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CONTENTS

Short Communication

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MORPHO-PHYSIOLOGICAL CHARACTERIZATION AND PETAL COLOR ANALYSIS OF *GLORIOSA* AS A POTENTIAL CUT FLOWER

A.F.M. Jamal Uddin*, M. Rakibuzzaman, A. Dina, I. Raisa and M.A. Husna

Department of Horticulture
Sher-e-Bangla Agricultural University (SAU), Dhaka. Bangladesh

Abstract

The study was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period of January-December, 2021 to observe the morpho-physiological characteristics of *Gloriosa* lily with respect to growth and flowering. Thirty tubers were used in this experiment and data on morphological attributes were recorded. The colors of flowers petals were measured from three floral parts and expressed as L* (lightness), a* and b* (two Cartesian coordinates) including C* and h_{ab} (Chroma & Hue angle) based on CIE Lab scale with standard observer 100 and standard illumination D65. On the basis of flower length (7.7 cm), flower diameter (13.5 cm), leaf number per stem (26-28), flower per plant (13-15), vase life (10-12 days) explore the criteria of a cut flower and obviously this flower has the potential edition for flower industry. The study provides key indicators of *Gloriosa* to be a potential cut flower for which research be directed.

Keywords: CIE Lab, Floral character, Flower industry, *Gloriosa rothschildiana*.

Introduction

Gloriosa is an eye-catching climber with unusual and charming red-yellow colored flower which looks like flame. *Gloriosa rothschildiana* species belongs to *Gloriosa* genus of Colchicaceae family. *Gloriosa* refers to full of 'glory'. *Gloriosa* lily has some other common names like glory lily, fire lily, flame lily, climbing lily, creeping lily, and cat's claw or tiger's claw. The origin of this flower mostly is in the jungle of Asia and Africa. *G. rothschildiana* is mainly known as a major high value medicinal crop. Seeds and tubers of *Gloriosa* species contain valuable alkaloids viz., colchicine and colchicoside, which are used to treat gout and rheumatism. But now it has become a popular ornamental flower in many homes and gardens. The important species found in Bangladesh are *G. superba* and *G. rothschildiana*. The physical characteristics of this flower has quite disparity than most other flowers. It is a nodding flower where petals are upward and backward leaving the stamen and ovary hanging at the bottom. However, it has already verified itself as a new cut flower in the floriculture industry. Several genera of *Colchicaceae* such as *Gloriosa* plants recently become popular worldwide as cut flowers because of their beautiful, unique flowers and good vase life (Nakamura *et al*., 2005). Preliminary studies have indicated that in cooler conditions it may be possible to produce stems with the good length, strength, flower color and vase life which make

* Corresponding Author: jamilsau@gmail.com

Gloriosa suitable as a cut flower (Morgan *et al*., 2003; Eason *et al.,* 2001). Flower cultivation has emerged as a lucrative business in Bangladesh also along with other agricultural crops. Demand for cut flowers in our local market as well as international market is flourishing gradually (Rakibuzzaman *et al*., 2018). The positive attitude of respondents toward flowers, multipurpose uses of flowers, increasing uses of flower made products and an unsatisfied demand of some flowers are all positive indicators of the business boom (Mou, 2012). Evaluation of various cut flowers is now time demanding and need them to explore the flower industry (Uddin *et al*., 2013). It is quite suitable for flower arrangements in bouquet and it has quite good vase life (7-8 days) also. In Bangladesh, no precise or systemic research has been done yet about *Gloriosa* lily as a cut flower. The objectives of this experiment were to study the morpho-physiological characteristics and petal color of *G. rothschildiana* and to find the quality of cut flower which could be valuable to future cut flower industry in Bangladesh.

Materials and Methods

The experiment was conducted at the Horticulture Research Field of Sher-e-Bangla Agricultural University, Dhaka, from January to December, 2021. The location of the site was $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8.2 meter from sea level and in the Agro-Ecological Zone of Madhupur Tract (AEZ No. 28). Thirty *G. rothschildiana* tubers, weighing 10-15 g, were planted in furrows of at a distance of 30 cm apart and covered with soil. The soil pH was 6.0-6.5.Cowdung @ 8 t ha^{-1} and vermicompost @ 5 t ha^{-1} were applied in the furrows. Management included irrigation as required. The selected plants were labeled for observing the characters that included morphological study. The stems of flower were harvested just above the second branch when the second flower had reached to an thesis and some were kept in plants where hand pollination was done to produce seed. Observations were made on several morpho-physiological characters viz., plant height, number of branch, number of leaf/stem, leaf length, leaf breadth, number of flower/plant, fruit length, number of seeds, tuber weight, number of tepal, length of tepal, breadth of tepal, number of stamen, length of stamen, length of style, pedicel length, flower diameter, flower weight, chlorophyll content, vase life, seed contain in fruit, fruit weight. Measurement of the petal color attribution was conducted using CIE Lab colorimeter. The colors of the *Gloriosa* lily were measured and expressed through L* (lightness), a* and b* (two Cartesian coordinates) including C* and h_{ab} (Chroma & Hue angle) based on CIE Lab color scale with standard observer 100 and standard illumination D65 by using precision colorimeter IWAVE WF32.

Results and Discussion

Plant observation

Gloriosa rothschildiana was semi-woody herbaceous, fibrous root, deciduous, summer growing, durable creeper with an average height of 2.0-3.0 m at mature stage (Table 1). It developed from tuberous underground stem during the rainy season. The dimensions and branching pattern of the plants were strongly correlated with tuber weight. As being climber glory lily required support in the form of trellis.

Leaf observation

The woody plant leaves were deciduous in characters found shiny bright green, sessile, 1-2 cm long, leaf feel smooth, simple types and were tipped in a short tendril (Fig.1A) which readily clung to anything as it touched and assisted the plant to climb up over vegetation. Leaves were alternately arranged and whorled with a prominent midrib, ovate-lanceolate in shape (Fig.1B), leaves were 26.0-28.0 in number on average where no hairs found, leaf length 12.3 cm, leaf breadth 2.8 cm, SPAD value of leaves measured ranges 39.3-43.3 (Table 1).

Tuber

The fresh tuber weighed in the range of 40-60 g in this study (Table-1). *Gloriosa* tubers sprouted within 10 days after planting. Two to four stems developed from single V-shaped fleshy cylindrical tubers which looked like a plough and tubers had hairy roots (Fig. 2A). Flower number, pod number and number of seed per pod were highly related to tuber size and weight.

Days for completion flower phase

Completion of flowering phases started from bud to mature flower was found to be 17-21 days, on average (Table 1).

Table 1. Plant morphology and floral morphology of *Gloriosa rothschildiana*

Plant Morphology		**Flower Morphology**	
Characters	Dimensions	Characters	Dimensions
Plant height (m)	2.0 - 3.0	Number of tepal/rays	6.0
Number of branch	3.0 - 4.0	Length of tepal (cm)	6.8
Number of leaf/Stem	26.0 - 28.0	Breadth of tepal (cm)	2.1
Leaf length (cm)	12.30	Number of stamen	6.0
Leaf breadth (cm)	2.80	Length of stamen (cm)	5.1
SPAD value	39.3 - 43.3	Length of style (cm)	5.2
Days to flowering from bud initiation (days)	17 - 21	pedicel length (cm)	11.2
Number of Flower/plant	13.0 - 15.0	Flower length (cm)	7.7
Fruit length (cm)	5.0 - 5.6	Flower diameter (cm)	13.5
Number of Seeds/fruit	25 - 35	Flower weight (g)	1.65
Tuber Size (cm)	12	Vase Life (days)	10-12
Tuber weight (g)	40.0 - 60.0		

Flower observation

Flowers bloomed during morning hours after the onset of sun and Lily like flowers on long stalks, 6-parted, yellow or red with wavy margins. The perianth segments become reflexed after anthesis (Fig. 3A). The beautiful-looked petals reflexed at 180^0 from bud to blooming stage (Fig. 3B). In this investigation on floral morphology, the flower was both self and cross pollinated. To overcome the barrier of pollination flowers developed fully on a branch and they opened in a sequential manner (Rajamani *et al*., 2015).

The top half of the tepal remained orange-red and from the middle to base was yellow in pollinated flowers. As the flower aged, the tepals became entirely reddish orange (Fig. 3B). It takes 17-21 days to withering as flowers from bud initiation. The average number of fowers 13-15 was per plant. Flowers were harvested at both young and mature stage for further observation. It had striking orange-yellow bi-colored with their wavy, curling margins, and they looked like fire flames (Fig.1A) at mature stage. The flower weight was 1.65 g, and flower inflorescences was mainly flower head where head diameter was recorded (13.5cm) with 6 tepals (3 sepal + 3 petal) having the length of 6.8 cm (on average), breadth of petal 2.1 cm, bearing 6 stamens (on average 5.1 cm), oblong - linear anthers and a style (5.2 cm) which splited into 3 short segments at the tip, vase life in normal water recorded 10-12 days (Table 1) make cup shape and (Fig 4. A-B). The style and stamen bent almost 90^0 at the attaching point of ovary. The flower had greenish 12.2 cm long pedicel (Table-1) which also bent almost 90^0 ending at the ovary. The green ovary enlarged as seeds produced inside. Flower number varied from 13-15 in numbers (Table- 1).

Fruits

Gloriosa fruits were large, fleshy, oblong and 3 valve capsules (Fig. 2B) which were recorded as 5.0-5.6 cm long and 1.8 cm wide that turned from green to yellow and eventually dark brown as they matured (Table-1). It also looked like Jalapeno peppers. These fruits contained numerous seeds approximately 25-35 in number. Seeds were generally 4-5 mm in diameter, rounded or egg-shaped and surrounded by a fleshy, red cover (Fig. 2B).

Colorimetric measurement using CIELab colorimeter

The colorimetric measurement of the *Gloriosa* lily under study was conducted using a precision colorimeter IWAVE WF32 (Shenzhen Wave) and L* (lightness), a* and b* (two Cartesian coordinates) including C* and hab (Chroma & Hue angle) based on CIELab color scale with standard observer 100 and standard illumination D65 (Mc Guire, 1992) (Table 2). The major anthocyanidins control the color variation of lisianthus petals and their cumulative quantities by extending chromas to individual color direction (Uddin *et al*., 2002).

(A) (B)

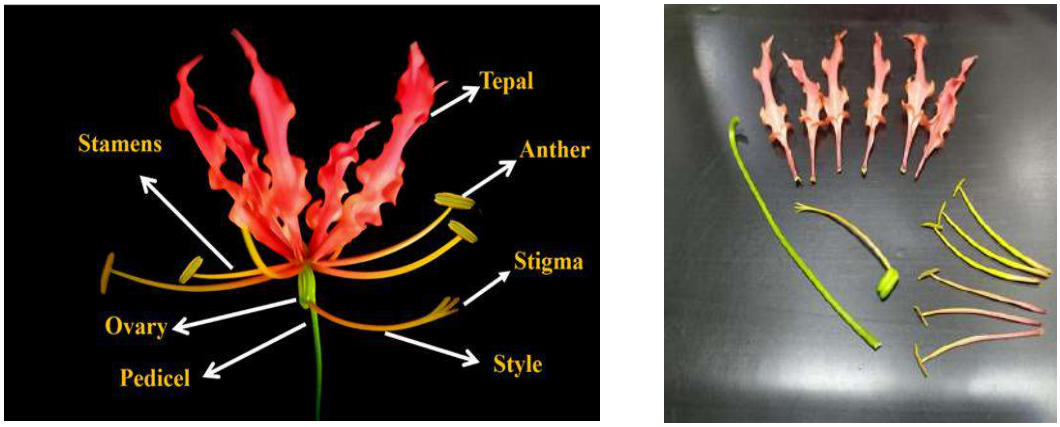
Fig. 1. A) Single stem with flower and leaves of *Gloriosa*, B) Leaves with tendrils at different stages

(A) (B)

Fig. 2. A) Single tuber of *Gloriosa rothschildiana*, B) Seeds of *Gloriosa rothschildiana* fruit

(A-B) (C)

Fig. 3. A-B) Flower developmental stages of gloriosa, C) Petal reflexed at 180^0 from bud to full boom



(A) (B)

Fig. 4. A) Different parts of *G. rothschildiana*, B) Dissection of the *G. rothschildiana* flower

Table 2. Tepal color attributes in *Gloriosa rothschildiana*

L*	a*	b*	c*	hab	Color Name	Illustration
37.10	36.13	30.30	47.15	39.99	Reddish Orange	
43.32	54.96	56.52	78.83	45.81	Light Brown	
42.29	42.82	26.89	50.56	32.13	Bright Yellow	

Conclusion

From the above morphological and colorimeter analysis, it can be concluded that *Gloriosa* has potential quality as cut flower and therefore, could be popularized as commercial flower. Furthermore, having demand of colorful, new flower and several morphological traits would be the excellent edition in flower sector for researchers for more research as well as flower industry in local market and international market.

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MANGROVE APPLE (*SONNERATIA CASEOLARIS*): A PROMISING FRUIT IN PATUAKHALI COAST OF BANGLADESH

M. Ferdous[1], M.F. Hasan[1], M. Ali[1], N.H. Mehedi[2*] and M.R. Islam[2]

[1]Department of Horticulture, Patuakhali Science and Technology University (PSTU), Patuakhali; [2]Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Bangladesh

Abstract

Mangrove apple *(Sonneratia caseolaris)* is a widespread underutilized fruit species of coastal region of Bangladesh. The present study was undertaken to find out the flowering, fruiting, nutritional quality and extent of variability among different mangrove apple germplasm. Twelve germplasm were selected from three locations - six (SC 02, SC 03, SC 04, SC 05, SC O6 and SC 07) from Dumki sadar, two (SC 01 and SC 08) from PSTU germplasm centre and four (SC 09, SC 10, SC 11 and SC 12) from Patabuniya, Dumki, Patuakhali. Flowering season started from May and continued up to November. Percentage of fruit setting ranged from 96.03 to 89.96% in SC 01 and SC 12, respectively. Required time for fruit maturation ranged from 106 days (SC 06) to 55 days (SC 05). Single fruit weight varied from 122.3 g (SC 01) to 54.33 g (SC 04). The length and diameter of fruit ranged from 2.9 cm (SC 05) to 2.20 cm (SC 07) and 5.20 cm (SC 05) to 3.60 cm (SC 04), respectively. The maximum edible portion (66.15%) was recorded in SC 01, and it was the lowest (51.45%) in SC 07. Chemical analysis was done with the pulp of selected germplasm where the germplasm SC 01 exhibited the best performance in all parameters of chemical analysis. This analysis was performed at four different ripening stages. The highest TSS (8.72%) was recorded in stage I. The highest pH level (3.51) was observed in stage III and the lowest pH level (2.83) was found in stage I. The highest ascorbic acid content (37.50 mg/100g) was noted in stage IV. Flower of mangrove apple produces a kind of honey. Fresh fruits and seeds have high nutritional and medicinal value. Wood of this plants provides great livelihood support to the local residents for fetching good price in the markets. Proper utilization of *S. caseolaris* may contributes the nutritional security of the women and children of this area by fulfilling the demand for micronutrients, especially vitamin C.

Keywords: Coastal region, Diversity, Germplasm, Mangrove apple, Underutilized fruit

Introduction

In Bangladesh over 10 million people live in coastal areas. Roughly 55% of the coastal population lives within 100 km of the 710 km long coastal belt of Bangladesh. The majority of those living in this area are highly vulnerable to cyclones and storm surges. Most of them are low-income agricultural workers; 70% of whom are landless and relatively asset poor. These people are directly or indirectly live under the mangrove natural protection. Among the mangrove plant, mangrove apple (*Sonneratia caseolaris)*

* Corresponding Author: nazmul02348@gmail.com

under the family Lythraceae is the salt tolerant plants of tropical and subtropical intertidal regions of the world. It can be found widely in Malaysia, Indonesia, Philippines, Singapore, Sri Lanka, Vietnam and Thailand (Whitmore, 2002). In Bangladesh, this fruit is grown well in coastal districts such as Barisal, Patuakhali, Pirozpur, Khulna, Chittagong coastal area and many other coastal regions. This plant is more familiar to the coastal people of Bangladesh as "*Soila"*.

Mangrove apple plant growing up to 15m tall, they have cream, grey to brown bark with slight vertical fissures, with no buttresses or prop roots. Their pneumatophores are cone-shaped (unlike the pencil-like ones of Avicennia). Leaves are rounded, leathery, opposite, with similar upper and undersides of the leaf. Flowers are white and pom-pom-like and open only for one night. Their fruits are large (4cm) green, leathery berries with a star-shaped base containing 100-150 tiny seeds that are white, flattened and buoyant (Peter and Sivasothi, 1999). They are able to survive inundation by salt water twice a day, and in "soil" which is unstable and poor in oxygen (anaerobic). They also have to deal with swollen rivers carrying silt during the wet season, as well as violent storms that hit the coasts. They provide a variety of important ecosystem roles: a refuge and food for a variety of flora and fauna, a natural water filter, and an important stabilizer of coastal and river banks. This plant is highly used in dam, dyke and embankment preparation to protect the coast from water wave, flood, stream, flow-tide and swelling of water. The heavy timber is resistant to shipworm and pests and is used for building boats, piling and posts for bridges and houses.

This valuable mangrove plant is not only helpful for the protection of coastal area but also provides a lot of nutrition. Almost all the people including children like it very much in coastal region due to its test. The ripe fruit contain high amount of vitamin c (30g/100g) (Ray *et. al.*, 2015). Mangrove apple fruits are consistent with the optimal value of carbohydrate, protein and vitamin-c mainly regarding culinary property and nutritional perspectives. Electrospray Ionization Mass Spectrometry (ESI-MS) study proves the presence of phenolic compounds responsible antioxidant nature. As far as our knowledge goes, there was little work done in Bangladesh to characterize this plant. Hence, the study was undertaken to observe flowering characters and behaviors, fruit parameters and the nutritional quality of mangrove apple at different maturity stages.

Materials and Methods

The field experiment was conducted in different locations of Dumki upazilla at Patuakhali district following Randomized Complete Block Design (RCBD) with four replications and lab experiment in the Department of Horticulture, Patuakhali Science and Technology University following Completely Randomized Design (CRD) with three replications. After primary observation of 12 germplasm (single plant) were selected having better performance and diversity which were SC01, SC02, SC03, SC04, SC05, SCO6, SC07, SC08, SC09, SC10, SC11 and SC12 to characterizes morpho-chemically. Randomly one branch was selected in each direction (North, South, East and West) to collect field data from each plant. Data on (48 flower buds where 1 bud × 4 branches × 12 plants) plant characteristics viz. tree age, branching pattern and leaf area measurement: morphological parameters like days required for flower bud development, duration of flowering season, length of flower bud, length of petal, width of petal, number of stigma, percent fruit setting, percent fruit drop, time required for fruit

maturation (days), fruit shape, weight of fruit, length of fruit, diameter of fruit, number of seeds per fruit, rind weight, seed weight, weight of non-edible portion (rind + seed), percentage of edible and non-edible portions; chemical characteristics like titratable acidity (TA), total soluble solids (TSS), pH and ascorbic acid content were recorded at the time of flowering, fruiting and after harvest.

Ascorbic acid (Vitamin C)

Ascorbic acid was determined according to the dye method by Ranganna (1977). Ten gram of pulp tissue was homogenized with 40 mL of 3% cold metaphosphoric acid (HPO_3) using a blender for two minutes. Five milliliters of aliquot was titrated with 2, 6-dichlorophenol-indophenol dye until the filtrate changed to pink color that persisted for at least 15 seconds. The titre volume of dye solution used was recorded and ascorbic acid content was calculated using the following formula:

$$\text{Ascorbic acid (mg /100 g)} = \frac{\text{Titre (mL) x dye factor x vol. made up x 100}}{\text{Aliquot used for estimation (5mL) x sample weight (10 g)}}$$

To standardize the dye, 5 mL of standard ascorbic acid solution was added to 5 mL of 3% cold HPO_3. The mixture was titrated with the dye solution to a pink colour, which persisted for 15 seconds. The dye factor was calculated as follows:

Dye factor = Titre (mL) x dye factor x vol. made upx100

Titratable acidity (% citric acid)

Titratable acidity (TA) was determined according to the method by Ranganna (1977). Ten gram of pulp tissues was homogenized with 40 ml of sterilized water using a kitchen blender (MX-798S, National, Malaysia) for two minutes. Five milliliters of the filtrate was transferred into a 100 ml conical flask and two drops of 1% phenolphthalein solution as an indicator was added. The sample was titrated with 0.1 M sodium hydroxide (NaOH) solution until the colour changed to pink and persistent at least 15 seconds. The titre volume was recorded and the result was expressed as percentage citric acid using the following formula:

$$\text{Citric acid (\%)} = \frac{\text{Titre (0.5 mL) x NaOH normality x vol. made up x citric acid eq. weight x 100}}{\text{Volume of sample for titrate x weight of sample taken x 1000}}$$

Determination of pH

The pH of fruit juice was recorded by using an electric pH meter. The pH meter was standardized with the help of a buffer solution as described by Ranganna (1997).

Total soluble solids (TSS)

The TSS of guava pulp was determined by using a digital refractometer (Model N-1 α, Atago, Japan). The remaining of the filtrated juice from TA determination was

used to measure the TSS of the fruit pulp. Before measurement, the refractometer was calibrated with sterilized water to give a 0% reading. About 1-2 drops of the filtrate was placed on the prism glass of the refractometer to obtain the % TSS reading. The readings were multiplied by dilution factor to obtain an original % TSS of the pulp tissues. Since differences in sample temperature could affect the measurement of TSS (Boourne, 1982), each of the reading was standardized to a temperature of 20 ºC by adding 0.28% to obtain % TSS at 26 ±1 ºC.

The collected data on various parameters were statistically analyzed using MSTATc statistical package. The means for all the treatments were calculated and analyses of variances (ANOVA) for all the parameters were performed by F-test. The significance of difference between the pairs of means was compared by Duncan Multiple Range Test (DMRT) at 5% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

Plant characteristics

The age of twelve germplasm under study was in the range of 9 to 25 years. The trees had optimum growth and good canopy area. Although no recorded data were found but counted as possible as correctly. The branching patterns of the germplasm were found to be different (Table 1). Opposite pattern was found in germplasm (SC 01, SC 02, SC 03, SC 04, SC 06, SC 07, SC 11 and SC 12), verticillate (SC 09) and irregular (SC 05, SC08 and SC10). Peter KLNg *et. al.,* 1999 have been reported that the plant is small to medium- sized evergreen tree 8 to 10 m tall with open spreading crown, horizontal branches and slender twigs. Significant variation was observed among the studied germplasm in respect of area of leaves. The largest size of leaf area was found in germplasm SC 10 (48.21 cm^2) and the smallest size was exhibited in germplasm SC 02 (37.17cm^2). Colin Field, 1995 have been reported that leaves simple, opposite-decussate, estipulate; petiole 5-10 mm long, stout, red, glabrous; lamina 4-11 x 3.5-6.5 cm.

Flowering and fruiting behavior

The required days for flower bud development of twelve germplasm varied considerably ranging from 28 to 39 days (Table 2). The longest duration (39 days) required to develop flower bud was recorded in the germplasm SC 10, while SC 05 was found to require shortest duration (28 days). The maximum duration of flowering season (days) was found in germplasm SC 08 (104.3 days) followed by SC 10 (101.3 days) and the minimum duration of flowering season (days) was found in germplasm SC 02 (78 days). (Tan *et al.,* 2001) who reported that flowering season includes from May to August. From close observation it was found that the maximum flower buds setting position was on the tip of the branch and were green in color. The Length of flower buds ranged from 4.70 cm (SC 06) to 1.40 cm (SC 04). The length of petal of flowers also differed considerably. The highest length was exhibited in SC 10 (2.89 cm) which was followed by that of SC 11 (2.84) while the lowest length was found in SC 05 (2.46 cm). The highest width was found in SC 07 and SC 11 (1.59) but it was statistically identical with all germplasm except SC 02 (0.47 cm), SC 07 (0.45 cm) and SC 08 (0.50 cm). The lowest width was exhibited in SC04 (1.21cm). The highest number of stigma (280) was

found in SC 04 and SC 07 followed by SC 12 (277) and the lowest (210) in SC 09. The percentage of fruit setting under natural pollination showed a wide range of significant variation. The highest percentage of fruit setting was found in germplasm SC 01 (96.03 %) which was statistically similar to SC 07 (95.07%) while the lowest percentage of fruit setting was found in SC 07 (89.96%). It was found that; fruit drop percentages were low in south branches. The highest fruit drop percentage was exhibited in germplasm SC12 (30.34%) followed by SC 08 (24.30%) and the lowest percentage of fruit drop was found in SC01 (16.20%) which was statistically similar with SC 10 (17.85).

Table 1. Branching pattern and leaf area of 12 mangrove apple germplasm

Acc. No.	Branching pattern	Leaf Area (cm^2)
SC01	Opposite	44.27d
SC02	Opposite	37.17j
SC03	Opposite	42.90f
SC04	Opposite	39.17i
SC05	Irregular	39.37h
SC06	Opposite	42.47g
SC07	Opposite	43.14e
SC08	Irregular	44.21d
SC09	Verticillate	47.34b
SC10	Irregular	48.21a
SC11	Opposite	45.01c
SC12	Opposite	44.24d
CV (%)		0.26

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

It is the most important character for a fruit crop. A wide range of significant variation was observed among the selected germplasm in respect of time required for fruit maturation (Table 3). Time required for fruit maturation may be depending on the genetic characteristics of plant or availability of water and essential nutrients. The highest time required for fruit maturation was recorded in the germplasm SC 06 (106 days) while the lowest time was recorded in the germplasm SC 07 (50 days). Fruit shapes of different germplasm were classified into different categories such as spheroid, flatted–globes and ellipsoid. Most of the fruits (SC 02, SC 03, SC 04, SC 06, SC 07, SC 09 and SC 12) were globular in shape, globosely, slightly flattened in SC 01, SC05 and SC 11 (Table 3). (Tan *et. al.*, 2001) who reported that fruit is a drupe, globosely, slightly flattened, calyx lobes horizontal, pericarp smooth. The highest fruit weight was recorded in SC 01 (122.3g) followed by SC 10 (112.3 g) while the lowest fruit weight was recorded in SC 07 (52.33 g). A wide range of significant variation was observed among the selected germplasm in respect of fruit length. The highest fruit length was obtained from germplasm SC 05 (2.90 cm) followed by SC 07 (2.20 cm) and the lowest fruit length was found in SC 04 (2.35

cm) followed by SC 07 (2.20 cm). The highest fruit diameter was found in SC 05 (5.20cm) and the lowest fruit diameter was in SC 07 (3.28 cm). The highest rind weight was exhibited in SC10 (2.82 g) which was statistically identical to SC 06 (2.76 g) and the lowest rind weight was recorded in germplasm SC08 (1.79 g). The highest seeds weight was recorded in germplasm SC 11 (8.34 g) which was statistically identical with SC 10 (8.24 g), SC 06 (8.20 g), SC 05 (8.12 g) and SC 02 (8.12 g) while the lowest seeds weight was recorded in SC 08 (7.42 g). The maximum weight of non-edible portion was found in germplasm SC 06 (46.37 g) followed by SC 10 (44.0 g) while the minimum weight was noted in SC 03 (29.20 g). The highest percentage of non- edible portion was found in the germplasm SC 07 (48.54%) followed by SC 04 (45.66%). The lowest percentage was found in SC 10 (12.67%) which was statistically similar to SC 02 (36.19%). The highest percentage of edible portion was found in the germplasm SC 01 (66.15%) followed by SC 10 (64.37%) while the lowest percentage was observed in germplasm SC 07 (51.45%).

Table 2. Flowering and fruiting behavior of 12 Mangrove apple germplasm

Acc. No.	Days required for floral bud development	Duration of flowering (Days)	Length of flower bud (cm)	Length of petal (cm)	Width of petal (cm)	Number of stigma/ fruit	% fruit setting	% fruit drop
SC01	37.00b	83.67f	4.48b-e	2.51gh	1.40d	230g	96.03a	16.20e
SC02	30.00h	78.67g	4.48c-f	2.83b	1.32e	255f	92.07d	20.01d
SC03	32.00f	82.00f	4.63a-c	2.61f	1.46bc	260d	92.01d	20.66d
SC04	34.64d	82.33f	4.27f	2.54g	1.21f	280a	90.00e	22.30c
SC05	28.00j	94.33d	4.39d-f	2.46h	1.3d	220h	92.83cd	20.80d
SC06	29.00i	94.33d	4.70ab	2.55g	1.50b	188j	93.75bc	22.30c
SC07	31.00g	99.00c	4.69a-c	2.72cd	1.59a	280a	95.07ab	18.34d
SC08	32.00f	104.3a	4.69a-c	2.73c	1.48bc	270c	91.64d	24.03b
SC09	36.00c	95.33d	4.60a-d	2.62ef	1.43cd	210i	93.77bc	22.13c
SC10	39.00a	101.3b	4.50b-e	2.89a	1.48bc	255e	94.39b	17.85e
SC11	30.00h	90.67e	4.32ef	2.84b	1.59a	260d	92.87cd	20.55d
SC12	33.00e	88.33e	4.60a-d	2.67de	1.46b	277b	89.96e	30.34a
CV (%)	0.51	1.47	2.48	1.12	1.73	1.48	0.84	5.31

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

Chemical analysis

Ascorbic acid (Vitamin C)

Significant variation was observed among different stages in respect of ascorbic acid content (Fig. 1A). The trend of development of ascorbic acid in mangrove apple fruit in this study increased during ripening. The highest amount of ascorbic acid was obtained in stage IV (31.36 mg/100g) and the lowest amount in the stage I (16.37 mg/100g). This gradual increasing of ascorbic acid content in different stage might be due to increased

internal oxygen that resulted in accelerating the oxidation of ascorbic acid. A similar trend in increased ascorbic acid content has been reported on coated apples, pear and apricot during storage (Sumnu and Bayindrili, 1995).

Titratable acidity (% citric acid)

A significant variation was observed among different stages in respect of titratable acidity (Fig. 1B). In this study, the increase in titratable acidity of mangrove apple fruits followed a linear trend with increased the maturation days and time of senescence. The highest percentage of titratable acidity was obtained from stage IV (13.23%) while the lowest percentage was recorded in stage I (3.33%). This result is consistent with Garcia *et al.*, (1998) on strawberry that the decreased in acidity during ripening demonstrated fruit senescence.

Table 3. Fruit characteristics of 12 mangrove apple germplasm

Acc. No.	Days required for fruit maturation	Weight of fruit (g)	Length of fruit (cm)	Diameter of fruit (cm)	Rind weight (g)	Seed weight (g)	Weight of non-edible portion (g)	Non-edible portion (%)	Edible portion (%)
SC01	80d	122.3a	2.60e	4.48d	2.19b	8.06bc	33.43d	37.43d	66.15a
SC02	90c	92.33d	2.70d	4.58c	2.24b	8.12a-c	30.83e	36.19e	63.80bc
SC03	75e	77.33g	2.60e	3.87f	2.12b	7.97c	29.20g	37.74d	62.25d
SC04	80d	54.33j	2.35h	3.60g	1.97c	7.69d	24.77j	45.56b	54.43f
SC05	52g	107.3c	2.90a	5.20a	2.69a	8.12a-c	36.34c	44.10b	62.56cd
SC06	106a	57.33i	2.75c	4.60c	2.76a	8.20a-c	46.37a	37.89d	62.14d
SC07	50h	52.33k	2.20i	3.28h	1.85cd	7.49de	25.4i	48.54a	51.45g
SC08	59f	61.33h	2.50f	4.45d	1.79d	7.42e	26.53h	43.24c	56.75e
SC09	75e	77.67f	2.50f	4.48d	2.11b	7.98c	29.83f	37.96d	62.03d
SC10	100b	112.3b	2.80b	4.90b	2.82a	8.24ab	40.37b	35.62e	64.37b
SC11	105a	82.33e	2.60e	3.90f	1.89cd	8.34a	36.34c	43.71c	56.28e
SC12	55g	82.34e	2.42g	4.00e	1.90cd	7.62de	25.63i	33.84f	55.89e
CV (%)	1.48	0.20	1.68	1.60	3.66	1.63	1.20	1.87	1.07

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

pH

The pH of fruit decreased gradually as different stages progressed with yielding significant differences (Fig. 1C). In this study, the decrease in pH of mangrove apple fruits followed a linear trend with increased the maturation process and time of

senescence. The highest pH content was recorded in stage I (3.82) while the lowest pH content (2.68) was recorded in stage IV.

Total Soluble Solids (TSS)

Changes in the TSS of mangrove apple fruits with different stage of maturity are presented in Fig.1D. The percentage of total soluble solids (TSS) showed significant variation among different stages. The TSS of SC01 germplasm fruits were highest initially and decreased gradually with advance in ripening which indicates the increases of ascorbic acids. The highest percentage of TSS was found in stage I (8.72 %) while the lowest percentage was recorded in stage IV (1.76 %). Similar observation has also been reported on *S. alba* (Lee, 1996).

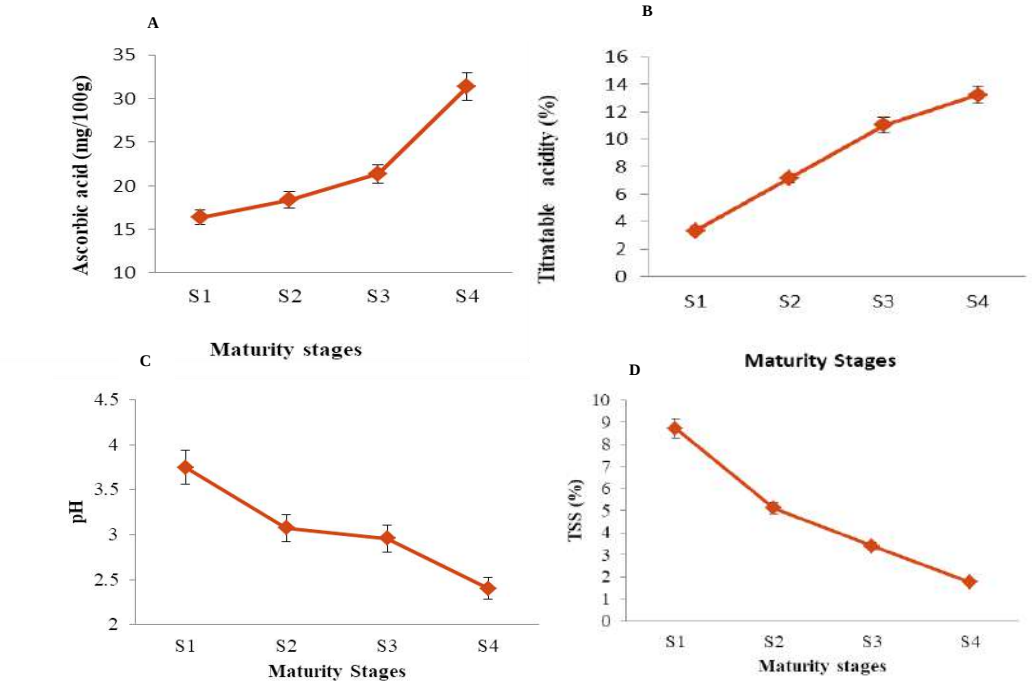

Fig. 1. Chemical analysis of germplasm SC 01 at different maturity stages. A. Ascorbic acid (mg/100g) content, B. % Titratable acidity (TA), C. pH and D. Total soluble solids (TSS) content. Error bar means?

Conclusion

From the above discussion, it may be said that mangrove apple has the potentiality for growing in the coastal region of Bangladesh. So, research and development activities should be initiated on mangrove apple for its improvement and popularization.

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EFFECT OF TEMPERATURE STRESS ON *BRASSICA RAPA* GENOTYPES DURING GERMINATION AND REPRODUCTIVE GROWTH

K.M.K. Huda[1*], M.S.A. Banu[2], M.H. Rashid[1], S. Parveen[1] and M.A.M. Hussen[2]

[1]Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University (SAU), Dhaka; [2]Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka. Bangladesh

Abstract

The effect of temperature stress on the reproductive development and yield of five *Brassica rapa* was studied in a controlled growth chamber. The seeds of five *Brassica* genotypes namely BARI Sarisha-6, Tori 7, Kallayania, BARI Sarisha-9 and BINA Sarisha-4 were grown under day/night temperatures at 22/17^{0}C until early flowering or early siliqua development stage. The high temperature stress i.e., 28 /17^{0}C or 35/17^{0}C, both at early flowering stage and early siliqua formation stage were imposed for 7d and then allowed to recover at 22/17^{0}C for normal growth. Shoot dry matter accumulation varied with temperature and genotype. The highest shoot dry matter was recorded by Kallayania followed by BARI Sarisha-9. The optimum day temperature for seed yield of the main shoot showed closer to 28^{0}C. The largest seeds were produced in the 22/17^{0}C, the size, however, remained similar with 28/17^{0}C temperature stress. During this temperature regime, the highest seed yield was observed with BARI Sarisha-6 while BARI Sarisha-9 produced the lowest seed yield. Severe temperature stress (35/17^{0}C) reduced seeds per siliqua and 1000 seed weight in all genotypes. Maximum pollen viability and germination were recorded at 20^{0}C by Kallayania followed by Tori 7 at 25^{0}C. However, the temperature above 30^{0}C reduced pollen viability and germination for all the genotypes. In another set of treatments, the high temperatures exposure (28/23^{0}C) for 5d reduced oil content and increased protein concentrations. Plant exposed to 25/20^{0}C temperature stress showed significant changes in oleic, linoleic, and linolenic acids. The levels of saturated fatty acids were similar across the five genotypes in the control treatment, but palmitic acid and stearic acids increased with the temperature.

