUE} = 84.2 kg kg^{-1}). This might be because photosynthesis has an impact on tomato NUE in the end. Dilip and Bao-LuoMa (2016) reported that the NUE of crops has been significantly affected by the effects of N sources on the photosynthetic pigments in leaves. Higher nitrogen use efficiency (NUE) in corn is significantly influenced by the source of fertilizer N (Freeman *et al.,* 2007, Bushong *et al.,* 2014).

Table 4. Agronomic use efficiency (N_{AUE}) of different forms of nitrogen in 2020-21

Treatments	Quantity of nitrogen applied	Increase nitrogen over N-control (T_0 treatment)	Quantity of fruit yield obtained	Increase fruit yield over N control (T_0 treatment)	Agronomic use efficiency of nitrogen (N_{AUE})
	(kg ha^{-1})				(kg kg^{-1})
T_0: N-control	0	-	40300	-	-
T_1: 100% RD of N as PU	120	120	48400	8100	67.5
T_2: 100% RD of N as USG	120	120	46900	6600	55.0
T_3: 100% RD of N as NCU	120	120	45200	4900	40.8
T_4: 125% RD of N as PU	150	150	54900	14600	97.3
T_5: 125% RD of N as USG	150	150	58600	18300	122.0
T_6: 125% RD of N as NCU	150	150	60300	20000	133.3

On the other hand, in 2020-21 the agronomic use efficiency of different forms of nitrogen (N_{AUE}) ranged from 40.8 to 133.3 kg kg^{-1} (Table 4). The highest N_{AUE} (133.3 kg kg^{-1}) was obtained from 125% RD of N as NCU treated plot (T_6 treatment). Among the three sources, N_{AUE} was the highest in the 125% NCU treated plot followed by the 125% urea super granule (USG) treated plot. The lowest agronomic use efficiency of nitrogen (N_{AUE}) was obtained from a 100% neem-coated urea (NCU) treated plot (T_3 treatment, N_{AUE} = 40.8 kg kg^{-1}). This may be due to more availability of nitrogen. Because when plants receive more nitrogen than they need, they can take up and utilize the excess nitrogen more efficiently, resulting in higher nitrogen use efficiency. Beatty *et al.,* (2010) stated that the NUE of barley grown in a field depends on the varied amount of N applied. On the other hand, neem-coated urea reduces nitrogen loss through slow release and nitrification inhibition characteristics and enhances nitrogen availability resulting positive growth effect in plants. Rehman *et al.,* (2021) reported that neem-coated urea significantly improved, AUE, N uptake efficiency (NUptE), NUE, and N productive efficiency (NPE) compared to the normal urea.

Conclusion

Considering the yield, nitrogen fertilizer supplied from neem-coated urea performed better compared to other nitrogen sources. Performance of the 125% recommended dose of N was superior to 100% of RD of N. The highest chemical nitrogen dose gave the most significant yield advantage for tomato. The treatments using 125% NCU and 100% RD of N as DAP showing the higher agronomic use efficiency of nitrogen (N_{AUE}). The neem-coated urea treatment yielded higher potential than the prilled urea due to higher plant growth.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Akanbi, W.B., Dris, R. and Togun, A.O. 2003 Influence of compost and nitrogen fertilizer on growth, nutrient uptake and fruit yield of tomato (*Lycopersicon esculentum*). *Crop Res*. 26:98-105.

Barraclough, P. B., Lopez-Bellido, R. and Hawkesford, M. J. 2014. Genotypic variation in the uptake, partitioning, and remobilisation of nitrogen during grain-filling in wheat. *Field Crops Res*. 156:242-248.

BBS (Bangladesh Bureau of Statistics). 2020. Yearbook of Agricultural Statisitics-2020. Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka.

Beatty, P. H., Anbessa, Y., Juskiw, P., Carroll, R. T., Wang, J. and Good, A. G. 2010. Nitrogen use efficiencies of spring barley grown under varying nitrogen conditions in the field and growth chamber. *Ann Bot.* 105:1171-1182.

Bufogle. J. A., Bollich, P. K., Kovar, J. L., Lindau, C. W. and Macchiavelli, R. E. 1997. Rice plant growth and nitrogen accumulation from a midseason application. *J. Plant Nutri.* 20(9):1191-1201.

Bushong, J. T., Arnall, D. B. and Raun, W. R. 2014. Effect of preplant irrigation, nitrogen fertilizer application timing, and phosphorus and potassium fertilization on winter wheat grain yield and water use efficiency. *Inter. J. Agron*. 2014.

Dilip, K. B. and Bao-LuoMa. 2016. Effect of nitrogen rate and fertilizer nitrogen source on physiology, yield, grain quality, and nitrogen use efficiency in corn. *Canadian J. Plant Sci*. 96(3):392-403. https://doi.org/10.1139/cjps-2015-0186.

Dobermann, A. 2005. Nitrogen Use Efficiency-State of the Art. IFA International Workshop on Enhanced-Efficiency Fertilizers, Frankfurt, Germany. pp. 1-18.

FAOSTAT. 2020. Statistical data base of food and agriculture of the write donation Maria, Jose Diez and Fernano neuzh and book of plant breeding vegetable (152-156).

Fageria, N. K. and Carvalho, M. C. S. 2014. Comparison of conventional and polymer coated urea as nitrogen sources for lowland rice production. J. *Plant Nutr*. 37(8):1358-1371.

Freeman, K. W., Girma, K., Arnall, D. B., Mullen, R. W., Martin, K. L., Teal, R. K. and Raun, W. R. 2007. By plant prediction of corn forage biomass and nitrogen uptake at various growth stages using remote sensing and plant height. *Agro. J*. 99(2):530-536.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research, John Wiley & Sons, New York.

Liu, C. W., Sung, Y., Chen, B. C. and Lai, H. Y. 2014. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa* L.). *International J. Environ. Res. Public Health*. 11(4):4427-4440. https://doi.org/10.3390/ijerph110404427

Nardi, P., Neri, U., Di Matteo, G., Trinchera, A., Napoli, R., Farina, R., Subbarao, G.V. and Benedetti, A. 2018. Nitrogen release from slow-release fertilizers in soils with different microbial activities. *Pedosphere*. 28(2):332-340.

Olaniyi, J. O. and Ajibola A. T., 2008. Effects of inorganic and organic fertilizers application on the growth, fruit yield and quality of tomato (*Lycopersicon lycopersicum*). *J. Applied Biosci.* 8 (1):236-242.

Rehman, A., Nawaz, M., Chattha, M. U., Khan, I., Chattha, M. B., Hussain, F. and Hassan, M. U. 2021. Neem coated urea improves the productivity, nitrogen use efficiency and economic return of wheat crop. *Int. J. Agric. Biol*. 26:450-460.

Umar, S., Iqbal, M. and Abrol, Y. P. 2007. Are nitrate concentrations in leafy vegetables within safe limits? *Current Sci.* 92(3):6.

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INFLUENCE OF BORON AND MOLYBDENUM ON YIELD ATTRIBUTES OF MUSTARD

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Abstract

Boron and Molybdenum play a remarkable role in crop production and they are especially important for oil seed crops. Mustard is a very important oil seed crop in Bangladesh. The optimum and adequate levels of boron and molybdenum are very important for attaining a higher quality yield of oil seed crops. This study was carried out to investigate the influence of boron, molybdenum, and their interactions on yield and yield attributes of mustard var. Binasarisha-5 at the experimental field of Bangladesh Institute of Nuclear Agriculture, Mymensingh. Three levels of boron (0,1 and 2 kg/ha) and two levels of molybdenum (0 and 20 ppm) were used as treatment variables. Molybdenum was sprayed at the maximum vegetative growth stage. The experiment was laid out in a randomized complete block design with four replications. Results showed that the mean effects of boron and molybdenum significantly influenced the growth and yield of mustard. Application of 2 kg B/ha gave a significant influence on most of the yield contributing characters which resulted in the highest seed yield/ha (1294 kg/ha). Interactions of boron and molybdenum significantly influenced the seeds/siliqua, seed yield/plant, shoot weight/plant, shell weight/plant, seed yield /ha, straw yield/ha, and biological yield /ha. Seed yield (1337 kg/ha) was the highest with the interaction of 2 kg/ha application of boron and foliar spary of 20 ppm molybdenum. So, it is concluded that B and Mo application may increase the seed yield of mustard.

Keywords: Boron and Molybdenum application, Micronutrient, Mustard, Binasarisha-5

Introduction

Edible oil is an integral part of our daily diet and mustard (*Brassica* sp.) is the most important oil seed crop in Bangladesh. In Bangladesh, about 3.01 percent of the total cropped area is used for edible oilseed crop cultivation with an annual production of 358 thousand metric tons covering 763 thousand acres of (BBS, 2021). If mustard covers 70% of the total oil-cropped area and produces 64% of the oil seed production (BBS, 2021). Bangladesh is facing a huge deficit of edible oil. Bangladeshis consume 20 lakh

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tonnes of edible oil a year, while the local production covers around only around 2 lakh tonnes. The imported 18 lakh tonnes of edible oil incorporate 46% soybean and 53% palm oil (Ali and Faruque, 2022). Domestic production of edible oil almost entirely comes from mustard, groundnut, and sesame. Mustard is grown in the rabi season usually under rain-fed and low input conditions with the average yield of mustard being very low 1.15 t/ha (BBS, 2021) only as compared with the world average yield (2.32 t/ha) (USDA, 2022). The poor yield of mustard might be attributed to inappropriate uses of production inputs like fertilizers, and seeds and a lack of knowledge on improved technologies for crop production.

The practice of intensive cropping with modern varieties causes a marked depletion of inherent nutrient reserves in the soils of Bangladesh. Consequently, along with N, P, and K deficiencies, some micronutrient deficiencies *viz*. B, Zn, and Mo have also appeared in some soils and crops (Khanam *et al.*, 2001, Islam *et al.*, 1997; Jahiruddin *et al.*, 1995). Molybdenum deficiency was found in soils with very low p^H and in strongly weathered soil (William and Bennet, 1996). Brassica is sensitive to low boron supply and severe deficiency may result in floral abortion and a significant drop in seed production (Yang *et al*., 1989). The ranges between the deficiency and toxicity of B are quite small and an application of B can be extremely toxic to plants at a concentration only slightly above the optimum rate (Gupta *et al*., 1985). The uptake and requirement of molybdenum differ in different development stages, soil, plant part, sampling dates, and treatment among cultivars and species (Thompson *et al.*, 1970). Keeping the view of the above discussion, the present study was undertaken to standardize the optimum amount of B and Mo required for the growth and development of mustard.

Materials and Methods

The experiment was conducted at the experimental field of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The experimental site is belonging to Agroecological Zone AEZ- 09 of Old Brahmaputra Floodplain. The geographic coordinates of the trial site are $24^{\circ}75^{0}$ N latitude and $90^{\circ}50^{0}$ E longitude with its elevation about 18 meters above sea level. Three levels of boron (B_1-0, B_2-1, and B_3-2 kg/ha) and two levels of molybdenum (Mo_1-0 and Mo_2-20 ppm) were used as treatments variables the treatments were laid out in a factorial randomized complete block design with four replications and the unit plot size was 3m x 1m. The B fertilizer was applied as a basal dose in the form of borax and the Mo fertilizer as ammonium molybdate. Seeds of mustard var. Binasarisha-5 was sown on 10 October 2006 at the seed rate of 10 kg/ha in a line 15 cm apart. The field was also fertilized with 150, 40, 60, 40, and 4 kg/ha of N, P, K, S, and Zn, respectively as a source of Urea, TSP, MP, Gypsum, and Zinc sulphate (Z_nSo_4). The whole amount of TSP, gypsum, and zinc sulphate was applied as a basal dose. Urea was applied in three splits: $^1/_3$ as basal, $^1/_3$ at 28 DAS, and the rest $^1/_3$ at 50% flowering stage, respectively. Other intercultural operations such as weeding, thinning, water management, and pest management were done as and when necessary.