Keywords: *Brassica*, Oil, Protein, Temperature stress, Yield

Introduction

The global temperature is predicted to rise up to 5.8^{0}C as a result of increasing greenhouse gases in atmosphere, which can have harmful effect on crop yield in northern temperate areas where plants are adapted to grow in lower temperatures. Oilseed rape lines can greatly vary in their adaptation abilities in high temperature. This can in worst cases lead to reductions in yield and oil content during flowering (Aksouh *et al.,* 2006). Optimum temperature for yield formation can be lower than the optimum temperature for

* Corresponding Author: mashnuk@gmail.com

leaf appearance rate, vegetative growth, or reproductive progression yield (Peñuelas and Filella, 2001). High temperature often accelerates phenological development which can result in smaller plants, shorter reproductive phase, and lower yield. In addition to acceleration in life cycle and interrupted carbohydrate accumulation, reproductive stage including micro sporogenesis and mega sporogenesis is highly sensitive to high temperature and its disturbance can decline seed yield. When pollen or egg cell development is delayed or interrupted, fertilization fails and unfertilized ovules can become aborted (Seavey *et al.,* 2000). Short exposure (1-2 weeks) to high temperature (35^0C) for 4 h/day impaired pollen viability and seed set (Young *et al.,* 2004). Four-hour exposure daily for one week to 30^0C depleted the pollen development and germination in turnip rape. Moreover, pollen development was slowed and germination ability of pollen from heat treated plants was also impaired. Short heat treatment of oilseed rape during seed filling influenced oil quality by decreasing the amount of saturated fatty acids and decreasing mono-unsaturated oleic acid content (Aksouh *et al.,* 2001). The number of siliquae in oilseed rape, as well as seed weight, was also affected by heat treatment and varied highly between different genotypes.

Research institutes in Bangladesh have developed improved verities of *Brassica* including BARI Sarisha-6, BARI Sarisha-9, BARI Sarisha-14, BARI Sarisha-15, Kallayania and BINA Sarisha-4 and improved Tori. In Bangladesh, mostly research are focused on different management practices for improving yield but less on stresses such as climate change, soil salinity, drought, flooding, metal toxicity, pollution, and extreme temperatures. The genotypes BARI Sarisha-6, BARI Sarisha-9, Kallayania and BINA Sarisha-4 and Tori are moderately waterlog tolerant but the effect of temperature on these genotypes was not yet investigated. Therefore the objectives of this study were to determine the response of five genotypes of *Brassica* to high temperature stress and to assess the effect of high temperature stress on yield forming traits, pollen viability, germination, oil, protein and glucosinolate and fatty acid profiles.

Materials and Methods

The experiment was conducted at the Department of Genetics and Plant Breeding laboratory of Sher-e-Bangla Agricultural University, Bangladesh during 2020. All plants were grown in a controlled environment chamber at $22/17^0$C day/night temperature until the high temperature treatments were imposed. High temperature was imposed in a growth cabinet for 7 days during at early flowering and early siliqua formation stage. After imposing temperature stress, plants were return to $22/17^0$C growth chambers. Five temperature were used in this experiment : (i) control = continuous $22/17^0$C; (ii) $28/17^0$C at early flowering stage; (iii) $28/17^0$C at early siliqua formation stage; (iv) $35/17^0$C at early flowering stage; and (v) $35/17^0$C at early siliqua formation stage. The seeds of five genotypes (BARI Sarisha-6, Tori 7, Kallayania, BARI Sarisha-9 and BINA Sarisha-4) were used. Data were collected on shoot dry matter, seed yield, fertile pods, seed per pod and 1000 seed weight. In another experiment, more than 100 inflorescences for each genotype were randomly cut and immediately brought to the laboratory. Pollen grain from a single genotype were collected, mixed and immediately stored at -20^0C.

Method described by Singh *et al.* (2008) was used to check the pollen viability (PV) and pollen germination (PG). With the help of a clean, fine bristle paint brush, a homogenous layer of pollen grains were spread on the surface of the germination medium in a petri plate and transferred to the incubator at the respective temperature treatments: (i) 15^0C; (ii) 20^0C (iii) 25^0C (iv) 30^0C and (v) 35^0C . To analyse the oil, protein and fatty acid, when the plants had flowered and siliquae set properly, all the plant were transferred to a growth chamber and exposed to a moderately high temperature treatment for a short period of 9 d following a day of acclimation to make 10d of treatment. During the acclimation, 25^0C/20^0C temperature was applied. For high temperature treatment, a shorter period of 4d of very high temperature (28^0C/23^0C) following a day of acclimation to make 5d of treatment was applied. Similar temperature was applied during the acclimation day as that of the previous treatment. For control treatment, plants were kept at 22^0C/17^0C temperature. Oil and protein concentration was determined by a previously described method (Young *et al.,* 2004). Glucosinolates was calculated by using the method described by Mailer and Pratley (1990). Fatty acid composition of the oil (oleic, linoleic, linolenic, palmitic and stearic acids) was determined by gas chromatography as adapted from Ayton *et al.,* (2001) and Mailer *et al.,* (2002).

Results and Discussion

Effect of temperature stress on dry matter, seed yield, fertile siliquae, seeds per siliqua and thousand seed weight in *Brassica rapa*

Shoot dry matter accumulation varied with temperature and genotypes. The temperature 28/17^0C had no influence on shoot dry matter accumulation however; increased temperature to 35/17^0C showed decreased shoot dry matter accumulation (Table 1). The response varied between two growth stages, early flowering was more sensitive to 35/17^0C (shoot dry matter decrease) compared to early siliqua stage. Seed yield of the main shoot of all genotypes was reduced on 35/17^0C at early flowering stage relative to the control while yield increased with 28/17^0C at early flowering stage. This suggests that the optimum daytime temperature for seed yield of the main shoot is closer to 28^0C. The temperature treatment (28/17^0C) produced more siliqua during early flowering stage compared to control. However, temperature stress (35/17^0C) during early flowering stage produced less number of siliquae (Table 1). For temperature treatment 28/17^0C and 35/17^0C, did not produce difference in the genotypes during early siliqua formation stage (Table 1). This indicated that a short exposure of extreme temperature at a sensitive stage could be critical for crop yield as a mild temperature stress over a longer period. Among the genotypes, the largest seeds were produced by the 22/17^0C (control), but similar to at 28/17^0C treatment during early flowering stage. On the other hand, severe temperature stress (35/17^0C) at early flowering stage tended to reduce seeds per siliqua (Table 1).

Table 1. Mean plant dry matter, seed yield, fertile siliquae, seed per siliqua and thousand seed weight for temperature treatments in five *Brassica* genotypes

Treatment	BARI Sarisha-6	Tori 7	Kallayania	BARI Sarisha -9	BINA Sarisha-4	Mean
			Shoot dry matter (g/plant)			
22/17°C (control)	22.15	20.83	24.91	24.3	23.8	23.19
28/17°C @ early flower	21.7	22.55	20.2	22.8	21.72	21.79
28/17°C @ early siliqua	19.43	18.28	21.3	19.66	18.93	19.52
35/17°C @ early flower	18.2	18.32	22.44	21.83	17.73	19.70
35/17°C @ early siliqua	18.79	19.03	22.67	20.55	20.45	20.29
Mean	20.05	19.80	22.30	21.82	20.52	
LSD (T) and LSD (G)			1.56 and 1.45			
			Seed yield (g/plant)			
22/17°C (control)	0.74	0.63	1.68	1.75	0.94	1.14
28/17°C @ early flower	1.83	1.72	1.25	1	1.65	1.49
28/17°C @ early siliqua	0.71	0.62	0.83	0.84	0.81	0.76
35/17°C @ early flower	0.88	0.2	0.13	0.25	0.18	0.32
35/17°C @ early siliqua	0.86	1.04	0.83	0.9	0.79	0.88
Mean	1.00	0.84	0.94	0.94	0.87	
LSD (T) and LSD (G)			0.61 and 0.49			
			Fertile siliqua /main stem			
22/17°C (control)	40	33	43	38	41	39.0
28/17°C @ early flower	75	58	48	35	37	50.6
28/17°C @ early siliqua	38	29	29	18	22	27.2
35/17°C @ early flower	20	15	19	10	8	14.4
35/17°C @ early siliqua	48	24	30	28	40	34.0
Mean	44.2	31.8	33.8	25.8	29.6	
LSD (T) and LSD (G)			6.0 and 7.0			
			Seeds/ siliqua			
22/17°C (control)	27	16	18	16	12	17.8
28/17°C @ early flower	22	12	13	13	10	14
28/17°C @ early pod	10	15	12	9	7	10.6
35/17°C @ early flower	15	7	10	12	11	11.0
35/17°C @ early siliqua	12	11	9	14	5	10.2
Mean	17.2	12.2	12.4	12.8	9.0	
LSD (T) and LSD (G)			2.2 and 1.98			

Table 1. Contd.

Treatment	BARI Sarisha-6	Tori 7	Kallayania	BARI Sarisha -9	BINA Sarisha-4	Mean
			1000 Seed weight (g)			
22/17°C (control)	3.33	1.8	4.28	2.73	2.88	3.00
28/17°C @ early flower	2.95	1.52	3.95	2.52	2.71	2.73
28/17°C @ early siliqua	3.13	1.75	3.98	2.66	3.1	2.92
35/17°C @ early flower	1.51	0.78	1.44	1.08	1.07	1.17
35/17°C @ early siliqua	1.11	0.46	1.08	0.67	0.84	0.83
Mean	2.40	1.26	2.94	1.93	2.12	
LSD (T) and LSD (G)			0.54 and 0.42			

All the genotypes produced a lower seeds at moderate ($28/15^0$C) to high temperature stress ($35/17^0$C) at early siliqua formation stage. Furthermore, high temperature stress ($35/17^0$C) at early flowering stage and at early siliqua formation stage reduced 1000 seed weight in all genotypes. The temperature stress affected the yield forming traits for all the genotypes. High heat stresses have direct effect on flowering (Tayo and Morgan 1975; Angadi *et al.,* 2000) to support the plant photosynthetically. Therefore, fertile siliqua only developed from early flowers while the later flowers may not capable to form fertile siliqua. Previous report showed reduced seed weight under shorter exposure to high temperature stress in canola (Aksouh *et al.,* 2001) and declination in the duration of grain filling in cereals (Sofield *et al.,* 1977). Yield loss due to temperature stress has been reported in many crops including broccoli (Heather *et al.,* 1992), peanut (Vara Prasad *et al.,* 1999) and pea (Guilioni *et al.,* 1997).

Effect of temperature stress on pollen viability and germination

To test the effect of temperature on pollen viability and germination, pollen were grown in solid pollen germination medium. A pollen grain was considered to be germinated when the pollen tube length exceeded or equalled the grain diameter. Maximum pollen viability and germination were recorded at 20^0C followed by 25^0C and 30^0C [Fig. 1 (A and B)]. The lowest pollen viability and germination was recorded during high temperature stress (35^0C). Maximum pollen viability (96%) and germination (58%) were recorded at 20^0C by Kallayania followed by Tori 7 (83% and 48% respectively) at 25^0C. However, the temperature above 30^0C reduces pollen viability and germination for all the genotypes (22% and 9% respectively). Reduced pollen viability and germination was observed by imposing increasing temperature in *Brassica rapa* genotypes. This might be due to the changes of proteins and lipids on the pollen coat (Lahlali *et al.,* 2014), loss of membrane integrity (Jain and Shivanna, 1989) and sugar presents in pollen grains (Pressman *et al*., 2002).

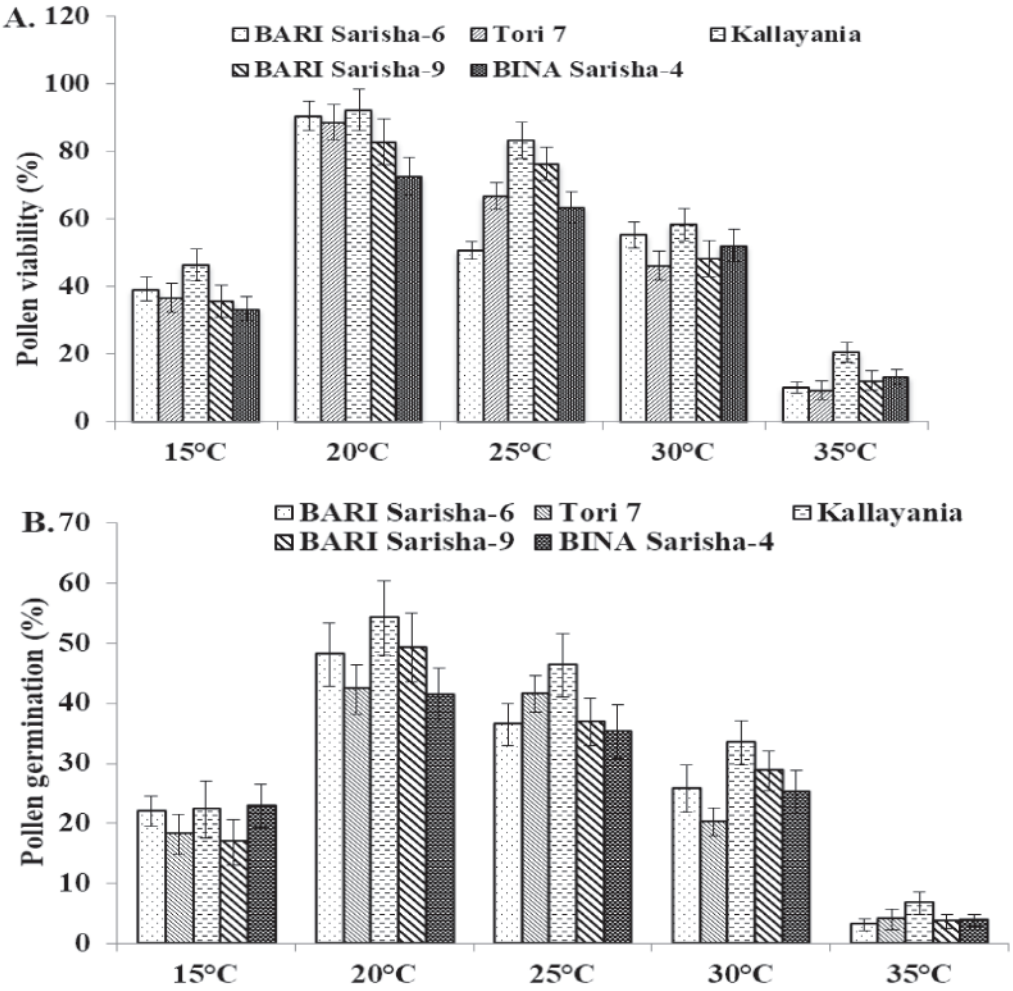

Fig. 1. Effect of temperature stress on pollen viability (PV) and pollen germination (PG) in five *Brassica* genotypes. A. Effect on pollen viability (PV) and B. Effect on pollen germination (PG). Error bars denote for ± SE of 15 measurements.

Effect of temperature stress on oil, protein and glucosinolate concentration in *Brassica* genotypes

Out of the five genotypes, Tori 7 had the highest average oil concentration in the control (Table 2). The temperature stress ($25/22^0$C) imposed for 10d increased the oil and protein in BARI Sarisha-6 (Table 2). Very high temperature stress imposed for 5d decreased the oil concentration only in BARI Sarisha-9 and did not influence the protein fraction. Thus, very high temperatures exposure for 5d reduced the average oil and increased protein concentrations (Table 2). The result showed that high temperatures stress reduces the oil concentration and increase the protein concentration for all the

genotypes. Previous report also showed that the moderately high temperature treatment increased the oil/protein ratio in Canola (Aksouh-Harradj *et al.,* 2006). Strong negative correlation exists between oil and protein with high temperatures which might be explained by an increase of grain nitrogen (Aksouh-Harradj *et al.,* 2006) due to suppression of starch synthesis rather than to a change in the nitrogen quantity (Bullar and Jenner, 1985). High temperature alter protein biosynthetic pathway along with nitrogen concentration in the grain that changes different protein composition (Aksouh-Harradj *et al.,* 2006). Glucosinolate concentration differed between genotypes exposed to $25/22^0$C and $28/23^0$C temperature respectively (Table 2). High glucosinolate also reduces the feeding value of the rape (Mendham and Salisbury, 1995). In this context, genotype BARI Sarisha-9 showed low glucosinolate and much higher in Tori-7. Therefore breeding lines with low glucosinolate level need to be developed for future breeding program. Temperature stress during seed filling altered the chemical nature of *Brassica* oil especially in the unsaturated fatty acid.

Table 2. Effect of temperature stress on the oil, protein and glucosinolate concentration in five *Brassica* genotypes

Treatment	BARI Sarisha-6	Tori 7	Kallayania	BARI Sarisha-9	BINA Sarisha-4	Mean
			Oil concentration (%)			
22/17°C (control)	38.8	40.33	39.25	38.18	37.88	38.88
25/20°C	36.9	34.15	35.36	36.48	33.4	35.25
28/23°C	32.2	31.23	32.48	30.55	32.66	31.82
Mean	35.96	35.23	35.69	35.07	34.64	35.32
LSD (T) and LSD (G)			4.0 and 3.0			
			Protein concentration (%)			
22/17°C (control)	45.68	44.54	43.95	41.33	44.88	44.07
25/20°C	44.25	40.22	41.35	42.68	40.83	41.86
28/23°C	42.23	43.22	41.82	40.96	43.68	42.38
Mean	44.05	42.66	42.37	41.65	43.13	42.77
LSD (T) and LSD (G)			5.0 and 6.0			
			Glucosinolate concentration (%)			
22/17°C (control)	22.22	30.5	19.8	11.52	17.65	20.33
25/20°C	18.4	22.8	20.3	13.96	16.88	18.46
28/23°C	11.4	31.8	18.4	9.64	20.33	18.31
Mean	17.34	28.36	19.5	11.70	18.28	19.04
LSD (T) and LSD (G)			2.98 and 1.87			

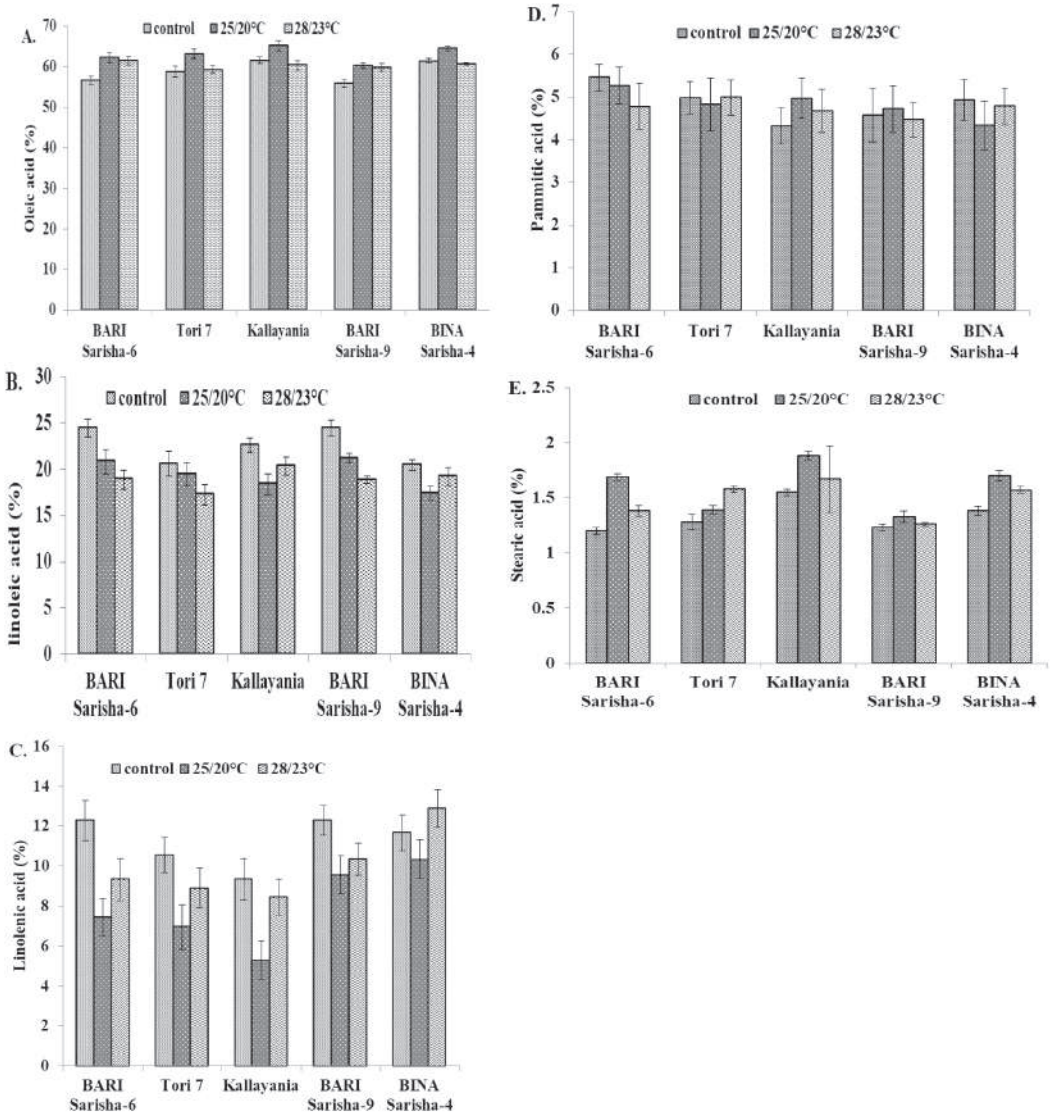

Fig. 2. Effect of temperature stress on the fatty acid composition in five *Brassica* genotypes. A. Effect on oleic acid, B. Effect on linoleic acid, C. Effect on linolenic acid, D. Effect on palmitic acid and E. Effect on stearic acid. Error bars denote the mean of at least 15 measurements ± SE.

Effect of temperature stress on fatty acid profile in *Brassica* genotypes

No change was observed in oleic acid concentration in response to temperature stress (Fig. 2A) but linoleic acids concentration decreases with increasing the temperature (Fig. 2B) for all the genotypes. Plant exposed to $25/20^0$C temperature stress showed greatest changes in linolenic acid concentration (Fig. 2C). The lowest linolenic acid

concentration was observed by Kallayania (almost 5%) at 25/20^{0}C temperature stress while at 28/23^{0}C temperature BINA Sarisha-4 had highest (almost 13%) (Fig. 2C). The results showed that the levels of unsaturated fatty acids were elevated due to imposing temperature stress among the genotypes. This might be due to desaturase activities were restricted during high temperature. Similar reports in rapeseed and other species also showed that desaturase activities changes when plants exposed to high temperature (Gibson and Mullen, 1996, Aksouh-Harradj *et al.*, 2006). The saturated fatty acids level was similar for the genotypes in the control (Fig. 2D and E). No changes was observed in palmitic acid concentration (Fig. 2D) for all the genotypes, only stearic acid concentration increased by imposing the temperature stress (Fig. 2E). Similar finding were also showed that palmitic and stearic acids increases substantially by the elevated temperatures (Canvin, 1965; Percy, 1978; Green, 1986).

Conclusion

Temperature stress not only had an effect on yield components but also effected oil concentration and fatty acid composition of *Brassica rapa* genotypes of Bangladesh. This could be a major issue in many regions of the country where high temperature combined with drought are common for cultivation of oilseeds. The optimum temperature for seed yield was closer to 28^{0}C. The temperature above 28^{0}C tended to reduce seed yield. The ideal temperature to get viable pollen and germination was 20^{0}C. The high temperature also affects oil and protein content for all the genotypes. BARI Sarisha-9 showed low glucosinolate level and could be used for future breeding program. The results of this experiment suggest a way for the breeders to select the genotypes that were affected by the high temperature.

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INTEGRATED MANAGEMENT OF PURPLE BLOTCH DISEASE COMPLEX FOR ONION SEED PRODUCTION IN BANGLADESH

M.R. Ara[1*], M.M.H. Masud[2], K. Akter[3], M.R. Islam[4] and A.N.F. Ahmmed[4]

[1]Bangladesh Agricultural Development Corporation (BADC), Dhaka; [2]Directorate of Secondary and Higher Secondary Education (DSHE), Shikkha Bhaban, Dhaka; [3]Department of Agricultural Extension (DAE), Khamarbari, Dhaka; [4]Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka. Bangladesh

Abstract

Onion suffers from many diseases and among them purple blotch complex is devastating for both bulb and seed production in Bangladesh. To formulate an integrated approach for its management, different IPM components viz. three fungicides viz. Rovral 50 WP (Iprodione), Dithan M-45 (Mancozeb) and Score 250 EC (Difenconazol); two botanicals viz. Alamanda leaf extract (*Allamanda cathartica*) and Neem leaf extracts (*Azadiracta indica*); four soil amendments viz. Poultry manure, bioagent, saw dusts and micronutrients **(**Zn @ 0.45/L +B @ 2.5g/L**)** were evaluated under field condition. The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, during 2011-2012. Pathogeninicity test indicated that *Alternaria porri* and *Stemphylium vesicarium* were the pathogens where *S. vesicarium* initiated the infection and *A. porri* facilitated the subsequent infection and made a complex form of disease. Among the chemical fungicides, Score 250 EC was found promising followed by Rovral 50 WP against purple blotch complex in terms of reduction of disease incidence and severity ultimately contributing to increased yield (134% and 129%, respectively) over control. Among botanicals, Alamanda leaf extract produced better result compared to neem leaf extract (99.6% and 67.6% respectively). In terms of increasing yield, poultry manure showed better performance (72.3%) followed by micronutrient (69.5%) and bioagent (58.2%).

Keywords: *Allium cepa* L., *Alternaria porri*, Integrated management, Purple blotch complex, Seed production, *Stemphylium vesicarium*

Introduction

Onion is a popular vegetable in Asia and very common and favorite spices in Bangladesh. Our annual requirement of onion bulb ranges between 2.2 and 2.5million tons whereas Bangladesh produces 19.54 lac metric tons from 185346 hectare of land (BBS 2020). In the country, Faridpur is the second-biggest onion-producing district, followed by Pabna. In Bangladesh, farmers produce about 700 tons of onion seeds annually, and Faridpur accounts for 60-65 per cent of the production (Das, 2021). Thus, a deficit of onion bulb for consumption and seed bulb for production per annum creates

* Corresponding Author: bithi.treno@gmail.com

market crisis among the onion farmers in the growing season in Bangladesh. The government meets up the deficit of bulb and onion seed by importing from neighboring countries in exchange of foreign currency.

Onion suffers from different diseases like purple blotch, seed rot, black mould, damping off and white blotch or *Stemphylium* blight (Fakir, 2002). Among the diseases, purple blotch of onion caused by *Alternaria porri* and white blotch of onion caused by *Stemphylium vesicarium* are presently considered as the most damaging diseases both for bulb and seed production. In many occassions, these two diseases simultaneously attack the onion crop and make a complex form of disease which is known as 'purple blotch disease complex' of onion. This disease is most devastating and affects both bulb yield and seed production all over the world including Bangladesh (Islam *et al*., 2001 and Mishra and Gupta, 2012). In Bangladesh, it has been reported as 41-44% yield losses of onion due to this disease (Fakir, 2002). The fungi *A. porri* and *S. vesicarium* produce injurious toxin and metabolites, which affect seed germination and seedling growth (Lou *et al.,* 2013).

The present concept of plant disease management is to maintain the pest population below the economically damaging level by integrated management practice(s) rather it eliminates entirely from the environment by using toxic chemicals. Hence, attempts to be made to evaluate different treatments including eco-friendly components along with fungicides to manage the disease. Based on the above facts the present research was undertaken to evaluate different treatments to formulate integrated disease management of purple blotch disease complex of onion for seed production in the field.

Materials and Methods

Experimental site

The field experiments were conducted at the farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207.

Soil type

The soil of the experimental site belonged to the agro-ecological region of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belongs to "Nodda" cultivated series. The top soil was clay loam in texture. Organic matter content was very low (0.82%) and soil pH varied from 5.47-5.63.

Experimental period

The experiments were conducted during November 2011 to March 2012.

Experimental design and data analysis

Completely Randomized Design (CRD) was exercised with 4 replications for Laboratory experiments and Randomized Complete Block Design (RCBD) with 4 replications was used for field experiments.

Treatment of onion bulb

The onion bulbs were treated for each treatment with the respective plant extracts and fungicidal solutions by dipping the bulbs in the suspension for 15 minutes before plantation. The bulbs were than drained off, shade dried and sown in the field without delay. For control treatment the bulbs were treated with plain water only. Bulbs of onion were planted on 15 November' 2011 maintaining row spacing of 25 cm and bulb spacing of 20 cm in each plot.

Preparation of plant extracts solution

The plant extracts were prepared by using the method of Islam (2005). For this purpose, collected leaves/rhizome/bulb were weighed in an electric balance and then washed in the tap water. After washing, the big leaves/rhizome/bulb was cut into small pieces. For getting extract, weighed plant parts were blended in an electric blender adding required amount of water. The pulverized mass was squeezed through cheese cloth. For getting 1:2 (w/v) ratio 200 ml of distilled water was added with 100 g plant parts. This solution was used in field trial.

Treatments

Altogether 10 different treatments comprising different plant extracts, fungicides, bioagent and soil amendments were explored in this experiment were stated below:

T_0 = Control (Bulb treatment with plain water followed by foliar spraying with the same)

T_1 = Rovral 50 WP - Ipridione 50% (Bulb treatment @ 2g/L+ Foliar spraying @ 2g/L)

T_2 = Dithane M-45- Mancozeb 45% (Bulb treatment @ 4.5g/L+ Foliar spraying @ 4.5g/L)

T_3 = Score 250 EC- Difenconazol 25% (Bulb treatment @ 0.5g/L+ Foliar spraying @ 0.5g/L)

T_4 = Alamanda (*Allamanda cathartica*) leaf extract - S/N (Bulb treatment @ 1:2 (w/v)+ Foliar spraying @ 1:2 (w/v))

T_5 = Neem (*Azadirecta indica*) leaf extract - S/N (Bulb treatment @ 1:2 (w/v)+ Foliar spraying @ 1:2 (w/v))

T_6 = Soil amendment with Bioagent- *T. harzianum,* (Basal application @ 2.5kg/ha+ Foliar spraying @ 5g/L)

T_7 = Soil amendment by Poultry manure @ 60t/ha

T_8 = Soil amendment by Saw dust @ 60t/ha

T_9 = Soil amendment by Micronutrient **(**Zn @ 0.45g/L +B @ 2.5g/L**)**

Isolation and identification of *A. porri* and *S. vasicarium* from infected leaf sample of onion

For isolation of causal pathogens, diseased specimens were collected from the major onion growing areas of the country. Isolation done by tissue planting method and single spore/tip culture method was followed to purify the epagoges. The diseased leaves were cut

into pieces (5mm diameter) and surface sterilized with $HgC1_2$ (1: 1000) for 30 seconds. The cut pieces were washed in sterile water thrice and were placed on acidified PDA medium in petridish. The plates containing leaf pieces were incubated at room temperature for seven days. When the fungi grew well and sporulated, then the organisms were re-cultured by single spore or tip culture method to obtain pure culture. Identification of the pathogen was done under compound microscope by making slides from the pathogenic culture. The pathogens, *A. porri* and *S. vasicarium* were identified with the help of relevant literature depending on physical structure and fruiting body (Ellis, 1971).

Preparation of inoculums for pathogenecity study

The conidia suspension of *Alternaria porri* and *Stemphylium vesicarium* were prepared with sterilized water using 10 days and 30 days old PDA culture and then incubated at 22-24^{0}C under NUV light and dark cycle (12/12). The suspension was sieved through a double layered of cheese cloth to remove mycelia fragments and conidiophores. One drop of tween-20 (polyoxyethylene 20 sorbitan monolaurate) was added to the suspension to maintain uniform dispersion of conidia in suspension. The concentrations of conidial suspensions were 21×10^5 per ml and 14×10^2 per ml, respectively for *Alternaria porri* and *Stemphylium vesicarium*.

Inoculation on onion plant

The inoculations were done with the respective spore suspension individually and in combination. In case of combined inoculation the spore suspension was mixed with 1:1 proportion. The inoculated plants were covered with transparent polyethylene sheet for 48 hours to keep the inside moist and humid (% RH) for infection and also to prevent natural contamination with other organisms. The plants were kept in a net house at 25 ± 2^0C for observation. For pathogenecity study, the isolation, re-isolation, observation and recording symptoms of pathogenic characteristics were done following Koch's postulate (Koch, 1891) to confirm the pathogenicity of the organisms.

Inoculation by *A. porri* and *S. vasicarium* and field spray

After germination of onion bulb, inoculation was done by the purple blotch complex pathogen, *A. porri* and *S. vasicarium* to ensure infection at an amount of pathogenecity test. Spraying of fungicides, plant extracts and bioagent were started from 36 days after bulb planting. Totally ten spraying were done at 7 days intervals with a hand sprayer.

Data collection and analysis

Twelve plants were selected randomly for each plot and tagged for data collection. Data collection was started after the onset of the disease and expression of symptoms and continued up to maturity of the crop with 7 days intervals. Data were collected on the parameters (disease incidence, leaf and stalk area diseased, disease severity, numbers of umbels per plot, diameter of umbel, weight of 1000 seeds). Complete package program MSTAT-C was used for analysis of all related data. Duncan's Multiple Range Test (DMRT) was explored for comparison of means (Gomez and Gomez, 1983).

Estimation of disease incidence

Number of infected leaves and number of infected floral stalk were recorded for calculation of disease incidence. The leaf with characteristic purple colored spot or blighted tip was denoted as diseased leaf. The percent disease incidence was calculated using the following formula (Wheleer, 1969):

$$\% \text{ Leaf infection} = \frac{\text{Number of leaf infected plant}}{\text{Total number of inspected plant}} \times 100$$

$$\% \text{ Stalk infection} = \frac{\text{Number of infected stalk}}{\text{Total number of inspected stalk}} \times 100$$

Leaf and stalk area diseased (LAD/SAD)

Leaf and stalk area diseased of the selected plants in every unit plot under each treatment were measured and recorded by conversion to percentage. Mean percentage of leaf and stalk area diseased were calculated by dividing number of total observation. Percentage of leaf and stalk area diseased were used to calculate the disease severity. The % LAD and % SAD were calculated using the following formula (Wheleer, 1969):

$$\% \text{ LAD or } \% \text{ SAD} = \frac{\% \text{ Leaf/Stalk area infected}}{\% \text{ Leaf/Stalk area inspected}} \times 100$$

Estimation of disease severity

The percent disease index (PDI) was calculated using the following formula (Wheleer, 1969):

$$\text{PDI (Leaf/stalk)} = \frac{\text{Total sum of numerical ratings}}{\text{Total No. of observation} \times \text{Maximum grade in the scale}} \times 100$$

The disease severity was calculated as PDI (Percent Disease Index) using '0 - 5' scale proposed by Horsfall and Barrett (1945) as stated below:

% Leaf/ Stalk area diseased	Grade/Ratting	Description
0	0	No disease symptoms
0.1 - 5.0	1	A few spots towards the tip covering 0.1 - 5.0 % leaf/stalk area diseased
5.1 - 12.0	2	Several purple-white patches covering less 5.1 - 12.0 % leaf/stalk area diseased
12.1 - 25.0	3	Several purple-white patches covering 12.1 - 25.0 % leaf /stalk area diseased
25.0 - 50	4	Long purple-white patches covering 25.0 – 50 % leaf /stalk area diseased
> 50	5	More than 50 % leaf/stalk area blotched and causing breaking of leaf/stalk.

Harvesting of umbels and seeds

Onion seeds were harvested on 30th March 2012. After drying of umbel, threshing, winnowing and cleaning of onion seeds were done. Later weight of seed for each unit plot under each treatment was taken separately and recorded. Numbers of umbels per plot, Diameter of umbel, Weight of 1000 seeds were measured and recorded. Seed yield was recorded after converting it to kg/ha.

Results and Discussion

Pathogenicity test of the purple blotch complex pathogens

On inoculation with spore suspension of *A. porri* and *S. vesicarium* the characteristic symptoms of purple blotch complex on onion leaf was observed after ten days of incubation. On re-isolations from diseased portion of artificially inoculated plants, the same causal organisms were found with similar cultural properties of original ones. The pathogenecity test revealed that the isolates produced purple and white blotch of onion on inoculation and the same organisms were found on re-isolation from the artificially produced diseased plant. Islam *et al*., 2001 reported that *A. porri* and *S. vesicarium* are involved in causing purple blotch complex of onion. They also stated that *S. vesicarium* initiated the infection causing white blotch which facilitated the subsequent infection of *A. porri* causing purple blotch and made the disease in complex form.

Effect of different treatments on disease incidence (% leaf infection)

The effect of different fungicides, botanicals and soil amendments on leaf infection differed significantly at different days after planting (DAP) (Table 1). At 99 DAP**,** the lowest leaf infection was recorded for the treatment T_3 (28.65%) followed by treatment T_1 (29.25%), while the highest leaf infection was recorded for the control treatment T_0 (99.58%). From the botanicals, Alamanda leaf extract gave better performance (76.93%) for controlling purple blotch complex of onion followed by Neem leaf extract (82.35%). In case of soil amendments, poultry manure gave better performance (82.46%) followed by bioagent (9.57%), micronutrient (93.21%) and sawdust (97.62%).

Effect of different treatments on disease severity (PDI-leaf)

Table 2 shows that the lowest PDI (19.22 %) was observed in treatment T_3 followed by T_1 (20.52%) and T_2 (38.93%). However, the highest leaf severity was recorded in untreated control plot, T_0 (98.72%). Alamanda leaf extract (T_4) gave lower PDI (52.36%) followed by Neem leaf extract (T_5) 65.50%). In case of soil amendments, poultry manure (T_7) showered better performance (58.62%) followed by bioagent (T_6) 74.43%, micronutrient (T_9) 79.50% and sawdust (T_8) 86.25%. At 99 DAP, the percent decrease of disease severity were 80.53% and 79.21%, respectively, over untreated control.

Effect of different treatments on disease incidence (% stalk infection)

At 136 DAP, the lowest infection (15.98%) was found in treatment T_3 which was statistically similar to T_1 (17.48%). The highest stalk infection (87.19%) was recorded in

control treatment (T_0) which was similar to treatment T_8 (87.05%). In case of botanicals, allamanda leaf extract (T_4) showed comparatively better performance than Neem leaf extract (T_5) Soil amendments showed significant differences among themselves. The lowest % stalk infection was found in poultry manure (T_7 = 68.81%) followed by micronutrient (T_9 = 71.80%), bioagent (T_6 = 71.81%) and sawdust (T_8 = 87.05%) (Table 3).

Table 1. Effect of different treatments on % leaf infection of purple blotch complex of onion in the field at different days after planting (DAP)

Treatments	% Infected leaf at different days after planting (DAP)										
	36 DAP	43 DAP	50 DAP	57 DAP	64 DAP	71 DAP	78 DAP	85 DAP	92 DAP	99 DAP	% decrease of disease incidence over control at 99 DAP
T_0	33.74 a	48.92a	61.41 a	68.64 a	73.62 a	74.15 a	78.64 a	81.56 a	97.72 a	99.58 a	-
T_1	21.58 h	22.55h	23.37 i	24.13 i	25.15 h	26.00 g	26.98 g	27.84 h	28.43 i	29.25 h	70.63
T_2	24.70g	38.83e	44.53g	48.52 g	55.25f	54.44f	58.48f	58.34 g	57.24 h	71.67 g	28.03
T_3	21.07 h	23.45g	24.39 h	25.61 h	26.36 g	27.60 g	27.84 g	28.10 h	28.33 i	28.65 h	71.23
T_4	26.36f	36.23f	47.62f	52.68 f	58.59e	57.22 e	57.01fg	60.50f	71.46 f	76.93 f	22.75
T_5	28.74d	41.55d	50.53e	57.92d	61.70d	61.49 d	63.30e	69.49d	83.28 d	82.35 e	17.30
T_6	29.65c	44.78c	53.64d	63.78c	64.53c	64.31c	65.23d	75.47c	86.73 c	89.57 d	10.05
T_7	27.55e	39.26e	48.33f	54.97e	61.72d	61.36d	58.22f	65.55e	77.09 e	82.46 e	17.19
T_8	32.19 b	47.42 b	56.74b	68.21a	72.95a	73.81a	74.57 b	80.29 ab	98.17 a	97.62 b	1.97
T_9	31.86b	45.26 c	55.53c	65.44b	67.28 b	67.60b	69.53c	79.25b	91.55 b	93.21 c	6.40
LSD (0.01)	0.61	0.74	0.86	1.37	1.17	1.40	1.70	1.53	1.47	1.52	
CV (%)	1.11%	0.94%	0.91%	1.27%	1.00%	1.20%	1.42%	1.18%	0.98%	0.97%	

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

Effect of different treatments on disease severity (PDI-floral stalk)

At 136 DAP, the highest performance of treatment i.e. the lowest PDI (16.73%) was recorded in case of treatment T_3 followed by treatment T_1 (17.65%) which was statistically indifferent. The highest stalk infection was recorded in untreated control plot (98.72%). At 99 DAP, % decreases of disease severity over control was 81.94% and 80.99% respectively. Alamanda leaf extract, (T_4) gave lower PDI (60.51%) than neem leaf extract (T_5= 64.54%). In case of soil amendments, poultry manure (T_7 = 61.49%) and bioagent (T_6 = 61.15%) showed statistically similar performance followed by micronutrient (T_9 = 85.52%) and sawdust (T_8 = 90.36%) (Table 4).

In the field evaluation with 3 different fungicides, Score 250 EC and Rovral 50 WP proved to be the promising fungicides in reducing the disease incidence and severity of purple blotch complex of onion. The disease incidence was reduced by 71.23% and 81.67% in case of Score 250 EC while it was 70.63% and 79.95% in case of Rovral 50

Table 2. Effect of different treatments on disease severity (PDI-Leaf) of purple blotch complex of onion in the field at different days after planting (DAP)

Treatments	Percent disease index (PDI leaf) at different days after planting (DAP)										
	36 DAP	43 DAP	50 DAP	57 DAP	64 DAP	71 DAP	78 DAP	85DAP	92DAP	99 DAP	% decrease of PDI over control at 99 DAP
T_0	25.21a	29.54 a	35.41a	38.55 a	48.38 a	53.03 a	62.43 a	71.39 a	84.17 a	98.72 a	-
T_1	11.48 e	12.27 f	13.46 f	14.75 g	16.52 h	17.66 j	18.17 i	19.04 j	19.84 j	20.52 i	79.21
T_2	15.21 d	17.15 e	19.38 e	20.95 f	23.59 g	25.70 i	29.08 h	32.51 i	36.01 i	38.93 h	60.57
T_3	11.02 e	12.84 f	13.96 f	15.15 g	16.02 h	16.84 j	17.20 i	17.53 j	18.13 j	19.22 j	80.53
T_4	17.70c	19.00 d	23.86 d	27.13 e	26.53 f	34.89 g	37.53 f	42.64 g	46.09g	52.36g	46.96
T_5	20.15 b	23.30 c	27.47 c	29.31 d	34.04 d	39.48 e	46.61 d	51.70 e	61.37e	65.50e	33.65
T_6	21.38 b	26.13 b	30.32 b	33.4 c	36.02 c	43.20 d	51.63 c	56.53 d	67.57d	74.43d	24.60
T_7	18.56 c	21.83 c	26.43 c	27.39 e	28.52 e	37.63 f	40.49 e	47.39 f	54.83f	58.62f	40.62
T_8	24.37 a	28.45 a	35.32 a	38.42 a	47.38 a	49.95 b	61.39 a	67.17 b	79.46b	86.25b	12.63
T_9	24.04 a	26.52 b	31.62 b	36.24 b	40.44 b	45.61 c	54.49 b	62.72 c	74.44c	79.50c	19.47
LSD (0.01)	1.52	1.56	1.60	1.63	1.86	1.76	1.38	1.54	1.73	1.31	
CV (%)	4.01%	3.58%	3.08%	2.82%	2.85%	2.35%	1.59%	1.58%	1.54%	1.06%	

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

WP. The PDI reduced by 80.53% and 81.98% in case of Score 250 EC while it was79.21% and 80.99% in case of Rovral 50 WP (Table 4). Islam (2005) found Score 250 EC as the most effective fungicide next to Rovral 50 WP in reducing mycelial growth of *A. porri.* Islam *et al.,* (2001) also reported that Rovral 50 WP was the most effective fungicide next to Score in reducing radial mycelial growth of *A. porri* in *in-vitro*. Ali (2008) observed that Rovral 50WP @ 0.2% reduced the highest mycelia growth of *A. porri* and *S. vesicarium* followed by Ridomil Gold MZ-72 @ 0.2% and Dithane M-45 @ 0.45% compared to control. Hossain (2008) stated that among seventeen fungicides against purple blotch of onion (*A. porri*), Rovral and Score totally inhibited the mycelial growth of the fungi. Akhter *et al.,* (2015) reported that among the fungicides Rovral 50WP (Iprodione) was found to be the most effective fungicide to retard the radial mycelial growth of *S. botryosum*.

Between two botanicals assayed against the causal pathogens, Alamanda leaf extract was found to be promising in controlling mycelial growth of *A. porri* and *S. vesicarium* as well as reducing the disease incidence and severity. The disease incidence

Table 3. Effect of different treatments on % stalk infection of purple blotch complex of onion in the field at different days after planting (DAP)

Treatments	% Infected stalk at different days after planting (DAP)									
	80 DAP	87 DAP	94 DAP	101 DAP	108 DAP	115 DAP	122 DAP	129 DAP	136 DAP	% decrease of disease incidence over control at 136 DAP
T_0	4.597 a	6.675 a	12.61 a	19.66 a	26.58 a	36.48 a	53.58 a	78.50 a	87.19 a	
T_1	2.35 d	2.38 e	3.80 e	4.58 f	7.03 f	8.88 f	11.18 f	13.94 g	17.48 g	79.95
T_2	3.18 bc	3.53 d	5.59 d	9.72 e	12.82 e	15.26 e	18.87e	21.04 f	26.41 f	69.71
T_3	2.01 d	2.88 e	4.80 e	5.28 f	7.53 f	9.18 f	12.14 f	13.51 g	15.98 g	81.67
T_4	3.48 c	5.26 bc	7.27 c	11.45 d	22.43 bc	25.20 c	41.38 c	55.40 e	67.06 e	23.09
T_5	3.79 ab	5.22 bc	8.53 b	13.52 bc	23.25 b	26.49 bc	43.52 b	58.45 c	70.35 c	19.31
T_6	3.84 ab	5.58 b	9.29 b	13.65 bc	21.61 c	26.46 bc	43.63 b	60.48 b	71.81 b	17.64
T_7	3.27 bc	5.44 bc	8.847 b	12.80 c	26.47 a	25.31 c	41.93 c	57.00 d	68.81d	21.08
T_8	4.60 a	6.65 a	12.60 a	19.40 a	25.65 a	35.59 a	52.99 a	77.57 a	87.05 a	0.16
T_9	4.38 a	6.22 ab	11.60 a	14.49 b	6.58 f	27.47 b	44.68 b	61.03 b	71.80 b	17.65
LSD (0.01)	0.87	0.99	1.12	1.07	1.55	1.47	1.28	1.25	1.28	
CV (%)	7.23 %	14.55%	8.75%	5.17%	3.53%	2.75%	2.30%	1.51%	1.11%	

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

was reduced by 22.75% and 23.09% in case of Alamanda leaf extract while it was 17.30% and 17.64% in case of Neem extract. The PDI was reduced by 46.96% and 34.82% in case of Alamanda leaf extract while it was 33.65% and 30.48% in case of Neem extract. Akhter *et al.*, (2015) reported that Alamanda and Neem leaf extract showed positive result against purple blotch disease of onion. In the field evaluation, the performance of Alamanda and Neem leaf extract against the disease was significantly better than control but not so praiseworthy like chemical fungicides Score 250EC and Rovral 50WP. The performance of Alamanda leaf extract was comparatively better than Neem leaf extract in reducing the incidence and severity of purple blotch complex of onion. Tiwari and Srivastava (2004) reported that Neem extract showed antifungal activity against A. porri and S. vesicarium causing purple blotch and white blight of onion. Tiwari *et al*., (2002) reported that *A. cathertica* acted as antidermatophilic agent against fungi. Islam *et al*., (2004) reported that Alamanda leaf extract inhibited even 100% mycelia growth of *Phomosis vexan* causing phomopsis blight and fruit rot of eggplant. Tiwari and Srivastava (2004) also reported that Neem leaf extract inhibited the growth of the onion pathogens, *A. porri* causing purple blotch of onion and *S. vesicarium* causing white blight of onion. *A. indica* have antifungal activities against *Alternaria sp.* (Bobbarala *et al.*, 2009 and Bhardwaj, 2012).

Table 4. Effect of different treatments on disease severity (PDI-stalk) of purple blotch complex of onion in the field at different days after planting (DAP)

Treatment	Percent disease index-stalk (PDI-stalk) at different days after planting (DAP)									
	80 DAP	87 DAP	94 DAP	101 DAP	108 DAP	115 DAP	122 DAP	129 DAP	136 DAP	% decrease of PDI over control at 136 DAP
T_0	4.08 ab	5.67 a	9.51 a	18.30 a	24.56 a	34.45 a	51.33 a	70.34 a	92.83 a	
T_1	1.36 g	1.45 e	2.82 d	3.85 e	5.93 g	8.00 h	10.97 g	14.26 j	17.65 h	80.99
T_2	1.81 f	3.27 d	3.63 cd	4.51 e	8.67 f	9.40 g	11.45 g	17.45 i	21.45 g	76.89
T_3	1.25 g	1.49 e	2.32 d	3.58 e	5.03 g	7.15 h	9.97 g	14.00 j	16.73 h	81.98
T_4	1.97 ef	4.64 a-c	6.26 b	12.35 b	18.56 c	24.62 d	40.44 c	55.53 d	60.51 e	34.82
T_5	2.62 d	4.28 b-d	6.47 b	11.02 c	17.51 cd	21.98 e	32.36 e	47.56 f	64.54 d	30.48
T_6	3.49 c	4.57 a-d	6.64 b	10.68 c	21.56 b	29.31 c	36.27 d	52.01 e	61.15 e	34.13
T_7	2.53 d	4.51 a-d	5.71 b	10.66 c	16.64 d	17.36 f	24.44 f	34.53 h	61.49 e	33.76
T_8	4.40 a	5.64 a	9.27 a	17.70 a	24.04 a	33.68 a	50.51 a	68.72 b	90.36 b	2.66
T_9	3.81bc	5.47 ab	9.29 a	18.35 a	23.63 a	31.71 b	48.48 b	65.26 c	85.52 c	7.87
LSD (0.01)	0.40	1.22	1.10	1.15	1.18	1.21	1.49	1.37	1.29	
CV (%)	12.50%	9.85%	6.73%	4.25%	4.02%	3.03%	1.71%	1.20%	1.04%	

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

Among the four different soil amendments, poultry manure was the promising options for the management of the disease. The disease incidence was reduced by 17.19% and 21.08% respectively in case of poultry manure while it was 10.05% and 17.64 respectively in case of bioagent. The PDI was reduced by 24.60% and 33.76% respectively in case of poultry manure while it was 24.60% and 34.13% respectively in case of Bioagent. Hafiz (2009) reported that for the management of purple blotch of onion soil application with poultry manure found effective. Hasanat (2011) and Bhuiyan (2010) reported that poultry manure had tremendous effect in the management of rhizome rot of ginger caused by *Fusarium oxysporum*. However the action of poultry manure increases the microbial activity of soil borne antagonist that indirectly contributed for the management of the plant pathogens.

Effect of different treatments on yield and yield contributing characters

The effect of fungicides, botanicals and soil amendments on height of seed stalk (cm) of onion that was slightly differed among the treatments and ranged from 46.34 cm to 65.48 cm. At maturity stage, the highest height recorded under treatment T_3 (65.48 cm) and T_1 (64.44 cm) (Table 5). The lowest height was found in untreated control plot (46.34 cm). In case of botanicals, alamanda leaf extract (T_4) gave higher stalk height (56.49 cm) followed by neem leaf extract, T_5 (60.11 cm). In case of soil amendments, bioagent (T6

=56.41 cm) showed highest height followed by sawdust (T_8 =55.08 cm), micronutrient (T_9 = 54.57 cm) and poultry manure (T_7 = 51.66 cm). The effect of fungicides, botanicals and soil amendmentson number of onion seed stalk/hill was insignificant for all the treatments. The highest number of effective umbel/plot recorded under treatment T_3 (92.58) which were statistically similar to treatment T_1 (92.30). The 3rd highest number of effective umbel/plot was recorded in T_2 (84.26) and the lowest number recorded in control treatment T_0 (59.98). In case of botanicals, alamanda leaf extract, (T_4) produced higher number of effective umbel/plot (81.42) followed by neem leaf extract T_5 (72.08). In case of soil amendments, poultry manure T_7 (57.91) and bioagent T_6 (67.43) produced statistically similar number of effective umbel followed by micronutrient T_9 (62.94) and sow dust T_8 (79.33). The umbel diameter (cm) of onion was slightly differed among the treatments that ranged from 5.11 cm to 6.21 cm (Table 5). Significantly the highest umbel diameter (6.21 cm) was recorded under treatment T_3 which was statistically similar to treatment T_1 (6.19 cm), T_2 (6.00 cm) and T_4 (5.44 cm). The lowest umbel diameter was measured in untreated control treatment T_0 (5.11 cm) which was statistically identical with treatment T_6 (5.15 cm), T_7 (5.15 cm), T_9 (5.15 cm), T_8 (5.16 cm) and T_5 (5.15 cm). The highest onion seed yield was recorded under treatment T_3 (600.0 kg/ha) which was statistically identical with treatment T_1 (586.0 kg/ha), T_2 (505.0 kg/ha) and T_4 (511.0 kg/ha). The lowest yield was recorded under treatment T_0 (256.0 kg/ha) preceded by treatment T_5 (429.0 kg/ha), T_9 (434.0 kg/ha) and T_7 (441.0 kg/ha). The highest percent increase of yield (134.34%) over control was recorded under treatment T_3 followed by T_1 (128.91%). The lowest percent of increase of yield over control was recorded under treatment T_8 (55.47%). The present findings of the experiment were well supported by the reports of previous workers (Khatun, 2007; Ahmed, 2007; Ali, 2008; Hossain, 2008; Islam *et al.*, 2001; and, Akhter *et al*., (2015). Hossain (2000) reported that application of micronutrient (Zinc+Boron) increased considerable seed yield against purple blotch of onion in field condition. Khatun (2007) while conducting a field experiment reported that Rovral 50WP (0.2%) minimized the disease incidence and severity of purple blotch complex of onion and increased bulb yield of onion. Akhter *et al.,* (2015) reported that there was a positive and significant impact of fungicides and plant extracts on plant height, bulb diameter and bulb yield of onion. All the plant parameters were increased with applying different fungicides and plant extracts with their effectiveness. The highest bulb yield (8.767 t/ha) and highest bulb diameter (3.787 cm) were obtained with Rovral treated plot. Antagonistic effect of poultry manure against other plant pathogen is also reported by several researchers (Meah, *et al.,* 2004; Islam, 2005, Bhuiyan, 2010; Hasanat, 2011; Yoldas *et al*., 2019). Poultry manure increases the microbial activity of soil borne antagonist that indirectly contributes for the management of the plant pathogens.

Table 5. Effect of different treatments on seed yield and yield contributing characters against purple blotch complex of onion

Treatment	Height of onion seed stalk (cm)	No. of onion seed stalk/hill	No. of umbel/plot	Umbel diameter (cm)	1000 Seed weight (gm)	Seed yield (kg/ha)	% Increase of yield over control
T_0	46.34 f	0.85 a	59.98 h	5.11 b	2.62 a	256 e	-
T_1	64.44 a	1.40 a	92.30 a	6.19 a	3.43 a	586 a	128.91
T_2	60.22 b	1.38 a	84.26 b	6.00 ab	3.36 a	505 a-d	97.27
T_3	65.48 a	1.42 a	92.58 a	6.21 a	3.41 a	600 a	134.38
T_4	56.49 c	1.38 a	81.42 c	5.44 ab	3.04 a	511 a-c	99.61
T_5	60.11 b	1.12 a	72.08 e	5.20 b	3.31 a	429 b-d	67.58
T_6	56.41 c	1.21 a	67.43i	5.15 b	3.28 a	405 cd	58.20
T_7	51.66 e	0.99 a	57.91 i	5.15 b	2.44 a	441 b-d	72.27
T_8	55.08 d	1.36 a	79.33 d	5.16 b	2.79 a	398 d	55.47
T_9	54.57 d	1.10 a	62.94 g	5.15 b	3.03 a	434 b-d	69.53
LSD (0.01)	1.05	0.58	0.85	0.80	0.99	96.00	
CV (%)	0.95%	24.72%	0.58%	7.47%	16.71%	11.00%	

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

Conclusion

Among the fungicides, Score 250 EC (Difenoconazole) was found most effective followed by Rovral 50 WP (Ipridione) against purple blotch complex of onion. At 99 DAP, these two fungicides reduced leaf incidence (71.23% and 70.63%) and leaf severity (80.53% and 79.21%) respectively over control. Similarly they reduced floral stalk incidence (81.67% and 79.95%) and stalk severity (81.94% and 80.99%) respectively over control at 136 DAP. Among the botanicals, alamanda leaf extract gave best result followed by neem leaf extract. At 99 DAP, 22.75% leaf incidence reduced by alamanda leaf extract over control. However, 46.96% and 33.65% leaf severity were decreased over control for alamanda leaf extract and neem leaf extract. Alamanda leaf extract reduced 19.31% floral stalk infection over control at 136 DAPS. Whereas, disease severity in floral stalk were reduced 34.82% and 30.48% for Alamanda and Neem, respectively at 136 DAP over control. At 99 DAP, 17.19%, 10.05% and 6.40% leaf incidence reduced for poultry waste, bioagent and micronutrient, respectively over control. In case of disease severity, poultry waste showed better performance followed by bioagent and micronutrient. In terms of yield it was counted that seed yield increased by 134.38%, 128.91%, 99.6 %, 72.27%, 58.20% and 69.53% for Score 250 EC, Rovral 50 WP and allamanda leaf extract, soil amendment by poultry waste; bioagent and micronutrient, respectively over control. Based on the performances of the treatments assayed in this experiment, Score250 EC (O.05%) as bulb treatment and foliar spraying at 10 days

intervals will be suited for the management of the purple blotch complex of onion for seed production. In addition, for best performance, soil amendment by poultry waste will be helpful for better seed yield.

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ENHANCING SEED GERMINATION AND SEEDLING GROWTH OF CHEBULIC MYROBALAN (*TERMINALIA CHEBULA* RETZ.) BY APPROPRIATE SOAKING AND SOWING TIME AFTER COLLECTION OF FRUITS

M.A. Alam[1], M.H. Rahman[2], M.A. Rahim[2], M.M. Hossain[2] M. Saifullah[3*] and K.N.A. Jewel[3]

[1]Department of Agricultural Extension (DAE), Khamarbari, Dhaka; [2]Department of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh; [3]Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka. Bangladesh

Abstract

The experiment was designed to enhance seed germination and seedlings' growth of chebulic myrobalan *(Terminalia chebula* Retz.) by proper seed soaking and sowing time after collection of fruits during March to July 2020 at BAU-GPC of Bangladesh Agricultural University, Mymensingh. In total 900 seeds were subjected to five pre-sowing treatments e.g. control or without soaking of seeds (C_1), soaking in water for two days (C_2), four days (C_3), six days (C_4), and soaking cow dung slurry for six days (C_5) and four sowing times: on collection date and after 10, 20 and 30 days of collection respectively. The field experiment was conducted following RCBD with three replications. Seeds soaked in cow dung slurry (C_5) showed the highest germination percentage (85.25%), germination energy (43.41%) and survival percentage (85.65%). Seeds sowing after 10 days of collection (P_2) recorded as the highest germination percentage (81.37%) and germination energy (39.60%) whereas the highest survival percentage was observed after 30 days of collection (P_4) (76.71%). After 30 days of collection, seeds soaked in cow dung slurry for six days (C_5P_4) showed highest germination (93%), survival percentage (92.86%), leaf number (60) and shoot length (32cm). The lowest germination percentage (60%) and leaf number (32.50) was observed in the treatment C_1P_4 and the lowest survival percentage (40%) and shoot height (12 cm) in C_1P_1.

Keywords: Cow dung slurry, Sowing time, Soaking, *Terminalia chebula* Retz.

Introduction

Chebulic myrobalan in Bengali horitoki (*Terminalia chebula* Retz.) belongs to the family 'Combretaceae' is an important medicinal tree species used for several purposes in the Indian sub-continent. It is a medium to large-sized tree distributed throughout the tropical and sub-tropical Asia including China and Tibet (Kannan *et al*., 2009). In Bangladesh, it is found in the hill forest of Chottogram, Gazipur, Tangail and in the dry areas of Sal forest in Mymensingh and Dinajpur (Das and Alam, 2001). This species is widely used in combination with *Terminalia belerica* and *Emblica officinalis* in

* Corresponding Author: m.saif@barc.gov.bd

Triphala which is believed to remove toxins and other undesirable accumulations from the body, improve digestion, assimilation and acts as an antioxidant. It is routinely used as traditional medicine by tribes of Tamil Nadu to cure several ailments such as fever, cough, diarrhea, gastroenteritis, skin diseases, candidiasis, urinary tract infection, and wound infections (Dash, 1991). Due to tremendous population pressure, poverty, absence of appropriate government policy and unsustainable utilization of forest resources, the population of this valuable tree species is declining rapidly. The success of plantation programs largely depends on the germination of seeds and the growth of seedlings in the nursery. The nursery technique should be efficient enough to produce an adequate number of quality seedlings within a reasonable time (Hossain *et. al.*, 2013).

Poor natural regeneration due to a lower rate of seed germination has led to the scarcity of this species in their natural habitat (Richa and Sharma, 1994). People don't get interested in raising the seedlings of this species in nursery due to poor germination percentage. Low germination percentage, as well as long time, requirement is believed due to the hard seed coat and thick fleshy pulp of fruits (Luna, 1996). Germination of seeds with hard seed coats could enhance by pre-sowing treatments (Palani *et al.,* 1996). Delayed and irregular germination of seeds in the nursery is a serious constraint of efficient nursery management and plantation establishment. However, literatures which have examined the effect of seed treatments of this medicinal plant are very scarce. So, under the present circumstances, the research work has been designed to explore the seed germination percentage and growth performance of *Terminalia chebula* Retz. Seedlings following different seed soaking and sowing time treatments. The purpose of this study is to enhance seed germination and grow vigorous seedlings of *Terminalia chebula* Retz.

Materials and Methods

The study was carried out at BAU-GPC, Bangladesh Agricultural University, Mymensingh, Bangladesh situated at the intersection of the 23°29´27.3768´´N latitude and 89°25´16.0860´´E longitude during the period from March to July 2020. Optimum matured, 900 uniform and disinfected fruits of Terminalia chebula Retz were collected from BAU campus and fruits were depulped at two ends with a sharp knife in such a way that the embryo was not damaged before soaking or sowing uniform and disinfected fruits of Terminalia chebula Retz were collected from BAU campus and fruits were depulped at two ends with a sharp knife in such a way that the embryo was not damaged before soaking or sowing. The pre-sowing treatments used in the experiment were: C_1 = without soaking seeds; C_2 = Seeds soaking in normal water for two (02) days, C_3 = for four (04) days; C_4 = for six (06) days; C_5 = soaking in normal cow dung slurry for six (06) days. Four sowing times, viz on collection date (P_1), after 10 days of collection (P_2); after 20 days of collection (P_3) and after 30 days of collection (P_4). A Randomized Complete Block Design (RCBD) was adopted for the study with three replications.

Growing media, seed sowing, intercultural operations and protection measures

The sandy loamy soils were collected, sieved (≤3 mm) and mixed with decomposed cow dung at a ratio of 3:1, after that filled in polybags (12.5 cm × 15.25 cm). To facilitate

aeration and proper drainage, several perforations were made in the polybags before filling them. One seed was sown in each polybags by the dibbling method in the germination media with a depth of 0.5 cm. Seeds and seedlings were protected from hot sun, heavy rain, birds, rodent pest, ants, termites and fungal infection. Watering, weeding and loosening of soil were done regularly to obtain maximum germination and growth of seedlings.

Data collection

Germination percentage

Seed germination percentage was calculated using the following formula:

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Number of Seeds sown}} \times 100$$

Germinating energy

Germinating energy (GE) was calculated based on the percentage of the total number of seeds that had germinated when the germination reached its peak (Zazai *et al.*, 2018).

$$\text{Germinating energy (GE)} = \frac{\text{Number of seeds germinated up to time of peak germination}}{\text{Total number of seeds sown}} \times 100$$

Survival percentage

The survival percentage of each treatment was recorded at 120 days after seed sowing. The survival percentage was calculated by using formula as given (Zazai *et al.*, 2018) below:

$$\text{Survival percentage of seedlings} = \frac{\text{Number of survived seedlings}}{\text{Total number of seedlings}} \times 100$$

Shoot height, leaf number and biomass

At the end of the experiment, all seedlings were measured for height and a total number of leaves in each seedling was counted. Ten seedlings from each replication were randomly selected and uprooted very carefully to estimate the seedling biomass. The uprooted seedlings were then separated into leaves, shoot and root components and were dried in an electric oven at 70°C until the constant weight was obtained for studying biomass productions in different pre-sowing treatments.

Vigor index

Seedling vigor index (VI) was calculated according to Abdul Baki and Anderson (1973) as germination percentage × (shoot length + root length).

Statistical analysis

Data were statistically analyzed by using computer software Microsoft Excel and Statistix.10 to explore possible treatment variations. The Least Significant Difference values were used for the analysis.

Results and Discussion

Germination percentage

Significant variation was observed on the germination percentage of *Terminalia chebula.* The highest germination percentage (85.25%) was ascertained from seeds soaked in cow dung slurry for six days and the lowest (63.00%) was recorded from control (Table 1). Hossain *et. al*. (2005a) noticed that seeds soaking in water for various periods significantly enhanced seed germination and seedling growth of *Terminalia chebula* and the result support the preset findings. Vigorous and higher survival percentage was observed in seeds treated by cow dung. The highest germination percentage (81.37%) was observed when seeds were sown after 10 days of collection and the lowest (70.20%) in seeds sown in 30 days after collection (Table 1). For combined effect of several pre-sowing treatments and seeds sowing time, the highest germination percentage (93.00%) was noticed in sown seed after 30 days of collection with six days soaking in cow dung slurry and the lowest germination percentage was recorded (60) from no treatment and sown seeds after 30 days of collection (Fig. 1). Our results are in conformity with similar study in other tree species like *Zizyphus mauritiana* (Singh *et al.*, 2004). Usually the seeds of legumes with hard seed coats show enhanced germination when various pre-sowing treatments are used (Ajiboye *et al.*, 2009).

Germination energy

Germination energy varied from 28.33% to 43.41% among the treatments. The highest germination energy was found in soaking in normal cow dung slurry for six days (43.41%) and the lowest 28.33% was in Control (Table 1). In case of sowing time after seeds collection, the highest germination energy (39.60%) was in seeds which were sown after 10 days of collection and lowest 34.46% was in 20 days of collection (Table 1). For combined effect of several pre-sowing treatments and seeds sowing time, the highest germination energy (53.67%) was observed in C_5P_4 followed by C_5P_2, C_3P_4 and C_4P_2 which was significantly higher than control. The lowest germination energy was recorded (20.00%) from C_1P_4 (Fig. 1). The findings of the present study showed the similarity of Jackson (1994) that germination speed, germination percentage, and seedling growth of *T. chebula* Retz. Significantly increase when seeds are soaked in water for 48h compared to without soaking. The results of the present study are consistent to Rashid *et al*., 1990.

Survival percentage of seedlings

The highest survival percentage of seedlings was found in soaking seeds in normal cow dung slurry for six (06) days (85.65%) and lowest (47.50%) was in Control (Table 1). Sowing times according to days after collection of seeds, the highest survival percentage (76.71%) was noted in seeds sown after 30 days of collection and the lowest (65.83%) was in seeds sown on collection date (Table 1). For combined effect of several pre-sowing treatments and seeds sowing time, the highest survival percentage (92.86%) was observed in C_5P_4 and the lowest was (40.00%) recorded from C_1P_1 (Fig. 1). Vijayalakshmi and Renganayaki (2017) conducted study about survival percentage of

Pterocarpus santalinus L. that the week acids, digestion of thin and strong veins by the microbes present in cow dung, both together might have resulted in the opening of pores; entry of growth stimulants of cow dung and adequate water through the opened pores might have resulted in positive performance.

Table 1. Effect of seed soaking and collection time on germination, survival percentage, leaf number and shoot length of *Terminalia chebula* Retz

Treatment	Germination percentage	Germination energy (%)	Survival percentage	Number of Leaf	Shoot height (cm)
C_1	63.00	28.33	47.50	36.00	15.04
C_2	67.75	37.71	59.13	42.60	20.06
C_3	74.24	39.99	82.13	41.11	24.00
C_4	81.91	32.83	84.19	43.65	22.55
C_5	85.25	43.41	85.65	51.38	24.75
$LSD_{0.01}$	1.64	1.08	1.45	1.45	1.43
Level of significance	**	**	**	**	**
P_1	71.80	35.70	65.83	38.70	18.60
P_2	81.37	39.60	69.82	47.51	23.00
P_3	73.40	34.46	74.19	42.45	20.18
P_4	70.20	36.66	76.71	43.90	25.40
$LSD_{0.01}$	1.35	0.97	1.30	1.38	1.28
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability

C_1 = without soaking seeds; C_2 = seeds soaking in normal water for two (02) days, C_3 = for four (04) days; C_4 = for six (06) days; C_5 = soaking in normal cow dung slurry for six (06) days.

P_1 = Seeds sowing on collection date; P_2 = sowing after 10 days of collection; P_3 = sowing after 20 days of collection; P_4 = sowing after 30 days of collection

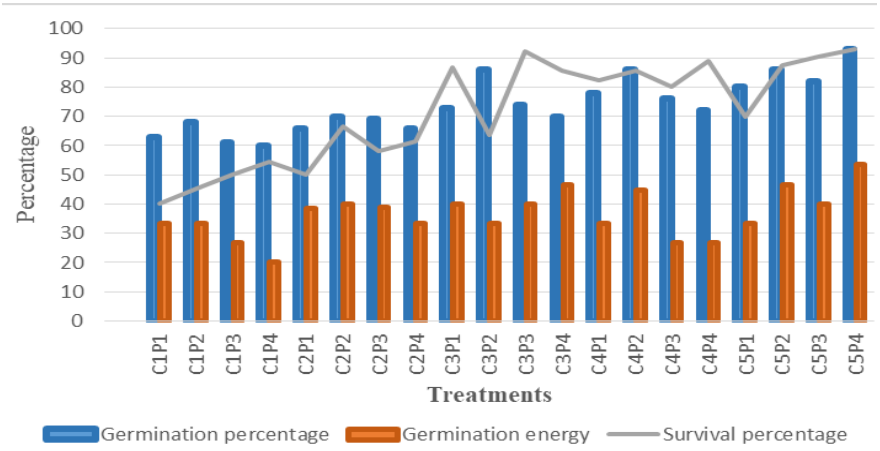

Fig. 1. Germination percentage, germination energy and survial percentage under several pre-sowing treatments and sowing time of *Terminalia chebula*

Number of leaves

The highest number of leaves (51.38) of the seedlings was found in soaking seeds in normal cow dung slurry for six (06) days and the lowest (36.00) in control (Table 1). For several seed sowing time, the highest leaf number 43.90 was in seeds were sown after 10 days of collection and the lowest 38.70 in seeds sown in collection date (Table 1). In case of several pre-sowing treatments and seeds sowing time, the highest leaf number was in C_5P_4 (60) and the lowest 32.50 was recorded in C_1P_4 (Fig. 3). Hossain *et al.,* (2005b) reported that average number of leaf per seedling of *Terminalia bellirica* varied significantly when the seeds were treated. Hossain (2006) mentioned that the number of leaves was positive response by seed treatment of *Gliricidu sepium* (Jacq.).

Shoot height

Shoot height of the seedlings developed under treatments was the highest 24.75 cm in soaking seeds in normal cow dung slurry for six (06) days and the lowest (15.04 cm) in control (Table 1 and Plate 1). Hossain *et al.,* (2013) observed the maximum total height of the seedlings of *Terminalia chebula* Retz. in depulped seeds soaked in cold water for 72 hrs. For several seed sowing times, the highest shoot height 25.40 cm was in P_4 and the lowest 18.60 cm was in seeds sown in collection date (Table 1). For combined effect of several pre-sowing treatments and seeds sowing time, the highest shoot height (32.00 cm) was observed in C_5P_4 followed by C_5P_2, C_3P_2 and C_3P_4 (Fig. 2). The lowest shoot height of seedlings was recorded (12.00 cm) from C_1P_1. Nadukeri *et al.,* (2018) investigated that seeds of *Annona reticulata* L soaked in water for 96 hours can be used to induce better germination and seedling growth. The rapid growth seedlings in cow dung slurry treatment might be due to the presence of growth promoting substances (auxin) and nutrition (Shinde and Malshe 2015).

Root length

Root length of the seedlings was the highest (28.00 cm) when seeds were soaked in normal cow dung slurry for six (06) days and the lowest in control (22.05 cm). For seed sowing times, the highest root length (26.05cm) of seedlings were observed when seeds were sown after 20 days of collection and the lowest 22.65 cm was in collection date (Table 2). For combined effect of several pre-sowing treatments and seeds sowing time, the highest root length (36.50 cm) was observed in C_5P_4 and lowest root length was recorded (18.00 cm) from C_1P_1 (Fig. 2).

Vigor index

The highest vigor index of the seedlings under treatments was the highest in soaking seeds in normal cow dung slurry for six (06) days (4496.94) and the lowest was in control (2336.67). For several seed sowing times, the highest vigor index (3845.10) was in sown seeds after 30 days of collection and the lowest was found in collection date (2961.75). For combined effect of several pre-sowing treatments and seeds sowing time, the highest vigor index (6217.00) was observed in C_5P_4 and the lowest was recorded

(1890.00) from C_1P_1. Pampanna and Sulkeri (2001) mentioned that the use of bio-regulators by cow dung enhance seed germination and seedling vigor of sapota.

Table 2. Effect of seed soaking and collection time on vegetative growth of *Terminalia chebula* Retz

Treatment	Root length (cm)	Vigor Index	LDW (g)	SDW (g)	RDW (g)
C_1	22.05	2336.67	1.41	2.12	0.84
C_2	23.84	2974.23	1.97	2.96	1.02
C_3	26.00	3712.00	1.81	2.86	0.95
C_4	25.00	3894.70	1.94	3.05	1.12
C_5	28.00	4496.94	2.04	3.37	1.17
$LSD_{0.01}$	1.67*	179.75	0.09	0.09	0.04
Level of significance	*	**	**	**	**
P_1	22.65	2961.75	1.51	2.48	0.94
P_2	24.25	3845.10	2.04	3.22	1.12
P_3	26.05	3393.28	1.74	2.65	1.02
P_4	25.50	3573.18	1.96	3.01	1.07
$LSD_{0.01}$	1.49	160.77	0.08	0.08	0.04
Level of significance	*	**	**	**	**

** = Significant at 1% level of probability

C_1 = without soaking seeds; C_2 = Seeds soaking in normal water for two (02) days, C_3 = for four (04) days; C_4 = for six (06) days; C_5 = soaking in normal cow dung slurry for six (06) days.

P_1 = Seeds sowing on collection date; P_2 = after 10 days of collection, P_3 = after 20 days of collection and P_4 = after 30 days of collection

LDW= leaf dry weight, SDW= shoot dry weight, RDW= root dry weight

Fig. 1. Growth performances of *Terminalia chebula* Retz. seedlings germinated under several sowing time

Biomass production

Statistically significant difference was found on dry weight of leaves, shoot and root of *Terminalia chebula Retz.* seedlings (Fig. 3). The highest leaf dry weight (2.04 g), shoot dry weight (3.37 g) and root dry weight (1.13 g) were in the treatment of cow dung slurry for six (06) days and the lowest in control (1.41 g, 2.12 g, 0.84 g respectively). For several seed sowing times, dry weight of leaves, shoot and root of *Terminalia chebula Retz.* seedlings were found the highest 2.04, 3.45, 1.42 g, respectively in the treatment sown seeds after 10 days of collection and the lowest recorded in seeds sown in collection date (1.51, 2.48 and 0.94 g respectively). The results of some study regarding the seedling growth and biomass production of *Terminalia chebula Retz.* seedlings mentioned by Hossain *et al.*, 2005a that the leaf dry weight, and shoot dry weight of *Terminalia chebula Retz.* seedlings were significantly enhanced by soaking of seeds in water.

The highest dry weight of leaves, shoot and root of *Terminalia chebula* Retz. seedlings under combined effect of soaking duration and seeds sowing times were found 2.74 g, 4.36 g and 1.34 g respectively in the treatment C_5P_4 and the lowest in C_1P_1 (Fig. 3). Kumar (2016) reported that the highest dry weight of root and shoot of *Terminalia bellirica* were recorded when seeds were soaked in cow dung slurry for 72 hrs. Hossain *et al.*, (2013) observed the average biomass of *Terminalia chebula* Retz. seedlings in depulped seeds soaked in water for 48 hours.