Soil samples were randomly collected at 0-30 cm soil depth for physical and chemical analysis before the commencement of the experiment. The physicochemical properties of the field experimental plot are summarized in the Table 1.

Table 1. Physical and chemical properties of the soil of the experimental field

Constituents	Sand	Silt	Clay	Textural Class	P^H	Physical properties		Chemical composition						
						OC	OM	N	P	S	K	Zn	B	Mb
	(%)					(%)		ppm			(%)	ppm		
Result	22.4	66.5	11.1	Silt loam	6.84	0.74	1.28	0.07	9.3	9.0	0.27	3.3	16	2
Critical Level								0.12	7.0	10.0	0.12	0.6	0.2	0.1

OC= Organic Carbon; OM=Organic Matter; N= Total nitrogen; P= Available phosphorus; S = Available sulphur; K= Exchangeable potassium; Zn= Available Zinc; B= Available boron, Mb = Available molybdenum and ppm= parts per million.

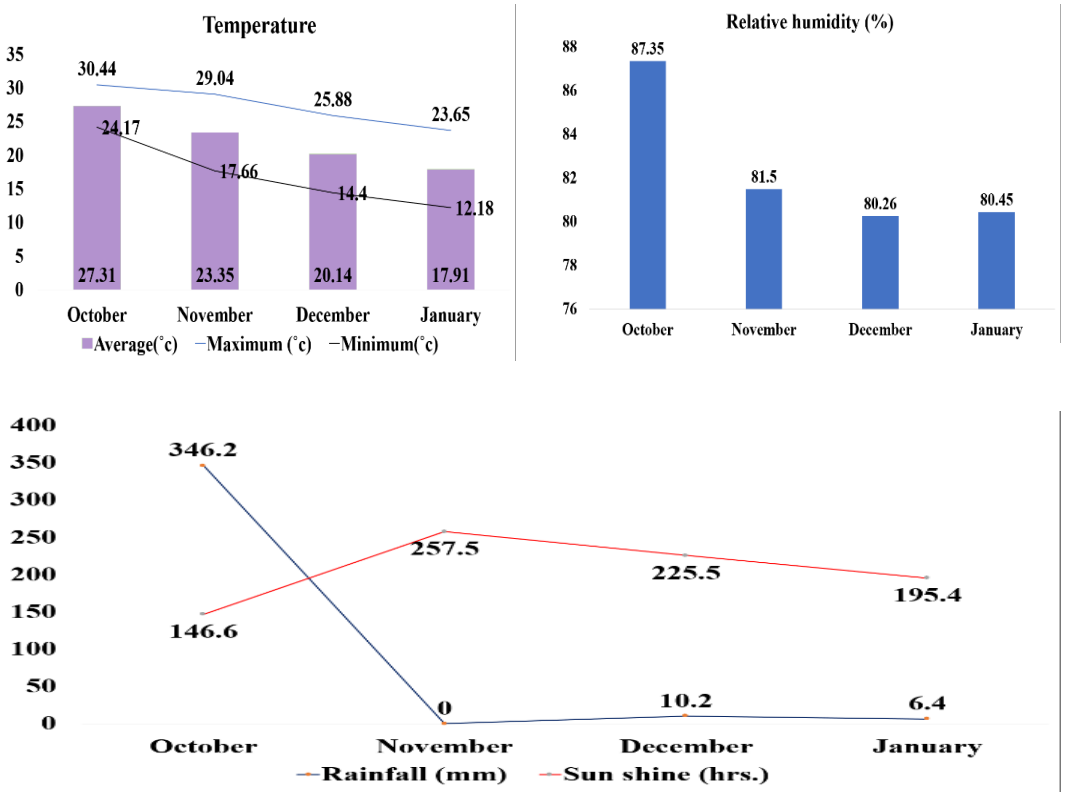

Fig. 1. Distribution of monthly average temperature and relative humidity Rainfall and duration of sunshine of the experiential site during the period from October 2006 to January 2007.

Source: Weather yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh.

High temperature and heavy rainfall characterize the climate of the experimental area during the *kharif* season (April to September) and scanty rainfall in *rabi* season

(October to March) is associated with moderately low temperatures and plenty of sunshine. The agro–climatic condition pertaining to monthly mean values of the daily maximum, minimum, and average temperature, relative humidity, monthly total rainfall, and sunshine hours receive at the experimental site during the study period is mentioned below.

Data on yield and yield components such as Plant height (cm), Number of branches/plant, Number of flowers/plant, Number of pod setting /plant, Percentage of siliqua/plant, Number of siliqua/plant, seeds/siliqua, 1000-seed weight (g), Seed yield /plant (g), Seed yield (kg/ha), Shell weight /plant (g), Shoot dry weight /plant (g), Straw yield (kg/ha), Biological yield (kg/ha), Harvest index (%) were recorded. All the collected data were analyzed statistically and mean differences were adjudged by LSD at 5% level of probability.

Results and Discussion

Effects of boron on morphological and yield attributing characters

Boron application had a significant effect on seed yield and yield attributes of all characters except the percentage of pod setting/ plant of mustard (Table 2). Results revealed that the tallest plant (93.57 cm) was produced with B_3 application and the lowest plant height (85.93 cm) was recorded in B_1 (Table 2). Hu *et al.*, (1994) and Pradhan and Sarkar (1993) also reported that the application of B to rape seed mustard significantly increased plant height. The maximum number of branches/plants (3.08) was found in the highest dose of boron application. The results are in agreement with that of Mathew and George (2013), who reported that the application of boron increased the number of branches/plants. The main reason for increasing branches might be the role of boron in cell division, tissue differentiation, carbohydrate metabolism, and maintenance of conducting tissue with regulatory effects on other elements. The highest number of flowers per plant (45.31) was recorded in those plots where 2 kg B/ha was applied as basal dose. The lowest number of flowers per plant (41.23) was found with control (0 kg/ha) which was statistically similar to 1 kg/ha boron application (42.27) (Table 2).

The study stated that 2 kg/ha boron application produced the maximum number of total pod sets/plant (34.58). The minimum number of total pod sets/plant (29.68) was found 1kg/ha boron application which was statistically similar to the control (29.95) (Table 2). Shen *et al*., (1993) also reported that B application markedly increased the pod setting of mustard. The beneficial effect of B on yield attributes may be due to its role in flower development, pollen grain formation, pollen viability, and pollen tube growth for proper pollination and seed development. The percentage of pod setting /plant was affected insignificantly by different levels of boron application and molybdenum spraying (Table2.). From the experimental results, it was evident that the highest percentage of pod setting/plant (76.16) was recorded in those plots where 2 kg B/ha was applied as basal. The lowest number of percentages of pod sets/plants (70.36) was found in 1kg B/ha (Table 2).

The number of siliqua/plant (69.67) obtained in 2 kg/ha differed significantly from the control in respect of the number of siliqua/plants (Table 2). The results were in

full agreement with the findings of Yadav *et al*., (2016) who reported that number of siliqua/plants increased significantly with increasing B levels. The number of seeds/siliquae ranged from 15.35 to 18.54. The maximum number of seeds/siliqua (18.54) was recorded with 2 kg/ha boron application and it was followed by 1 kg/ha boron (Table 2). But seeds/siliqua of control plots was identical to 1 kg B/ha although there were numerical differences. The lowest number of seeds/siliqua (15.35) was obtained with the control. Bowszys (1996) reported that the effect of boron on rape seed formation was good and it significantly increased seed yield. Yadav *et al*., (2016) mentioned some significant positive effects of B application on mustard seed yield attributes such as the number of siliquae per plant, length of siliqua, and the number of seeds per siliqua. The results presented in Table 2 indicated that the 1000-seed weight was the highest (3.78 g) when 2 kg B/ha has applied and the lowest 1000-seed weight in control (3.07 g). Similar results were found by Subbaiah and Mittra (1996) who reported that 1000-seed weight was increased by boron application. The maximum shell weight/plant (8.89 g) was found from 2 kg/ha boron which was statistically different from other treatments and the lowest in control (7.93 g) (Table 2). The highest shoot dry weight/plant (12.86 g) was found from 2 kg B/ha which was statistically different from 1 kg B/ha (11.66 g). The control plant showed significantly the lowest shoot dry weight/plant (10.68 g). Application of 2 kg/ha boron produced the highest seed yield /plant (10.70 g) which was statistically superior to other treatments (Table 2). The seed yield/plant (10.38 g) was obtained from 1 kg/ha boron which is statistically better than to control (10.22 g).

Table 2. Effects of boron on morphological and yield attributing characters of mustard (var. Binasarisha-5)

Treatment	Plant height (cm)	Number of branches/ plants	Number of flowers/ plants	Number of pod sets/ plant	Percentage of pod setting/ plant	Number of siliqua/ plant	Seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Shell weight (g)	Shoot dry weight (g)
B_1	85.93b	3.08c	41.23b	29.95b	72.75	60.93c	15.35c	3.07c	10.22 c	7.93 b	10.68 c
B_2	87.90b	3.47b	42.27b	29.68b	70.36	65.15b	17.45b	3.44b	10.38 b	8.44 ab	11.66 b
B_3	93.57a	3.81a	45.31a	34.58a	76.16	69.67a	18.54a	3.78a	10.70 a	8.89 a	12.86 a
LSD (0.01)	3.01	0.05	2.52	3.05	NS	3.07	0.17	0.15	0.11	0.25	0.14
CV (%)	4.12	2.13	2.63	4.12	3.00	2.31	2.43	3.26	9.12	3.45	2.42

Different levels of boron application showed a significant influence on the seed yield of mustard (Fig.2). The highest seed yield (1.29 t/ha) was recorded from 2 kg/ha boron application. The lowest seed yield was observed in control (B_1) (91.24 t/ha), which was significantly different from B_2 and B_3 treatments (Fig. 2).

Differences and Means in a column followed by the same letter(s) are not significantly different at 5% level of significance. B_1= No boron (control), B_2= 1kg B/ha and B_3=2kg B/ha, From the results it was clear that the application of B significantly increased the seed yield of mustard. Similar results were observed by Bora and Hazarika (1997) and Yadav *et al*., (2016) who reported that boron application increased the seed yield of mustard. The increase in seed yield might be due to the positive effect of B

application on yield-attributing characters. The maximum straw yield (1.61 t/ha) was observed when 2 kg boron was applied as basal which was statistically different from 1 kg boron/ha (1.53 t/ha) and also from the control. The minimum straw yield was observed with control (1.43 t/ha) which differed significantly from B_1 and B_2 treatments (Fig. 2). Biological yield is the sum of seed yield and stover (straw) yield (Bijalwan and Dobriyal, 2014). The application of 2 kg B/ha gave the highest biological yield (2.90 t/ha) and it was the lowest in control (2.67 t/ha) (Fig.2). The biological yield increased with increasing boron rates, which might be due to the cumulative and favorable effect of the seed and straw yield of mustard. The Harvest index helps to measure the difference between the potential and actual yield. It is the ratio between grain yield and plant yield. The highest harvest index (46.31%) was recorded in control and the lowest harvest index (44.65%) was in 2 kg B/ha which was similar to 1 kg B/ha (45.14%) (Fig. 2) application.

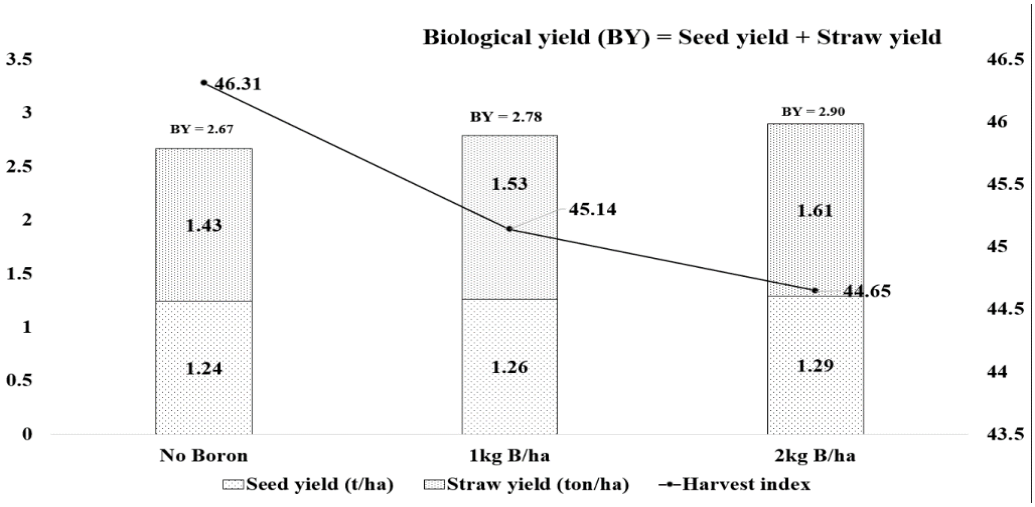

Fig. 2. Effects of Boron dosses on seed yield(t/ha), Straw yield (t/ha), Biological yield (t/ha), and Harvest Index (%) of mustard. B_1= No boron (control), B_2= 1kg B/ha and B_3=2kg B/ha

Effects of Molybdenum on morphological and yield attributing characters

Table 3, showed that molybdenum application had a significant effect on Plant height (cm), Number of branches /plant, Number of flowers /plant, Number of pod setting /plant, seeds /siliqua, 1000-seed weight (g), Seed yield /plant (g), Seed yield (kg/ha), Shell weigh t/plant (g) and Shoot dry weight /plant (g). But the percentage of pod setting /plant and no. of siliqua /plant gave statistically similar responses against molybdenum application. Rao *et al.*, (2006) also reported that the improvement of crop growth and additional yield depends on the additional application of micronutrients along with molybdenum. The plant height (90.50 cm), branches /plant (3.55), flowers /plant (44.74), total pod sets /plant (33.25), seeds /siliqua (17.60), 1000- seed weight (3.56 g), seed yield/plant (10.63 g), shell weight /plant (8.80 g), shoot dry weight /plant (12.13 g) were exhibited highest where molybdenum was sprayed @ 20 ppm at the maximum vegetative

growth stage. But pod setting /plant and number of siliqua /plants showed no effect on molybdenum application.

Table 3. Effects of molybdenum on morphological and yield attributing characters of mustard (var. Binasarisha-5)

Treatment	Plant height (cm)	Number of branches / plants	Number of flowers/ plants	Number of pod sets/ plant	Pod setting/ plant (%)	Number of siliqua / plant	Seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Shell weight (g)	Shoot dry weight (g)
Mo_1	87.77b	3.36b	41.14b	29.55b	71.92	64.72	16.82b	3.30b	10.23 b	8.03 b	11.34 b
Mo_2	90.50a	3.55a	44.74a	33.25a	74.26	65.79	17.60a	3.56a	10.63 a	8.80 a	12.13 a
LSD (0.01)	2.46	0.04	2.061	2.49	5.04	2.51	0.14	0.13	0.09	0.21	0.12
CV (%)	4.12	2.13	2.13	4.12	3.00	2.31	2.43	3.25	9.12	3.45	2.42

Means in a column followed by the same letter(s) are not significantly different at 1% level of significance. Mo_1 = No molybdenum (control) and Mo_2 = 20 ppm molybdenum spray

When molybdenum was applied @ 20 ppm at the maximum vegetative stage, the seed yield (1.29 t/ha), straw yield (1.59 t/ha), and biological yield (2.69 t/ha) remained superior over control (Bo_1) Similar result was observed by Hugar and Kurdikeri (2002) who reported that in molybdenum application increased seed yields. But in the case of harvest index (%), the treatment Bo_2 showed the lowest result (44.72%). (Fig.3)

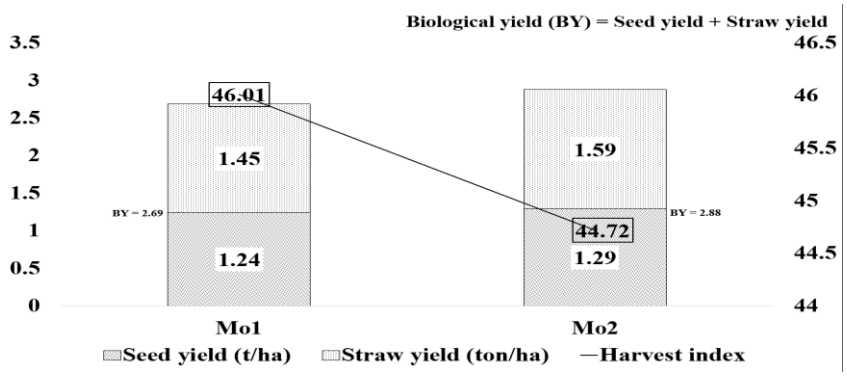

Fig. 3. Effects of Molybdenum dosses on seed yield (t/ha), Straw yield (t/ha), Biological yield (t/ha), and Harvest Index (%) of mustard. Mo_1 = No molybdenum (control) and Mo_2 = 20 ppm molybdenum spray

Interaction effect of boron and molybdenum on morphological and yield attributing characters of mustard

The result showed that basal application of 2 kg/ha boron fertilizer with one spray of molybdenum @ 20 ppm at maximum vegetative growth stage produced the tallest plant of 95.32 cm. Results also indicated that boron in combination with molybdenum had higher plant height and it was more prominent with a higher boron rate

(Table 4). The interaction of boron and molybdenum application did not show a significant effect on the number of branches per plant, number of total pod sets /plant, percentage of pod setting /plant, number of siliqua /plant, and 1000- seed weight (Table 4). The number of seeds/siliquae was influenced significantly by the combined application of boron and molybdenum where the basal application of 2 kg/ha boron with 1 spray of 20 ppm molybdenum at the maximum vegetative growth stage produced the maximum number of seeds/siliqua (19.13). Results also indicated that control plots had the lowest number of seeds/siliqua (14.80) (Table 4). So, boron in higher doses with molybdenum had a positive effect on seeds /siliqua in mustard. The interaction of boron and molybdenum had also a significant effect on seed yield /plant, shell weight /plant, and shoot dry weight /plant. The highest seed yield /plant (11.05 g) was found with B_3Mo_1 treatment combination and the lowest in B_1Mo_1 (10.15 g) (Table 4).

Table 4. Effect of molybdenum on morphological and yield attributing characters of mustard (var. Binasarisha-5)

Treatment	Plant height (cm)	Number of branches/ plants	Number of flowers/ plants	Number of pod sets/ plant	Percentage of pod setting/ plant	Number of siliqua/ plant	Seeds/ siliqua	1000-seed weight (g)	Seed yield/plant (g)	Shell weight (g)	Shoot dry weight (g)
B_1Mo_1	84.98	2.97	40.85	28.41	69.71	60.18	14.08f	2.99	10.15 d	7.68 d	10.14 f
B_1Mo_2	86.88	3.19	41.62	31.49	75.80	61.67	15.90e	3.15	10.28 cd	8.18 c	11.21 e
B2Mo1	86.51	3.40	40.40	29.15	72.29	64.69	17.11d	3.33	10.20 cd	8.15 c	11.43 d
$B2Mo_2$	89.30	3.53	44.15	30.22	68.42	65.62	17.78c	3.55	10.55 b	8.73 b	11.90 c
$B3Mo_1$	91.82	3.69	42.17	31.10	73.76	69.27	18.55b	3.58	10.35 c	8.27 c	12.44 b
B_3Mo_2	95.32	3.94	48.45	38.06	78.57	70.07	19.13a	3.97	11.05 a	9.50 a	13.27 a
LSD (0.01)	4.26	0.08	3.56	4.31	8.74	4.35	0.24	0.22	0.15	0.36	0.21
CV (%)	4.12	2.13	2.63	4.12	3.00	2.31	2.43	3.25	9.12	3.45	2.42

Means in a column followed by the same letter(s) are not significantly different at 1 % level of significance.

B_1= No boron (control), B_2= 1kg B/ha and B_3=2kg B/ha, Mo_1 = No molybdenum (control) and Mo_2 = 20 ppm molybdenum spray

The increase in seed yield /plant was mainly due to an increase in the seed/siliqua. Seed yield (t/ha), straw yield (t/ha), and biological yield (t/ha) responded significantly to the interactive application of boron and molybdenum. (Fig. 4). Biological yield increased due to an increase in seed yield and shoot dry weight. But interaction effect of boron and molybdenum had no significant effect on the harvest index. However, numerically maximum harvest index (46.93%) was recorded in control and the lowest harvest index (43.76%) in B_3Mo_2 (Fig. 4).

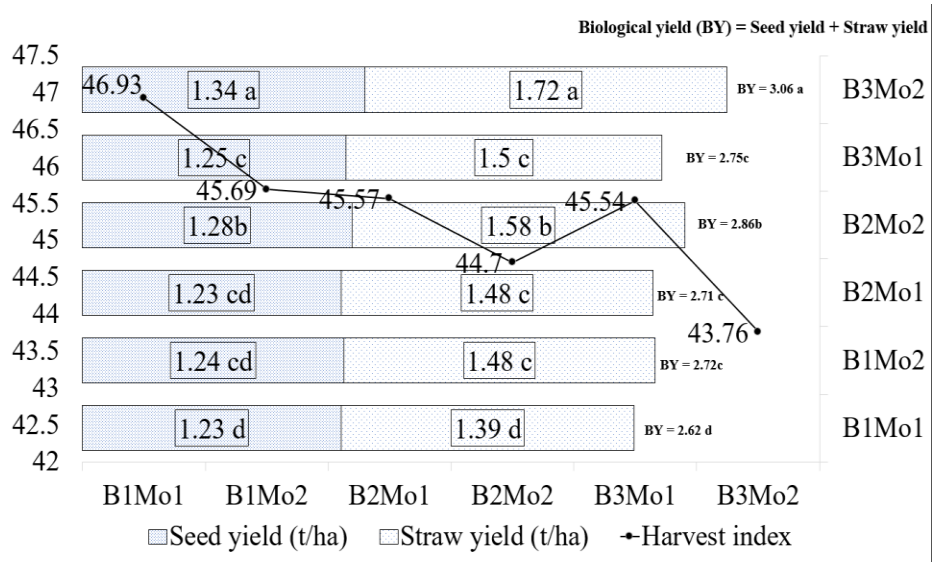

Fig. 4. Interaction effects of seed yield (t/ha), straw yield (t/ha), biological yield (t/ha), and harvest index (%) of mustard. B_1= No boron (control), B_2= 1kg B/ha and B_3=2kg B/ha, Mo_1 = No molybdenum (control) and Mo_2 = 20 ppm molybdenum spray

Conclusion

Boron fertilizer increased the yield. Molybdenum also influenced the yield. The highest seed yield was obtained by using 2 kg/ha boron ads basal and 20 ppm molybdenum spraying at the maximum vegetative stage.