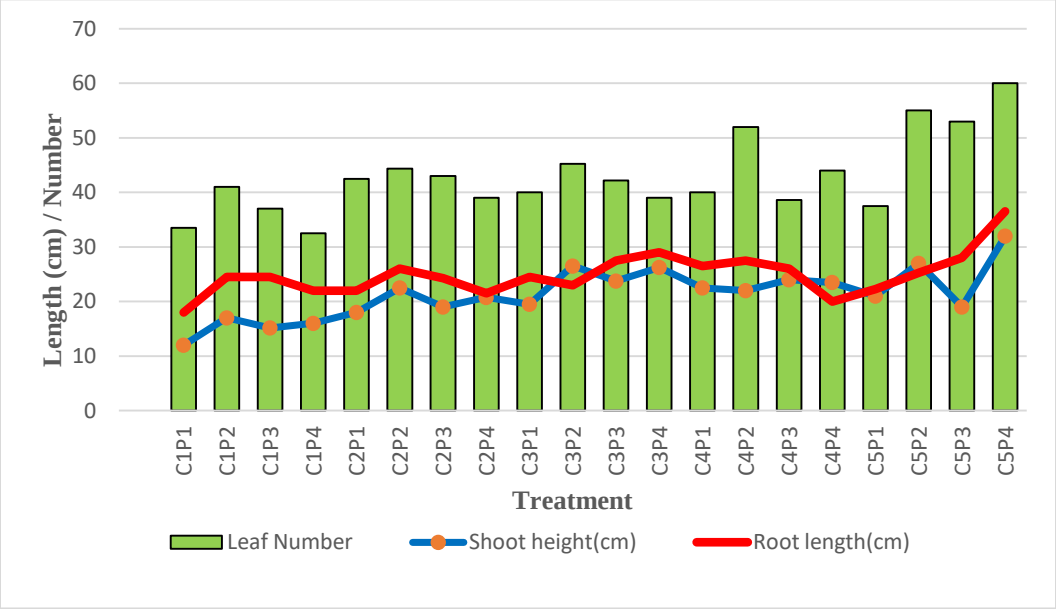

Fig. 2. Leaf number, shoot length and root length under several treatments of *Terminalia chebula Retz.*

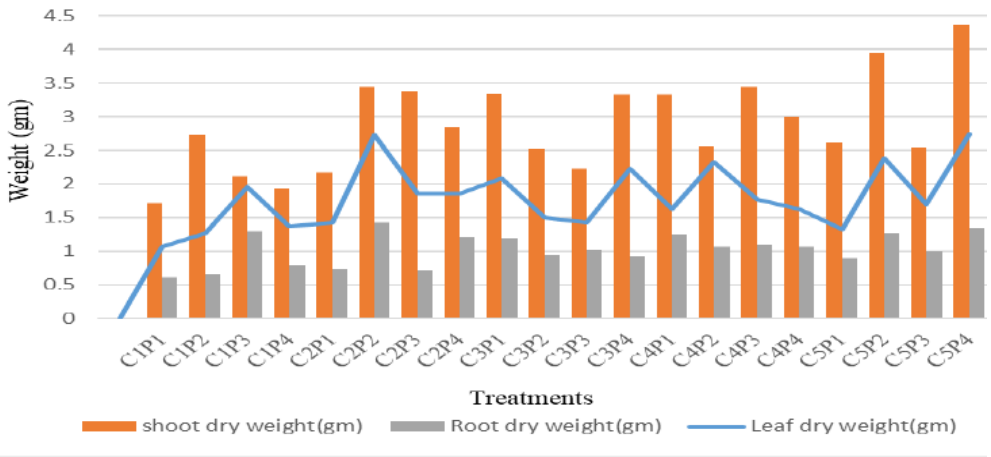

Fig. 3. Shoot dry weight, root dry weight (gm) and leaf dry weight of *Terminalia chebula*

Conclusion

From the study, it can be concluded that after 30 days of fruit collection, seeds soaked in cow dung slurry gave better germination rate (93%) and vigorous seedling growth of *Terminalia chebula* Retz. Considering the initial seedling growth performance, vigor index and dry matter of the seedlings, seeds soaked in cow dung slurry for six (06) days may be recommended for this species for maximum seed germination and seedling growth performance in the nursery. In summary, the results have suggested that seeds soaking in cow dung slurry for six days after 30 days of fruit collection can be used for propagation of *Terminalia chebula* Retz.

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THE ROLE OF RADIO AND TELEVISION IN THE DISSEMINATION OF AGRICULTURAL TECHNOLOGIES AMONG FARMERS OF BANGLADESH

S. Das*, K.U. Ahmed and M.A. Awal

Bangladesh Agricultural Research Council (BARC)
Farmgate, Dhaka. Bangladesh

Abstract

Radio and television are the most influential mass media to stimulate farming community to proper direction of their farming works. These two powerful media have proved to be most useful ICT tools in the field of agricultural information source. Different studies reveal that farmers obtained right and time bound information from radio and television channels. This study was carried out to assess the role of radio and television in the dissemination of agricultural technologies among farmers in some regions of Bangladesh. It was conducted to assess how radio and television are contributing to the growth of agriculture sector. The study also reveals some problems faced by the farmers in using radio and television. A random sampling technique was used on 1170 respondents to collect the data through a well structure questionnaire. The study results point out that the radio and television had an effective role in improving awareness and increasing the modern technological knowledge of farmers. The television and radio programs also helped farmers' access marketing information. The study showed that the respondents have different degree of accessibility to different radio and television channels on agricultural programs.

Keywords: Agricultural knowledge, Agricultural technology, Community television, Radio

Introduction

Radio and television are two of the greatest inventions of science which revolutionized communications among all sectors of human lives including agriculture (Jannat, 2018). Radio is the most effective communication medium which becomes evident during disasters and at the inaccessible locations like sea, hilly areas and other remote areas. In Asian countries large number of poor farmers uses radio to get agricultural information (Baig and Aldosari, 2013). Around 300,000 farmers were benefitted from the information broadcasted in the agricultural programs of four TV Channels in Bangladesh (Katalyst, 2018). Radio and television, the most wonderful inventions of science are regarded as the best means of communications. These two powerful media transform communications in a different way for transferring effective agricultural information and technologies. They help the farmers disseminate modern technological information to a wider range of audience which help them to increase their

* Corresponding Author: s.das@barc.gov.bd

agricultural production too. In the field of agricultural information dissemination, radio and television are useful intermediate for farmers to make their appropriate technologies easy access and learn how to effectively utilize them in their farming systems and practices. Here Das (2016) wants to call radio and television the most important media for diffusing the technical, systematic and scientific information to the farmer society.

A number of research interventions have focused on the role of radio and TV in the field of agricultural information dissemination for farmers to take appropriate decision for their farming. Hussain, (2005) exposed that there is need of using new farm technologies to enhance the productivity of agriculture in Pakistan with the help of mass media like radio, television, documentary film and print media. The study by CEDA (2001) on the impact of agricultural programs transmitted by Radio Nepal mentioned that agricultural programs like Sukrabarko Budhi Aamai helped the farmers improve the farming methods in Nepal. Sharma (2010) also stated that agricultural programs transmitted by Radio Nepal had positive impacts in both small and large scale development. Tortermvasana, (2011) found the lack of accessibility to other communication technologies leading to a combination of broadcasting and narrow-casting media to deliver agricultural information in a number of research projects. Irfan *et al.,* (2006); Alam and Haque, (2014) and Murty and Albino, (2012) analyze the contribution of various TV channels on the dissemination of agricultural information to the farmers for their agricultural enrichment. Their findings indicate a positive curve towards the dependency and contribution of TV channels. Buren, (2000) asserted that mass media like TV increased agricultural knowledge and information for good agricultural output. Age and Demenorgu, (2012) exposed that television created awareness and knowledge among farmers about the use of technologies in farming agricultural produce. Nazari and Hasbullah, (2008) believe that in India, Pakistan, Bangladesh, and Sri Lanka the farmers' education is low and therefore, television is one of the effective media of communication for them about the use of different techniques and pesticides in short time. Goyal, (2010) argued that agricultural communities use ICTs in different ways to get information about weather and markets regularly. Sher, (2001) described that TV producers invite agriculture experts to suggest on new techniques and methods of sowing, ploughing, harvesting and seeding the crop.

The study of Okwu *et al.,* (2007) revealed that majority of the farmers liked to listen to agriculture programs on agronomic, plant production and livestock information through radio. Ani and Baba, (2009) argued that radio and newspaper could transfer information among the farmers in remote areas and can enhance the knowledge and skills for the development of agriculture. It is found that radio was used to broadcast much useful agricultural content like discussions related to agricultural problems and solutions in Zambia. It is also used to broadcast 14 agricultural programs in multiple languages such as English, Hausa, Igbo and Yoruba in Nigeria. Nyareza and Dick, (2012) stated that community radio can successfully be incorporated into agricultural extension service programs in Zimbabwe for broadcasting agricultural information. Waters *et al.,* (2011) assessed the impact of community radio in Indonesia and concluded that effective radio activities can make a significant change in the community life. Research was conducted on the contribution of community radio movement for conscientization and development

of deprived rural people in various parts of world in general and south Asia (India) in particular.

In Bangladesh, Public television channels are BTV, BTV World and Sangsad Television. There are 29 private television channels in Bangladesh (Wikipedia, 2018). Among the television channels BTV, Channel i, Bangla Vision, ATN Bangla, Mohona TV, Boishakhi TV, My TV, Dipto TV, Ekattor TV etc. have prominent agricultural programs which are popular among farmers, entrepreneurs and interested people.

Many informative agricultural programs are broadcast on radio and public and private channels of television in Bangladesh. Mati o Manush, Banglar Krishi, Krishi Dibanishi, Bangladesh Krishi, SAARC Krishi, Hridoye Mati o Manush, Hridoye Mati o Manusher Dak, Fire Cholo Matir Tane, Shamol Bangla, Shabuj Bangla, Dipto Krishi, Matir Shubash, Shonali Din, Krishi Jog, Khamarbari etc. are broadcast on television. Desh Amar, Mati Amar, Krishi Samachar, Amar Desh, Shonali Fasal, Krishikatha etc. are broadcast on radio (Alam *et al.*, 2012; DAE, 2016). Agricultural news is also broadcast embedded in the national and regional news. Three categories of radio transmission are available now in Bangladesh: Bangladesh Betar, FM Radio and Community radio (abid). Seventeen community radio programs are in existence in the country (abid). The community radio established in Amtali, Barguna is dedicated for agricultural programme broadcasting and the slogan of this community radio is 'My Radio My Voice' (AIS, 2018).

Materials and Methods

The study was conducted on farmers from seven administrative divisions of Bangladesh- Dhaka, Chittagong, Rajshahi, Khulna, Barisal, Rangpur and Sylhet. The sampling covered almost 39 out of 64 districts of the country. Questionnaire, interviews and FDG were employed as data collection instruments in the study for data collection. Questionnaire was the main instrument served among rice, vegetable and fish farmers. Random sampling was used in the study. One thousand and seven hundred is the sample size of the present study. Semi-structured interviews were employed to triangulate the data. The arrangement of interviews was assisted by the local farmers. Seven Focus Group Discussions (FGDs) were conducted for generating information on collective views. Extensive field visits in those areas were also added. The data for the present study were collected at the end of 2019. All the questionnaires have been administered in the face-to-face sittings. While administering the questionnaire survey in different sites, the researcher collected the production and income information on rice, vegetable and fish. This production was the dependent variable, whereas radio and television programs were independent variables. The data were analyzed with statistical inference. Statistical Package for Social Sciences (SPSS) version 23.0 was used to interpret the quantitative data.

Results and Discussion

This section describes the sources of information from radio and television. It analyses access to television, and farmers' favourite television programs with channels. Its different subtitles describe different technologies access to radio, radio listener with

their station and programs along with weather forecast, crop variety selection. At present a great number of farmers possess a television set and most of them watch it regularly. Those who do not have a TV set can have an access to watching TV programs in a common place like tea stall or in neighbours' house. The number of TV watching farmers is more than that of TV owners.

The Table 1 illustrates that 60% of the respondents have television sets and 40% don't have any TV sets. About fifty percent farmers do not have television sets but next finding says more than 40% farmers watch TV programs. Communication gap is to some extent filled by TV which plays a vital role in the promotion of agriculture and rural development. So the usefulness of TV programs can't be denied.

Table 1. Frequency distribution of having television sets

Having Television	Number	%
Yes	702	60
No	468	40

The Fig. 1 shows that 50% of the respondents opined that TV programs are very useful, 39% think that these are also useful and 10% think are in between the two. Lastly 1% of the farmers think that these programs are not useful at all. The Fig.1 verifies that half of the farmers realize the necessity of TV programs.

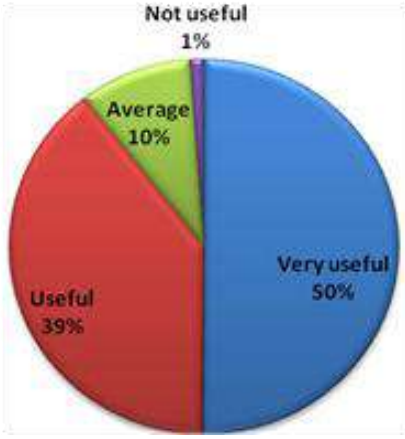

Fig. 1. Usefulness of TV programs

Farmers watch TV for different purposes. They watch TV for agricultural programs too. Almost all TV Channels telecast some programs related to agricultural at least once a week. Channel I and BTV have more focus on agriculture and the programs are becoming more popular and penetrated into urban and rural life as these channels broadcast special bulletin on agricultural activities and development every day. These agricultural programs have been graded by the farmers with a view to assessing their

needs. The results were showed in Fig. 2. About 41% of the farmers consider that these services are useful, about 20% consider them to be very useful but some farmers (35%) think that these services are neither useful nor useless. However, a small portion of the respondents (4%) are in favour of assessing that the services are not useful at all.

Farmers choose different programs for different purpose. Some of their favourite programs are mentioned here as news, movies, agricultural programs and some other programs like drama, short film, reality show (agriculture success stories). Farmers of both groups opt their favorite TV programs at will.

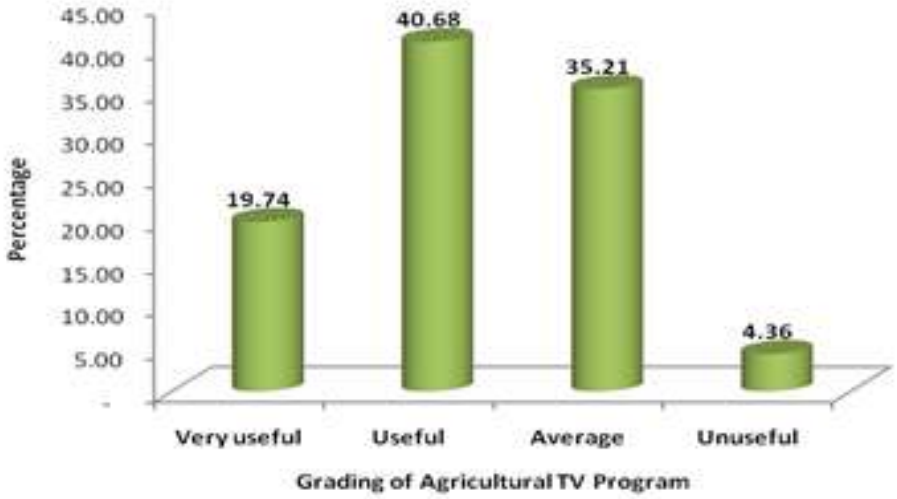

Fig. 2. Grading of agricultural TV programs

The Table 2 shows that about 74.36% farmers listen to news. Agricultural programs are watched by about 17% farmers. It is proved that farmers are more conscious of listening news than watching agricultural programs. Movies are watched by 17.09% farmers and few farmers watch other programs. Farmers watch TV for other purposes too. Out of 1170 farmers, 94.87% watch TV regularly and 5.13% do not watch TV programs. This percentage indicates that farmers have tendencies for watching TV regularly than they own TV sets (Table 3).

Table 2. Frequency distribution of television programs

Television Programs	Number	%
News	870	74.36
Movies	80	6.84
Agricultural Programs	200	17.09
Others	20	1.71
Total	1170	100.00

In the past, radio was the only common source of entertainment for the rural people when TV set was very expensive for them. In the early twentieth century TV occupied its place. However, very recently Band radios with FM, community and Krishi radios have become more popular among the farmer society. Mobile radio is another addition to easy and cheap access to information and entertainment world. The Table 4 illustrates that 47% of the respondents have access to radios whereas more farmers 63% don't have any access to radio but few listen to others' radios.

Table 3. Frequency distribution of television watching

Status of TV Watching	Number	%
Yes	1110	94.87
No	60	5.13
Total	1170	100.00

Table 4. Frequency distribution of access to radio

Access to radio	Number	%
Yes	550	47
No	620	63

Farmers' radio listening period varies from one service area to another. Famers of some area listen to radio for longer and some for shorter. Listening time is divided into three periods 1-10 year, 10-20 year and 20-30 year. Here the ICT farmers are regarded as long time radio listener. The Table 5 shows farmers' listening period (radio). 47% of the total respondents (1170) listen to radios whereas 63% of them do not have access to radios. 49.64% of farmers listen to radio programs for one to ten years. This is the highest percentage of radio listening farmers. For 10 to 20 years, radio is listened to by 45.64% farmers. This group is the second highest radio listening group of respondents. However, 30 to 40 years of listening radio is done by 4.73% farmers. It is also shown in the table that the farmers are more conscious of listening period.

Table 5. Frequency distribution of radio listening

Period	Number	%
01-10 years	273	49.64
10-20 years	251	45.64
20-30 years	26	4.73
Total	550	100.00

Farmers of different regions listen to different radio at different degrees of times. Bangladesh Betar, F M Radio, Regional Radios and Community Radios are listened to by the farmers for amusement, recreation and agricultural activities. Among these stations, they prefer Bangladesh Betar for the reason that the station is available to them and its frequency is

smooth and after all, they are habituated to listening Bangladesh Beter. The Table 6 indicates that 550 farmers listen to radio and out of them 69.09% listen to Bangladesh Betar. In comparison, Bangladesh Betar is listened to more farmers and 12.73% farmers listen to Community Radio, 12.72% FM Radio and 5.45% Regional Radio.

Table 6. Frequency distribution of radio station

	Number	%
Bangladesh Betar	380	69.09
FM Radio	70	12.72
Regional Radio	30	5.45
Community Radio	70	12.73
Total	550	100.00

Agro metrological information is an integral part of farm practice. Farmers use their common indigenous knowledge in farming. In fact, indigenous knowledge is a big resource for weather forecast information. Farmers' farming strategy and production largely depend on proper source of weather forecast that can change their production radically. Therefore, they are very eager to obtain weather forecast information from many sources. The information sources have been changed and are changing day by day. Some are traditional means and some modern sources have been added. The respondent groups still depend on TV, a widespread source of modern entertainment, for weather forecast. This service is more important for coastal farming as the region is prone to frequent cyclone attack for the Bay of Bengal. About 55.13% information about weather forecast comes from TV (Table 7). The second option is radio. 330 farmers gather weather news from radios including mobile FM stations. Therefore, it is an important finding in the study that 13.68% farmers play an important role in delivering reports of humidity, cloud, rainfall drought, fog, heat etc. Call center plays a little role in providing the farmers with this necessary information. Radio and TV are chosen as source of information more in ICT areas than non-ICT areas.

Table 7. Frequency distribution of the means for weather forecast by service area

	Number	%
Radio	330	28.20
Television	645	55.13
Ext. worker	160	13.68
Call centre	25	2.14
Total	1170	100.00
χ^2	= 185.46, Sig = 0.000	

Source of information for market price is a vital issue for the farmers. Findings from FGD reveal that farmers get the information from various sources- traditional sources and modern sources. At present, radio, television, mobile phone, call centers and ICT based information centers along with different websites are preferred by the farmers. For example, Aktar Hossain, an active member of Dariapur AICC, Magura Sadar and Abdul Hye, another active member of Nrisinghopur AICC of Jenaidah Sadar asserted that they use radio, TV, mobile communication more for obtaining the information of market price of agricultural commodities. They also informed that different zilla and Upazila wise websites (such as DAM website, MoA) are effective for wholesale and retail price of various agricultural commodities. The Fig. 3 illustrates that ICT farmers obtain information 65.32% from radio, 68.4% from television, 61.39% from mobile whereas 27.09% from extension workers, 21.23% from progressive farmers and local agents. 100% information comes from call center. So, traditional farmers depend on the extension workers, progressive farmers and local agents for the information of market price.

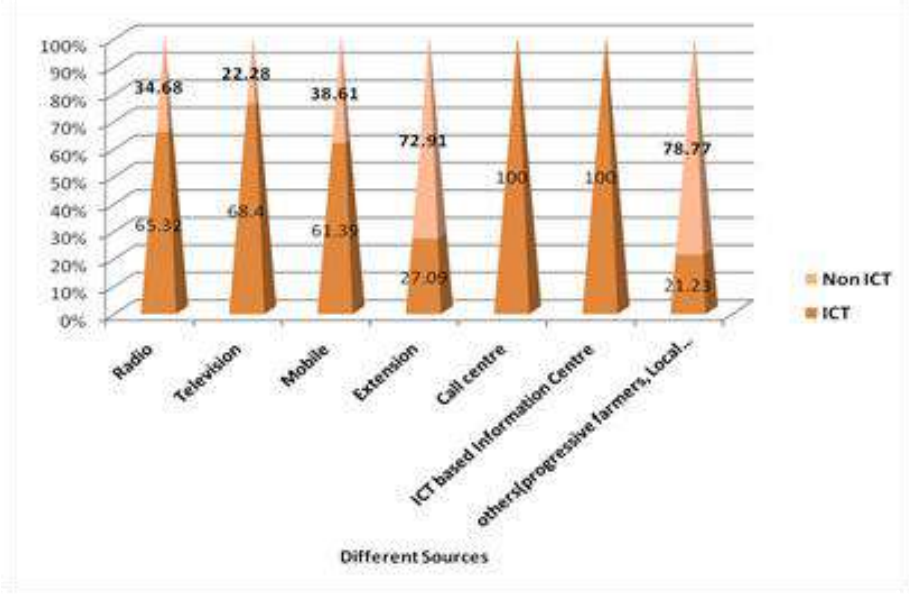

Fig. 3. Sources of information for market price

Conclusion

Radio & television have a positive role in increasing level of knowledge of the farmers and adoption of improved agricultural technologies. Regardless of their potential, the use of radio and television as sources of agricultural knowledge among farmers in Bangladesh is still low. Inadequate ownership of these tools and poor infrastructure & poor number of programs limiting the level of usage. It is therefore recommended that radio and television stations may promote their agricultural programs before airing them and should also increase the number of agricultural programs to be aired per week. The Government and the private sector should work together and improve the radio and television infrastructure in the country. Television has effective role in increasing

agricultural knowledge of the farmers, increasing production and agricultural income of the farmers. The programs of radio and television may be more frequent for agricultural development through their use along with other agricultural extension methods and integration with other technologies. Effective measures should be taken to overcome the constraints faced by the farmers in using radio and television.

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EVALUATION OF CHILLI GERMPLASM IN THE KHARIF SEASON

M.I. Haque[1], S. Ishtiaque[2], M.M. Islam[3*] and M.A. Rahim[4]

[1]Regional Spices Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur; [2]On-Farm Research Division, BARI, Gazipur; [3]Plant Pathology Division, BARI, Gazipur; [4]Department of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh. Bangladesh

Abstract

Thirty-six genotypes of chilli (*Capsicum* sp.) were evaluated at the Regional Spices Research Centre, BARI and Gazipur during February 2017 to November 2018 to identify the promising genotype(s) for variety development process. Distinct variation among the genotypes was observed in all the qualitative parameters except seed color and fruiting behavior. The genotype CO 525 and CO 631 took relatively short times for the 1st flower bud opening showing 44 and 42 days respectively, while the genotype CO 633 & CO 648 took 125 & 110 days for the 1st flowering and 130 and 141 days for the first fruit set Plant height ranged from 47.02 cm (CO 002) to 111.35cm (CO 525). The maximum number of primary branches was recorded in CO 648 (11.33/plant) and the lowest in CO 630 (4.00/plant). Single fruit weight ranged from 1.46 g (CO 626) to 11.70 g (CO 631) while fruit length varied from 2.90 cm (CO 645) to 10.63 cm (CO 002 & CO 631). Pedicel length was longest in CO 643 (5.06 cm) and shortest in CO 639 (1.53 cm). The highest pericarp thickness was recorded from CO 640 (4.72 mm) and the lowest in CO 635 (0.63 mm). The larger weight of pericarp was obtained from CO 640 (6.00 g) and the smaller from CO 645 (0.24 g). The genotype CO 631 had the maximum number of fruits/plant (308.00) and the genotype CO640 had the minimum number of fruits/plant (38.00). The genotype CO 631 produced the maximum weight of fruits/plant (606.43 g) which was identical to CO 525 (465.50 g/plant). The highest number of fresh seeds was obtained from CO 631 (89.66/fruit) and it was the lowest in C0 646 (20.33). The highest weight of fresh seeds/fruit was obtained from CO 631 (0.63 g) and the lowest from CO 645 (0.11 g). The genotypes CO 631 had the maximum 1000-fresh seed weight (5.20 g) which was statistically similar to BARI Chilli-2 and the minimum in CO 647 (1.50g). The maximum fruit yield was recorded with CO 631 (23.04 t/ha) followed by CO 525-1 (18.25 t/ha), CO 5251 (17.69 t/ha), CO 003 (17.13 t/ha), respectively while it was minimum in CO 002 (4.65 t/ha). The results revealed that the genotypes significantly differed in most of the parameters which offers a good scope for selection of better genotypes as parents for the desired traits.

Keywords: Chilli, Germplasm, Kharif season, Pericarp, Yield

* Corresponding Author: monirulbari@yahoo.com

Introduction

Chilli (*Capsicum* sp.) is a vital commercial crop, cultivated for vegetable, spice, and value-added processed products (Kumar and Rai, 2005) and is an important constituent of many foods, adding flavour, and colour, vitamins A and C and pungency and is, therefore, indispensable to world food industries. It can be used medically for the treatment of fevers, colds, indigestion, constipation and pain killing (Dagnoko *et al*., 2013) and also used by the security agencies in the preparation of tear gas. Chilli production in Bangladesh is mainly under rain-fed conditions resulting in a drop-in production and availability of fresh chilli during the monsoon. The consequence of this shortage in the supply of chilli is an increase in the market price of both fresh and dried fruit. The low production may be attributed to low soil fertility, pests and diseases, unavailability and/or high cost of irrigation, inadequate knowledge of improved technologies coupled with the use of unimproved varieties (MiDA, 2010). Most of the chilli varieties farmers cultivate unimproved chilli varieties that are low yielding. Chilli in Bangladesh cultivated both in Rabi and Kharif season. Total production of chilli in Bangladesh was about 1.30 lac metric tons cultivated in 1.02 lac ha of land (BBS, 2016).

Even though chilli is very popular in all the agro-ecological zones of Bangladesh, very little has been achieved in the improvement of the indigenous cultivars probably because of the limited information on the genetic diversity within the species. It has been observed that farmers select and disseminate seeds of elite genotypes to fellow farmers, and ultimately cultivated as various local names. These materials are named based on several criteria, such as the origin of the genotype, pungency, uses, size and shape of fruits. This ptactice has resulted in the treatment of some genotypes as different cultivars in different localities. For this reason, estimation of the genetic diversity among cultivated genotypes has become the fundamental requirement of the crop industry, purposely, for identification and crop improvement (Tam *et al*., 2005). Phenotypic characters such as fruit weight, fruit length, pericarp thickness, plant height etc., have been used to distinguish between chilli germplasm and classify them into groups (Fonseca *et al*., 2008; Weerakoon and Somaratne, 2010). The use of phenotypic characters in describing and classifying germplasm is the fundamental step in any characterization programme (Smith and Smith, 1989). However, studies have shown that morphological characterization in chilli, though a simple method of detecting differences in genotypes is highly influenced by environmental factors and may not be able to distinguish between individuals that are closely related (Gilbert *et al*., 1999; Geleta *et al*., 2005). In Bangladesh the study regarding collection, evaluation, characterization, selection and conservation of genetic resources of chilli is hardly been emphasized in the past. Since there are different types of chilli germplasm distributed throughout the country, it is necessary to collect and characterize them with a view to develop new variety.

Materials and Methods

The present investigation was carried out at Regional Spices Research Centre (RSRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during the month from February 2017 to November 2018. The location of the site was 24° North latitude to

90.43° East longitude with an elevation of 8.4 m from sea level and about 35 km north of Dhaka. The experimental field was medium high land. It was located in the center of Madhupur tract and the soils were developed later for research purpose. Thirty-six chilli germplasm, twenty indigenous and 15 exotics, were collected from different areas of the country including Spices Research Centre, BARI, and Gazipur. Background of the germplasm is presented in Table 1. The seeds were soaked in water for 24 hours in order to facilitate germination. They were dried and treated by Autostin @ 2 g/kg of seed to minimize the primary seed-borne diseases. The seeds were sown on beds in lines maintaining a depth of one centimetre for easy emergence. Each bed was then covered with one layer of newspaper to increase the soil temperature to facilitate germination and prevent evaporation. The seeds were nursed in seed boxes on 17th February, 2017 using potting mix sterilized by steam sterilization method. The potting mix consisted of two parts of top soil to one part of well decomposed cow dung. Nursery management practices, such as shading, forking, thinning, watering and hardening off, were carried out appropriately to ensure that healthy seedlings were produced. The field was ploughed, harrowed and ridged at a spacing of 75 cm between ridges. After this the trial was laid out and transplanted. Transplanting was done in the cooler period of the day (evening) after which watering was done to reduce transplanting shock. The experimental design used was the augmented design with single rows of each germplasm. The length of each row was 5 m long with inter and intra row spacing of 75 cm and 50 cm respectively. The germplasm were randomly assigned to plots by means of drawing lots to avoid bias. Seedling of 35 days old was transplanted on 23th March 2017 representing Kharif season (Mid-March to August). The experimental plots were manured and fertilized. Cow dung, Urea, TSP, MoP and Gypsum were used as 10 ton, 210, 330, 200 and 110 kg ha^{-1}, respectively. The total amount of Cow dung, TSP, Gypsum and one third of MoP were applied during land preparation. The rest MoP and Urea were applied at three equal splits after 20, 50 and 70 days of transplanting (FRG, 2012). The fertilizer application method was side placement which was done at about 5 cm away from the plants.

Table 1. Chilli germplasm codes with sources of collection

SL. No.	Germplasm	Source
1.	CO 001	SRC, BARI
2.	CO 002	SRC, BARI
3.	CO 003	SRC, BARI
4.	CO 446	SRC, BARI
5.	CO 446-1	SRC, BARI
6.	CO 525	SRC, BARI
7.	CO 525-1	SRC, BARI
8.	CO 525-2	SRC, BARI
9.	CO 525-3	SRC, BARI
10.	CO 610	SRC, BARI
11.	CO 610-1	SRC, BARI

Table 1. Contd.

SL. No.	Germplasm	Source
12.	CO 611-1	SRC, BARI
13.	CO 611-2	SRC, BARI
14.	CO 613	SRC, BARI
15.	CO 626	SRC, BARI
16.	CO 629	SRC, BARI
17.	CO 630	SRC, BARI
18.	CO 631	The World Vegetable Centre
19.	CO 632	The World Vegetable Centre
20.	CO 633	The World Vegetable Centre
21.	CO 634	The World Vegetable Centre
22.	CO 635	The World Vegetable Centre
23.	CO 636	The World Vegetable Centre
24.	CO 637	The World Vegetable Centre
25.	CO 638	The World Vegetable Centre
26.	CO 639	The World Vegetable Centre
27.	CO 640	The World Vegetable Centre
28.	CO 641	The World Vegetable Centre
29.	CO 642	The World Vegetable Centre
30.	CO 643	The World Vegetable Centre
31.	CO 644	The World Vegetable Centre
32.	CO 645	The World Vegetable Centre
33.	CO 646	SRC, BARI
34.	CO 647	SRC, BARI
35.	CO 648	SRC, BARI
36.	BARI Chilli-2	Released by SRC, BARI

SRC, BARI: Spices Research Centre, Bangladesh Agricultural Research Institute

Weeds were manually controlled using hand hoe at the second and sixth weeks after transplanting was done. Reshaping of ridges was carried out at the fourth and eighth weeks after transplanting with hand hoe. Insect pests and diseases were managed by spraying of Vertimec (Abamectin) 1.8EC @ I ml/L of water, Dithane M-45 (Mencozeb) @ 2g/L of water, Imetaf (Imedacloprid) 20 SL @ 0.5ml/L of water and Sex pheromone trap. The data pertaining to the days to first emergence, days to first flower bud open, days to first flowering, days to first fruit set, plant height (cm), number of branches per plant canopy (cm^2), single fruit weight (g), fruit length (cm), pedicel length (cm), pericarp thickness (cm), weight of pericarp (g), number of fruits per plant, weight of fruit per plant

(g), number of seeds per fruit, weight of seed per fruit (g), 1000 seed weight (g) and yield per hectare (ton)characters were recorded from randomly selected five plants from each plot. The data collected was analysed using Genstat statistical package (9th edition). Frequency distribution was used to classify the germplasm into groups based on the qualitative traits. For the quantitative traits mean, standard deviation, standard error, range and coefficient of variation were calculated using Microsoft Excel.

Results and Discussion

Observed characteristics of thirty-six chilli germplasm are presented in Tables 2, 3 and 4. In the morphological characters, non-significant variation was found on the 1st emergence days under studied germplasm where the thirty germplasm showed in similar value (Table 3). Significant variation was observed on the days to flowering bud open in thirty germplasm (Table 3). Among them, CO 525 and CO 631 took minimum days to flowering bud open (44 and 42, respectively), followed by BARI Chilli-2. However, CO 633 and CO 648 took maximum days for flowering bud open (Table 3). No significant variation was found on the 1st flowering days among the germplasm (Table 3). The germplasm CO 525 and CO 631 required minimum time (59 and 22 days, respectively) for first fruit setting and which was statistically similar to CO 002, CO 525-3, CO 629, CO 632 and CO 633 (Table 3).

The germplasm CO 631 also required minimum time (50 days) for first flowering, while the maximum time for this trait (125 days) was recorded by CO 633 (Table 3). The plant height showed significant variation among the germplasm (Table 3). The highest plant height (111.35 cm) was recorded in while the lowest (47.02 cm) in CO 602. Significant variation was observed on the number of branch per plant in the studied germplasm (Table 3), which varies in the range of 4.00 (CO 630) to 9.66 (CO 610 & CO 634) (Table 3. The single fruit weight varied from 0.1.46 to 11.70 g. The highest single fruit (11.70 g) was collected from CO 631 which was statistically similar to CO 525 (11.33 g). The lowest (1.46 g) was collected from CO 626 (Table 4). Germplasms exhibited significant variation exhibited on the fruit length (Table 4). The longest fruit length (10.63 cm) was recorded from CO 002 and CO 631 which was statistically similar to CO 525 (10.10 cm) and CO 641 (10.00 cm) whereas the shortest was recorded from CO 645 (2.90 cm) (Table 4). The pedicel length showed significant difference with in the germplasm (Table 4).

The germplasm CO 643 gained maximum (5.06 cm) pedicel length which was statistically narrowly similar to CO 646 (4.16 cm). Whereas, the minimum pedicel length (1.53 cm) was recorded from CO 639 (Table 4). Statistically significant difference was found on the pericarp thickness with in the germplasm (Table 4). Generally, pericarp addressed to quality of chilli and minimum thickness encourages to high quality of chilli. For instance, the lower level of pericarp thickness (0.63 mm) was obtained from CO 635

Table 2. Chilli germplasm used for the study with salient morphological characteristics

Germplasm code	Flower colour	Fruit fresh colour	Ripe Fruit colour	Seed colour	Position of fruit	Fruiting behavior
CO 001	White	Deep Green	Red	Straw	Pendant	Single
CO 002	White	Light Green	Dark Red	Straw	Pendant	Single
CO 003	White	Green	Red	Straw	Pendant	Single
CO 446	White	Green	Red	Straw	Pendant	Single
CO 446-1	Purple	Green	Dark Red	Straw	Pendant	Single
CO 525	White	Light Green	Dark Red	Straw	Pendant	Single
CO 525-1	White	Deep Green	Dark Red	Straw	Pendant	Single
CO 525-2	White	Green	Dark Red	Straw	Pendant	Single
CO 525-3	white	Green	Red	Straw	Pendant	Single
CO 610	White	Green	Red	Straw	Pendant	Single
CO 610-1	White	Green	Red	Straw	Pendant	Single
CO 611-1	White	Green	Red	Straw	Pendant	Single
CO 611-2	White	Green	Dark Red	Straw	Pendant	Single
CO 613	White	Green	Red	Straw	Pendant	Single
CO 626	White	Deep Green	Dark Red	Straw	Pendant	Single
CO 629	White	Green	Red	Straw	Pendant	Single
CO 630	White	Green	Red	Straw	Pendant	Single
CO 631	White	Green	Red	Straw	Pendant	Single
CO 632	Purple	Black	Dark Red	Straw	Erect	Single
CO 633	White	Green	Light Red	Straw	Cluster	Cluster
CO 634	White	Green	Red	Straw	Pendant	Single
CO 635	White	Green	Dark Red	Straw	Pendant	Single
CO 636	White	Green	Red	Straw	Pendant	Single
CO 637	White	Deep Green	Red	Straw	Pendant	Single
CO 638	White	Deep Green	Red	Straw	Pendant	Single
CO 639	White	Green	Red	Straw	Pendant	Single
CO 640	White	Creamy White	Red	Straw	Pendant	Single
CO 641	White	Green	Red	Straw	Pendant	Single
CO 642	White	Green	Red	Straw	Pendant	Single
CO 643	White	Green	Red	Straw	Pendant	Single
CO 644	White	Green	Red	Straw	Pendant	Single
CO 645	White	Green	Red	Straw	Pendant	Single
CO 646	White	Green	Red	Straw	Pendent	Single
CO 647	Purple	Black	Red	Straw	Pendant	Single
CO 648	White	Green	Red	Straw	Pendant	Single
BARI Chilli-2	White	Green	Red	Straw	Pendant	Single

Table 3. Performance of growth parameters of chilli germplasm in Kharif season

Chilli germplasm	1st emergence (days)	1st flowering bud open (days)	1st Flowering (days)	1st fruit set (days)	Plant height (cm)	No. of branch/plant
CO 001	7.00	51.00	60.00	70.00	100.74	7.33
CO 002	7.00	59.00	69.00	87.00	47.02	6.33
CO 003	7.00	51.00	59.00	75.00	73.49	5.33
CO 446	11.00	46.00	56.00	47.30	83.42	7.33
CO 446-1	11.00	46.00	58.00	59.54	92.00	7.00
CO 525	11.00	44.00	51.00	59.10	111.35	7.66
CO 525-1	11.00	51.00	58.00	70.00	90.46	7.00
CO 525-2	11.00	49.00	59.00	70.00	104.00	7.00
CO 525-3	11.00	51.00	60.00	82.00	92.31	8.00
CO 610	11.00	46.00	57.00	70.00	107.43	9.66
CO 610-1	11.00	49.00	60.00	74.00	97.47	6.33
CO 611-1	11.00	46.00	57.00	59.40	89.44	8.66
CO 611-2	11.00	46.00	56.00	47.80	98.00	8.33
CO 613	11.00	59.00	69.00	77.00	72.56	7.33
CO 626	11.00	51.00	63.00	81.00	83.66	6.66
CO 629	11.00	42.00	53.00	36.30	83.00	6.33
CO 630	11.00	59.00	69.00	77.00	53.22	4.00
CO 631	11.00	42..00	50.00	22.20	78.72	8.66
CO 632	11.00	77.00	89.00	103.00	100.27	8.00
CO 633	11.00	110.00	125.00	141.00	57.35	9.33
CO 634	11.00	45.00	54.00	19.10	81.59	9.66
CO 635	11.00	50.00	59.00	70.00	67.43	8.66
CO 636	11.00	59.00	69.00	77.00	73.66	8.00
CO 637	11.00	49.00	59.00	71.00	86.11	7.33
CO 638	11.00	59.00	67.00	76.00	57.35	6.66
CO 639	11.00	49.00	59.00	67.40	63.32	6.66
CO 640	11.00	51.00	60.00	69.00	65.42	6.33
CO 641	11.00	45.00	59.00	69.00	82.33	5.33
CO 642	11.00	48.00	58.00	70.00	58.66	6.66
CO 643	11.00	45.00	58.00	69.00	53.30	6.66
CO 644	11.00	51.00	60.00	70.00	84.77	7.00
CO 645	11.00	51.00	60.00	71.00	68.45	6.33
CO 646	11.00	59.00	67.00	76.00	57.71	6.00
CO 647	11.00	45.00	56.00	70.00	80.31	7.00
CO 648	11.00	100.00	110.00	130.00	78.23	11.33
BARI Chilli-2	11.00	41.00	52.00	68.00	87.53	7.33
LSD (5%)	-	1.713	-	3.196	17.52	2.460
LSD (1%)	-	2.298	-	4.288	23.51	3.301
Level of significant	NS	**	NS	**	**	**
CV (%)	0.00	6.91	4.00	7.54	12.73	20.26

** Significant at 1% level of probability

followed by rest of the germplasm. Whereas, the higher level of pericarp thickness (4.72 mm) was observed from CO 640 which was statistically similar to CO 002 (3.58 mm). The weight of pericarp varied from 0.24 to 6.00 g (Table 4). Among the studied germplasm, the maximum weight (6.00 g) was recorded from CO 640 while the lowest from CO 645 (0.24 g). Number of fruits per plant varied significantly, ranged from 38.06 to 308. The germplasm CO 631 produced maximum fruits per plant (308) that was statistically similar to CO 526 while the lowest (38.00) was in found from CO 640 (Table 4). The second highest fruit (290.3) per plant was recorded from CO 446. Highly significant variation was found on the weight of fruit per plant in all germplasm (Table 4). The highest weight of fruit (606.43 g) was recorded from CO 631. The data showed significant variation in respect of all chilli genotypes (Table 4). The maximum seeds per fruit (89.66) were collected from CO 631 which was nearly similar to CO 525. While, the minimum (20.33) was collected from CO 646 (Table 4). Weight of seeds per fruit varied from 0.11 to 0.63 g. However, the maximum quantity of seeds was collected from CO 631 that was statistically similar to CO 525 while the minimum was collected from CO 645 (Table 4).Over all similar trend was occurred in thousand seed weight under all chilli germplasm (Table 4). Nevertheless, the highest thousand seed weight (5.20 g) was recorded from CO 631 that was statistically similar to CO 525 while the lowest (1.50 g) was found from CO 647. The highest yield of green chilli was obtained from the germplasm CO 631 (23.04 t ha^{-1}) followed by CO 525-1 (18.25 t ha^{-1}), CO 525 (17.69 t ha^{-1}), CO 003 (17.13 t ha^{-1}) respectively whereas the lowest yield was recorded from the germplasm CO 002 and (4.65 t ha^{-1}) (Table 4).

From the results it is revealed that most of the growth parameters showed significant variation among the germplasm except for 1^{st} emergence days and 1^{st} flowering days. Among the thirty-six germplasm, CO 525 and CO 631 was advantegious with respect to 1^{st} flowering bud open days, 1^{st} fruit set days, number of branch/plants, canopy (cm^2). The rest of germplasm resulted in late appearance through 1^{st} flowering bud open days which lead to late fruit setting. Such variation might be due to inherent characters coupled with environmental effects. The critical observation of the data of this experiment showed a wide variation in physical characteristics such as plant height was the highest in CO 525 and CO 631. It might be due to environmental effects. Similar result was made by El-Tohamy *et al.*, (2006). Therefore, germplasm with wider canopy diameter might produced more fruits or pods than varieties with narrow canopy due to increasing number of secondary and tertiary branches which were the locations for fruit bud formation. The number of days to fifty percent flowering showed very highly significant ($p<0.001$) difference and as investigation comprised of 36 genotypes of chilli.

Yield parameters had also showed significant variation under thirty-six germplasm. CO 525 and CO 631 germplasm responded with better yield parameter (single fruit weight, number of fruit/plant, weight of fruit/plant, number of seeds /fruits, weight of seed/fruit, thousand seed weight and yield). However, the fewer fruit numbers

Table 4. Performance of yield and yield contributing characters of different chilli germplasm in *Kharif* season.

Chilli germplasm	Single fruit weight (g)	Fruit length (cm)	Pedicel length (cm)	Pericarp thickness (cm)	Wt. of pericarp (g)	No. of fruit/ plant	Wt. of fruit /plant (g)	No. of seed/fruit	Weight of seed/fruit (g)	Thousand seed weight (g)	Yield (t/ha)
CO 001	5.42	5.73	2.90	2.02	0.91	191.33	212.46	38.33	0.25	3.20	8.07
CO 002	8.76	10.63	3.53	3.58	5.51	43.33	122.32	48.33	0.40	3.60	4.65
CO 003	4.90	4.93	2.60	1.42	1.05	251.66	450.84	40.33	0.26	4.40	17.13
CO 446	2.08	5.60	3.13	1.23	0.58	290.33	311.26	40.33	0.18	4.86	11.83
CO 446-1	2.96	6.03	3.43	1.79	0.90	130.66	377.71	40.33	0.24	4.80	14.35
CO 525	11.33	10.10	3.10	0.84	1.04	273.00	465.50	70.33	0.56	5.10	17.69
CO 525-1	2.50	6.03	2.53	1.30	0.48	306.33	480.33	55.00	0.18	5.00	18.25
CO 525-2	2.33	8.96	3.96	1.49	1.03	154.66	321.35	27.33	0.24	5.00	12.21
CO 525-3	3.13	5.20	2.40	1.64	0.78	136.33	223.63	49.66	0.17	2.80	8.50
CO 610	2.53	5.96	3.30	1.08	0.44	206.33	304.50	21.33	0.20	5.00	11.57
CO 610-1	3.20	6.36	2.86	0.90	0.50	194.33	331.32	36.66	0.24	4.80	12.59
CO 611-1	2.46	7.16	3.86	1.23	0.89	238.66	340.16	61.66	0.19	4.40	12.93
CO 611-2	2.70	5.96	4.00	1.41	0.69	252.00	253.92	34.66	0.28	4.36	9.65
CO 613	2.02	3.20	1.70	0.69	0.60	191.66	266.43	69.66	0.23	3.10	10.12
CO 626	1.46	5.13	3.76	1.26	0.28	246.66	340.86	39.33	0.27	4.80	12.95
CO 629	1.73	3.96	3.00	1.15	0.48	207.33	221.45	54.33	0.22	2.80	8.42
CO 630	2.00	4.00	2.23	0.65	0.92	135.00	224.25	35.00	0.42	3.20	8.53
CO 631	11.70	10.63	3.53	1.58	0.82	308.00	606.43	89.66	0.63	5.20	23.04
CO 632	3.76	5.63	3.40	1.23	0.69	221.66	331.52	64.00	0.36	3.80	12.60
CO 633	2.63	4.80	2.86	1.00	0.61	121.66	211.03	67.00	0.21	4.20	8.02
CO 634	4.00	6.73	3.20	2.21	2.11	157.00	205.07	60.00	0.33	5.00	7.79
CO 635	4.56	5.93	2.56	0.63	1.91	127.33	401.50	42.00	0.43	4.66	15.26
CO 636	4.53	8.13	2.53	3.11	3.52	151.00	249.22	58.33	0.28	3.46	9.47

Table 4. Contd.

Chilli germplasm	Single fruit weight (g)	Fruit length (cm)	Pedicel length (cm)	Pericarp thickness (cm)	Wt. of pericarp (g)	No. of fruit/ plant	Wt. of fruit /plant (g)	No. of seed/fruit	Weight of seed/fruit (g)	Thousand seed weight (g)	Yield (t/ha)
CO 637	3.20	5.86	2.86	1.72	1.68	110.66	339.63	51.00	0.28	4.80	12.91
CO 638	4.13	9.83	2.26	1.69	0.73	102.00	197.85	60.33	0.17	3.60	7.52
CO 639	7.23	9.36	1.53	2.65	2.60	84.66	310.34	57.00	0.16	4.33	11.79
CO 640	2.40	7.96	2.76	4.72	6.00	38.06	460.64	24.33	0.38	4.70	17.50
CO 641	9.10	10.00	3.10	3.03	4.34	53.66	333.23	41.33	0.34	4.40	12.66
CO 642	2.03	9.23	3.86	2.23	3.23	50.66	191.04	58.33	0.27	4.13	7.26
CO 643	5.50	5.73	5.06	2.34	2.22	50.66	213.69	47.66	0.18	5.00	8.12
CO 644	3.13	5.20	2.90	1.02	0.36	268.00	386.20	32.33	0.15	2.80	14.68
CO 645	1.86	2.90	2.53	0.88	0.24	146.00	246.57	38.33	0.11	3.40	9.37
CO 646	1.83	6.93	4.16	0.69	1.19	140.66	278.99	20.33	0.30	2.90	10.60
CO 647	2.39	3.96	3.23	1.19	0.48	231.33	244.12	50.66	0.22	1.50	9.28
CO 648	2.27	2.93	2.90	1.78	0.95	45.66	126.22	48.00	0.22	4.50	4.80
BARI Chilli-2	3.05	7.56	3.66	1.24	0.59	218.00	292.99	48.00	0.22	5.20	11.13
LSD (5%)	4.023	1.190	0.737	0.875	1.468	109.40	92.52	67.46	0.157	0.381	9.00
LSD (1%)	5.397	1.596	0.989	1.175	1.969	146.80	124.10	90.51	0.211	0.512	12.21
Level of significant	**	**	**	**	**	**	**	**	**	**	**
CV (%)	12.00	10.98	14.48	12.40	11.92	19.09	18.47	17.18	14.67	5.56	12.17

** Significant at 1% level of probability

obtained in summer and rainy season may have been due to loss of fruits to dampness and decay because of much rainfall received (Idowu-Agida *et al*., 2010). This is also attributed to abscission of flower buds, flowers and young fruits induced by higher temperatures and excessive moisture from much rains during flowering and fruiting stages. The variations of fruit yield depended might be due to the influence of the growing environmental factors like temperature, associated traits like canopy diameter that might limit the number of branches. As a number of primary, secondary and tertiary branches increased, there might be a possibility of increasing the number of fruit producing buds which are the locations for fruit production. On the other hand, fruit yield as well as higher yield per hectare was comparatively less in *Kharif* season due to unfavourably affecting photosynthesis. Similar result was reported by Jahangir (2009).

The study revealed existence of genetic variability among the germplasm at morphological levels. Substantial variation existed among the accessions especially in fruit traits (colour, weight, length, thousand seed weight and pericarp weight and width). The first four principal components accounted for 72.44% of the total genetic variance among the accessions. The larger part of variance was accounted for by plant height, single fruit weight, number of fruit per plant and fruit length. Morphological cluster analysis revealed genetic dissimilarity of 0.88-0.99. C0 003 and C0 525-1 showed the widest diversity while the highest degree of similarity existed between C0 610-1 and C0 632. The introduced chilli germplasm out-performed local germplasm in flowering and maturity periods, bigger fruits and total marketable fruit yields. Local germplasm is, however, better in number of fruits produced per plant and seeds per fruit, plant height and width. Germplasm are most stable for average fruit weight, fruit length, fruit width, seed weight and days to fruit 50% maturity, canopy and number of seeds. The germplasm CO 631, CO 635, CO 637, CO 525-1, C0 644 and C0 525 produced high in yield across the seasons performing better than all germplasm in all traits with the BARI chilli-2 as a check. The commercially three germplasm perform better than all the local germplasm and most of the germplasm in terms of fruit yield and maturity periods and perhaps this is why popular as a commercial variety among the farmers. The germplasm C0 634 though the medium yielder is the earliest-maturing variety among all germplasm. Its genes can be used for early yield improvement in chilli pepper. Thirty-six chilli germplasm were evaluated for characterization. The germplasm under investigation showed a wide range of variation for most of the characters. Based on yield and yield attributes of the germplasm C0 631, C0 635, C0 637, C0 525-1 and C0 644 were promising under the agro-ecological condition of Bangladesh as they produced higher yield. Germplasm C0 446, C0 001 and C0 613 may be considered as early crop. The present result provided some esstential information to the breeders for selecting parents' in future breeding programme.

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GENETIC EVALUATION OF BORO RICE (*ORYZA SATIVA* L.) GENOTYPES UNDER IRRIGATED AND RAINFED CONDITIONS

M.N. Jomadder[1], K.M.K. Huda[1*], M. Jony[1], M.S. Islam[1], M.S.A. Banu[2], M.H. Rashid[1] and S. Parveen[1]

[1]Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University (SAU), Dhaka; [2]Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka. Bangladesh

Abstract

Drought is a major abiotic constraint for growing rainfed rice in Bangladesh. A set of 18 boro rice genotypes were evaluated under irrigated and rainfed conditions to identify the high yielding and stress tolerant genotypes. The experiment was conducted by using randomized complete block design with three replications. Significant variations were observed among the genotypes both in irrigated and rainfed conditions. The genotypes BRRI dhan55, Gopal Deshi and Soilerpona showed the superior performance in terms of grain yield and yield contributing characters under rainfed condition. Based on stress tolerance index (STI) value, the genotypes BRRI dhan55, BRRI dhan58, Soilerpuna and Gopaldeshi were graded as drought tolerant genotypes. Under rainfed condition, yield per plant showed the positive and significant correlation with flag leaf length, number of primary branches per panicle, number of secondary branches per panicle, number of grains per panicle and thousand-seed weight. Path analysis revealed that the number of primary/secondary branches per panicle, and number of unfilled grains per panicle showed the highest positive and direct effect on grain yield under irrigated condition while Plant height, panicle length and thousand-seed weight had the highest direct but negative effect on grain yield.Thousand seed weight, number of primary branches per panicle and number of unfilled grains per panicle showed the highest positive and direct effect on grain yield under rainfed condition. Based on the results, seven genotypes from among the eighteen tested namely BRRI dhan36, BRRI dhan55, BRRI dhan58, BRRI dhan59, Soilerpona, Gopal Deshi and Borail were identified as drought tolerance genotypes with high yield potential.

Keywords: Drought, Genetic evaluation, Rainfed, Rice

Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in tropical and subtropical regions (Singh *et al.,* 2012) of the world. It is cultivated at least in 114 countries and is the primary source of income and employment for more than 100 million households in Asia (Singh *et al.,* 2015). So, we need more rice production for the increasing population such as high yielding and abiotic stress tolerant varieties by using modern technologies (BRRI, 2019). China is the first position as producer of rice in the

* Corresponding Author: mashnuk@gmail.com

world (FAO, 2020). As a cereal grain, rice is the second most important food crop next to maize and wheat in the world, but its position in Bangladesh is first in terms of providing food, income, and employment. Bangladesh is the fourth largest producer of rice in the world with the annual productions of 35.3 million metric tons (MMT) in the area of 11.8 million hectares. It is being cultivated under diverse ecologies ranging from irrigated to rainfed, upland to lowland and deep water conditions. Drought is considered one of the main constraints that limit rice yield in rainfed and poorly irrigated areas. Drought is a common feature in Bangladesh (north-western part), especially in the dry season (winter and pre monsoon) which causes a substantial reduction of rice yield (Pervin *et al.,* 2015). Rice is sensitive to water stress and shows several morphological changes at different growth stages in response to drought stress (Henry *et al.,* 2016). These involve plant height reduction, leaf rolling, leaf senescence, stomatal closure, decreased leaf elongation and lower dry matter production (Kumar *et al.,* 2015). The local rice varieties are long (up to one meter) and can survive in deep water and as such are suitable to grow in the flooded lands whereas the modern varieties cannot be grown (Ullah *et al.,* 2014). In Bangladesh, Rajshahi division is highly drought affected. Chittagong and Khulna divisions are also known as drought prone area. Water shortage at the grain filling stage may cause drastically seed yield loss. Water stress after or before panicle initiation reduces potential spike number and decreases translocation of assimilates to the grains, which results low in gain weight and increases empty grains (Davatgara *et al.,* 2009).

Drought is a common phenomenon both for the local land races as well as for the modern rice varieties. The effect of drought at the grain filling stage on the local rice yield has not been evaluated so far. Therefore the performance of both the local and the modern varieties under drought stress condition at the reproductive stage should be needed. Considering the above statement, the present study was designed to know the effect and relationship of different yield and yield contributing traits on rice grain yield at both the irrigated and rainfed conditions. It is essentially required to know the morphological potentiality of drought tolerance rice genotypes in order to select drought tolerant varieties. To identify drought tolerant rice varieties, the present study was undertaken to evaluate the effect of rainfed condition at reproductive stage of different local and BRRI released boro rice genotypes.

Materials and Methods

The present investigation was carried out during the boro season of 2018 at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207. The healthy seeds of genotypes of boro rice collected from southern part of Bangladesh along with some BRRI rice varieties were used as experimental materials. The experiment was laid out in randomized complete block design (RCBD) with three replications. Germinated seeds were sown on the seed bed separately and proper tags were maintained. The N, P, K fertilizers were applied in the form of urea, TSP and MP, respectively as recommended dose. After establishment, the 21 days old seedlings were transplanted to the main field. Intercultural, after care operations and necessary gap filling was done as when needed for

better growth and development of rice seedlings. In irrigated condition, flood irrigation was given to maintain a constant level of standing water up to 2 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourage late tillering. In rainfed condition, drain out water from the plots to maintain the rainfed condition at reproductive stage. The plots are maintained as a way that's why no water could pass into it as the plots were bordered from surroundings in the reproductive stage. The other stages are same as irrigated condition. Proper weeding and tagging were done. The rice genotypes were harvested manually according to their maturity. Harvested crop from each crop were bundled separately and tagged properly. Stress tolerance index (STI) were calculated by using the following formula:

$$STI = \frac{Y_{pi} \times Y_{si}}{{Y_p}^2}$$

Where,

Y_{pi}= yield of individual genotypes without drought stress

Y_{si}= yield of individual genotypes with drought stress

Y_p = average yield of all genotypes of without drought stress

Data were collected on the following parameters *viz.*, plant height, flag leaf length, flag leaf width, number of primary branches per panicle, number of secondary branches per panicle, panicle length, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight and yield per plant. Statistical analysis was done with GENSTAT software program.

Results and Discussion

Mean separation table showed the significant variations were present among the genotypes. Number of unfilled grains per panicle showed the highest CV percentage in both irrigated (20.35%) and rainfed (18.73%) conditions. Plant height showed the lowest CV percentage in both irrigated (10.40%) and rainfed (10.49%) conditions (Tables 1 and 2). BRRI dhan55 (4.42 ton/ha), Gopal Deshi (4.26 ton/ha) and Soilerpona (4.15 ton/ha) showed the highest grain yield under rainfed condition (Table 1 and 2). These water stress tolerance genotypes may be used as the base material for the development of water stress tolerant rice variety, because the development of base materials is the prime work in any breeding program. The genotypes BRRI dhan36 (7.64 ton/ha), BRRI dhan59 (7.23 ton/ha), BRRI dhan58 (7.03 ton/ha) and BRRI dhan55 (7.0 ton/ha) showed the highest grains yield in irrigated condition (Table 1). This study revealed a decrease in mean grain yield among the genotypes due to imposing stress. Adhikari *et al.,* (2017) found similar result in rainfed and drought prone areas. All the genotypes produced higher grain yield in the irrigated compared to rainfed condition. These might be due to that continuous irrigation ensured sufficient field capacity level through until harvest. Reduction of grain yield due to stress in crops has been previously reported by many workers (Dadbakhsh *et al.,* 2011; Farshadfar and Elyasi, 2012; Dixit *et al.,* 2014; Bennani *et al.,* 2017). Moderate level of grain yield was observed here under irrigated condition. Ali and El-Sadek, (2016) also stated that moderate level of grain yield reduction is suitable for selecting stress tolerant genotypes in wheat.

Table 1. Performance of different genotypes under irrigated condition

Genotypes	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YH
Poshusail	119.00 g	26.00 j	1.75 ab	9.00 e	21.00 j	21.13 h-j	170.0 b	22.00 de	30.00 cd	5.700 i
Gorchihail	118.00 h	27.80 g	1.50 hi	7.00 i	23.00 hi	22.23 d-i	110.0 h	28.00 b	29.00 de	6.240 e-g
Birion	140.00 b	27.60 g	1.55 f-i	10.50 b	27.00 d	23.46 cde	210.0 a	11.67 i	26.00 gh	5.800 hi
Soilerpuna	134.90 d	24.50 m	1.60 c-h	10.00 c	24.00 gh	22.52 c-h	120.0 g	12.33 i	28.00 ef	6.400 d-f
Pankaich	134.00 e	25.50 k	1.65 a-g	8.00 gh	24.00 gh	20.50 j	80.0 j	34.33 a	29.30 de	5.900 g-i
Gopal Deshi	141.00 a	29.20 d	1.77 a	12.00 a	27.00 d	20.93 ij	110.0 h	18.33 fg	31.00 bc	6.200 e-h
Borail	108.90 j	28.80 e	1.56 f-i	9.00 e	32.00 b	20.97 ij	130.0 de	17.67 g	29.60 c-e	6.380 def
BRRI dhan28	89.63 n	33.00 a	1.58 d-i	9.40 d	26.00 def	22.97 c-f	125.9 f	21.37 d-f	28.00 ef	6.133 e-h
BRRI dhan55	100.50 l	32.00 b	1.64 a-g	8.50 f	36.00 a	22.10 e-i	120.0 g	23.17 cd	26.27 gh	7.000 bc
BRRI dhan45	100.00 l	25.20 kl	1.71 a-d	9.50 d	35.00 a	25.21 ab	130.0 de	26.00 bc	31.00 bc	6.500 de
BRRI dhan50	82.00 q	28.23 f	1.66 a-f	9.00 e	26.00 d-f	23.23 c-f	128.0 ef	12.67 i	34.00 a	6.000 f-i
BR 25	138.00 c	27.22 h	1.52 g-i	8.00 gh	23.00 hi	21.22 g-j	122.0 g	19.00 e-g	32.00 b	4.500 j
BRRI dhan86	106.00 k	25.96 j	1.73 a-c	9.00 e	26.00 d-f	25.96 a	119.0 g	12.33 i	29.00 de	4.500 j
BRRI dhan29	91.03 m	23.35 n	1.59 d-h	8.22 fg	26.80 de	23.64 cd	132.2 d	8.33 j	23.23 k	6.500 de
BRRI dhan35	84.00 p	26.00 j	1.62 b-h	8.00 gh	25.00 e-g	21.91 f-j	130.0 de	19.30 e-g	25.73 gh	6.700 cd
BRRI dhan36	79.00 s	27.00 h	1.70 a-e	8.40 f	24.80 f-h	22.64 c-g	129.5 de	21.53 def	26.90 fg	7.637 a
BRRI dhan58	85.00 o	30.00 c	1.50 hi	9.47 d	29.33 c	22.12 e-i	142.3 c	23.50 cd	25.37 g-i	7.027 bc
BRRI dhan59	80.00 r	26.50 i	1.64 a-g	7.80 h	24.13 gh	22.00 e-i	129.9 de	17.43 gh	24.03 i-k	7.220 b
(%) of Lsd	0.7129	0.3387	0.1383	0.3387	1.801	1.468	3.392	3.310	1.611	.4149
Level of significance	**	**	**	**	**	**	**	**	**	**
% CV	10.40%	10.76%	15.08%	12.33%	14.13%	13.94%	11.59%	20.35%	13.50%	14.09%

Note: PH= Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YH= Yield per hectare (ton/ha).

** indicates significant at 1% level. Each letter indicates significantly different from other.

STI was used to identify genotypes that produce higher grain yield (ton per hectare) under both irrigated and rainfed conditions. The higher value of STI indicates higher tolerance to stress of the genotypes. Rice genotypes BRRI dhan55 (0.824), BRRI dhan58 (0.726) Soilerpuna (0.707) and Gopaldeshi (0.703) showed the highest value of STI value (Table 3). Therefore, these genotypes were graded to be tolerant to water stress at reproductive stage. With respect to STI value, BRRI dhan55, BRRI dhan58, Soilerpuna, Gopaldeshi, BRRI dhan36, Borail and BRRI dhan59 were the top 7

Table 2. Performance of different genotypes under rainfed condition

Genotypes	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YH
Poshusail	115.00 d	23.40 h	1.60 a	7.50 gh	19.00 l	RC	100.0 c	22.67 de	19.00 hi	2.570 ij
Gorchihail	111.00 f	24.00 g	1.44 c-f	6.50 j	25.00 fg	20.78 f	30.0 k	38.67 a	23.00 e	2.873 hi
Birion	126.00 a	26.00 d	1.45 b-e	11.90 a	28.50 de	21.51 de	130.0 a	12.33 j	26.50 ab	3.630 cd
Soilerpuna	118.00 c	25.00 ef	1.50 a-d	11.00 c	29.00 cd	23.04 a	85.0 d	12.33 j	26.00 b	4.150 ab
Pankaich	106.00 h	20.00 l	1.25 g	9.20 e	22.50 i	22.09 bc	60.0 i	38.33 a	22.00 f	3.080 gh
Gopal Deshi	126.00 a	27.00 b	1.55 a-c	11.50 b	27.50 e	22.00 bc	80.0 e	17.56 hi	26.30 b	4.260 a
Borail	92.00 l	26.80 bc	1.36 d-g	9.50 e	33.80 b	21.67 d	85.0 d	18.33 g-i	27.20 a	3.850 bc
BRRI dhan28	84.83 m	25.00 ef	1.42 c-f	8.23 f	22.00 ij	23.05 a	110.0 b	27.43 c	23.00 e	3.160 e-h
BRRI dhan55	94.00 j	28.00 a	1.44 c-f	10.60 d	38.00 a	21.79 cd	112.0 b	25.78 cd	24.00 d	4.420 a
BRRI dhan45	93.00 k	20.40 k	1.47 a-d	8.20 f	30.00 c	20.00 g	65.0 h	20.33 e-h	24.00 d	1.470 l
BRRI dhan50	80.00 p	26.60 c	1.50 a-d	7.80 g	22.20 ij	22.14 b	70.0 g	21.00 e-g	25.00 c	3.450 de
BR 25	119.00 b	24.80 f	1.37 d-g	7.70 g	20.60 k	21.29 e	65.0 h	31.00 b	26.00 b	2.300 jk
BRRI dhan86	95.00 i	23.20 h	1.52 a-c	10.50 d	24.20 gh	22.05 bc	76.0 f	18.33 g-i	23.00 e	2.250 k
BRRI dhan29	82.00 n	22.50 i	1.36 d-g	7.50 gh	22.00 ij	20.70 f	68.0 gh	16.00 i	18.50 hi	2.750 i
BRRI dhan35	81.00 o	21.20 j	1.43 c-f	7.20 hi	20.00 kl	19.28 i	80.0 e	23.40 de	18.20 i	3.100 f-h
BRRI dhan36	76.00 s	25.30 e	1.59 ab	7.50 gh	21.00 jk	19.25 i	102.0 c	17.60 hi	19.30 gh	3.400 d-f
BRRI dhan58	78.00 q	23.40 h	1.36 d-g	8.20 f	25.00 fg	19.67 h	82.0 de	23.20 de	21.20 f	3.880 bc
BRRI dhan59	77.00 r	22.20 i	1.46 a-e	8.30 f	22.20 ij	20.10 g	79.0 ef	19.30 f-h	20.00 g	3.210 e-g
(%) of Lsd	0.7944	0.3347	0.1478	0.3222	1.238	19.00 i	3.310	3.271	0.8181	0.3136
Level of significance	**	**	**	**	**	0.3179	**	**	**	**
% CV	10.49%	10.85%	16.29%	12.23%	12.99%	**	12.55%	18.73%	12.21%	16.24%

Note: PH= Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YH= Yield per hectare (ton/ha).

** indicates significant at 1% level. Each letter indicates significantly different from other.

performer under stress condition (Table 3). The genotypes BRRI dhan45 (0.255), BRRI dhan86 (0.271), BR 25 (0.277) and Poshusail (0.391) showed the lowest STI (Table 3) value which implies that these were highly susceptible to stress, especially at reproductive stage. Based on STI value, some promising drought tolerant genotypes were identified namely BRRI dhan55, BRRI dhan58, Soilerpuna, and Gopaldeshi. Previously a number of studies showed that STI was an important index for identifying drought tolerant genotypes (Raman *et al.*, 2012; Kumar *et al*., 2014; Muthuramu and Ragavan, 2020).

The analysis of correlation co-efficient among different characters under irrigated (Table 4) condition showed that plant height exhibited significant but negative correlation (-0.535^{**}) with grain yield and non-significant correlation (-0.09^{ns}) under rainfed condition (Table 5). Flag leaf length (0.634), thousand-seed weight (0.480), number of primary branches per panicle (0.438), number of filled grains per panicle (0.472), number of secondary branches per panicle (0.370) were showed the positive and significant correlation with grain yield under rainfed condition (Table 5). Selection based on these important yield contributing traits would be effective for the development of drought tolerant rice varieties because grain yield depends on the contribution of many independent variables.

Table 3. Stress Tolerance Index (STI) of different characters among the genotypes

Genotypes	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YH
Poshusail	1.189 d	0.828 j	1.077 a	0.874 hi	0.571 l	0.864 h-j	1.020 b	1.340 de	0.736 g	0.391 h
Gorchihail	1.112 e	0.908 i	0.830 f-j	0.589 m	0.824 f-h	0.940 c-f	0.198 n	2.901 b	0.861 ef	0.477 g
Birion	1.511 a	0.977 f	0.860 e-i	1.617 b	1.105 c	1.063 ab	1.637 a	0.378 j	0.889 de	0.561 ef
Soilerpuna	1.394 b	0.834 j	0.918 c-f	1.423 c	0.997 d	0.978 cd	0.612 gh	0.403 ij	0.938 cd	0.707 bc
Pankaich	1.260 c	0.694 n	0.794 h-j	0.953 fg	0.776 g-j	0.887 e-i	0.288 m	3.524 a	0.830 f	0.484 g
Gopal Deshi	1.518 a	1.073 c	1.050 ab	1.787 a	1.066 cd	0.893 e-i	0.528 ij	0.853 gh	1.051 ab	0.703 bc
Borail	0.865 g	1.050 d	0.817 g-j	1.107 e	1.553 b	0.951 c-e	0.663 f	0.873 gh	1.039 b	0.656 cd
BRRI dhan28	0.664 h	1.123 b	0.863 e-i	1.002 f	0.820 f-i	0.985 cd	0.830 c	1.574 cd	0.830 f	0.518 fg
BRRI dhan55	0.818 g	1.219 a	0.903 d-g	1.166 de	1.963 a	0.869 g-j	0.806 cd	1.604 cd	0.814 f	0.824 a
BRRI dhan45	0.811 g	0.700 mn	0.967 b-d	1.008 f	1.505 b	1.098 a	0.507 j	1.416 c-e	0.960 c	0.255 ij
BRRI dhan50	0.550 i	1.022 e	0.953 b-e	0.909 gh	0.828 e-h	0.973 cd	0.538 i	0.718 g-i	1.097 a	0.551 f
BR 25	1.430 b	0.919 hi	0.796 h-j	0.797 jk	0.678 k	0.921 d-h	0.476 k	1.581 cd	1.074 ab	0.277 i
BRRI dhan86	0.851 g	0.820 j	1.006 a-c	1.224 d	0.904 e	1.057 ab	0.542 i	0.611 h-j	0.861 ef	0.271 i
BRRI dhan29	0.660 h	0.715 m	0.832 f-j	0.798 jk	0.845 e-g	0.896 e-h	0.539 i	0.349 j	0.555 kl	0.476 g
BRRI dhan35	0.571 i	0.750 l	0.891 d-h	0.746 kl	0.718 jk	0.830 ij	0.624 g	1.200 ef	0.603 jk	0.554 f
BRRI dhan36	0.526 i	0.930 h	1.034 ab	0.816 ij	0.747 i-k	0.876 f-j	0.792 d	1.020 fg	0.670 hi	0.692 bc
BRRI dhan58	0.582 i	0.955 g	0.785 ij	1.005 f	1.052 cd	0.875 g-j	0.700 e	1.453 c-e	0.695 gh	0.726 b
BRRI dhan59	0.536 i	0.801 k	0.921 c-f	0.838 ij	0.768 h-j	0.822 j	0.616 gh	0.892 f-h	0.619 ij	0.619 de

Note: PH = Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YH= Yield per hectare (ton/ha).

Each letter indicates significantly different from other.

Table 4. Correlation co-efficient among different characters under irrigated condition

	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YP
PH	1	-0.161 ns	-0.065 ns	0.309 ns	-0.204 ns	-0.253 ns	-0.004 ns	0.080 ns	0.261 ns	-0.535 **
FLL		1	-0.028 ns	0.330 *	0.407 **	-0.227 ns	0.017 ns	0.225 ns	0.211 ns	0.249 ns
FLW			1	0.260 ns	0.022 ns	0.190 ns	-0.001 ns	0.017 ns	0.304 ns	0.091 ns
NPBP				1	0.299 ns	0.001 ns	0.271 ns	-0.228 ns	0.294 ns	0.063 ns
NSBP					1	0.120 ns	-0.017 ns	0.122 ns	0.029 ns	0.316 ns
PL						1	0.195 ns	-0.395 *	-0.050 ns	-0.152 ns
NFGP							1	-0.441 **	-0.141 ns	0.067 ns
NUGP								1	0.129 ns	0.097 ns
TSW									1	-0.219 ns
YP										1

Note: PH = Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YP= Yield per plant (g).

* indicates: significant at 5%, ** indicates: significant at 1% and ns indicates: not-significant

In the path analysis flag leaf width (0.084), number of primary branches per panicle (0.274), number of secondary branches per panicle (0.166), number of filled grains per panicle (0.101), number of unfilled grains per panicle (0.138) showed positive and direct effect on grain yield under irrigated condition (Table 6). Flag leaf length (0.509), number of primary branches per panicle (0.310), number of filled grains per panicle (0.117), number of unfilled grains per panicle (0.153) and thousand seed weight (0.349) showed the positive and direct effect on grain yield under rainfed condition (Table 7). Flag leaf width (0.084) and number of secondary branches per panicle (0.166) showed the positive direct effect under irrigated condition (Table 6) but these two traits showed the negative direct effect under rainfed condition (Table 7). Sahu *et al., (*2017) observed the similar findings. Selection based on leaf width and number of secondary branches per panicle would not be effective for the development of drought tolerant varieties. Flag leaf length (0.509) showed the positive effect on yield under rainfed condition but revealed negative direct effect on yield under irrigated condition (Table 6 and 7). Therefore, selection based on flag leaf length would be effective. By observing the direct and indirect effects of different yield contributing traits on yield, the breeder can select the best promising genotypes. Results in this study indicated a positive and

highly significant correlation exist between grain yield and other yield contributing characters under stress level. The genotypes that showed high grain yield under non-stressed condition also revealed high yield under stressed condition**.**

Table 5. Correlation co-efficient among different characters under rainfed condition

	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YP
PH	1	0.076 ns	0.002 ns	0.423 **	0.153 ns	0.616 **	-0.035 ns	0.095 ns	0.357 *	-0.090 ns
FLL			1	0.334 *	0.439 **	0.442 **	0.213 ns	0.510 **	-0.297 ns	0.634 **
FLW			1	0.091 ns	-0.039 ns	-0.119 ns	0.277 ns	-0.308 ns	0.186 ns	0.223 ns
NPBP				1	0.601 **	0.395 *	0.499 **	-0.479 **	0.525 **	0.438 **
NSBP					1	0.340 *	0.241 ns	-0.206 ns	0.528 **	0.370 *
PL						1	0.014 ns	0.046 ns	0.655 **	-0.026 ns
NFGP							1	-0.521 **	0.167 ns	0.472 **
NUGP								1	-0.102 ns	-0.237 ns
TSW									1	0.480 **
YP										1

Note: PH = Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YP= Yield per plant (g).