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Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Ali, S. and Faruque, O. 2022. Edible oil now becomes another worry. The Business Standard, 24 April 2022, https://www.tbsnews.net/markets/edible-oil-now-becomes-another-worry-408446

BBS (Bangladesh Bureau of Statistics). 2021. Statistical Year Book of Bangladesh. Ministry of planning, Govt. Peop. Repub. Bangladesh, Dhaka.

Bijalwan, A. and Dobriyal, M. J. 2012. Productivity of Wheat (*Triticum aestivum*) as Intercropin Grewia Optiva Based Traditional Agroforestry System along Altitudinal Gradient and Aspectin Mid Hills of Garhwal Himalaya, India. *American J. Envi.Protection*. 2:89-94. https://doi.org/10.12691/env-2-5-3

Gupta, U. C., Jame, Y. W., Cambell, C. A., Leyshon, A. J. and Nichoaichuk, W. 1985. Boron nutrition on crops. *Canada J. Soil. Sci*. 65:381.

Hu, Y. S., Ma, Y. H., sun, Y. L. and Guo, G. 1994. Effect of B application on the agronomic trails, yield and oil content of a double-low rape (*Brassica napus* L.) cultivar. Oil Crops (China). 16(3):43-46.

Hugar, A. B. and kurdikeri, M. B. 2002. Effect of application methods and levels of zinc and molybdenum on field performance and seed yield in soybean. *Karnataka J. Agri. Sci.* 13(2):439-441.

Islam, M. R., Islam M. S., Jahiruddin, M. and Hoque, M. S. 1999. Effect of sulphur, zinc and boron on yield, yield componests and nutrient uptake of wheat. *Pak J. Sci. Ind. Res.* 42(3):137-140.

Islam, M. R., Riasat, T. M. and Jahiruddin, M. 1997. Direct and residual effects of S, Zn and B on yield and nutrient uptake in a rice mustard cropping system. *J. Indian Soc. Soil Sci.* 45(1):126-129.

Jahiruddin, M., Ali, M. S., Hossain, M. A., Ahmed, M. U. and Hoque, M. M. 1995. Effect of boron on grain set, yield and some other parameters of wheat cultivars. *Bangladesh J. Agric. Sci.* 22:179-184.

Jaiswal, A. D., Singh, S. K., Singh, Y. K., Singh, S. and Yadav, S. N. 2015. Effect of sulphur and boron on yield and quality of mustard (*Brassica juncea* L.) grown on Vindhyan red soil. *J. Indian Soc. Soil Sci.* 63:362-364.

Khanam, M., Rahman, M. M., Islam M. R. and Islam, M. R. 2001. Effect of manures and fertilizers on the growth and yield of BRRI Dhan 30. *Pakistan J. Biol. Sci*. 4(2): 172-174.

Mathew, J. and George, S. 2013 Synergistic-influence of sulphur and boron on enhancing the productivity of sesame (*Sesamum indicum* L.) grown in an Entisol of Kerala. *J. Indian Soc. Soil Sci*.61:122-127.

Pradhan, A. C. and Sarkar, S.K. 1993. Growth and yield of rapeseed mustard varieties as influenced by sulphur and boron application. *Dept. Agron. Indian Agriculturist.* 37(1):21-26.

Rao, K. T., Naidu, G. J. and Subbaiah, G. 2006. Effect of foliar application of micronutrient on yield and yield attributes on indian mustard (*Brassica juncea* L.), *Agric. Sci. Digest*. 26(2):144-146.

Shen, K., Shen, Z. G., Xu, H. Q. and Huang, Q. Y. 1993. A study of boron nutrition and seed setting in rape (*Brassica napus*). *Acta Agronomica Sinica.*19(6):539-545.

Subbaiah, G. and Mittra, B. N. 1996. Effect of foliar spray of micronutrients on yield and oil content of Indian mustard (*Brassica juncea*). *Indian J. Agron.* 41(1):95-97.

Thompson, J. E., Smith, I. K. and More, D. P. 1970. Sulphur in plant nutrition. In. O. H. Muth and J. E. Oldfield (ed). pp. 80-90. [Symposium: sulphur in nutrition. AVI Publ. co., westport, CT].

USDA (United States Department of Agriculture). 2022. World Agriculture Production, Circular Series of Foreign Agriculture Service, USDA.

William, F. C. and Bennet, P. K. 1996. Effect of molybdenum on quality of Soybean Science. 14(4):26-28.

Yang, Y. A., Xu, H. K., Jie, Z. Q. and Wang, B.Y. 1989. Influence of B. N and K. nutritional level on B uptake, quality and yield of rapeseed. *Scienti. Agril. Sci.* 22(1):44-51.

Yadav, S. N. Singh, S. K. and Kumar, O. 2016. Effect of boron on yield attributes, seed yield and oil content of mustard (*Brassica juncea* L.) on an Inceptisol. *J. Indian Soc. Soil Sci.* 64:291-296. https://doi.org/10.5958/0974-0228.2016.00041.4

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EFFECTS OF CYANOBACTERIA ON SOIL PROPERTIES IN FOREST AND CULTIVATED LANDS OF MADHUPUR TRACT

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Abstract

A laboratory experiment was conducted at the Department of Soil Science of Bangladesh Agricultural University, Mymensingh to assess the effect of cyanobacteria on soil properties of cultivated and forest lands of Madhupur Tract. The population of cyanobacteria in two soils from Madhupur and one fromfrom BAU farm was counted followed by their identification up to genera level by fluorescence microscope. A marked variation was observed in cyanobacterial population among the soils: $27.8x10^5$ g^{-1} in BAU farm soil, $2.70x10^5$ g^{-1} in Madhupur cultivated soil and $1.62x10^5$ g^{-1} in Madhupur forest soil. A total of 21 isolates were identified from all the soils taking eight isolates from each of Madhupur cultivated and BAU farm soils, and five from Madhupur forest soil . Of the 21 isolates, six isolates taking two from each soil were inoculated into all the three soils to see their effect on soil properties. These were *Fischerella* Mc and *Aulosira* Mc from Madhurpur cultivated soil; *Calothrix* Mf and *Scytonema* Mf from Madhurpur forest soil; *Anabaena* Bf and *Nostoc* Bf from BAU farm soil. The results reveal that there was an increase of soil pH, organic matter, total N, available P, exchangeable Ca, available S and CEC and a decrease in exchangeable K and exchangeable Na concentrations. The impact of different isolates on most of the soil properties was significant except their effect on exchangeable K for all soils, exchangeable Na for BAU farm soil and CEC for Madhurpur cultivated soil. Usually isolates showed better performance in their native soils than in other soils and cyanobacteria inoculation showed a positive indication towards improving fertility of soils.

Keywords: BAU farm, Cynabacterial population, N_2 fixation, Soil fertility

Introduction

Cyanobacteria are widely distributed in many habitats. Many of them have a capability to fix atmospheric N (N_2) and thereby improve the nitrogen status of soil. As photosynthetic organism, they can also fix atmospheric CO_2, thus reduce its concentration, and thereby help decrease the greenhouse effect. They can improve soil

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organic matter, stable aggregates, increase P availability by surface bound and extracellular phosphates activities, control soil erosion and maintain soil ecosystem (Kaushik and Murti, 1981).

Cyanobacteria grow abundantly in tropical and subtropical regions and are particularly common in rice fields (Dey *et al.,* 2010). The occurrence of these organisms are ubiquitous and has been recorded in soils throughout the world, but no definite geographical locations of families, genera or species has yet been presented. Kaushik (2000) reported that application of cyanobacteria biofertilizers to rice crops improves soil structure (aggregation), increases P availability and in saline alkali soils reduces soil pH, hence there is an overall improvement of physical, chemical and nutritional properties of soil. The present agriculture practices heavily rely on the application of chemical fertilizers and pesticides, and practices like intensive tillage and excess irrigation which otherwise lead to ever increasing cost of agricultural production, over exploitation of natural resources likes oil and water, and also create environmental pollution (Kumar *et al.,* 2012). Soil properties such as texture, mineralogy composition, organic matter and nutrients contents, pH, and electrical conductivity greatly influence cyanobacterial growth and EPS production. So far, most of cyanobacteria inoculation experiments have been performed on sandy soils (Lan *et al.,* 2017, Mugnai *et al.,* 2018). Cyanobacteria are more abundant in habitat in which moisture is adequate and light is accessible. Some Cyanobacteria grow in hot springs at temperatures as high as 90^0C, although the optimal growth temperatures of these thermal cyanobacteria are between 50 to 54^0C (Haque, 2004). They have been widely used as biofertilizers in agriculture, mainly in paddy rice fields in Asia (Prasanna *et al.,* 2009, 2013; Priya *et al.,* 2015; Singh *et al.,* 2016).

Cyanobacteria can contribute to about 20-30 kg N ha^{-1} as well as the organic matter to the soil, quite significant for the economically weak farmers unable to invest for costly chemical nitrogen fertilizer (Issa *et al.,* 2014). In Bangladesh, there is a bright scope for utilizing cyanobacteria because it is a major rice growing country. The rice field provides congenial atmosphere for the establishment of cyanobacteria. Besides this, most of the farmers of this country belong to low income category, getting cheap source of N is very much helpful for them.

Materials and Methods

Soil sample collection and processing

The experiment was conducted at the Soil Science Laboratory of the Department of Soil Science of Bangladesh Agricultural University (BAU), Mymensingh. Three types of soils were selected for the study – (i) Madhupur rice field soil (cultivated soil), (ii) Madhupur forest soil and (iii) BAU farm soil. Soil samples were collected from 0-15 cm depth of soil. After collection, soils of each location were mixed thoroughly by hand on a thick brown paper sheet to make a composite sample at the Soil Science Laboratory, BAU, Mymensingh. Soil samples were air dried, ground and passed through a 2 mm sieve. Thereafter the samples were analyzed for physico-chemical properties.

Soil analysis

Particle size analysis of soil samples was done by hydrometer method (Piper, 1950) and the textural classes were determined following Marshal's Triangular Coordinates using USDA system. Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being 1:2.5 as described by Jackson (1962). Organic carbon of soil was determined by wet oxidation method with 1N $K_2Cr_2O_7$ and conc. H_2SO_4 (96%) mixture, followed by rapid titration with freshly prepared 1N $FeSO_4$ solution (Walkley and Black, 1935). Organic matter content was then calculated by multiplying the percent organic carbon with the Van Bemmelen factor, 1.73. Total N content of soil was determined by semi Micro-Kjeldahl method. The samples were digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4:$CuSO_4.5H_2O$: Se in the ratio 100:10:1). Nitrogen in the digest was trapped by boric acid indicator solution following distillation with 40% NaOH and titration was made with 0.01 N H_2SO_4 (Brammer, 1965).

For the determination of available P, extraction was made with 0.5M $NaHCO_3$ adjusted at pH 8.5 following the method of Olsen *et al.,* (1954). The P in the extract was then determined by developing blue colour using stannous chloride was measured by spectrophotometer at 660 nm wave length and available P was calculated with the help of a standard curve. Available S content of soil was extracted from the soil with $CaCl_2$ solution (0.15%) followed by its determination by Bardsley and Lanacaster (1965) and soil S concentration in the extract was determined turbidimetrically of the intensity of turbid by spectrophotometer at 420 η m. Exchangeable Na & K (Pratt, 1965) and Ca (Heald, 1965) were determined by flame photometer on the neutral ammonium acetate $9NH_4OAC$) extract.

CEC

CEC was measured by sodium saturation method where NaOAc was used to leach out all the cations from the exchange sites, excess salt was removed by washing with iso-propanol, and finally Na brought into solution by extracting with 1M NH_4OAc, pH 7.0 (Chapman, 1965). The Na concentration of extract was measured by atomic absorption spectrophotometer.

Microbiological experiment

Twenty one cyanobacterial isolates were identified from the selected soils. Among them six isolates viz., *Anabaena* S, *Nostoc* S, *Fishcherella* Mc, *Aulosira* Mc, *Calothrix* Mf and *Scytonema* Mf had been selected for inoculation. The selected isolates were grown in the laboratory in conical flask in modified version of Chu 10D-N medium (Sinclair and Whitton, 1977) at room temperature (25±2°C) under constant light of 100 watt bulbs fixed at 20 cm apart and 50 cm away from the culture. An equal amount of cyanobacterial cultures of all these six isolates were homogenized by reciprocating shaker and followed by hand shaking. Homogenized cultures were inoculated in 200 g of soil kept in plastic pots collected from all the three selected areas. All individual isolate was considered as a treatment and three replications were maintained. A treatment without cyanobacteria inoculation was maintained as control. Thus, there were seven

treatments including control. They were as follows: T_1: Control; T_2: *Fishcherella* Mc; T_3: *Aulosira* Mc; T_4: *Anabaena* Bf; T_5: *Nostoc Bf*; T_6: *Calothrix* Mf; T_7: *Scytonema* Mf. Water was added to the pots from time to time to keep the soil moist so that cyanobacteria can easily grow and the inoculated pots were kept under light for 90 days. After this period soil properties such as soil pH, organic matter, total N, available P, exchangeable K, exchangeable Ca, available S, exchangeable Na and CEC were determined. The readings were converted to most probable number (MPN) of cyanobacteria for determination of abundance of organisms in soil And a modified version of Chu 10D-N medium (Sinclair and Whitton, 1977) was used to study the growth of cyanobacteria.

Statistical analysis

Completely randomized design was followed for the experiment. The collected data were analyzed statistically by F-test (LSD value at 5% level) to ascertain the treatment effects and the means were ranked by Duncan's Multiple Range (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Soil pH

Soil pH increased in all cases due to the treatment of soils with cyanobacterial isolates (Table 1). The ability of cyanobacteria to change the soil pH was not same for all soils. It differed from soil to soil and from isolate to isolate. The soil pH value increased up to 7.01 due to application of cyanobacterial isolates in Madhupur cultivated soil from 6.22 recorded in control. The maximum increase was recorded due to the treatment of *Fishcherella* Mc and the minimum increase was recorded for *Calothrix* Mf treatment. In Madhupur forest soil, the pH value of control was 5.60. The maximum increase was observed due to application of *Calothrix* Mf and the minimum increase was for *Aulosira* Mc. In BAU farm soil, the pH value of control was 6.89 and the highest increase in pH value (7.2) was due to application of *Anabaena* S, while the lowest pH (6.99) was recorded due to both *Fishcherella* Mc and*Scytonema* Mf applications. It is noted that the pH of Madhupur cultivated soil, Madhupur forest soil and Soil Science Farm soil turned to neutral condition as influenced by cyanobacteria application. As the pH of three soils changed towards neutral, it might be said that cyanobacteria play an important role in lowering acidity of soils. Saha and Mandal (1979) reported that algal growth caused an increase in soil pH. This finding can be considered as supportive to the current results.

Organic matter

Soil organic matter content increased due to application of cyanobacterial isolates. The increase was statistically significant (Table 1). In Madhupur cultivated soil, the highest organic matter content of 2.56% was observed due to the inoculation of *Fishcherella* Mc followed by organic matter contents of 2.46, 2.45, 2.41 and 2.40% due to the application of *Aulosira* Mc, *Nostoc* S, *Anabaena* S, *Scytonema* Mf and *Calothrix* Mf, respectively. The lowest organic matter content was 1.97% in control.

Table 1. Effects of different cynabacterial isolates on pH, organic matter and total N content of soils

Treatments	Soil pH			Organic matter content			Total N concentration (%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest Soil	BAU farm soil
Control	6.22	5.60	6.89	1.96 e	1.24 g	1.94 d	0.135	0.076	0.125
Fischerella Mc	7.01	6.80	6.99	2.56 a	1.50 d	2.27 bc	0.175	0.084	0.160
Aulosira Mc	7.00	6.55	7.04	2.50 b	1.62 c	2.23 bc	0.170	0.080	0.175
Anabaena Bf	6.80	6.65	7.20	2.45 c	1.34 f	2.35 ab	0.155	0.087	0.175
*Nostoc***f**	6.79	6.70	7.15	2.46 c	1.48 e	2.40 a	0.165	0.082	0.165
Calothrix Mf	6.65	6.99	7.01	2.40 d	1.67 b	2.17 c	0.170	0.091	0.155
Scytonema Mf	6.75	6.89	6.99	2.41 d	1.69 a	2.20 c	0.160	0.111	0.145
SE (±)	0.06	0.05	0.07	0.04	0.04	0.05	NS	NS	NS

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

The minimum increase of organic matter in soil was recorded in *Calothrix* Mf cyanobacteria inoculation. In Madhupur forest soil, the highest organic matter content of 1.69% was due to the use of *Scytonema* Mf followed by organic matter in *Calothrix* Mf, *Aulosira* Mc, *Fishcherella* Mc, *Nostoc Bf* and *Anabaena* f. The lowest organic matter was recorded in control treatment (1.24%). The minimum increase of organic matter was due to use of *Anabaena* Bf. In BAU farm soil, the highest organic matter content of 2.40% was observed in *Nostoc* Bf inoculation which was statistically similar to 2.35% due to application of *Anabaena* Bf. Again the organic matter content recorded in *Anabaena* S inoculation was statistically similar to the organic matter recorded in *Fishcherella* Mc and *Aulosira* Mc inoculation. The lowest organic matter (1.91%) was found in absence of cyanobacterial isolates. The minimum increase of organic matter was recorded in *Calothrix* Mf inoculation. Islam *et al.* (1993) observed that the growth of cyanobacteria in soil can increase organic matter in soil up to 840 kg ha^{-1}. Our result is in good agreement with the present finding. Because cyanobacteria use the energy of sunlight to drive photosynthesis, a process where the energy of light is used to synthesize organic compounds from carbon dioxide.

Total N

Results show that there was an increase in total N concentration of all the studied soils with cyanobacterial inoculation (Table 1). The increase in total N was statistically significant. There was a variation in the ability of the cyanobacterial isolates in increasing N concentration in different soils. In Madhupur cultivated soil, the highest total N concentration (0.175%) was observed in *Fishcherella* Mc inoculation which was statistically identical to those resulted from of the inoculation of *Aulosira* Mc and *Calothrix* Mf cyanobacteria. The value of total N concentration of 0.135% was the lowest

as recorded in control. The minimum increase in total N concentration was due to the inoculation of *Anabaena* B**f**. In Madhupur forest soil, the highest total N concentration (0.111%) was recorded in *Scytonema* Mf cyanobacteria inoculation, followed by the total N concentration of 0.091, 0.087, 0.084 and 0.082% in the *Calothrix* Mf, *Anabaena* S, *Fishcherella* Mc and *Nostoc* B**f** inoculation, respectively. The lowest N concentration was 0.076% which was recorded in control treatment. The minimum increase was recorded due to the addition of *Nostoc* S cyanobacteria. In Soil Science Farm soil, total N concentration (0.175%) was maximum and was observeddue to the effect of *Aulosira* Mc and *Anabaena* S. The effects of *Nostoc* S, *Fishcherella* Mc and *Calothrix* Mf cyanobacteria were statistically similar on total N content of soil at BAU farm. The lowest total N conc. (0.125%) was observed in control. The minimum increase was due to addition of *Calothrix* Mf. Haque (2004) observed a value of 0.140 to 0.180% increase in total N of soils due to application of cyanobacterial isolates. Thus, our present results indicate that N status of soils can be increased by the application of cyanobacterial isolates.

Available P

Available P in different soils was influenced by different isolates of cyanobacteria (Table 2). Results indicate that available P in the studied soils increased significantly by the treatments. The maximum available P (18.8 ppm) in Madhupur cultivated soil was recorded in *Aulosira* Mc inoculation which was statistically identical to 18.1, 18.1, 18.0 and 18.2 ppm recorded in *Anabaena* B**f**, *Nostoc* B**f**, *Calothrix* Mf and *Scytonema* Mf inoculation, respectively. The lowest value of 16.8 ppm was found in control. The minimum increase in available P was recorded with the application of *Fishcherella* Mc. In Madhupur forest soil, the highest available P of 8.69 ppm was recorded in *Scytonema* Mf inoculation, followed by 8.50, 8.00, 7.89 and 7.60 ppm in *Calothrix* Mf, *Nostoc* S, *Aulosira* Mc and *Fishcherella* Mc inoculation, respectively. The lowest available P of 7.30ppm was recorded in control. The minimum increase in available P was due to the treatment of *Anabaena* S (7.45ppm). In BAU farm soil, the highest P concentration P was 12.0 ppm due to the application of *Anabaena* B**f** which was statistically identical to those noticed in all the treatments except in control. The lowest value of available P (10.9 ppm) in these soils was recorded in control which was statistically identical to that recorded in *Aulosira* Mc. Kaushik (2000) reported that application of cyanobacterial biofertilizer helped increase the availability of P.