* indicates: significant at 5%, ** indicates: significant at 1% and ns indicates: not-significant

Table 6. Path coefficient among different characters under irrigated condition

	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YP
PH	**-0.650**	0.014	-0.005	0.085	-0.034	0.088	0.000	0.011	-0.042	-0.535
FLL	0.105	**-0.088**	-0.002	0.090	0.068	0.078	0.002	0.031	-0.034	0.249
FLW	0.042	0.002	**0.084**	0.071	0.004	-0.066	0.000	0.002	-0.049	0.091
NPBP	-0.201	-0.029	0.022	**0.274**	0.050	0.000	0.027	-0.032	-0.048	0.063
NSBP	0.133	-0.036	0.002	0.082	**0.166**	-0.041	-0.002	0.017	-0.005	0.316
PL	0.165	0.020	0.016	0.000	0.020	**-0.346**	0.020	-0.055	0.008	-0.152
NFGP	0.002	-0.002	0.000	0.074	-0.003	-0.068	**0.101**	-0.061	0.023	0.067
NUGP	-0.052	-0.020	0.001	-0.063	0.020	0.137	-0.044	**0.138**	-0.021	0.097
TSW	-0.170	-0.019	0.026	0.080	0.005	0.017	-0.014	0.018	**-0.162**	-0.219

Residual Value (R): 0.699

Note: PH = Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YP= Yield per plant (g).

A positive correlation between grain yields has also been reported earlier by many workers (Dadbakhsh *et al.*, 2011; Rahman, 2014; Bennani *et al.*, 2017). Positive and significant correlation also exists between STI and yield/plant as previously reported by other workers (İlker *et al.*, 2011; Toorchi *et al.*, 2012).

Table 7. Path coefficient among different characters under rainfed condition

	PH	FLL	FLW	NPBP	NSBP	PL	NFGP	NUGP	TSW	YP
PH	**-0.143**	0.039	0.000	0.131	-0.011	-0.241	-0.004	0.014	0.125	-0.090
FLL	-0.011	**0.509**	-0.025	0.136	-0.031	-0.083	0.060	-0.045	0.221	0.731
FLW	0.000	0.170	**-0.075**	0.028	0.003	0.047	0.033	-0.047	0.065	0.223
NPBP	-0.061	0.223	-0.007	**0.310**	-0.042	-0.154	0.059	-0.073	0.183	0.438
NSBP	-0.022	0.225	0.003	0.186	**-0.070**	-0.133	0.028	-0.032	0.184	0.370
PL	-0.088	0.108	0.009	0.122	-0.024	**-0.391**	0.002	0.007	0.229	-0.026
NFGP	0.005	0.259	-0.021	0.155	-0.017	-0.006	**0.117**	-0.080	0.058	0.472
NUGP	-0.014	-0.151	0.023	-0.148	0.014	-0.018	-0.061	**0.153**	-0.036	-0.237
TSW	-0.051	0.323	-0.014	0.162	-0.037	-0.256	0.020	-0.016	**0.349**	0.480

Residual Value (R): 0.5

Note: PH = Plant height (cm), FLL= Flag leaf length (cm), FLW=Flag leaf width (cm), NPBP=Number of primary branches per panicle, NSBP=Number of secondary branches per panicle, PL=Panicle length (cm), NFGP=Number of filled grains per panicle, NUGP=Number of unfilled grains per panicle, TSW=Thousand seed weight (g), YP= Yield per plant (g).

Conclusion

The study was designed to investigate the relationship of different yield and yield contributing traits on grain yield and observe the yield performance of different Boro rice genotypes under irrigated and rainfed conditions. Among the eighteen genotypes, BRRI dhan55, Gopal Deshi and Soilerpona showed the superior performance in terms of gran yield and yield attributes under rainfed condition. Therefore, these genotypes could be used for the future water stress breeding program. The genotypes BRRI dhan55, BRRI dhan58, Soilerpona, Gopaldeshi and BRRI dhan36 showed the highest STI value therefore could be recommended as parent materials to develop drought tolerant varieties.

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EFFICACY OF TURMERIC (*CURCUMA LONGA*) AND GARLIC (*ALLIUM SATIVUM*) POWDER TO PROTECT BROILER CHICKEN RECEIVING DIET CONTAINING EXOGENOUS AFLATOXIN

A.A. Bhuyan[1], A.A. Bhuiyan[2*], M.M. Rana[3], M.R. Islam[2], M.A. Rashid[3] and M.S.K. Sarker[3]

[1]Animal Biotechnology Division, National Institute of Biotechnology (NIB), Ashulia, Dhaka;
[2]Livestock Division, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka;
[3]Poultry Production Research Division, Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka. Bangladesh

Abstract

Aflatoxin (AF), a secondary metabolite of *Aspergillus* species, is carcinogenic and mutagenic for chicken. Chickens are highly sensitive to the adverse effect of AF and it is causing economic loss in poultry industry. The aim of the current study was to evaluate the efficacy of turmeric powder (TP) and garlic powder (GP) on broiler receiving diet containing exogenous AF. Randomly selected 14 days old cobb-500 broiler chicks (N=84) were equally divided into four treatments. Four isonitrogenous and isocaloric experimental diets were prepared viz; diet-A: 1.5 mg of AF; Diet-B: 1.5 mg of AF and 1g of TP; Diet-C: 1.5 mg of AF and 1 g of GP contained per kg feed and control diet had no AF, TP and GP. Each dietary treatment had 3 replications (having 7 birds in each) and respective feed was offered to the broilers according to the entire duration (35 days) of experiment. All experimental broilers were reared following same management practices. At 36 days of age all experimental broiler were slaughtered for examining the necroscopic changes in internal organs such as liver, kidney and spleen to estimate AF residues. Growth of the broiler chicken was monitored and feed conversion ratio (FCR) was calculated. The study demonstrated significant ($P<0.01$) effect of turmeric and garlic powder on final body weight of birds and so also the FCR. Liver and kidney weight use showed significantly ($P<0.01$) the highest in diet-A, followed by diet-B, diet-C and the control diet, respectively but, spleen weight did not differ significantly ($p>0.05$) with the treatments. The residue of AF in different internal organs was also significantly ($P<0.05$) different between the treatments; being higher in diet-A as compared to the rest of the dietary treatment groups. Evidently, the present study substantiated the potentiality of TP in broiler chicken to overcome the adverse effect of AF, a common mycotoxin.

Keywords: Aflatoxin, Broiler diet, Deactivating, Garlic, Turmeric

Introduction

Aflatoxins (AF) are the most commonly known mycotoxin resulting adverse effects in poultry. Aflatoxins are produced by certain molds of the genus Aspergillus, particularly *A. flavus* and *A. parasiticus* which grow in soil, decaying vegetation, hay, and grains. The molds can colonize and contaminate food before harvest or during storage, especially following prolonged exposure to a high-humidity environment, or to stressful

* Corresponding Author: aab76_blri@yahoo.com

conditions such as drought. In addition, the accumulation of toxin residues in tissues such as liver muscle and milk above the permissible limit are considered to represent a human health hazard to consumers of such animal products (Gareis *et al.,* 2000; Hussain *et al.,* 2010). So, prevention of mold growth and AF contamination in feed and foodstuffs is utmost important in view of public health, food safety and safe food production. Although 18 different aflatoxins have been identified, only aflatoxin B1, B2, G1 and G2 have been detected as natural contaminants of feed and feedstuffs (Leeson *et al.,* 1995). Aflatoxicosis in chickens causes mortality, listlessness, anorexia, decreased growth rates, negative feed conversions, fatty liver, decreased egg production, poor pigmentation, and increased susceptibility to other diseases (Tedesco *et al.,* 2004; Rangsaz *et al.,* 2011; Gholami- Ahangaran *et al.,* 2013). Aflatoxin B1 (AFB1) is the most biologically active form of AF (Boutrif, 1998) and causes poor performance, liver lesions and immune-suppression in poultry (Ledoux *et al.,* 1999; Rosa *et al.,* 2001; Magnoli *et al.,* 2011). Many scientists applied different chemicals during storage and prior to feeding of feed for control of fungi and detoxification of mycotoxins (Phillips *et al.,* 1988; Smith *et al.,* 1994; Harper *et al.,* 2010).

Herbal components like turmeric (*Curcuma longa*), garlic (*Allium sativum*) and green algae (*Spirulina platensis*) counteract mycotoxins, improve growth performance and also act as good antioxidants (Sawarkar *et al.,* 2012). Garlic extract was found to be the most effective in the prevention of aflatoxin-induced toxicity and free radical generation in rats (Mosaad *et al.,* 2003) and turmeric provide protection against the toxic effects of aflatoxin on liver and kidney (Majid *et al.,* 2015). In view of the above perspective, the current research was aimed to evaluate the efficacy of turmeric powder (TP) and garlic powder (GP) to overcome the adverse effect of mycotoxin in broiler maintained on diet containing exogenous AF. The study also encompassed assay of AF residues in vital organs of birds.

Materials and Methods

Production of aflatoxins

Aflatoxins producing mold (*A. parasiticus* NRRL 2999) was obtained from the Toxicology Laboratory of Huazhong Agricultural University, Wuhan, P. R. China and was grown on rice after following the standard protocol (West *et al.,* 1973). The AF containing rice was autoclaved and ground to powder. Thereafter, the concentration of AF was determined applying indirect method of quantitative Enzyme-Linked Immunosorbent Assay (ELISA).

Preparation of turmeric and garlic powder

Fresh garlic bulbs (*Allium sativum*) and turmeric rhizomes (*Curcuma longa*) were obtained from local market. Then, they were washed, dried and milled (Fig.1). The powder was prepared according to the method as previously described by Ahmadi *et al.,* (2007).

Garlic powder (GP) **Turmeric powder (TP)**

Fig. 1. Preparation of garlic and turmeric powder

Experimental diets

Four isonitrogenous and isocaloric experimental diets were prepared , such as in diet-A: 1.5 mg of AF; in Diet-B 1.5 mg of AF and 1g of TP; in Diet-C 1.5 mg of AF and 1 g of GP contained per kg of feed and control diet had no AF, TP and GP (Table 1).

Table 1. Ingredients and calculated composition of diets

Ingredients	Diet A	Diet B	Diet C	Control Diet
Maize/ Corn (kg/100kg)	53	52.5	50	50
Rice polish (kg/100kg)	14	14	13	11
Soybean meal (kg/100kg)	23	23.5	27	29
Protein concentrates (kg/100kg)	8	8	8	8
Aflatoxins (mg/kg)	1.5	1.5	1.5	0
Turmeric powder (TP, g/kg)	0	1.0	0	0
Garlic powder (GP, g/kg)	0	0	1.0	0
Others (2% of the total)*	2	2	2	2
ME (kcal/kg)	2898	2893	2882	2881
CP (%)	22.12	22.14	22.07	22.04

*****Calcium carbonate, Dicalcium phosphate, Vitamin.-mineral premix, Salt, Lysine and Methionine

Experimental birds and design

A total of 100 day old Cobb 500 broiler chicks were purchased from a commercial hatchery, weighted, wing banded and reared with proper brooding up to 14 days. Afterwards, randomly 84 chicks were equally divided into four dietary groups with 3 replications and assigned to 12 pens, where each pen having 7 chicks. Respective feed was offered to the broilers according to the strain standard for the duration (35 days) of experiment (Fig. 2). All experimental broilers were reared following same management practices. On 36 days of age, all experimental broiler chickens were slaughtered for

examining the necroscopic changes in internal organs. Liver and muscle tissues were also collected to estimate AF residues. Weekly growth rate and FCR were monitored during the experimental period.

Experimental house **Brooding**

Fig. 2. Experimental house and brooding of birds

Determination of aflatoxin residues

Detection of AF residues was performed according to Tavcar-Kalcher *et al.*, (2007). Briefly, 1g ground sample was mixed thoroughly with an aqueous solution of citric acid and diatomaceous earth. The mixture was extracted with dichloromethane. The filtered extract was dried, filtered again, and an aliquot was evaporated near to dryness. The residue was dissolved in methanol and mixed with buffer and applied into an immune affinity column. Aflatoxin was eluted from the column and its concentration of AF in the final solution was determined by an HPLC method with fluorescence detection.

Results and Discussion

The results revealed that there were significantly different ($P<0.01$) in body weight gain and FCR among the dietary treatment. Body weight gain and FCR use showed highest in diet-B, followed by diet-C as well as control diet and the lowest in diet-A. But there was no significant ($p>0.05$) difference in feed intake among the dietary treatments (Table 2). The findings of the current research indicated positive effects of TP and GP on body weight gain and FCR in broiler chicken. Evidently, a usage of TP and GP as a feed additive in the diet of broiler chicken was successful to minimize the loss of weight gain and FCR caused by exogenous source of AF.

Table 2. AF deactivating effect of TP and GP on feed intake, body weight and FCR in broiler

Parameters	Diet-A	Diet-B	Diet-C	Control Diet	P-value
Feed intake (g)	4333±189	4138±88	4019±86	4095±170	^{NS}
Body weight (g)	1705±11.31^{c}	2066±14.5^{a}	1907±20.29^{b}	1711±21.98^{c}	*
FCR	2.54±0.12^{a}	2.0±0.04^{b}	2.11±0.5^{c}	2.4±0.12^{c}	*

Mean ± SEM; *Significant at $P < 0.01$; ^{NS} Not-significant

Relative liver and kidney weight showed significantly (P<0.01) the highest in diet-A followed by diet-B, diet-C, respectively and the control diet but relative spleen weight was not significantly difference (P>0.05) among the diets (Table 3). A gross observation of internal organs of broiler chicken was showed in Fig. 3. Control group of broilers did not found any changes (Fig. 3A). Same lesions were found in liver of broilers (Fig. 3B). But, aflatoxin uncontaminated diet (control diet) fed group of broilers were showed no gross lesions in kidneys (Fig. 3C). The relative kidneys weights from the aflatoxin fed group of broilers were enlarged, pale or congested with a few petechial (Fig. 3D).

Table 3. Relative organ weight of broilers comparing different dietary treatments

Parameters	Diet-A	Diet-B	Diet-C	Control Diet	P-value
Liver wt. (g/100 g of BW)	2.56±0.065[b]	2.23±0.024[a]	2.21±0.023[a]	2.09±0.056[c]	*
Kidney wt. (g/100 g of BW)	1.13±0.025[b]	0.85±0.016[a]	0.93±0.016[a]	0.74±0.031[c]	*
Spleen wt. (g/100 g of BW)	0.183±0.002	0.181±0.003	0.184±0.002	0.180±0.003	NS

*Significant at P < 0.01

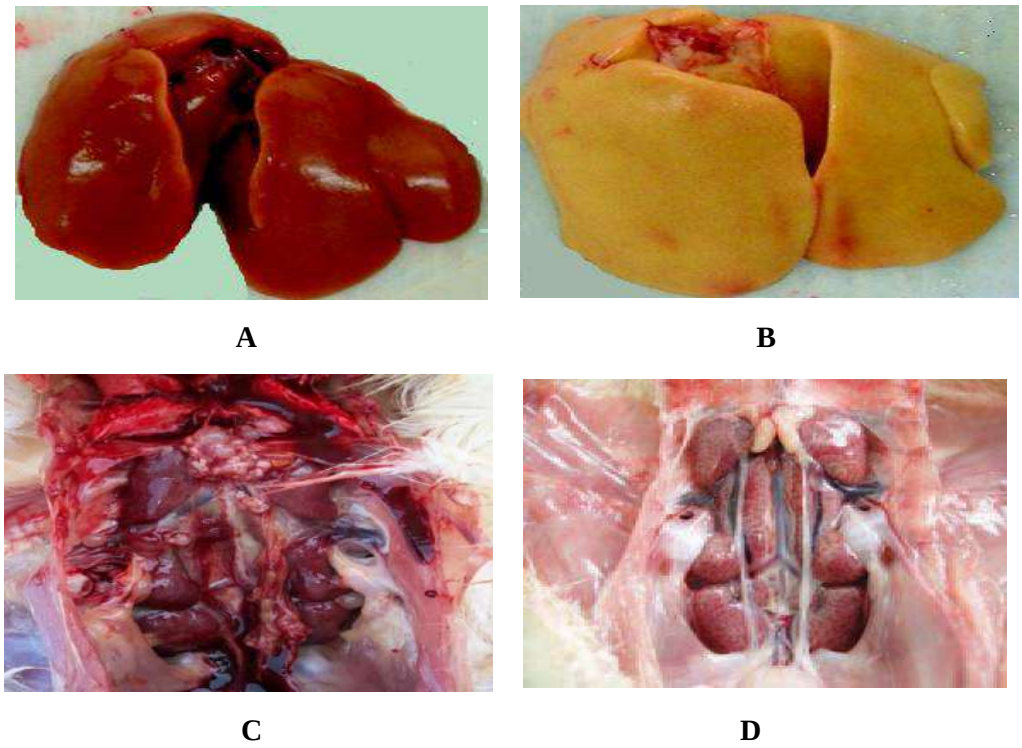

Fig. 3. Gross observations of internal organs of broiler chicken; A: Liver of control diet, B: Livers of AF fed diet, C: Kidney of control diet and D: Kidney of AF fed diet

These changes in liver and kidney in broilers receiving AF plus TP or AF plus GP were much less than broilers fed AF alone. There was no gross lesion on spleen and the weight of spleen was not significantly difference (P>0.05) among the diets. The residues of AF found in muscle and liver was also significantly (P<0.05) higher in broiler diet-A as compared to the chicken diet-B and diet-C, respectively but in the control diet group had no detectable concentration of AF residues in liver and muscles of broilers, where the detection limit of analytical method were 0.05 µg/kg and threshold permissible value were > 2.0 ng/g (Table 4)

Table 4. The Concentration of AFB1 in liver and muscle of broiler at 35 days old

Parameters	Diet-A	Diet-B	Diet-C	Control Diet	[1]P-value
AF residues in liver (ng/g)	3.06 ± 0.25^{a}	2.03 ± 0.29^{b}	2.13 ± 0.25^{c}	ND	**
AF residues in muscle (ng/g)	1.99 ± 0.207^{a}	1.03 ± 0.292^{b}	1.46 ± 0.169^{c}	ND	**

**Significant at P < 0.05; [ND] Not detected

Conclusion

It was confirmed that dietary aflatoxin has negative effects on the body gain, FCR, and organ function of broilers. The current study demonstrated the effects of dietary inclusion of turmeric and garlic powder as a feed additive in overcoming the detrimental effect of AF in broiler chicken. Therefore, it may be concluded that turmeric powder and also garlic powder can decrease adverse effect of aflatoxin on liver and kidney and can be used as a supportive treatment against aflatoxicosis in broiler rearing. Practical application of this research is supplementation of turmeric powder and garlic powder in the diet of broiler to prevent or reduce the adverse effects of feeding AF contaminated diets.

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PHENOTYPIC PERFORMANCE AND RESPONSE TO SELECTION FOR REPRODUCTIVE TRAITS OF BLACK BENGAL GOAT (BBG) IN A COMMUNITY BREEDING PROGRAM

A. Akhtar[1], M.A. Hoque[2], A.K.F.H. Bhuiyan[2*], M.R. Amin[2] and M.A. Habib[3]

[1]Department of Livestock Services (DLS), Farmgate, Dhaka; [2]Department of Animal Breeding and Genetics, Bangladesh Agricultural University (BAU), Mymensingh; [3]Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka. Bangladesh

Abstract

Black Bengal Goat (BBG) is only one goat breed in Bangladesh popularly known for its' fecundity and carcass quality. The study aimed to investigate the genetic improvement of this goat breed *in-situ* through a community-based breeding program under a low input production system in three villages namely *Gangatia*, *Borochala*, and *Pachpai* in Bhaluka upazila of Mymensingh district. Data on a total of 657 individuals included with three progressive generations taken during 2009 - 2015 were analyzed for performance evaluation and genetic improvement as a result of two breeding strategies (BS) viz. mating within superior bucks and does, and within superior bucks and existing does and also compared with a control group mated among existing bucks and does. Statistical analysis was performed by SPSS 17.0 and genetic parameters by VCE 4.2.5. The average age at sexual maturity (ASM), age at first kidding (AFK), services per conception (SPC), litter size (LS), postpartum heat period (PPHP), and kidding interval (KI) were 233.09±2.71d, 383.01±2.61d, 1.13±0.03, 1.90±0.05, 42.41±0.84d and 186.44±0.95d, respectively. Generation and BS had significant effect on all traits, except SPC, except AFK, all other traits differed significantly among the flocks. The heritability estimates of all reproductive traits were medium ranging from 0.32 to 0.57. Genetic and phenotypic correlations among reproductive traits were low to medium (-0.03 to 0.37). The overall responses of up to three generations for ASM, LS, PPHP, and KI were -15.59d, 0.12 no, -6.14d and -7.66d per generation, respectively. It is concluded that community based breeding program with selected superior bucks and does is very rationale under a low input production system, as it improves reproductive performance in progressive generations. However, estimates of heritability and genetic correlations indicate the scope of improvement for reproductive traits with selection and breeding among does and bucks with proven genetic worth.

Keywords: Black Bengal Goat, Community breeding, Genetic parameters, Reproductive traits

Introduction

Black Bengal Goat (BBG) is the most suitable small ruminant species in Bangladesh that is easily manageable and profitable with its best environment almost all over the country. As a reservoir of genetic resources, BBG occupies a very illustrious position among the dwarf meat-type goat in the world. They have several desirable

* Corresponding Author: bhuiyanakfh@bau.edu.bd

characteristics. They attain sexual maturity quite earlier and breed around the year, kid twice a year or more commonly thrice in two years, can produce and reproduce in the very low plane of nutrition, are well adapted to the stressful adverse environmental condition, higher resistance against common diseases and parasites. Besides, it also produces high-quality flavoured, tender and delicious chevon and superior skin, which have a tremendous demand at home and abroad (Devendra and Burns, 1983; Husain, 1993). But, due to their poor genetic potentiality in terms of milk production, the kid mortality is higher. However, another limitation is not directly due to genetics, but rather the system of breeding, often the poorest males are used for breeding, leading to negative selection response (Amin, 2014).

Community breeding program may lead to improve the genetic potentiality of indigenous goat in Bangladesh like other countries. Community breeding means breeding program with participating farmers. The basic steps in community based breeding program are selection of the target community and breeds, description of the production system, definition of breeding goals in participatory manner, assessment of alternative schemes and implementation of feasible schemes (Haile *et al.,* 2011). As about 98% of BBG are being reared in the traditional village system of the country (Husain, 1998), therefore, farmer's participatory breeding program like community breeding program may play a vital role in the improvement of BBG. In this consideration, the study was aimed to determine the performance and response to selection for some economically important reproductive traits of BBG in three community goat breeding flocks at Bhaluka upazila under Mymensingh district of Bangladesh.

Materials and Methods

Location of the study

The study was conducted at rural community level goat flocks of three villages; Gangatia, Borochala, and Pachpaiat Bhaluka under upazila in Mymensingh district of Bangladesh. Bhaluka is geographically located in between 24°16´ and 24°29´ N latitude and in between 90°14´ and 90°29´ E longitudes. The study area is located at 70 km north from the capital city, Dhaka.

Ecology and climate

The ecology of the three villages of Bhaluka is more or less same having temperature ranges from 12^0C (Winter) to 33^0C (Summer), and the annual rainfall averages 2147mm during the research period. High lands was available which were reddish in color, some forests present in Pachpai village. Grazing lands were available in Gangatia, Borochala, and Pachpai villages for the goat.

Selection of sire and dam

Superior bucks and does were selected to establish community foundation flocks of BBG in three villages. The superior bucks were selected from Bangladesh Livestock Research Institute (BLRI), Department of livestock Services (DLS), and simultaneously from the flocks of the community farmers based on physical appearance and reproductive performance. Parent's history was also collected from the goat owner during the selection

process of bucks and does from farmer's community. Superior bucks were selected on the basis of body weight at 6-month of age ≥ 8 kg, good body conformation, early age at puberty <180 days, dams yielded ≥250ml milk/day and kidded ≥ 2 kids in previous birth(s). Superior does were selected on the basis of kidding interval (earlier, preferably <180 days), litter size (preferably multiple, ≥2 kids per kidding), age at first kidding (earlier, preferably <360 days), daughter of a prolific dam who yielded at least 250 ml milk/day and kidded ≥2 kids in previous birth(s) and free from any kind of physical defects and diseases.

Husbandry practices

Traditional housing with semi-intensive management systems was practiced by the BBG keeper farmers. The bucks and does were allowed to graze separately tethered by rope in naturally available pasture land and adjoining fields of the farmer's house. Goats were also provided with tree leaves, kitchen waste, leftovers of family meals, table salt and cut and carry green grass ad lib during the day time. Goats were allowed to feed concentrate feed such as rice gruel, rice bran, broken rice, wheat bran etc. during pregnancy and lactation period @ 200 g/day. The breeding bucks were also fed whole gram @ 50 g/day in the morning. Drinking water was also supplied for the goat ad lib. All goats under the project areas were vaccinated and de-wormed routinely against prevalent diseases and parasites.

Breeding and selection

For mating does with superior bucks, three "Buck Parks" in each village were established by the foreign aided project. Superior bucks were kept in the buck park most of the time except feeding and exercise for half an hour twice in a day. Three breeding strategy (BS) were followed; mating among selected superior bucks and does (those supplied to the farmers by the project aid) denoted as BS1, mating of existing does (owned by the community farmers) with selected superior bucks denoted as BS2 and mating among existing does and bucks (test group) denoted as BS3. Only superior males were selected as sire to produce progeny in progressive generations. The selection criteria were based on the reproductive potential of their dam.

Recording and data collection

All animals were neck tagged and data-sheet for each individual was maintained for recording data. The data was collected over 3 progressive generations from three flocks. There were a total of 657 individuals (101 males and 556 females) consisting 285 base populations (25 males and 260 females) and 372 progeny (76 males and 296 females) from three flocks in three progressive generations were included in this study.

Statistical model and data analysis

The study covered various economic traits of BBG in progressive generations. The animals were of different populations and ages as well as both parents and progeny groups. Therefore, data were sufficient un-balanceness and hierarchy in nature. So, statistical design of the study was essentially non-orthogonal factorial in nature. Descriptive statistics, analysis of variance and phenotypic correlations (Pearson's model)

were performed using SPSS 17.0 (1998) program. The significance of independent variables (fixed or non-genetic factors) was tested by least-squares analyses of variance using the general linear model (GLM) procedure of the following model:

$Yijkl = \mu + Gi + Bj + Fk + eijkl$

where,

Yijkl= Record of lth kid born in ith generation under jth breeding strategy in kth village flock.

μ = Overall population mean for reproductive traits;

Gi = Effect of ith generation (where i = 1st generation, 2nd generation and 3rd generation),

Bj= Effect of jth breeding strategy (where j = BS1, BS2 and BS3),

Fk= Effect of kth flock (where k = Gangatia, Borochala and Pachpai),

eijkl = Random residual error associated with Yijkl observation

Estimation of genetic parameters

The genetic parameters including (co)variance components, heritability and genetic correlations were estimated by using VCE 4.2.5 (Groeneveld, 1998) package with residual maximum likelihood (REML) approach. For REML analysis, animal model was used considering generation, breeding strategy and flock as fixed effects. The general form of the animal model was as follows:

$Y = Xb + Za + Wc + e$

Where, Y = Vector of observations, X, Z, and W = Known incidence matrices associated with levels of b, a and c with Y, b = Unknown vector of fixed effects (i.e. generation, flock etc.), a = Unknown vector of breeding value, c = Unknown vector of permanent environmental effects and e = Vector of residual effect.

Estimation of selection response

The predicted or expected responses to selection in the progressive generations for the economic important traits were estimated using the following formula given by Falconer (1989):

$R= i \times sdp \times h2$

Where,

R = response to selection in the next generation for the trait,

i = selection intensity, h^2 = heritability of the trait,

sdp = phenotypic standard deviation of the trait.

The observed or actual response due to selection was the difference of phenotypic mean between progeny of the selected parents and group of the selected parents.

Results and Discussion

Reproductive performance

The least squares means for reproductive traits of economic importance in BBG as affected by sex (S), generation (G), BS and flock (F) are described in the Table 1.

Age at sexual maturity (ASM)

The ASM as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The overall mean ASM of BBG is 233.09±2.71 days, irrespective of generation, BS and flock which closely agrees with 234.16 days as reported by Halim *et al.,* (2011). Ray *et al.,* (2016) reported ASM to be 249.15±1.01 days for indigenous goat in northern Odisha, India. Earlier, Amin *et al.,* (2001) in a selective breeding program of BBG obtained ASM in first and second generation were 249.63±15.57 and 241.68±11.45 days, respectively. Their reports are in the line of our study. Sexual maturity depends on sex, hormonal activity, and development of reproductive organs, photoperiod and nutritional status of the goat.

Table 1. Reproductive performance of BBG as affected by various non-genetic factors

Factor	Reproductive parameters (Mean±SE)					
	ASM (d)	AFK (d)	SPC (no)	LS (no)	PPHP (d)	KI (d)
Generation	***	***	NS	***	***	***
G_0	260.54^{d}±2.91 (177)	212.45^{c}±2.28 (233)	1.15±0.03 (127)	1.60^{c}±0.05 (169)	47.99^{c}±1.09 (122)	296.23^{d}±1.19 (129)
G_1	237.67^{c}±2.66 (241)	192.33^{b}±2.38 (202)	1.14±0.03 (161)	1.84^{bc}±0.05 (162)	46.50^{c}±0.93 (161)	289.06^{c}±1.05 (162)
G_2	220.88^{b}±4.02 (75)	175.60^{a}±4.90 (048)	1.11±0.06 (055)	2.02^{b}±0.09 (055)	39.24^{b}±1.55 (055)	283.66^{b}±1.76 (055)
G_3	213.27^{a}±6.11 (038)	151.64^{a}±8.27 (016)	1.13±0.09 (021)	2.15^{a}±0.14 (021)	35.92^{a}±2.47 (021)	276.81^{a}±2.78 (021)
BS	***	***	NS	***	***	**
BS_1	204.91^{a}±2.88 (217)	147.94^{a}±6.15 (207)	1.07±0.05 (133)	2.12^{a}±0.11 (164)	38.14^{a}±1.68 (144)	281.50^{a}±2.21 (154)
BS_2	223.63^{b}±3.44 (233)	179.47^{b}±6.42 (196)	1.13±0.03 (122)	1.98^{b}±0.09 (138)	40.88^{b}±1.80 (147)	290.22^{b}±2.28 (144)
BS_3	270.73^{c}±5.95 (81)	221.61^{c}±5.55 (096)	1.20±0.06 (109)	1.61^{c}±0.09 (105)	48.21^{c}±1.81 (068)	308.09^{c}±2.33 (069)
Flock	*	NS	*	*	***	***
Gangatia	238.77^{b}±4.24 (223)	183.05±7.09 (180)	1.19±0.04 (125)	1.86^{b}±0.09 (124)	41.88^{b}±1.96 (112)	287.04^{b}±2.64 (125)
Borochala	237.17^{b}±5.47 (159)	179.36±4.39 (133)	1.17±0.05 (109)	1.75^{c}±0.08 (130)	53.17^{c}±1.31 (125)	307.53^{c}±1.57 (112)
Pachpai	223.32^{a}±2.71 (149)	186.61±6.40 (186)	1.03±0.04 (130)	2.10^{a}±0.11 (153)	32.19^{a}±2.01 (122)	264.74^{a}±2.38 (130)
Overall mean	233.09±2.71 (531)	183.01±2.61 (499)	1.13±0.03 (364)	1.90±0.05 (407)	42.41±0.84 (359)	286.44±0.95 (367)

ASM, AFK, SPC, LS, PPHP, KI and BS denote age at sexual maturity, age at first kidding, number of services per conception, litter size, postpartum heat period, kidding interval and breeding strategy, respectively; G_0, foundation flock; G_1, generation 1; G_2, generation 2; G_3, generation 3; Figures in the parenthesis indicate number of observations; NS, not significant ($p>0.05$); *, significant at 5% level ($p<0.05$); **, significant at 1% level ($p<0.01$); ***, Significant at 0.1% level ($p<0.001$); #means with uncommon superscripts within the same column differ significantly ($p<0.05$).

About 76% of the goats produced from the breeding strategy 1 attained sexual maturity within 8-month of age (Fig. 1). On the otherhand, only about 25% of the goats produced from the third breeding strategy attained sexual maturity within this age. The age at sexual maturity was intermediate between breeding strategy 1 and breeding strategy 3 for goats of the second breeding strategy.

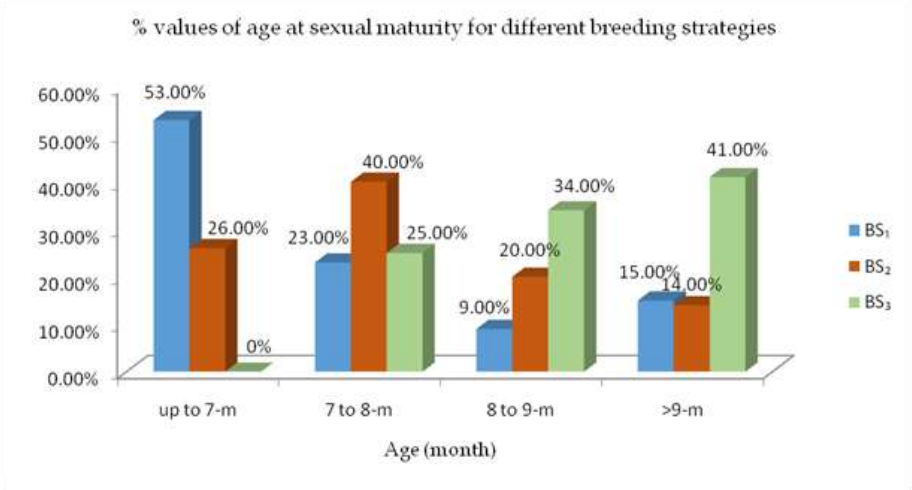


Fig. 1. Distribution of age at sexual maturity for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

Age at first kidding (AFK)

The distribution of age at first kidding for different breeding strategies is illustrated in Fig. 2 which showed that about 49% of the goats produced from the breeding strategy 1 dropped first kid within 12-month of age. On the other hand, none of the goats produced from the breeding strategy 2 dropped first kid within this age. The age at first kidding was intermediate between breeding strategy 1 and breeding strategy 3 for goats of breeding strategy 2.

The AFK as affected by generation, breeding strategy and flock is given in Table 1, which shows that except flock, other fixed factors had significant effect on it. The average AFK was obtained in this study (383.01±2.61 days) closely agree with the study of Faruque *et al.,* (2010) and Husain (1993) for the same genotype (370.26±25.48 and 391.94±10.72 days, respectively). Chowdhury *et al.,* (2002) observed that doe under semi-intensive rearing system gave birth to their first kid at an average age of 13.5-months (equivalent to 405 days) and Hossain *et al.,* (2004) reported was 401.5 days. Ray *et al.,* (2016) reported 410.721±.17 days for giving first kid for indigenous goat in northern Odisha, India. Their estimates were somewhat higher than our study. Earlier, lower AFK of 283.83±31.16 and 360.5days, respectively were reported by Faruque *et al.,* (2010) in an intensive system and Hassan *et al.,* (2007) for the same breed. However, very higher estimates of AFK were reported by Hassan *et al*., (2010) (448-450 days) and Haque *et al.,* (2013) (465.6±12.45 days) for the same genotype. Variations within same genotype could be due to variable environment, management and feeding provided by the farmers**.**

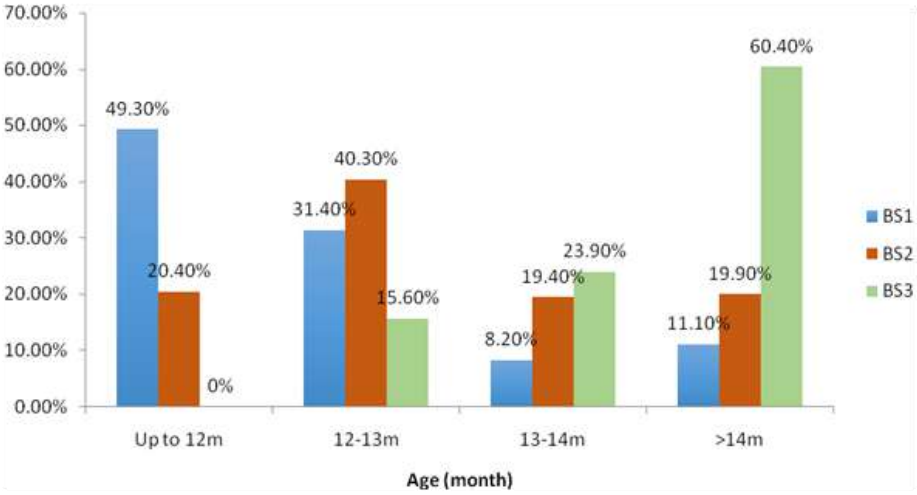


Fig. 2. Distribution of age at first kidding for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

Service per conception (SPC)

The distribution of service per conception for different breeding strategies is illustrated in Fig. 3 which showed that about 88% does conceived from single service for the breeding strategy 1; 86.8% for the breeding strategy 2 and 85.5% for the breeding strategy 3.

The SPC as affected by generation, breeding strategy and flock is given in Table 1, which shows that except flock, other fixed factors had no significant effect on it. The mean SPC in the present study was 1.13±0.02, irrespective of generation, BS and flock. However, the present estimate was very close to 1.10±0.05 (Choudhury *et al*., 2012), 1.10±0.02 (Majumder, 2011) and 1.16±0.19 (Faruque *et al.* 2010) and lower than 1.27 (Hossain *et al.* 2004), 1.45 (Chowdhury *et al.*, 2002) and 1.76 (Islam, 2014). It is evidenced that almost 100% goat keepers mated their does naturally in the rural community; as a result required number of services is vicinity to one.

Litter size (LS)

The distribution of litter size for different breeding strategy is illustrated in Fig. 4 which shows that the highest about 66% does produced from the breeding strategy 3 gave single kid per kidding, about 56% does produced from the breeding strategy 2 gave twin kids per kidding and about 30% does produced from the breeding strategy 1 gave triple kids per kidding. Interestingly, about 2.5% and 0.7% does produced from the breeding strategy 1 and breeding strategy 2 gave quadruple kids per kidding.