Exchangeable K

Isolates of cyanobacteria had no significant effect on the exchangeable K concentration of the selected soils (Table 2). Results indicate that exchangeable K concentration in the studied soils by value decreased due to the application of cyanobacterial isolates. In Madhupur cultivated soil, the highest exchangeable K concentration was 0.309 me% in control and the lowest was 0.284me% due to the application of *Fishcherella* Mc. In Madhupur cultivated soil, the effects of *Nostoc* Bf and *Scytonema* Mf application were same which was 0.297 me%. The minimum decrease in

exchangeable K was recorded in *Scytonema* Mf and *Nostoc* Bf inoculation. In Madhupur forest soil, the highest exchangeable K concentration was recorded 0.160me% in control. The lowest exchangeable K concentration was 0.153me% due to the application of *Calothrix* Mf which was followed by exchangeable K in *Scytonema* Mf, *Nostoc* Bf, *Fishcherella* Mc and *Anabaena* Bf inoculation. The minimum decrease in exchangeable K was recorded in *Aulosira* Mc added soils. The highest exchangeable K (0.236 me%) concentration was recorded at BAU farm soil in case of control. The lowest exchangeable K was 0.215me% recorded in soils applied with both *Nostoc* S and *Fishcherella* Mc. The minimum decrease in exchangeable K was found in soils inoculated with *Calothrix* Mf and *Aulosira* Mc. Haque (2004) reported that the exchangeable K decreased due to the treatment with cyanobacteria but this decrease was statistically insignificant. This finding resembled the finding recorded in the present study.

Exchangeable Ca

Exchangeable Ca also increased due to different of cyanobacterial isolates and such increase was statistically significant (Table 2). In Madhupur cultivated soil, the highest exchangeable Ca concentration was 4.95 me% due to the inoculation of *Fishcherella* Mc followed by the application of *Aulosira* Mc, *Calothrix* Mf, *Nostoc* Bf, *Scytonema* Mf and *Anabaena* Bf. The lowest exchangeable Ca of 4.43 me% was observed in the control treatment which was statistically identical to those observed with the treatment *Anabaena* Bf and *Scytonema* Mf. The maximum and minimum increase in exchangeable Ca concentration was due to addition of *Fishcherella* Mc and *Anabaena* S, respectively. In Madhupur forest soil, the highest exchangeable Ca concentration was 5.36 me% in soils inoculated with *Calothrix* Mf followed by the addition of *Scytonema* Mf, *Fishcherella* Mc, *Aulosira* Mc, *Nostoc* Bf and *Anabaena* Bf, respectively. The lowest value of exchangeable Ca (4.40 me%) was recorded in control. The minimum increase in exchangeable Ca was due to use of *Anabaena* Bf. In BAU farm soil, the highest exchangeable Ca concentration (4.53 me%) was recorded in soils inoculated with *Anabaena* Bf which was statistically identical to 4.43 and 4.33 me% due to the application of *Nostoc*Bf and *Fishcherella* Mc, respectively. The lowest value of exchangeable Ca (3.91 me%) was recorded in the control treatment. The minimum increase in exchangeable Ca was due to the effect of *Scytonema* Mf. frit

Available S

Different isolates of cyanobacterial treatments showed a significant increase in available S content for all types of soil (Table 3). In Madhupur cultivated soil, the highest available S (15.5ppm) was recorded in soils inoculated with *Aulosira* Mc, which was statistically identical to 15.5, 15.4, 15.3 and 14.8 ppm available S recorded in the inoculation of *Fishcherella* Mc, *Anabaena* Bf, *Nostoc* Bf and *Scytonema* Mf, respectively. But the effect of *Nostoc* Bf and *Scytonema* Mf was statistically identical to the effect of *Calothrix* Mf.

Table 2. Effects of cynabacterial isolates on available P, exchangeable K and exchangeable Ca concentrations of soils

Treatments	Available P concentration (ppm)			Exchangeable K concentration (me%)			Exchangeable Ca concentration (me%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm Soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest Soil	BAU farm soil
Control	16.8 c	7.30 g	10.8 b	0.309	0.160	0.236	4.43 d	4.40 g	3.91 d
Fischerella Mc	17.5 bc	7.60 e	11.6 a	0.284	0.156	0.215	4.95 a	4.99 c	4.33 ab
Aulosira Mc	18.7 a	7.89 d	11.4 ab	0.285	0.159	0.227	4.69 b	4.83 d	4.17 bc
Anabaena S	18.1 ab	7.45 f	12.0 a	0.296	0.157	0.220	4.48 d	4.56 f	4.53 a
Nostoc S	18.1 ab	8.00 c	11.9 a	0.297	0.155	0.215	4.63 bc	4.75 e	4.43 a
Calothrix Mf	18.0 ab	8.50 b	12.0 a	0.302	0.153	0.227	4.69 b	5.36 a	4.07 cd
Scytonema Mf	18.2 ab	8.69 a	11.7 a	0.297	0.154	0.221	4.58 cd	5.30 b	4.06 cd
SE (±)	0.15	0.11	0.11	NS	NS	NS	0.04	0.07	0.05

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

The lowest available S (13.2 ppm) concentration was recorded in control. The minimum increase in available S concentration was recorded in *Calothrix* Mf. In Madhupur forest soil, the highest available S concentration (9.91ppm) was recorded in *Calothrix* Mf. This was followed by 9.87, 9.65, 9.60, 9.56 and 4.49 ppm due to the effects of *Scytonema* Mf, *Nostoc* Bf, *Aulosira* Mc, *Anabaena* Bf and *Fishcherella* Mc, respectively. The lowest available S concentration was recorded in control. The minimum increase in available S concentration was recorded due to the inoculation of *Fishcherella* Mc. In BAU farm soil, the highest available S concentration was 17.6 ppm recorded due to the effect of *Anabaena* Bf inoculation. Available S concentration was statistical identical due to the effect of *Nostoc* Bf, *Calothrix* Mf, *Fishcherella* Mc and *Aulosira* Mc. The lowest available S concentration was recorded in control. The minimum increase in available S was due to the addition of *Scytonema* Mf. Paul and Clark (1989) reported that algal sulphate esters show a 2 - 3% of the total organic S in soils which are mineralized under favourable conditions to available SO_4^{-2}. This clearly indicates that cyanobacterial biomass might be the cause for increasing available S in soil. Thus it is found that cyanobacterial isolates clearly increase the available S concentration in soils.

Exchangeable Na

Effects to the different treatments on exchangeable Na (me%) of the selected soils under study are shown in Table 3. Exchangeable Na in soil was decreased by different cyanobacterial isolates. The decrease in exchangeable Na was statistically significant in case of Madhupur cultivated and forest soil but not significant in case of BAU farm soil. In Madhupur cultivated soil, the highest exchangeable Na (0.783 me%) percentage was recorded in control and the lowest exchangeable Na (0.716 me%) was

due to the application of *Aulosira* Mc, which was statistically identical to the effect of *Aulosira* Mc (0.717 me%) and *Calothrix* Mf (0.732 me%), respectively. The minimum decrease in exchangeable Na concentrations was due to the effect of *Scytonema* Mf. In Madhupur forest soil, the highest exchangeable Na (0.59 me%) was recorded in control and the lowest exchangeable Na (0.50 me%) was by the application of *Scytonema* Mf, which was followed by the addition of *Calothrix* Mf, *Nostoc* Bf, *Aulosira* Mc, *Fishcherella* Mc and *Anabaena* Bf, respectively. The minimum decrease of exchangeable Na was recorded in the treatment of *Anabaena* Bf. In BAU farm soil, the highest exchangeable Na percentage of 0.716 me% was recorded in the control treatment and the effect of *Aulosira* Mc. The lowest value of exchangeable Na of 0.662 me% was recorded in *Nostoc* Bf inoculation. The minimum decrease of exchangeable Na was observed in*Scytonema* Mf. Sodium is essential for the growth, N fixation and photosynthetic functions of cyanobacteria (Apte and Thomas, 1983). Subhashini and Kaushik (1981) reported that the exchangeable Na status can be brought down appreciably by the addition cyanobacterial isolates. The reduction in exchangeable Na by cyanobacteria was reported by Hashem et al. (1995) and Hashem (1997). These findings indicated that the decrease in exchangeable Na level might be due to its utilization by the cyanobacterial isolates.

Table 3. Effects of different cynabacterial isolates on available S , exchangeable Na and CEC value of soils

Treatments	Available S concentration (ppm)			Exchangeable Na (me%)			Cation Exchange Capacity (me%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil
Control	13.2 c	9.21 g	16.1 d	0.783 a	0.59 a	0.716	14.0	13.4 g	9.19 b
Fischerella Mc	15.5 a	9.49 f	17.2 b	0.716 c	0.55 c	0.705	14.7	13.5 d	9.61 a
Aulosira Mc	15.5 a	9.60 d	17.0 bc	0.717 c	0.54 d	0.716	14.7	13.4 f	9.75 a
Anabaena S	15.4 a	9.56 e	17.6 a	0.740 b	0.56 b	0..664	14.6	13.5 c	10.2 a
Nostoc S	15.3 ab	9.56 c	17.3 b	0.741 b	0.53 e	0.662	14.3	13.4 e	9.95 a
Calothrix Mf	14.5 b	9.91 a	17.2 b	0.732 bc	0.52 f	0.665	14.3	13.5 b	9.19 a
Scytonema Mf	14.8 ab	9.87 b	16.9 c	0.742 b	0.50 g	0.669	14.1	13.5 a	9.47 a
SE (±)	0.18	0.05	0.1	0.01	0.01	NS	NS	0.03	0.04

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

Cation Exchange Capacity (CEC)

CEC of the selected soils presented in the Table 3. The results showed that CEC was increased in cyanobacterial isolates inoculation. But the increase was significant in Madhupur forest and BAU farm soil and insignificant in Madhupur cultivated soil. In Madhupur cultivated soil, the highest CEC was 14.7 me% due to addition of *Aulosira* Mc. The lowest value was noted 14.0 me% in the control treatment. The minimum

increase in CEC was due to treatment of *Scytonema* Mf. In Madhupur forest soil, the highest CEC of 13.5 me% was recorded in *Scytonema* Mf in soil, followed by the application of *Calothrix* Mf, *Anabaena* Bf, *Fishcherella* Mc and *Nostoc* Bf. The lowest value (13.40 me%) was recorded in the control. The minimum increase of CEC was observed in *Aulosira* Mc treated soil. In BAU farm soil, the highest CEC of 10.18 me% was recorded due to the application of *Anabaena* Bf. Rest of them are statistically identical with this. The lowest CEC was 9.19 me% recorded in control which was statistically identical with *Calothrix* Mf.

Conclusion

Selected cyanobacterial isolates showed a considerable impact on the chemical properties of soils. Cyanobacteria can be used to improve soil fertility, especially for the purpose of increasing the level of soil organic matter, total N, available P, available S, exchangeable Ca and CEC and also in decreasing soil acidity. In most of the cases, cyanobacterial isolates performed the best in the soils of their habitats. As a result, *Fischerella* Mc and *Aulosira* Mc showed the best results in case of Madhupur cultivated soil compared to other soils. Further research works at field and incubation levels should be carried out in a manner for practical and applied purposeseritseh and to identify their best uses.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Apte, S. K. and Thomas, J. 1983. Impairment of photosynthesis by sodium deficiency and its relationship to nitrogen fixation in the cyanobacterial Anabaena torulosa FEMS Microbiol. Lett. 16:153-157.

Bardsely, C. E. and Lanacaster, J. D. 1965. Sulfur. In Methods of Soil Analysis. Part-II C.A. Black ed., Amer. Soc. Agron., Inc. Publisher, Madison, Wisconsin, USA.

Brammer, J. M. 1965. Nitrogen. In Methods of Soil Analysis. Part-II C.A. Black ed., Amer. Soc. Agron., Inc. Publisher, Madison, Wisconsin, USA.