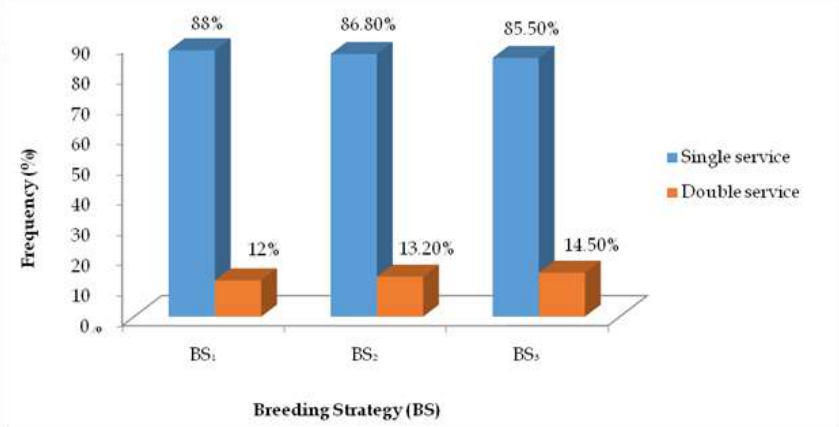


Fig. 3. Distribution of service per conception for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

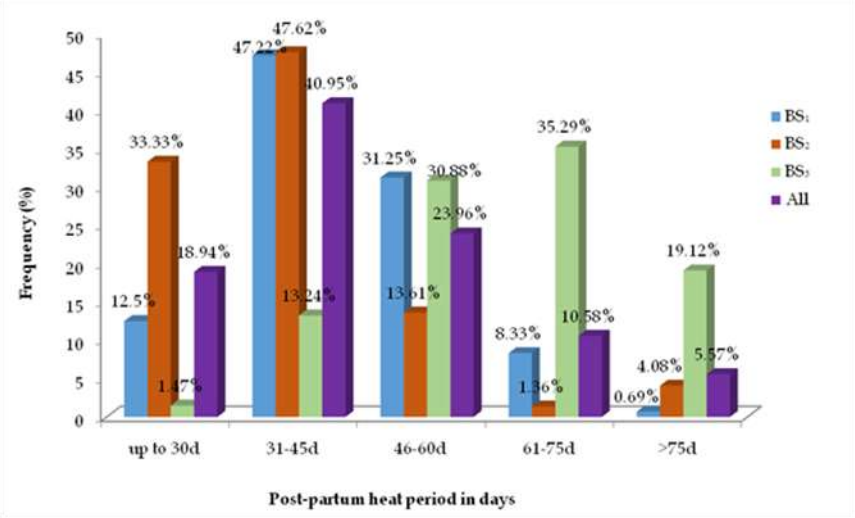


Fig. 4. Distribution of litter size for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The LS as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. Irrespective of generation, BS and flock, the mean LS obtained in this study is 1.90±0.05 (Table 1), which is in general consistent with Majumder (2011) and Husain (1993) who reported it to be 2.03±0.09 and 1.93±0.05, respectively for the same genotype. Comparatively lower estimates (1.50 to 1.61) were reported by Haque (2014); Choudhury *et al.*, (2012); Mia (2011) and Faruque *et al.*, (2010), respectively. In another study, Amin *et al.* (2001) studied LS of BBG in a selective breeding program under farmer's house and obtained

2.15±0.14 kids per kidding in second generation which is higher than our study. Variations among different reports for the same breed could be due to variations of kidding parities among authors from which data were taken, because multiparous does give birth more kids than maiden does

Post-partum heat period (PPHP)

The distribution of post-partum heat period for different breeding strategies is illustrated in Fig. 5 which shows that about 19% goats came into post kidding estrous within 1 month, 41% within 1 to 1.5- months, 24% within 1.5 to 2-months, 11% within 2 to 2.5-months and 6% above 2.5-months. However, more than 90% of the goats produced from the breeding strategy 1 and breeding strategy 2 had post-partum heat period within 2-months. On the other hand, about 46% of the goats produced from the breeding strategy 3 had kidding interval within this age.

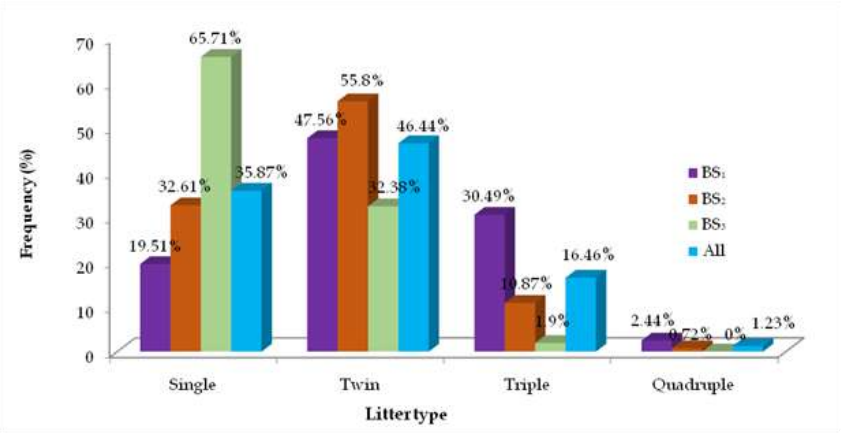


Fig. 5. Distribution of post-partum heat period for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The PPHP as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The PPHP was obtained in this study averaged 42.41±0.84 days, irrespective of generation, BS and flock (Table 1). Majumder, (2011) and Hossain *et al.,* (2004) reported PPHP in BBG to be 46.3 and 43.07 days, respectively which clearly matches with the findings of the present study. On the other hand, Faruque *et al.,* (2010) reported PPHP for the same genotype to be 28.53 days, which was lower than this study. However, higher PPHP (60 and 123.84 days) were obtained by Devendra and Burns, (1983) and Haque *et al.,* (2013) for the same breed. Apparently, generation, parity, better management and nutrition were reported to be the most contributing factors responsible for lowering the PPHP (Hossain *et al*., 2004). BBG are renowned for their fecundity as they give birth kids twice in a year. This is possible if does come into estrous 35-days post kidding.

Kidding interval (KI)

The distribution of kidding interval for different breeding strategies is illustrated in Fig. 6 which shows that about 34% goats had kidding interval within 6-months, 54% within 6 to 7-months, 9% within 7 to 8-months and 3% above 8-months. However, about 91% of the goats produced from the breeding strategy 1 had kidding interval within 7-months. On the other hand, only about 9% of the goats produced from the breeding strategy 3 had kidding interval within this age. The kidding interval was intermediate between breeding strategy 1 and breeding strategy 3 for goats of the breeding strategy 2.

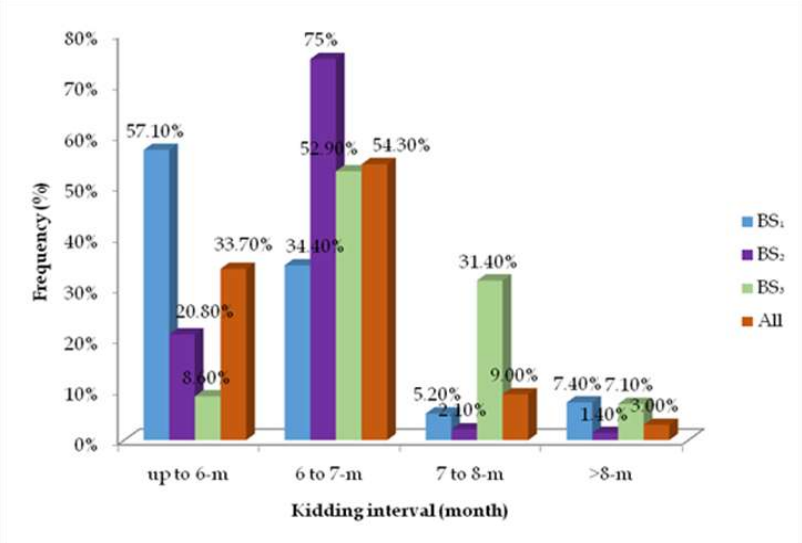


Fig. 6. Distribution of kidding interval for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The KI as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The mean KI without considering generation, BS and flock is 186.44±0.95 days (Table 1), which closely agrees with Choudhury *et al*., (2012) who studied BBG in the same villages and reported it as 188.55±8.82 days. The finding of the present study also corroborates with earlier reports of 181.23±4.55 and 190.2±0.20 days, respectively as obtained by Faruque *et al.*, (2010) and Hasan *et al.*, (2014) for the same breed. On the other hand, Haque *et al.*, (2013) reported 302.5±4.55 days KI for the same genotype, which looks much higher than our study. The variations of KI with wider ranges among investigators within same genotype could be due to difference of management practices, feeding, reproductive care, seasonality or insufficient breeding bucks.

Effect of non-genetic factors on reproductive traits

Generation had highly significant ($p<0.001$) effect on all reproductive traits studied here, except that of SPC, those improved steadily in later generations. This could be due

to selection of superior parents in successive generations under two breeding policies mentioned earlier. Similar finding was also obtained by Amin *et al.,* (2001) and Haque *et al.,* (2013). Faruque *et al.,* (2010) reported KI to have no significant difference among generations, which contradicts with our result. It was reported by many researchers (Islam, 2014; Khandoker *et al.,* 2011) that almost 100% goat keepers mated their does naturally in the rural community, as a result SPC was very close to single, as had been found in this study. Consequently, SPC was not influenced significantly ($p>0.05$) for the effect of generation and BS. Actually, genetic influence on SPC was very negligible, rather than environment. This is in consistence with Choudhury *et al.* (2012), Chowdhury *et al.,* (2002) and Amin *et al.,* (2001). Among three BS practiced in the community breeding program, best reproductive performances were obtained from the population produced from BS_1, followed by BS_2 and BS_3. This is obviously due to genetic potentially of superior parents transmitted to their offspring. Conversely, Choudhury *et al.,* (2012) in the same flocks did not find any significant differences of LS and KI between natural control and natural uncontrolled breeding practices followed in those populations. The variation between works in the same flocks could be due to sample size, as the author evaluated only from 31 kidding records. While in the present study, 367 kidding records in 3 progressive generations were considered. Significant variations were also noticed for all reproductive traits estimated among three flocks, except that of AFK. The variations among flocks could be due to genetic (selection differential of the parents) or other environmental factors like parity, age, management, feeding etc. Haque *et al.,* (2013); Faruque *et al.,* (2010) and Hasan *et al.,* (2014) obtained significant variations for the same traits among different flocks of BBG in their investigations, which clearly ensue of our findings. However, Choudhury *et al.,* (2012) disagrees for LS and KI in the same village flocks, but what the author found may not be reliable enough, as the author worked with very small population.

Heritability of reproductive traits

The heritability estimates for different reproductive traits in BBG are presented in Table 2 which shows medium magnitudes for all parameters studied ranging from 0.32 to 0.48. Haque *et al.,* (2013) in their study reported heritability to be 0.21±0.11, 0.14±0.12, 0.24±0.14 and 0.17±0.11, respectively for AFK, LS, PPHP and KI in the same breed, which seem to be medium estimates of heritability. The corresponding values of this study was though, somewhat high, but agree with magnitude of heritability. Many estimates appeared to be low estimates of reproductive traits (Mia *et al.,* 2013; Faruque *et al.,* 2010). High variability exists in the literatures with respect to the estimates of heritability of reproductive traits in BBG could be due to estimation errors associated with the sample size, structure of the data, management conditions, and estimation methodology used (Moioli *et al.,* 2007). The heritability estimates for reproductive traits as obtained in this study confirms that selection based on the said parameters could be effective for modifying these traits in BBG.

Table 2. Variance components and heritability estimates for reproductive traits in BBG

Reproductive trait	Variance component			h^2 ±SE
	σ^2_a	σ^2_e	σ^2_p	
ASM	448.079	53.027	949.185	0.47±0.03
AFK	537.795	623.108	1698.698	0.32±0.02
SPC	0.055	0.033	0.143	0.38±0.07
LS	0.207	0.020	0.434	0.48±0.03
PPHP	97.362	36.611	231.335	0.42±0.06
KI	85.441	50.406	221.288	0.39±0.07

ASM, AFK, SPC, LS, PPHP and KI denote age at sexual maturity, age at first kidding, number of services per conception, litter size, postpartum heat period and kidding interval, respectively; σ^2_a, additive genetic variance; σ^2_e, permanent environmental variance; σ^2_p, total phenotypic variance; h^2, heritability for the trait; SE, standard error.

Genetic and phenotypic correlations among reproductive traits

The genetic (r_g) and phenotypic correlations (r_p) among reproductive traits were estimated and illustrated in Table 3 which shows both synergistic and antagonistic relationship, though the strengths are merely poor among the pairs of traits. BWSM has antagonistic r_g with other traits, except that of ASM and LS. ASM has negative r_g with LS and KI, but positive with PPHP, although the magnitudes are vicinity to zero. LS have negative r_g and r_p with PPHP, but positive r_g and r_p with KI. PPHP has positive r_g and r_p with KI. The literatures related to r_g and r_p on reproductive traits in BBG are not available for justification of these findings. In other works, Belay *et al.*, (2011) found medium to high r_g among reproductive traits of Arsi-Bale goats, and Ray *et al.*, (2016) reported r_g of 0.78±0.14, 0.08±0.11 and 0.17±0.16 between pairs of ASM and BWSM, ASM and KI and BWSM and KI, respectively, with their corresponding r_p of 0.74±0.22, 0.24±0.09 and 0.27±0.12 for indigenous goat in Odisha, India. Their estimated correlations appear to be inconsistence with our study and this could be due to difference of genotype, environmental and maternal effects, sample size or methods of estimation. However, estimation of r_g among reproductive traits are very tricky, as the products of the respective genetic variance components are usually either zero or negative in most cases. However, it is necessary to carry out further research on the adverse or undesirable genetic relationships observed in this study between BWSM with ASM and LS and between ASM and KI, to obtain correct foundations to know whether these traits may be used in indirect selection.

Based on these findings, it can be said that the strengths of r_g and r_p among reproductive traits indicate that genes controlling for different reproductive traits are probably different, and due to very apart antagonistic relationships, selection for one trait will not result any significant adverse effect for other traits. However, r_g and r_p also suggest for tandem selection or independent culling method for genetic improvement of more than single trait. Further, reproductive traits could be improved adopting good management practices.

Table 3. Genetic correlations (below diagonal) and phenotypic correlations (above diagonal) among reproductive traits in BBG

Traits	BWSM	ASM	LS	PPHP	KI
BWSM	-	-0.155**±0.054	0.012±0.054	-0.159**±0.054	-0.260**±0.05
ASM	0.091±0.042	-	-0.165**±0.054	0.356**±0.051	0.372**±0.05
LS	-0.026±0.047	-0.084±0.041	-	-0.172**±0.054	0.010±0.054
PPHP	-0.088±0.067	0.068±0.058	-0.101±0.064	-	0.286**±0.052
KI	-0.113±0.008	-0.043±0.066	0.133±0.072	0.047±0.105	-

BWSM, ASM, LS, PPHP and KI denote body weight at sexual maturity, age at sexual maturity, litter size, postpartum heat period and kidding interval, respectively; **significant at 1% ($p<0.01$)

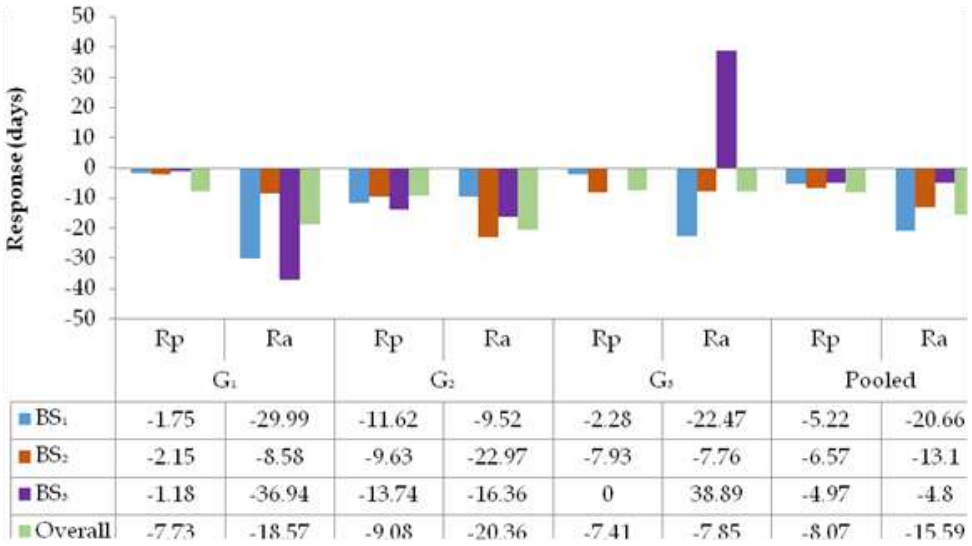
Table 4. Response to selection for reproductive traits in BBG

Traits	Response (R) to selection measured per generation							
	BS_1		BS_2		BS_3		All population	
	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}
ASM	-5.22d	-20.66d	-6.57d	-13.10d	-	-4.80d	-8.07d	-15.59d
LS	0.13	0.21	0.10	0.14	-	0.13	0.12	0.12
PPHP	-1.76d	-8.26d	-2.72d	-5.22d	-	-0.62d	-0.75d	-6.14d
KI	-2.57d	-8.78d	-1.96d	-7.09d	-	-0.43d	-3.13d	-7.66d

ASM, LS, PPHP and KI denote age at sexual maturity, litter size, postpartum heat period and kidding interval, respectively.

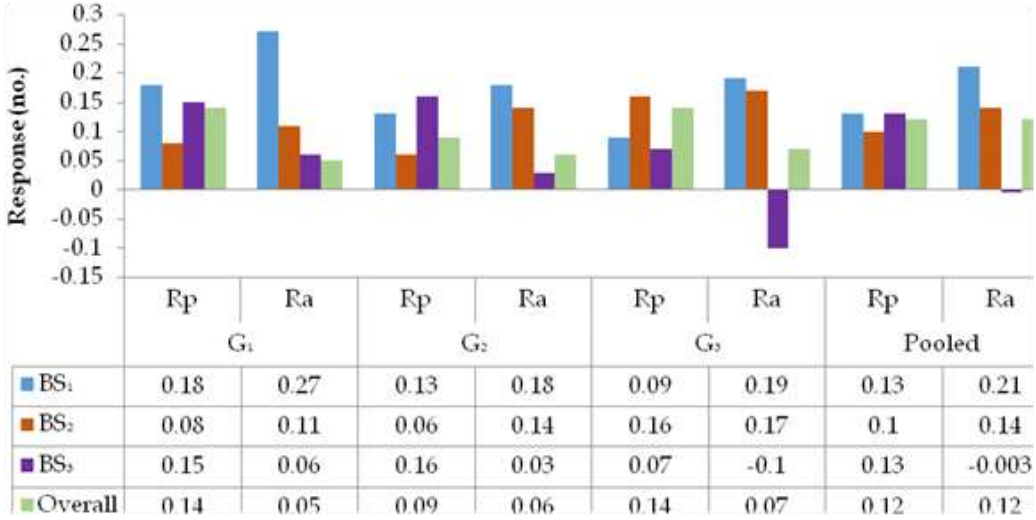
Response for reproductive traits

The response or genetic gain per generation due to selection for some economic important reproductive traits in BBG are presented in Table 4 and Fig. 7 to Fig. 10 which reveal that actual genetic trends were obtained higher than genetic trends predicted for all traits in first two BS. In all population, overall genetic trends per generation for ASM, PPHP and KI were predicted to decrease by 8.07, 0.75 and 3.13 days, respectively, but actual genetic trends were 15.59, 6.14 and 7.66 days, respectively. Besides, response predicted for LS was to increase by 0.12 kids per kidding, while actual response was obtained unchanged. The results also reveal that actual genetic improvement for the said traits in BS_1 population was higher than actual response for the same traits as found in BS_2 and BS_3 populations. This could be due to genetic effect of superior parents transmitted to the progeny of that population. The literatures in regards to genetic improvement of reproductive traits of BBG in Bangladesh are not available to compare with this study. However, this parameter may vary from breed to breed, environment to environment or different breeding policy with different issues.



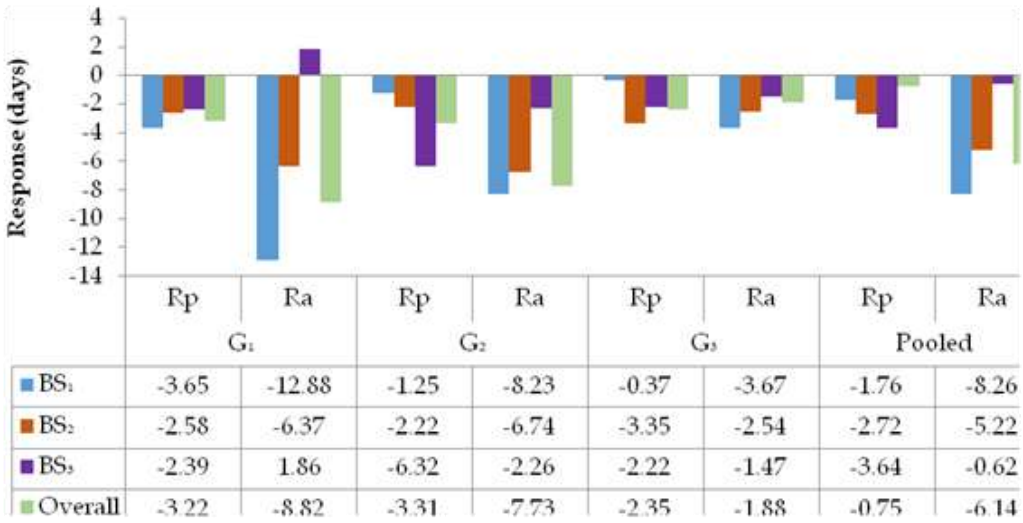
	Rp	Ra	Rp	Ra	Rp	Ra	Rp	Ra
	G_1		G_2		G_3		Pooled	
BS_1	-1.75	-29.99	-11.62	-9.52	-2.28	-22.47	-5.22	-20.66
BS_2	-2.15	-8.58	-9.63	-22.97	-7.93	-7.76	-6.57	-13.1
BS_3	-1.18	-36.94	-13.74	-16.36	0	38.89	-4.97	-4.8
Overall	-7.73	-18.57	-9.08	-20.36	-7.41	-7.85	-8.07	-15.59

Fig. 7. Response to selection for age at sexual maturity (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3; Rp, predicted response; Ra, actual response; G1, generation 1; G2, generation 2; G3, generation 3)



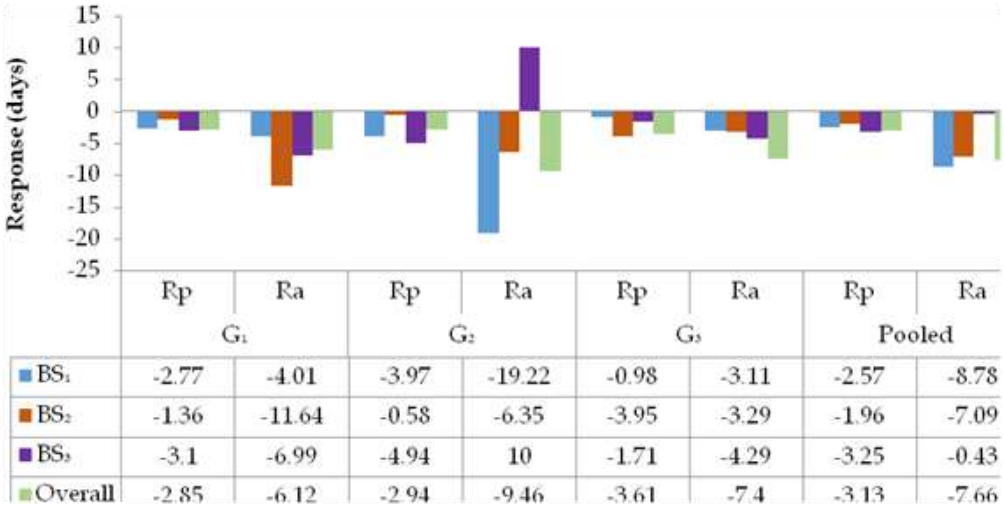
	Rp	Ra	Rp	Ra	Rp	Ra	Rp	Ra
	G_1		G_2		G_3		Pooled	
BS_1	0.18	0.27	0.13	0.18	0.09	0.19	0.13	0.21
BS_2	0.08	0.11	0.06	0.14	0.16	0.17	0.1	0.14
BS_3	0.15	0.06	0.16	0.03	0.07	-0.1	0.13	-0.003
Overall	0.14	0.05	0.09	0.06	0.14	0.07	0.12	0.12

Fig. 8. Response to selection for litter size (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3)



	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS1	-3.65	-12.88	-1.25	-8.23	-0.37	-3.67	-1.76	-8.26
BS2	-2.58	-6.37	-2.22	-6.74	-3.35	-2.54	-2.72	-5.22
BS3	-2.39	1.86	-6.32	-2.26	-2.22	-1.47	-3.64	-0.62
Overall	-3.22	-8.82	-3.31	-7.73	-2.35	-1.88	-0.75	-6.14

Fig. 9. Response to selection for post-partum heat period (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3)



	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS1	-2.77	-4.01	-3.97	-19.22	-0.98	-3.11	-2.57	-8.78
BS2	-1.36	-11.64	-0.58	-6.35	-3.95	-3.29	-1.96	-7.09
BS3	-3.1	-6.99	-4.94	10	-1.71	-4.29	-3.25	-0.43
Overall	-2.85	-6.12	-2.94	-9.46	-3.61	-7.4	-3.13	-7.66

Fig. 10. Response to selection for kidding interval (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3)

Conclusion

It may be concluded that community-based goat breeding approach under low input production system at rural areas by exchanging superior bucks and does, even exchange only of superior bucks with proper selection and culling for screening progeny with good genetic merit may accelerate reproductive performance of BBG in Bangladesh.

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IMPACT OF COVID-19 ON ACADEMIC PERFORMANCE OF STUDENTS IN THE DISADVANTAGEOUS AGRICULTURAL WETLAND (HAOR) AREAS OF BANGLADESH

F. Islam[1] and M.W. Ahmed[2*]

[1]Department of Development and Poverty Studies, Sher-e-Bangla Agricultural University (SAU), Dhaka; [2]Department of Agricultural Engineering, SAU, Dhaka. Bangladesh

Abstract

The pandemic COVID-19 has adverse impacts in almost every sector, including agriculture and education. As an agricultural country, Bangladesh Govt. have prioritized the livelihood, socio-economic condition, especially the education programs in the *haor* areas. This study aimed to assess the impact of COVID-19 on academic performances of primary to higher secondary students in the haor areas of Netrokona and Sunamganj districts. A total of 620 individuals took part in this study. All the participants thought their academic performance were affected by the COVID-19 pandemic in varying degrees. Half of the respondents had no opportunity to join online learning during school closures due to COVID-19 lockdown. The majority of online learners (61.54%) used software-based online classes, while a significant amount of students (39.74%) watched only government-provided Bangladesh Television (BTV) classes during the lockdown. Numerous problems regarding online learning, like financial crisis, lack of smart gadgets, expensive and slow internet, lack of training etc., were predominantly identified in haor areas. It is recommended that concerned authorities should take initiative to provide study loans, free or cheaper data packages, training to teachers and motivation to students and guardians to overcome the temporary loss of education in haor areas of Bangladesh. The findings of this study might help the educationists and policymakers to implement pandemic recovery programs for rural development in the agricultural region of the country.

Keywords: Academic performance, Education, COVID-19, Haor, Online learning

Introduction

In December 2019, a contagious epidemic caused by a novel coronavirus, popularly known as the COVID-19 pandemic, was initially identified in Wuhan, Hubei Province, China (WHO, 2020). COVID-19 has already wreaked havoc on global healthcare systems and impacted every element of human life (Repon *et al.,* 2021). Already, the flu strain has expanded to over 190 nations (UN, 2020). More than 300 million people have been infected with the COVID-19 virus worldwide, with over 5.5 million people causing death (WHO, 2022).

To protect the national healthcare system from this contagious disease, different governments have taken numerous preventive approaches by restricting social gatherings,

* Corresponding Author: wahmed@sau.edu.bd

including closures of all educational institutions (Lal *et al.*, 2021). Bangladesh confirmed the first cases of COVID-19 on 8 March 2020 in the capital city Dhaka (Dutta and Smita, 2020; Emon *et al.*, 2020; Paul *et al.*, 2021). The Government of Bangladesh, like that of most other nations, has chosen to close educational institutions as a precautionary step to prevent the virus from spreading across the country. Since 17 March 2020, the Bangladesh Government has closed all educational institutions and reopened from 12 September 2021 after almost 18 months, one of the world's longest coronavirus closures (Aljazeera, 2021; Li *et al.*, 2020). During writing this manuscript, the government closed all educational institutions countrywide from 22 January 2022 onwards due to the rapid transmission of the new COVID-19 variant (Daily Star, 2022). During closures, students from all over the country were physically detached from educational institutions (Ela *et al.*, 2021). However, the impact of COVID-19 on academic performance and other aspects of life varied on the basis of region, socio-economic condition and availability of modern facilities including digital devices and access of internet (Alam *et al.*, 2020; Li *et al.*, 2020; Paul *et al.*, 2021).

To reduce learning interruptions, the Bangladesh Government rapidly implemented mitigation plans that included the use of online educational paradigms (Shammi *et al.*, 2021). The government started broadcasting classes based on the national curriculum on BTV and internet platforms like Facebook and YouTube (Dutta and Smita, 2020). Though online platform helps continue to study, the system has many negative consequences. Nonetheless, it has detrimental effects on children's academic studies, notably cognitive interruptions and evaluation disruptions, and the impact is worsened for students from low-income families (Hossain, 2021a). As of now, educational establishments shutdown has impacted approximately 1.5 billion students worldwide (UN, 2020). The global shutdown of educational institutions during COVID-19 impacted almost 60% of the world's student population (UNESCO, 2022). Simulated data showed that about 31% of children worldwide could not be reached by digital devices and online platforms (World Bank, 2021). Only about 50% of poor secondary students in Bangladesh have access to a TV-based learning program (Dutta and Smita, 2020).

The vast bowl-shaped wetlands known as Haor areas are situated in the north-eastern region of Bangladesh. There are around 373 Haors in the Sunamganj, Habiganj, Netrokona, Kishoreganj, Sylhet, Maulavibazar, and Brahmanbaria districts (Jakariya and Islam, 2017). Low productivity, flash floods, and other natural disasters, a lack of communication and other infrastructure, and a lack of proper state intervention has resulted in poor socio-economic condition to the people of Haor areas (Kamruzzaman and Shaw, 2018; Kazal *et al.*, 2010). Although the precise figure of inhabitants in Haor regions living below the poverty line is unclear, it is presumed that a significant portion of the population in these places is extremely poor (Kazal *et al.*, 2010). The Haor regions lack suitable educational facilities for children and even adults for livelihood training. Because the Haor areas lack sufficient learning activities for students, literacy rates are very low (Sharma, 2010). Even though COVID-19 has a devastating impact on all aspects of life, the academic performance of students and teachers from vulnerable areas worsens due to the lack of proper facilities (Hossain, 2021a). Because most families live in poverty, virtual learning through reasonably priced devices is usually out of budget for many students. In addition, most school or college teachers do not have enough

technological know-how about digital devices. If the scenario persists, it will be a tremendous setback for many students and teachers across a large part of the state resulting in a socio-economic collapse in these areas.

The relation of COVID-19 to the academic performance of students was investigated in different studies (Marinoni *et al.*, 2020; Repon *et al.*, 2021; Tarkar, 2021). Studies highlighted that students from developing countries including Bangladesh (Dutta and Smita, 2020; Emon *et al.*, 2020), India (Jena, 2020), Pakistan (Mumtaz *et al.*, 2021; Zahra, *et al.*, 2020), Sri Lanka (Rameez *et al.*, 2020), Philippines (Toquero, 2020), and Indonesia (Putri *et al.*, 2020; Rahiem, 2021) experienced significant learning interruption due to COVID-19 interfere. Though there exist a few research papers on COVID-19 impacts on mental health and socio-economic condition (Islam *et al.*, 2020; Khan *et al.*, 2020; Sifat, 2021; Yeasmin *et al.*, 2020), to the best of our knowledge, no research has been done concerning corona pandemic effect on academic performance of students in the underprivileged Haor areas of Bangladesh. Therefore, this study aimed to explore the impact of COVID-19 on the academic performance of primary to higher secondary students (1 to 12 grades) in selected Haor areas of Bangladesh.

Materials and Methods

A draft questionnaire was created, and a preliminary test with 30 students and 10 teachers was conducted to confirm the comprehensiveness of the survey. The purpose of the survey was mentioned at the beginning of supplied papers. The qualitative and quantitative data were collected by providing an offline questionnaire. Students from randomly selected primary school (1-5 grade), secondary school (6-10 grade), and higher secondary school (11-12 grade) from selected upazilas (emphasized on disadvantageous area) of Netrokona and Sunamganj districts were asked to provide information. Data collection covers highly Haor prone upazilas of Netrokona (Kolmkakanda, Barhatta, Mohangonj, Khaliajuri) and Sunamganj (Madhyanagar, Tahirpur, Biswamvarpur, Dharampasha) districts. The data were collected from October to December 2021 by well-trained local data collectors.

Since people from rural areas usually have limited knowledge and access to the internet, we conducted the physical interview maintaining social distance or telephone conversation for primary data collection. Students and teachers from 64 educational institutions (24 primary schools+ 24 secondary schools + 16 higher secondary schools) across the selected upazilas were considered for qualitative and quantitative data collection. After primary data collection, a number of teachers (from three levels: primary, secondary, and higher secondary) from each upazila were interviewed in-depth for cross-checking of qualitative information collected from students.

Data analysis was performed using Microsoft Excel 2016 and IBM SPSS Statistics version 25.0. We applied descriptive statistics to analyze the characteristics of the respondents. The 5-Point Likert Scale (5= greatly affected, considerably affected =4, moderately affected =3, slightly affected=2, and 1= not affected) was used to assess the impact of the pandemic on academic performance, and a 10-Point Likert Scale (1 is the lowest score and 10 is the highest score) was used to assess online education system during lockdown (Mahdy, 2020). In addition to Likert scale questions, information from other close- and open-ended questions was ordered in excel for further analysis.

Results

Socio-demographic characteristics of participants

Six hundred twenty (620) interviews were recorded from eight different disadvantageous Haor prone upazilas of Netrokona and Sunamganj districts of Bangladesh. Among them, 412 (66.45%) were male, 208 (33.55%) were female, 504 (81.29%) were students, and 120 (19.35%) were teachers (Table 1). About 29.68% of the respondents were aged between 5-10 years, 28.39% were aged between 11-15 years, 20.81% were aged between 16-20 years, 5% were aged between 21-34 years, 9.68% were between 35-50 years, and the remaining 6.45% were aged over 50 years. Out of total 620 participants, highest 272 (43.87%) were from secondary schools, whereas primary schools and higher secondary schools comprised of 196 (31.61%) and 152(24.52%), respectively.

Table 1. Socio-demographic profile of participants (N=620)

Variables	Groups	Percentage
Gender	Male	66.45
	Female	33.55
Participants type	Student	81.29
	Teacher	19.35
Age of participants (Years)	5-10	29.68
	11-15	28.39
	16-20	20.81
	21-34	5.00
	35-50	9.68
	Above 50	6.45
Institution level	Primary	31.61
	Secondary	43.87
	Higher secondary	24.52

Assessment of COVID-19 impact on education

This study revealed that the impact of COVID-19 pandemic academic performance varied in different degrees. It was found that more than half of the participants (54.48%, n=340) was greatly affected, whereas the amount of considerably affected, moderately, and slightly affected participants were 38.71% (n=240), 7.10% (n=44), and 1.29% (n=8), respectively (Table 2). Unfortunately, no participant was found in the interview whose academic performance was not affected by the COVID-19. Most importantly, data showed that nearly half of the participants (49.68%, n= 308) had no opportunity to join online learning during the COVID-19 lockdown. However, data showed that overall 50.32% (n=312) participants have participated in online learning.

Table 2. Assessment of the COVID-19 impact on academic performance of participants

Variable	Response	Percentage
The level of impacts of COVID-19 on participants	Greatly affected	54.84
	Considerably affected	38.71
	Moderately affected	7.10
	Slightly affected	1.29
	Not affected	0.00
Participation of online learning during lockdown	Yes	50.32
	No	49.68

Assessment of online education in Haor areas

COVID-19 lockdown has varying degrees of impact on online learning of primary to higher secondary students of Haor areas. Among online learners, smartphone was the highest used device (48%) followed by television (45%), laptop (4%), and personal computer (3%) (Fig.1A). The most followed platform was live online classes (62%), followed by BTV (40%), whereas the least used platform was YouTube (17%) (Fig. 1B). Apart from government-provided BTV classes, Facebook live was the highest (43%) used online learning tool followed by YouTube videos (27%), zoom (17%), Facebook messenger (9%), and Whatsapp (4%), respectively (Fig. 1C). The time spent on online learning ranged between 1 and 4 hours. Out of 312 online learning participants, only about 7.69% spent 4 hours, 35.90% spent 3 hours, 33.33% spent 2 hours, while 24.36% participants spent only 1 hour (Fig. 1D).

The mean assessment score of the online learning was 4.43± 1.40 for theory classes and 1.23 ± 0.54 for practical classes. The highest, 34.62% participants were given 5 points to online theory classes, while 19.23% of participants were given 4, and the same amount (2.56%) of participants were given points 2 and 8 on 10 points Likert scale (Fig. 2). Study showed that most of the participants (73.17%) evaluated online practical classes with point 1 out of 10 points, while 19.51% of participants marked 2, and 7.32% of participants marked 3. However, none of the participants has given more than 3 based on 10 points Likert scale.

Identified problems with online learning in Haor areas

- Lack of electronic devices due to economic problems
- Watched BTV classes on neighbor's TV
- Dropout from online class due to slow internet
- Expensive mobile data
- Teachers were not skilled enough to deliver effective online lectures
- Dishonesty (present in online class but doing something else e.g., using social media, playing online games, doing household chores etc.)