Chapman, H. D. 1965. Cation exchange capacity. In Methods of Soil Analysis. Part-II C.A. Black ed., pp. 891-901. Amer. Soc. Agron., Inc. Publisher, Madison, Wisconsin, USA.

Dey, H. S., Tayung, K. and Bastia, A. K. 2010. Occurrence of nitrogen-fixing cyanobacteria in local rice fields of Orissa, *India. Ecolo. Soc. Nepal*. Ecoprint 17:77-85

Gomez, K. A., Gomez, A. A. 1984. Statistical Procedures for Agricultural Research, John Wiley & Sons, New York.

Haque, H. 2004. Role of Cyanobacteria on Soil Properties in Three Selected AEZs of Bangladesh. M. S. Thesis. Department of Soil Science, Bangladesh Agricultural University, Mymensingh..

Hashem, M. A. 1997. Role of blue-green algal inoculation for improving soil fertility and reclaiming salinity of soil. Second Year Annual Report of the research project. BAURES.

Hashem, M. A., Islam, M. R. and Banu, N. A. 1995. Nitrogen fixation and salinity reduction by blue-green algae. *Bangladesh J. Agril. Sci.* 22(2):251-256.

Heald, W. R. 1965. Calcium and Magnesium. U.S. Soils Laboratory, ARS, USDA, Betsville, Maryland. *In* Methods of Soil Analysis. Part-II C.A. Black ed., Amer. Soc. Agron., Inc. Publisher, Madison, Wisconsin, USA.

Islam, M. R., Hashem, M. A. and Rahman, M. A. 1993. Vertical distribution of cyanobacteria (blue-green algae) in different rice field of Bangladesh. *Progress Agric.* 4 (1&2):67-72.

Issa, A. A., Abd-Alla, M. H. and T. Ohyama. 2014. Nitrogen fixing Cyanobacteria: future prospect, in Advances in Biology and Ecology of Nitrogen Fixation, ed. T. Ohyama (Rijeka: In Tech).

Jackson, M. L. 1962. Soil Chemical Analysis. Constable and Co. Ltd. London.

Kaushik, B. D. 2000. Algal biotechnology in rice cultivation. Int. Conf. on Biotech and Biodiversity (Nov. 14-16) Kathmandu, Nepal. pp.65.

Kaushik, B. D. and Krishna Murti, A. S. R. 1981. Effect of blue-green and gypsum application on physico-chemical properties of alkali soils. *Phykos. 20 (1&2)*:91-99.

Kumar, M., Bauddh, K., Sainger, M., Sainger, P. A., Singh, J. S. and Singh, R. P. 2012. Increase in growth, productivity and nutritional status of rice (*Oryza sativa* L. cv. Basmati) and enrichment in soil fertility applied with an organic matrix entrappedurea. *J. Crop Sci. Biotech.* 15:137-144.

Lan, S., Wu, L., Yang, H., Zhang, D. and Hu, C. 2017. A new biofilm based microalgal cultivation approach on shifting sand surface for desert cyanobacterium Microcoleus vaginatus. *Bioresource Technol*. 238:602–608.

Mugnai, G., F. Rossi, V. J. M. N. L., Felde, C. Colesie., Büdel, B. and Peth, S. *et al.* 2018. Development of the polysaccharidic matrix in biocrusts induced by a cyanobacterium inoculated in sand microcosms. *Biol. Fert. Soils* 54:27-40.

Olsen, S. R., Cale, C. V., Watanabe, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium carbonate. U. S. Dept. Agr. Circ. p. 929.

Paul, E. A. and Clark, F. E. 1989. Soil Microbiology and Biochemistry. Academic Press. Inc. USA. pp. 241-242.

Piper, C. S. 1950. Soil and Plant Analysis. Adelaide Univ. Hassel Press, Australia.

Prasanna, R., P. Jaiswal, S., Nayak, A. S. and Kaushik, B. D. 2009. Cyanobacterial diversity in the rhizosphere of rice and its ecological significance. *Indian J. Microbiol.* 49:89-97.

Pratt, P. F. 1965. Potassium and Sodium. *In* Methods of Soil Analysis. Part-II C.A. Black ed., Amer. Soc. Agron., Inc. Publisher, Madison, Wisconsin, USA.

Priya, H., R. Prasanna, B., Ramakrishnan, N., Bidyarani, S., Babu, S., Thapa, *et al.* 2015. Influence of cyanobacterial inoculation on the culturable microbiome and growth of rice. *Microbiol. Res.* 171:78-89.

Saha, K. C. and Mandal, L. N. 1979. Effect of algal growth on the availability of phosphorus, iron and manganese in rice soils. *Plant and Soil*. 52:139-149.

Sinclair, C. and Whitton, B. A. 1977. Influence of nitrogen sources on morphology of Rivulariaceae (cyanophyta). *J. Phycol.* 13:335-340.

Singh, J. S., Kumar, A., Rai, A. N. and Singh, D. P. 2016. Cyanobacteria: a precious bio-resource in agriculture, ecosystem, and environmental sustainability. *Front. Microbiol*. 7:529.

Subhashini, D. and Kaushik, B. D. 1981. Amelioration of sodic soils with blue green algae. *Aust. J. Soil Res.* 19:361-366.

Walkley, A. and Black, A. I. 1935. An examination of the Degtijareff method for determining soil organic matter and a proposal modification of the chromic acid titration method. *Soil Sci.* 37:29-38.

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Short Communication

MORPHOLOGICAL VARIATIONS IN SOME BRINJAL (*Solanum melongena* L.) GENOTYPES

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Abstract

Fifteen brinjal genotypes were grown under field condition during the period from September 2019 to March 2020 to study the variation in their morphological characters. Based on the growth habit, the genotypes were classified as erect, semi-erect, and spreading types. Hair was observed generally on the leaf and stem while variability in spine, fruit color, and fruit shape were found among the genotypes. Days to first fruit harvest ranged from 79.67 to 103 days, while the leaf area ranged from 44.33 to 83.67 cm in the genotypes studied. The highest values for the fruit length and breadth had the means of 37.93 and 8.03 cm, respectively. The number of fruits per plant ranged from 9 to 23 with an average yield of 1.08 to 7.65 kg per plant. This study revealed significant morphological variations among the genotypes evaluated, which could be utilized into future breeding programs.

Keywords: Calyx length, Egg plant, Genotype, Qualitative traits, Quantitative traits

Introduction

Brinjal or eggplant (*Solanum melongena* L.) is one of the most important, popular, and extensively cultivated vegetable crops in Bangladesh. It grows throughout the year in the country and it is also grown in the tropics and sub-tropics. Brinjal is a good source of minerals and vitamins; primarily the unripe fruits are used for the preparation of various dishes (Islam *et al.,* 2018) and as raw material for pickle production industries (Singh *et al.,* 1963). Not only that, brinjal or eggplants also have indigenous medicinal value, therefore used for weight reduction, and treatment of several diseases including asthma, skin infections, and constipation (Okon *et al.,* 2010). For any crop improvement programme, screening, evaluation and conservation of genetic resources have great significance (Dash *et al.,* 2019). Many local eggplant landraces/varieties are found in Bangladesh and are grown by the farmers in almost all the districts. Those genotypes act as an important genetic resource for plant breeders because of their considerable genotypic variations. Morphological characterization is the first step to assessing the similarities and dissimilarities among the various genotypes

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(Rajan *et al.*, 2020). Therefore, the studies on the variations among the genotypes are pre-requisite for hybridization/breeding programs (Ansari *et al.*, 2011). So far, several traits have been used for morphological characterization of brinjal including growth habit, leaf shape, fruit color, fruit shape (round, oblong, egg-shaped, and curved) fruit size, etc., (Dash *et al.*, 2019; Tümbilen *et al.*, 2011). The eggplant of Bangladesh shows high variability in morphological characters such as fruit sizes, fruit shape, fruit color, and fruit weight and these variations have not been adequately characterized. This study aimed to find out the morphological variations among 15 genotypes of brinjal grown in Bangladesh. The findings of this study will help to select suitable genotypes which could be used for the future breeding programmes.

Materials and Methods

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, ($23^0$77' N longitude and $90^0$33' E latitude; 8.6 meters above sea level). during the period from September 2019 to March 2020. The selected plot was a medium-high land with a pH of 4.66 to 5.93. Seeds of 15 brinjal genotypes collected from the local market of Joypurhat, Kushtia, Dinajpur, Jamalpur, and BARI PGRC. Seedlings were raised following in the seedbed and subsequently planted in the field in a Randomized Complete Block Design (RCBD) with three replications. Each replication contained 75 plants of 15 genotypes where the plant-to-plant distance was 75 cm and row-to-row distance was 125cm, respectively. The amount of organic carbon content, total N, available P, and available K were 0.82%, 0.12%, 21 ppm, and 0.27mg per 100g of soil, respectively. The recommended cultural practices were followed for growing the genotypes and necessary plant protection measures were applied to protect the genotypes from diseases and pests. The genotypes were evaluated for five (5) qualitative and ten (10) quantitative traits. The qualitative traits included growth habits, hairiness, spinyness, fruit color, and fruit shape. The quantitative traits were; days to 50 % flowering (DFIF), days to first fruit harvest (DFFH), leaf area (LA), calyx length (CL), number of primary branches per plant (PBPP), fruit length (FL), fruit breadth (FB), fruit number per plant (FNPP), the weight of single fruit (WSF) and fruit yield per plant (FYPP). All observations for quantitative characters were recorded from five competitive and randomly selected plants in each replication except days to fifty percent flowering and days to first fruit harvest, which was noted on a whole plot basis. Data were analyzed by using STAR, version 2.0.1 for all quantitative traits. Tukey's test was performed for mean comparison when varietal differences were found to be significant.

Results and Discussion

Qualitative traits

Based on the investigation, the genotypes G1, G7, G12, G13, and G14 were found to be erect while the genotypes G2, G3, G11, and G15 were semi-erect and the rest of the genotypes were found to be spreading in their growth habit (Table 1). The

variations in the growth habit of brinjal were earlier reported by many researchers (Khan and Singh, 2014; Dash *et al.*, 2019). Hairiness is also an important character of brinjal which is thought to protect the plant from insects and pests. Hair was observed generally on the leaf and stem in all the genotypes in this study (Table 1).

Table 1. Variations in qualitative traits among 15 brinjal genotypes

Genotype	Growth Habit	Hairiness	Spine character	Fruit Color	Fruit Shape
G1	Erect	Leaf, stem	No spine	Dark purple	Semi long
G2	Semi erect	Leaf, stem	Spine on stem	Whitish green	Oval
G3	Semi erect	Leaf, stem	No spine	Whitish green	Round
G4	Spreading	Leaf, stem	No Spine	Purple	Round
G5	Semi erect	Leaf, stem	Spine on stem, leaf, lower petiole	Green	Round
G6	Spreading	Leaf, stem	Spine on leaf lower petiole	Dark purple	Round
G7	Erect	Leaf, stem	No spine	Green	Round
G8	Spreading	Leaf, stem	Spine on leaf lower petiole, calyx	Purple	Long curved
G9	Spreading	Leaf, stem	Spine on calyx	Purple	Long curved
G10	Spreading	Leaf, stem	No spine	Purple	Semi long
G11	Semi erect	Leaf, stem	No spine	Purple	Semi oval
G12	Erect	Leaf, stem	No spine	Purple	curved oval
G13	Erect	Leaf, stem	Spine on leaf, stem	Green	Oval
G14	Erect	Leaf, stem	Spine on leaf, stem, calyx	Whitish green	Round
G15	Semi erect	Leaf, stem	Spine on leaf, stem, calyx	White	Oval

Note: G1= Mukta Keshi, G2= Kushtia-2 Lomba begun, G3= Shabuj sathi, G4=Mental, G5= Gol begun, G6=Brinjal black beauty, G7=Nice ball, G8=Purple king hybrid, G9= Shingnath, G10=Chumki, G11= Majic ball (F1), G12= Altapon, G13= India-1, G14= Dinajpur katali begun, G15= Aveo round (F1).

Variability in spinyness were recorded among the genotypes; In some varieties, spinyness was observed only in the stem (G2), stem and leaf (G13), leaf, stem, and leaf lower petiole (G5), leaf, stem, and fruit calyx (G14 and G15), leaf lower petiole (G6), fruit calyx (G9) and leaf, lower petiole and in fruit calyx (G8). For the remaining genotypes G1, G3, G4, G7, G10, G11, and G12 no spine was found (Table 1).

Fig. 1. Variation in fruit and fruit color of 15 brinjal genotypes. Upper row indicates the genotypes G1, G2, G3, G4 and G5; Middle row indicates the genotypes G6, G7, G8, G9 and G10 and Lower row indicates the genotypes G11, G12, G13, G14 and G15.

These results conform with the findings of Konyak *et al*., 2020. The deviation in fruit color provides an excellent possibility for breeding consumers' favorite characteristics. In this study, the genotypes fell into five fruit color groups namely white (G15), whitish green (G2, G3, and G14), green (G5), purple (G4, G8, G9, G10, G11 and G12), and dark purple (G1 and G6) (Table 1 and Fig.1). The variations in a different color of brinjal fruits were also reported by Shindhe *et al.*, 2012 and Khan and Singh, (2014). The fruit shape was observed to be variable and found to be oval, semi-oval, semi-long, long curved, and round (Table 1 and Fig. 1). Six of the fifteen genotypes produced round fruits, three produced oval fruits, and two produced semi-long and long curved fruits. Tiwari *et al.*, 2016 studied the morphological traits of brinjal and classified them based on fruit characteristics like shape and color.

Table 2. Variation in quantitative traits among 15 brinjal genotypes

Genotype	DFIF	DFFH	LA	CL	PBPP	WSF	FL	FB	FNPP	FYPP
G1	83.00ab	94.33a-c	70.33bc	4.47f	9.84c	328.33a	20.00c	7.90a	23.33a	7.65a
G2	93.33a	97.67ab	76.00ab	6.90b	9.53c	154.00ef	18.23cd	5.77de	20.00a-c	3.07de
G3	92.67ab	96.00ab	83.67a	6.63bc	10.00bc	170.67de	16.00de	7.07a-c	20.67ab	3.52d
G4	91.67ab	94.00a-c	49.67de	5.10d-f	11.18a-c	126.33fg	14.51ef	6.40b-d	20.33ab	2.57ef
G5	93.33a	98.00ab	77.00ab	5.13d-f	9.43c	117.00g	11.67fg	6.30cd	14.00ef	1.64gh
G6	91.67ab	97.33ab	56.00de	5.20d-f	10.76bc	111.67g	13.30efg	7.50ab	9.67g	1.08h
G7	80.00ab	88.33a-c	58.67cd	5.73c-e	9.97c	188.67cd	16.07de	8.03a	19.00bc	3.58d
G8	88.00ab	93.33a-c	69.00bc	9.00a	9.67c	313.33ab	37.93a	4.60e-g	21.33ab	6.68b
G9	84.00 ab	87.33bc	53.33de	8.27a	12.88a	124.67fg	26.63b	3.95g	18.00b-d	2.24g
G10	86.33ab	87.33bc	44.33e	5.83cd	10.57bc	187.00c-e	20.63c	4.77e-g	13.00fg	2.43ef
G11	88.33ab	97.00 ab	46.33e	5.40d-f	10.84bc	287.67b	21.57c	5.60d-f	16.67c-e	4.79c
G12	91.00ab	92.67a-c	51.33de	6.90b	9.85c	97.33gh	20.68c	4.47fg	12.00fg	1.16 h
G13	78.33ab	79.67c	45.33e	4.77ef	10.53bc	76.67h	10.47g	4.23g	15.00d-f	1.15h
G14	91.00ab	103.00a	45.33e	5.43d-f	12.02ab	217.33c	10.73g	7.50ab	10.33g	2.24 fg
G15	89.00ab	93.00a-c	49.33de	4.43f	10.00bc	183.67c-e	13.83e-g	7.17a-c	14.00ef	2.56 ef

Note: Numerical values followed by different letters indicate significant deference from the other. DFIF= Days to 50 % flowering, DFFH= Days to first fruit harvest, LA= Leaf area, CL= Calyx length, PBPP= Number of primary branches per plant, WSF= Weight of single fruit, FL= Fruit length, FB= Fruit breadth, FNPP= Fruit number per plant, FYPP= Fruit yield per plant.

Quantitative traits

Significant ($P<0.05$) variations were observed among genotypes for all quantitative traits assessed in the study (Table 2). Earliness and lateness in flowering were detected by the genotypes G13, G2 and G5 recorded at 78.33 days and 93.33 days to 50 % flowering, respectively (Table 2). Early fruiting is an important trait for crop improvement. Days to first fruit harvest ranged from 79.67 days to 103 days (Table 2). The earliest fruit harvesting was recorded in genotype G13 (79.67 days) while the maximum was recorded in genotype G14 (103.01 days). The variations in first fruit harvesting results conform to the previous findings by Begum *et al.,* (2013) and Umesh *et al.,* (2018). The leaf area of the genotypes ranged between 44.33 and 83.67 with an average of 58.38 (Table 2). The highest calyx length was observed in genotype G8 and the lowest was in G15 (Table 2). Dissimilarity in the calyx length of brinjal genotypes was also observed by some scientists (Kumar *et al.,* 2016; Dash *et al.,* 2019). The genotypes showed a few to a very high number of primary branching habits (9.43 to 12.88). Similar findings were also reported by Hazra *et al.,* 2003 and Shindhe *et al.,* 2012. The fruit length and breadth are important parameters of brinjal as the small and medium fruits have better acceptance than big fruits. The highest values for the fruit length and breadth had a mean of 37.93 cm (G8) and 8.03 cm (G7) respectively, while the genotypes G13 and G9 had the smallest fruit recorded a mean fruit length of 10.47 cm and fruit breadth of 3.95 cm (Table 2). Genotype G1 produced the highest number of fruits per plant (23 fruits) while genotype G6 produced the least number of fruits with an

average of 9.0 (Table 2). Similar variation in fruit number per plant in different brinjal genotypes was observed by Mohanty and Mishra (2021). Variations observed in the present study for single fruit weight ranged from 76.67g (G13) to 328.33g (G1) as well as for fruit yield per plant that ranged from 1.08 kg/plant (G6) to 7.65 kg/plant (G1) (Table 2). The single fruit weight and yield variation in brinjal genotypes were also observed by Khan and Singh, (2014).

Conclusion

High levels of variation were detected for both quantitative and qualitative traits among the brinjal genotypes evaluated in the present study. The wide variations in quantitative characters viz., days to 50 % flowering, days to first fruit harvest, leaf area, number of primary branches per plant, the weight of single fruit, fruit number per plant, and fruit yield per plant indicate the potential for genetic improvement of brinjal by selection and cross-breeding methods. Considering earliness, fruit size, fruit shape, fruit number and yield, several brinjal genotypes viz., G1, G2, G3, G4, G8, and G13were found to be superior. Further research is needed to conserve and preserve these genetic resources, as they could be used as potential donors for future breeding programs.

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Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Ansari, S. F., N. Mehta, S. Ansari and J. P. Gavel. 2011. Variability studies in Brinjal (*Solanum melongena* L.) in Chhattisgarh plains. *Electronic J. Plant Breed.* 2(2):275-281.

Begum, F., A. K. M. Aminul, M. G. Rasul, M. A. Mian and M. M. Hossain. 2013. Morphological diversity of eggplant (*Solanum melongena*) in Bangladesh. *Emir. J. Food Agri.* 25(1):45-51.

Dash, S. P., J. Singh and D. Sharma. 2019. Morphological characterization of brinjal (*Solanum melongena* L.) germplasm. *J. Pharma. Phytochemis.* 8(2):1574-1578.

Hazra, P., A. Rout, U. Roy, S. Nath, T. Roy, R. Dutta, S. Acharya and A. K. Mondal. 2003. Characterization of brinjal (*Solanum melongena* L.) germplasm. *Veg. Sci.* 30(2):145-149.

Islam, M. T., R. A. Chhanda and N. Pervin. 2018. Characterization and genetic diversity of brinjal germplasm. *Bangladesh J. Agril. Res.* 43(3):499-512.

Khan, R. and Y. V. Sigh. 2014. Germplasm characterization in eggplant (*Solanum melongena* L.). *The Asian J. Hort.* 9(2):356-359.

Konyak, W. L., S. P. Kanaujia, A. Jha, H. P. Chaturvedi and A. Ananda. 2020. Genetic variability, correlation and path coefficient analysis of brinjal. SAARC J. Agric. 18(1):13-21.

Kumar, S. R., T. Arumugam and V. Ulaganathan. 2016. Genetic diversity in eggplant germplasm by principal component analysis. *J. Breed. Genet.* 48(2):162-171.

Mohanty, K.K. and H. Mishra. 2021. Morphological profiling and assessment of genetic divergence of brinjal (*Solanum melongena* L.) genotypes. *J. Pharmaco. Phytochem*. 10(1):602-607.

Okon, U.E., A. A. Enete and M. O. Oluoch. 2010. Characterization of African eggplant for morphological characteristics. *J. Agric. Sci. Tech.* 4(3):3337.

Rajan, N., S. Debnath, A. K. R. Dutta, B. Pandey and A. K. R. Singh. 2020. Characterization of indigenous brinjal (*Solanum melongena* L.) lines using morphological traits under Jharkhand condition. *Annals Plant and Soil Res.* 22(4):425-431.

Shindhe, K. G., M. N. Bhalekar and B. T. Patil. 2012. Characterization in brinjal (*Solanum melongena* L.) germplasm. *Veg. Sci.* 39(2):186:188.

Singh, S., S. Krishnamurti and S. L. Katyal. 1963. Fruit culture in India. *Indian Council Agril. Res.* New Delhi. p. 412.

Tiwari, S. K., I. S. Bisht, G. Kumar and J. L. Karihaloo. 2016. Diversity in brinjal (*Solanum melongena* L.) landraces for morphological traits of evolutionary significance. *Veg. Sci.* 43(1):106-111.

Tümbilen, Y., A. Frary, S. Mutlu and S. Doganlar. 2011. Genetic diversity in Turkish eggplant (*Solanum melongena*) varieties as determined by morphological and molecular analyses. *Int. Res. J. Biotechnol.* 2(1):16-25.

Umesh, B. C., M. G. Patil and S. S. Patil. 2018. Performance of different types of brinjal for their physical fruit parameters and flowering parameters. *J. Pharmaco. Phytochem.* 7(4):2798-2800.

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