- Lack of immediate feedback and group discussion
- Lack of self and guardian motivation
- Very few practical classes were conducted in online
- Load shading
- Monotonous learning

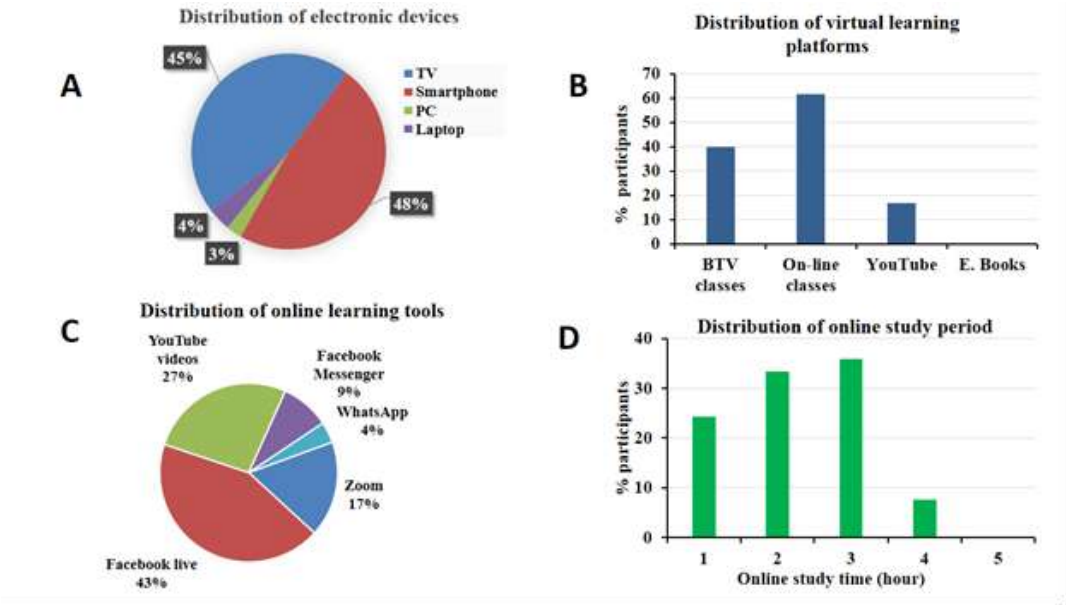

Fig. 1. A. Distribution of electronic devices used by participants for online study; B. Distribution of virtual learning platforms used by participants during COVID-19 lockdown; C. Distribution of online learning tools used by participants during COVID-19 lockdown; D. Distribution of daily online study hours during COVID-19 lockdown

Participants' opinions to improve online education

Participants' suggestions for the improvement of online education were collected and summarized carefully. The listed points were also cross-checked with in-depth interviewees. The most frequent suggestions are listed below:

- Provide electronic devices from government/ institution
- Provide need-based student grants
- Free/low-cost internet packages
- Training to teachers
- Motivate self-paced studies such as uploading recorded videos and other study materials on an easily accessible online site

- Provide shortened syllabus
- Student and guardian counseling
- Class assessment by online quizzes, such as google form
- Animated video for practical lessons
- Online group discussion

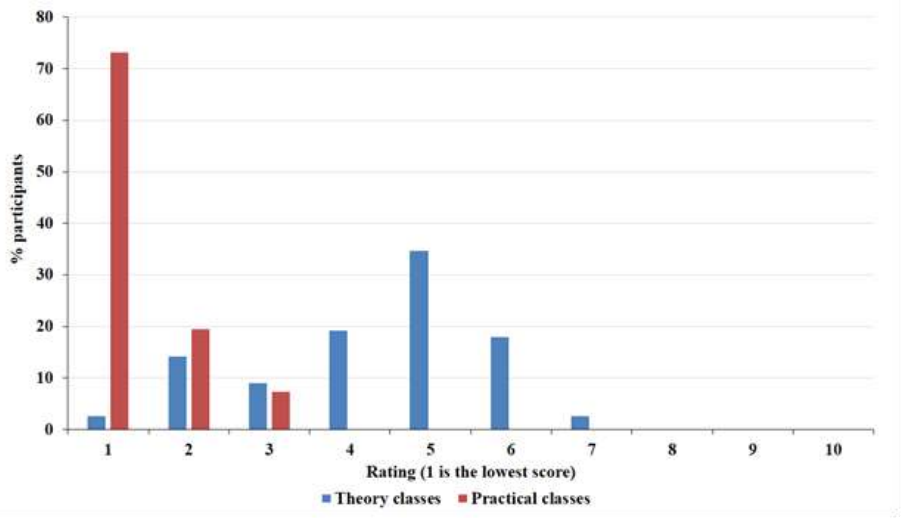

Fig. 2. Evaluation of online education system during COVID-19 lockdown by participants

Discussion

The novel coronavirus, first discovered in Wuhan, China, was quickly spreading in China and throughout the world. COVID-19 has impacted the teaching-learning process from kindergarten to university levels in Bangladesh, as it has in other countries. Many social distancing measures implemented by the state's authorities to prevent the disease's spread, such as the closing of educational establishments and the transition to online education, have substantially impacted the education sector. The government of Bangladesh has taken several steps to ensure non-disrupted education throughout the epidemic (Li *et al.*, 2020). The influence of the COVID-19 pandemic on the academic performance of the learners from disadvantaged wetland (locally known as Haor) communities was underlined in this research.

This study collected total of 620 responses of which 66.45% were male and 33.55% female. The majority of the participants were students (81.29%), whereas primary, secondary, and higher secondary school comprised of 31.61%, 43.87%, and 24.52%, respectively. This study revealed that almost all respondents were affected by the covid-19 pandemic in different degrees, while 54.84% believed this pandemic greatly affected their academic performances. This finding aligned with previous studies (Ela *et*

al., 2021; Emon *et al.,* 2020; Khan *et al.,* 2020; Li *et al.,* 2020; Sifat, 2021) which revealed that Covid-19 had a great influence on the education from primary to tertiary level in Bangladesh. Our study showed that about 49.68% did not attend online learning. According to a previous study (Li *et al.,* 2020), about 46% of students from disadvantaged areas had no access to online study. A slightly higher figure in our study might be due to geographical variation and poor socio-economic conditions.

The most frequent answers regarding online education problems are lack of digital devices, very slow internet speed, cost of internet, lack of training, frequent power cut, lack of guardian motivation, hostile family environment, and financial crisis. According to many participants, poverty due to COVID-19 hit increased in their families drastically affecting their livelihoods, mental and physical health and education. Previous studies reported that COVID-19 has increased poverty in disadvantaged areas impacting all aspects of human life (Hossain, 2021b; Kabir *et al.,* 2021; Li *et al.,* 2020; Mottaleb *et al.,* 2020). As COVID-19 decreased guardian's income, they could not provide smart gadgets to their children. Moreover, regularly buying internet packages was an unbearable burden to many parents. Internet speed is slowest in disadvantageous Haor areas of Bangladesh (Emon *et al.,* 2020). A recent study showed that Bangladesh has the slowest internet (7.8Mbps) speed among 42 countries, whereas the highest internet speed was recorded in Canada (63 Mbps) (Emon *et al.,* 2020). Many participants acknowledged their lack of digital devices for online learning. Many participants said that their teachers were not trained enough to conduct smooth online classes even though they had smart devices. From in-depth interviews of teachers, it was known that female students in Haor areas were in more stress as they were continuously pressurized to get married. In addition to child marriage, child labor also increased alarmingly as many families were compelled to send their children to child labor. Participants also said they felt drowsy and less motivated due to less feedback during online classes. Moreover, the family environment was not favorable for online classes in many participants. Participants said they experienced severe interference by children and elderly family members as it was very difficult to convince them.

To overcome online learning-related problems in Haor areas, it is suggested to make appropriate plans and strategies. Government should provide financial support and education loans for students. It is highly recommended to take the necessary steps to reduce load shedding, improve internet speed, provide free or cheaper data packages, train teachers, and provide proper guardian counseling. However, the Government, Ministry of Education, different national and international agencies and local communities must come forward to reduce the COVID-19 derived problems associated with online learning. The Ministry of Education should provide helping hands to those in vulnerable situations. Moreover, school teachers and family members have to play a vital role in motivating students for online study. Mass awareness must be assured to save the education system in Haor areas; otherwise, the system might be ruined in the near future.

Conclusion

This study outlined the impacts of the COVID-19 pandemic on online learning to primary to higher secondary school level students of Haor areas of Bangladesh. COVID-19 lockdown affected different participants in varying degrees. A significant amount of students had no opportunity to join online learning during COVID-19 lockdown. Online learning of students from Haor areas had faced several problems, including lack of digital devices, high internet price but low speed, lack of skills, lack of motivation, etc. It was recommended to provide financial supports to students, training to teachers, and ensure internet facilities to facilitate online learning. The findings of this study would help educationists and concerned authorities to take necessary steps to overcome the loss of education in Haor areas of Bangladesh.

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LAND USE / LAND COVER CHANGES MONITORED BY NDVI INDEX IN RANGAMATI, BANGLADESH FOR THE LAST FOUR DECADES

M.M. Rahman[1*], K.M. Hossain[1], M.T. Islam[2] and D. Zahid[1]
[1]Institute of Disaster Management and Vulnerability Studies, Dhaka University (DU), Dhaka;
[2]Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), Dhaka. Bangladesh

Abstract

The study of land use/land cover dynamics has been increasingly important in the research of earth surface natural resources. The normalized difference vegetation index (NDVI) is a widely used method for observing land use/land cover change detection. The surface land resources are easily interpreted by computing their NDVI. This study aimed at analyzing Land Use/Land Cover (LULC) changes between 1977 and 2019 in the Rangamati district, Bangladesh using reclassify the NDVI values of the Landsat satellite image and identifying the main drivers to change LULC by household survey. Five different years of Landsat images were used to extract the NDVI values January of 1977, 1989, 2000, 2011 and 2019. The NDVI values are initially computed using the user define method to reclassify the NDVI map to create land use land cover map and change detection. The highest NDVI value was found in 1977 (0.88) which indicates healthy vegetation at that time and thereafter it followed a decreasing trend (0.79 in 1989, 0.74 in 2000, 0.71 in 2011 and 0.53 in 2019) which shows a rapid vegetation cover change in the study area. Analysis of the household survey revealed that population growth, migration from plain land, rapidly urbanization, Kaptai Dam, migration policy of government, high land price, unplanned development, development of tourism industry, firewood collection and poverty have been identified as the major drivers of LULC changes in the study area. Furthermore, analysis of NDVI confirms that the forest vegetation area is being decreased and settlement area and sparseness of vegetation are being increased. The accuracy of the NDVI-based classified images is assessed, using a confusion matrix where overall classification accuracy and Kappa coefficient are computed. The overall classification accuracy was 84% - 90% with corresponding Kappa statistics of 80% - 88% for TM and OLI-TIRS images, respectively. The study serves as a basis of understanding of the LULC changes in the southeastern part of Bangladesh.

Keywords: ETM+, LULC, Landsat, OLI, Remote sensing, TM

Introduction

Land use / land cover (LULC) represents the natural and physical cover of the earth as well as various human uses of land like settlement, agricultural land, reservoirs, transportation network, etc. The change detection of LULC is one of the significant techniques, which is broadly used for planning and managing land (Sahebjalal and Dashtekian, 2013). The multi spectral remote sensing image is the science and art of

* Corresponding Author: mdmaksud107@gmail.com

acquiring information and extracting the features in form of spectral, spatial and temporal about some objects, areas or phenomena, such as vegetation, land cover classification, urban area, agriculture land and water resources without coming in to physical contact of these objects (Karaburun and Bhandari, 2010). Remote sensing technique play an important role in many fields, such as air temperature estimation (Pelta and Chudnovsky, 2017), land cover monitoring (Restrepo *et al.*, 2017), fire incidence assessment (Alves and Perez-Cabello, 2017), drought prediction (Nichol and Abbas 2015) and monitoring of crop distribution (Zhong *et al.*, 2014). Several methods have been used for analyzing LULC, such as conventional image differencing, multi-date image classification, image differencing rationing, vegetation index differencing, principal component analysis, and change vector analysis (Lu *et al.*, 2005). The normalized difference vegetation index (NDVI) is one of the widely used significant classification methods in detecting land cover and land use changes (Aburas *et al.*, 2015). Remote-sensing and GIS technologies only identify the nature, extent, and rate of LULC changes on the landscape; however, they do not provide an explanation about the underlying causes of LULC dynamics on the landscape (Kindu *et al.*, 2013). Therefore, this study aims at quantifying and mapping land use land cover dynamics between 1977 and 2019 in Rangamati district using the NDVI index. The study also explores the local people's perceptions of major drivers of LULC changes in the study area. The outcome of the study would be useful to planners, environmentalists, resource managers, policymakers, and other stakeholders in formulating sound management and environmental planning strategies for conservation of natural resources in Rangamati district.

Materials and Methods

Study area and its geographic location

Rangamati is the largest district of Bangladesh by area. It is a district of natural beauties & cultural heritage. It is located at 22º 00' 27"& 23º 00' 44" N and 91º 00' 56" & 92º 00' 33" E. It is surrounded by Tripura of India at the north, Bandarban at the south, Mizoram of India at the east, and Khagrachari & Chittagong at the west (Fig. 1). It is under Chattogram Division and is a part of the Chittagong Hill Tracts. It consists of 10 upazilas, 2 pourashavas, 50 unions, 1349 villages and 159 mouzas. It became a subdivision in 1891 and was upgraded to a district in 1983. Rangamati district occupies an area of 6116.13 sq. km ; its population is 6,20,214 . Rangamati district has a long history and heritage of a very rich culture of tribal & Bengali people. Rangamati is famous for cashew nut, watermelon, Bangla banana, fresh fishes of Kaptai lake. The district has a hydraulic Power Plant at Kaptai and Terrestrial Earth Satellite at Betbunia, Kawkhli. The main economic activities in the study area are intensive tourism, hydroelectric power, agriculture, fisheries, and forest resources.

Primary and secondary data collection tools

Household surveys

Semi-structured household questionnaires were used in face-to-face interviews in this study employing a random sampling method to select respondents for the household interviews. The questionnaire was pretested by 20 households and then modifications were made before the actual interviews of the sampled households (Munthali *et al.*, 2019). The questionnaire was administered to 300 households during April 04-30, 2019.

Moreover, the questionnaire was administered to respondents who were aged between 25 to 87, and the mean age was 48.41; 73.3% of the Rangamati Sadar residents are permanent residents and 26.7% are migrants but not settlers. Most of the respondents were decision-makers in the household. But in the absence of a family head, it was made with appropriate representatives and knowledgeable members of the household. The questionnaires consisted of both open and closed-ended questions to gather data about the socio-economic and environmental impacts of changing land use patterns of the study area. So, the drivers of LULC changes were extracted by the significant related part of the questionnaire.

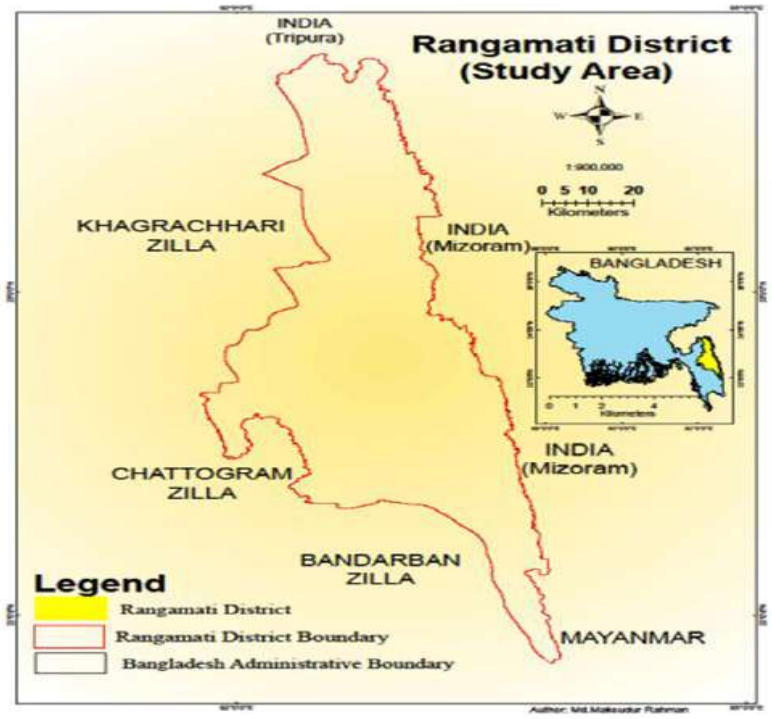

Fig. 1. Rangamati district map as study area (source: author)

Satellite data acquisition

Landsat is the Earth Observatory System (EOS) satellite series that has been providing data since the 1970s (Almazroui *et al.*, 2017). Landsat satellites are considered a valuable source of observation and monitoring of global changes because of the medium spatial resolution and the availability of long term data (Masek *et al.*, 2008). Most of the Landsat satellite data is available free of charge to users via the internet. Landsat satellite data can be acquired via the FTP (File Transfer Protocol) system from the USGS or the GLOVIS (USGS Global Visualization Viewer) website (http://glovis.usgs.gov/). In this study, Landsat time series of LULC data sets were produced from the imagery of MSS, TM, and OLI_TIRS, which were acquired from January 1977, 1989, 2000, 2011 and 2019. The selected five years and their

corresponding months and days have been determined to get the near accurate changes of the temporal changes. Because of the images of the same month and day in a same gap of cloud and noise free are the most useful and reasonable for understanding the maximum changes. The selected images of this study cover most of these features.

The dry season was selected because there is less cloud cover affecting the Landsat images (Tovar, 2011). All images were geometrically corrected and acquired in level 1T (L1T). In addition, the time gap between all the Landsat satellite images was more than 16 days, because of cloudiness or noise-free scenes. Two criteria were followed to choose the satellites images in this study, agreeing to (Sun *et al.,* 2009): (1) the satellite images must have less than 10% cloud coverage (if possible, cloud free); (2) the satellite images should be available for a long time series. Table 1 shows the summary information of the remotely sensed data.

Table 1. Detailed information of Landsat Images used in this study

Year	Date of acquisition	WRS Path	WRS Row	Cloud Cover	Image Quality	Sensor Id	Spatial Resolution
1977	02/01/1977	146	44	0	5	MSS	60
	02/01/1977	146	45	0	5	MSS	60
	01/01/1977	145	45	2	7	MSS	60
1989	13/01/1989	136	44	0	9	TM	30
	13/01/1989	136	45	0	9	TM	30
	10/02/1990	135	45	0	7	TM	30
2000	28/01/2000	136	44	0	9	TM	30
	12/01/2000	136	45	0	7	TM	30
	23/01/2001	135	45	0	9	TM	30
2011	26/01/2011	136	44	0	7	TM	30
	26/01/2011	136	45	0	7	TM	30
	04/02/2011	135	45	0	7	TM	30
2019	16/01/2019	136	44	3.18	9	OLI_TIRS	30
	01/02/2019	136	45	.03	9	OLI_TIRS	30
	09/01/2019	135	45	1.27	9	OLI_TIRS	30

Data preprocessing

This study comprehensively employed GIS and Remote Sensing techniques. There are several methods for detecting seasonal changes in vegetation through satellite images, one method of which is to apply vegetation indices relating to the measurement of greenness (Chuvieco, 1998). NDVI is one of the most extensively used indices in remote sensing of vegetation (Wheeler and Dietze, 2019). It is also used in a variety of observations including that of phenological change (Loveland *et al.,* 2003), land cover classification (Loveland *et al.,* 2000), land cover change (Lunetta *et al.,* 2006), vegetation

cover degradation (Pettorelli *et al.,* 2005), environmental change (Jacquin *et al.,* 2010) and fire damage (Fernandez *et al.,* 1997).

The study considered the spectral index NDVI and classification using NDVI to explore and identify estimating land cover changes. (Akter and Ahmed, 2017). Several data sets (Table 1) were prepared by ERDAS IMAGINE 2014 and ArcGIS 3.4.1 software and field survey data prepared by the statistical software of SPSS 20 and spread sheet. Three Landsat time-series imagery of Level 1 MSS, TM, and OLI_TIRS were acquired and used to evaluate LULC changes by "Defined Interval" method of reclassifying NDVI values for this study. The range of threshold value or greenness value is divided into discrete classes by partitioning the range of NDVI values into five ranges by fixing the thresholds for NDVI classification (Table 2). The downloaded images were layer stalked first and then radiometric corrected, mosaicked and subset using ERDAS IMAGINE 2014. The NDVI values were generated using ArcGIS 10.4.1.

Spectral band 5 as visible Red band and spectral band 6 as visible Near Infrared band for Landsat(1-3) MSS (Multispectral Scanner) with 60 m spatial resolution; Spectral band 3 as visible Red band and spectral band 4 as visible Near Infrared band for Landsat TM sensor with 30 m spatial resolution; and spectral band 4 as visible Red band and spectral band 5 as visible Near Infrared band for Landsat OLI TIRS sensor with 30 m spatial resolution were used for the development of NDVI (Akter and Ahmed, 2017).

Landsat (1-3) MSS spectral Band 5 has wavelength from 0.6 to 0.7 μm and band 6 has wave length from 0.7 to 0.8 μm. Landsat TM spectral Band 3 has wave length from 0.63 to 0.69 μm and Band 4 has wave length from 0.76 to 0.90 μm. Land6sat OLI TIRS spectral Band 4 has wave length from 0.636 to 0.683 μm and Band 5 has wave length from 0.851 to 0.879 μm [http://glovis.usgs.gov].

The NDVI spectral index equation (Rouse et al.1973) is given below –

NDVI = (Near Infrared Band − Red Band) / (Near Infrared Band + Red Band)

The NDVI should be larger for greater chlorophyll density. It takes the (NIR-Red) difference and normalizes it to balance out the effects of uneven illumination such as shadows of hills or trees or clouds (Gandhi *et al.*. 2015). Table 2 presents the threshold value used in the NDVI classification.

Table 2. Threshold value used in NDVI classification

LULC type	Threshold Value				
	1977	1989	2000	2011	2019
Water body	-0.9 -0	-0.45-0	-0.45-0	-0.5-0	-0.09-0
Bare land	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1
Settlement	0.1-0.15	0.1-0.15	0.1-0.15	0.1-0.15	0.1-0.15
Sparse vegetation	0.15-0.25	0.15-0.25	0.15-0.25	0.15-0.25	0.15-0.25
Forest/Dense vegetation	0.25-0.9	0.45-0.8	0.45-0.75	0.45-0.75	0.45-0.55

Accuracy assessment

Satellite imagery-based classification and analysis accuracy depend on different climatic conditions, cloud cover, haze, leaf pattern, chlorophyll content and moisture content including sample selection procedures (Foody, 2008; Gaur and Chouhan, 2017). The information of ground truth data was compared to the classified image in order to check the accuracy. The accuracy of user and producer was carried out to measure the classification accuracy (Singh, 2012; Taufik *et al.,* 2017). Generally, classification accuracy refers to the extent of correspondence between the remotely sensed data and reference information (Congalton, 1991). The classification process is incomplete unless accuracy assessment is performed on it (Lillesand, 2004). For this, the 50 stratified random samples of testing pixels were selected from each (2000, 2011 and 2019) classified image and their classes compared with the land use/land cover field reference and in Google map (Thakkar *et al.*,2014), but accuracy assessment is impossible of others (1989 and 1977) previous images because of vague Google map or noisy Google image. The results were recorded in a confusion matrix. A non-parametric Kappa test was also used to measure the classification accuracy as it accounts for all the elements in the confusion matrix rather than just the diagonal elements (Rosenfield and Fitzpatirck-Lins, 1986).

Land use type

The NDVI value-based statistics are categorized in the following types i.e., water body, bare land, settlement area, sparse vegetation and forest or dense vegetation. Description of these LULC types are given in Table 3.

Table 3. Land use/land cover classes used in this study

LULC type	Description
Water body	All source of water (like river, stream, lake, pond, creek) which able to detect by RS in the study area.
Bare land/Char land	Areas with no vegetation cover, including exposed soils, char land, fallow land and landfill sites also included.
Settlement area	Residential, commercial and services, Industrial, Transportation, Roads, Mixed urban and all buildup area like Stadium, shop, office, school, college, Factory etc.
Sparse vegetation	All cultivated lands area, permanent and seasonal grasslands along lake, river, stream, marshy land and swamps. Which vegetation surrounding the buildup areas are included this class. Crop fields, agricultural land fallow land and vegetable land also included.
Forest/Dense vegetation	Reserve forest, plantations, deciduous forest, mixed forest, palms, conifer and scrubs

Results

Change detection

Fig. 2 shows the spatial representation of LULC types from 1977-2019 and Fig. 3 shows the different NDVI ranges of Rangamati district of selected years. Table 4 presents

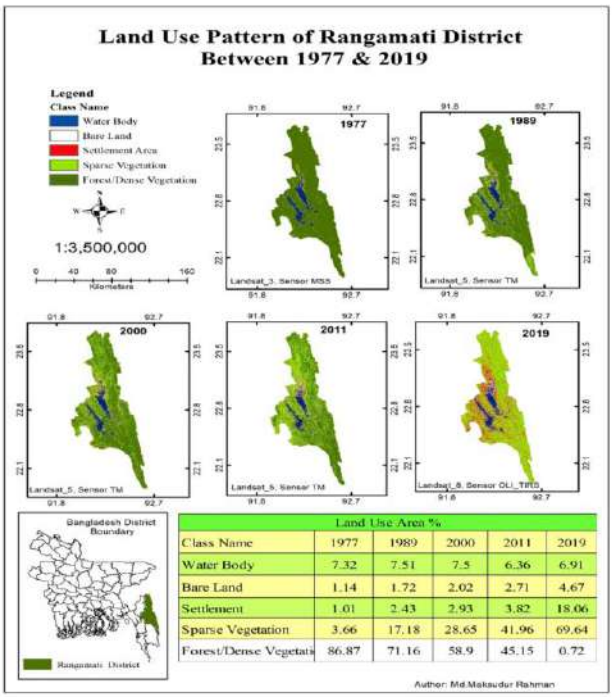

Fig. 2. NDVI derived classified map of Rangamati district for five different years (1977-2019), Source: Based on Satellite image processing (1977-2019)

the percentages of each class of different year out of total area of the study area. The area percentage of each class is calculated by converting those pixels value of each class after classification. The proportionate coverage area of each of the five classes extracted in Rangamati from 1977-2019 of LULC change trends are summarized in Table 5 and Fig. 2. The NDVI is a dimensionless index, so its values are between -1 and +1 (Munthali *et al.*, 2019). Higher NDVI values indicate a healthy vegetated area, while lower NDVI values indicate unhealthy vegetation, close to zero but not negative values indicate settlement, bare land, rock, sand beach respectively and negative values represent the absence of green vegetation (Tovar, 2011). The remote sensing data is broadly used for large area vegetation cover change monitoring (Nath and Acharjee, 2013).

Table 4. Decadal land use land cover area (%) of Rangamati district during 1977-2019

	Area (%)				
LULC type	1977	1989	2000	2011	2019
Water body	7.32	7.51	7.5	6.36	6.91
Bare land/Char land	1.14	1.72	2.02	2.71	4.67
Settlement area	1.01	2.43	2.93	3.82	18.06
Sparse vegetation	3.66	17.18	28.65	41.96	69.64
Forest/Dense vegetation	86.87	71.16	58.9	45.15	0.72
Total %	100	100	100	100	100

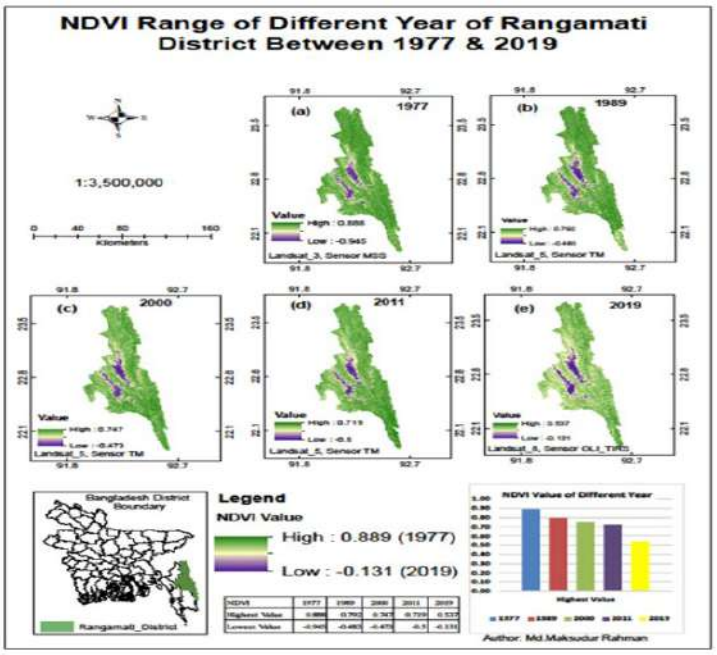

Fig. 3. NDVI range of Rangamati district for five different year (1977-2019), Source: Based on Satellite image processing (1977-2019)

Table 5. Land use change area %

LULC type	Change Area (%)			
	1977-1989	1989-2000	2000-2011	2011-2019
Water Body	0.19	-0.01	-1.14	0.55
Bare Land/Char land	0.58	0.3	0.69	1.96
Settlement Area	1.42	0.5	0.89	14.24
Sparse Vegetation	13.52	11.47	13.31	27.64
Forest/Dense Vegetation	-15.71	-12.26	-13.75	-44.43

Source: Authors' calculation based on Satellite image processing, (1977-2019)

Results of accuracy assessment

The NDVI derived and use classes overall accuracy were 84 to 90% and with corresponding Kappa statistics of 80, 88 and 87.5%, respectively (Table 6), corroborating the standard accuracy of 85-90% for LULC mapping studies as recommended (Anderson *et al.*, 1976).

Table 6. Results of accuracy assessment of land use/cover map produced from Landsat TM and OLI_TIRS data

LULC type	2000		2011		2019	
	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)
Water body	90.91	100	90.91	100	83.33	100
Bare land	88.89	80	100	90	80	80
Settlement	77.78	70	88.89	80	90	90
Sparse vegetation	66.67	80	75	90	100	90
Forest	100	90	100	90	100	90
Overall accuracy	84%		90%		90%	
Kappa Coefficient (T) 80%	80%		88%		87.50%	

Source: Based on Satellite image classification calculated by author, (2000, 2011 & 2019)

Major drivers of LULC changes

The major drivers of LULC changes are demographic factor, economic growth, land use policy factor, industrialization, housing and tourism. The annual population growth rate was 7.11% between 1974 -1981, 3.1% between 1981 -1991 and 4.1% in 1991- 2001 in Rangamati district shown in Fig 4.

The field survey was conducted in the rural, semi-urban, and urban areas. The majority of respondents agreed to the point that population growth, urbanization, unplanned development, and increase in economic activities are the factors for changes in the land use pattern over the past few decades (Fig. 5).

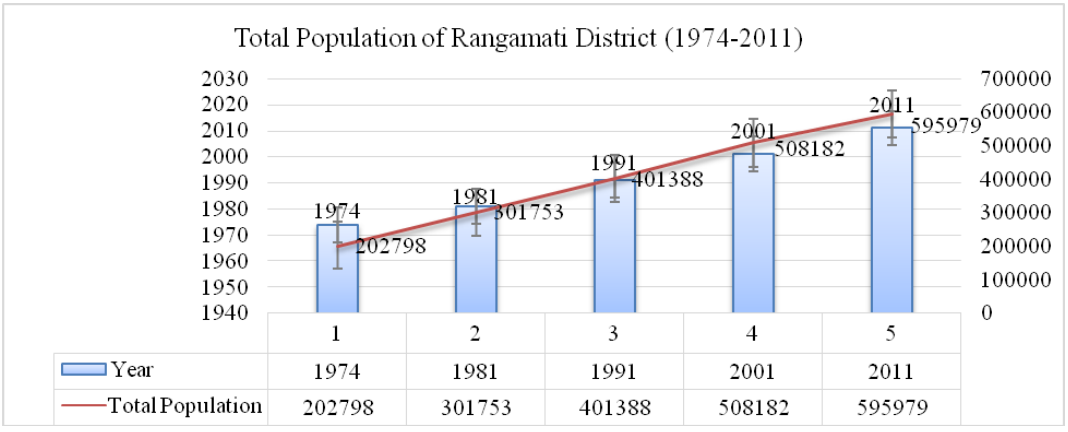

Fig. 4. Population trend of Rangamati district (1974-2011), Source: Population Census of various census years of BBS (Bangladesh Bureau of Statistics).

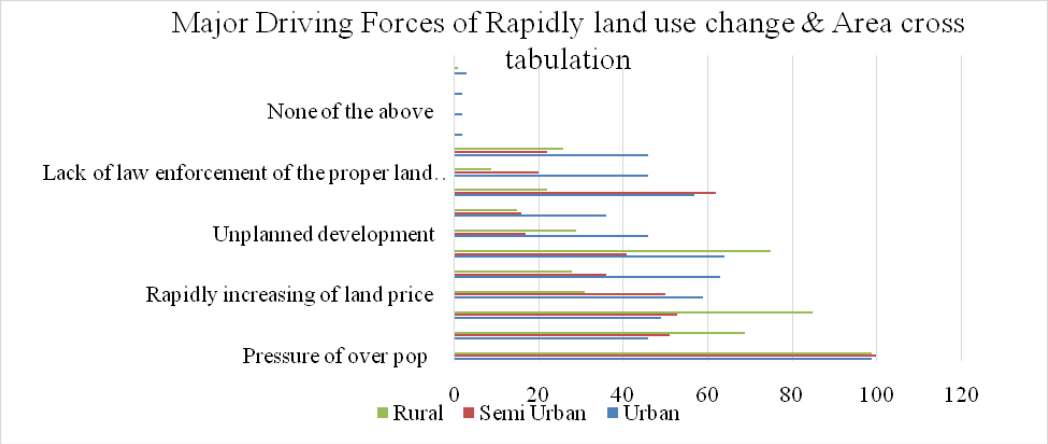

Fig. 5. Major driving forces for rapidly land use changes. Source: Field Survey, Rangamati 2019

Causes of forest degradation

Forest is a very vital renewable resource in Rangamati. It provides materials like timber, pulp, pole, fuel wood, food and medicine, habitat for wildlife, and primary base for biodiversity. It also influences the precipitation and sustained water yield in the river systems etc. But the pattern of our LULC map shows that the forest of Rangamati is degrading year by year which is alarming news to all. This research work also worked on the major causes of Rangamati forest degradation. In Fig. 6, the field study result shows that poverty is the major cause of all the other factors which is affecting the environmental sustainability of Rangamati District.

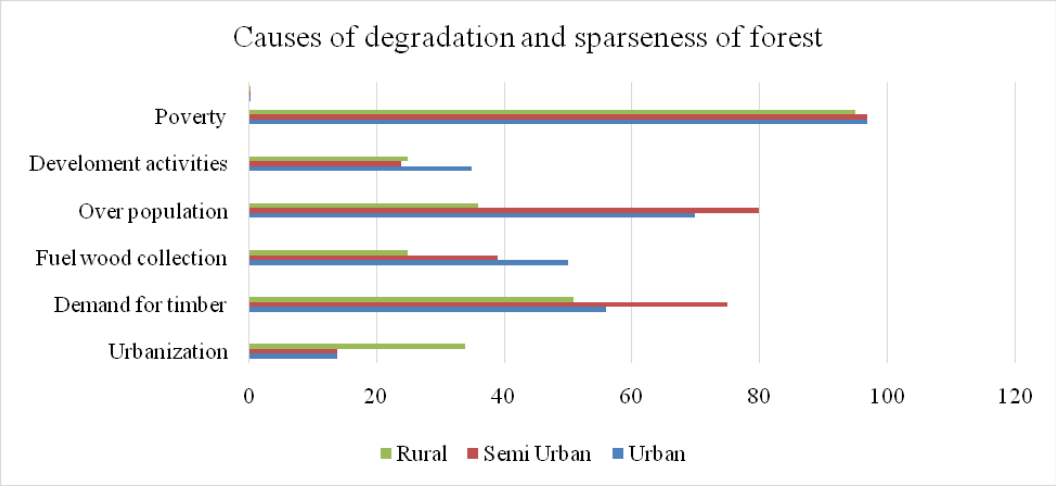

Fig. 6. Causes of degradation and sparseness of forest, Source: Field Survey, Rangamati 2019

Discussion

The NDVI values of these land use land cover classes differ significantly from 1977-2019. Figure 3 shows that the highest NDVI value was found in 1977 (0.88) which represents healthy vegetation at that time and after 1977, the highest NDVI value shows a decreasing trend (0.79 in 1989, 0.74 in 2000, 0.71 in 2011 and 0.53 in 2019) which represents a rapid vegetation cover change in the study area. Slightly changed or an irregular change trend observed in the Kaptai lake and water body area due to the seasonal variation (Table 4 & 5, Fig. 3) of water like scarcity and availability. Results confirmed that the forest or dense vegetation area is decreased rapidly and on the other hand bare land settlement area are increased gradually, and sparseness of vegetation are increased rapidly (Table 4 & 5), which may be considered as a great threat regarding proper ecosystem functioning and climate change.

Figs. 2 & 3 and Tables 4 & 5 show the spatial representation of LULC types from 1977 to 2019. The trend is changing land-use patterns is a dynamic process. It depends on different time and space. This research has found a major variation of settlement area and sparse vegetation and forest area were changed rapidly. The bare land area was changed gradually and the water body was found slightly irregular changed due to seasonal variation of water body. Dense forest & sparse vegetation were played a major role in many conversions to settlement and bare land area. This conversion could be related to the rapid increase of population (Fig. 4) and faster economic development in Rangamati district.

The major drivers of land use change and causes of degradation of forest interprets the environmental degradation of Rangamati over the decades which is alleviating the true beauty of landscape in Rangamati district. It is believed that eco-tourism could be an alternative mechanism for environmentally sustainable development without depleting the forest resources and its habitat.

Conclusion

The settlement area, bare land and the vegetation sparseness area have increased and dense forest area has decreased rapidly in the study period of 1977 to 2019. Slightly changed or an irregular change trend observed in the Kaptai lake and total water body area due to the seasonal variation of water like scarcity and availability. Thus the present study explains the temporal land-use trend of the Rangamati district, which is very important for sustainable land use planning decisions and also forecasting possible future changes in growth patterns.

Considering all these, results of this study have shown that remote sensing and GIS are important tools in land-use change studies. Based on the findings of this study, the followings are recommended as future research directions:

- Expansion of settlement should be regulated.
- Sustainability of environmental aspects should be focused.
- Deforestation must be stopped and the afforestation program should be undertaken.

- The use of high-resolution imageries such as IKONOS and Quick Bird is important in generating good quality of land use maps. Because urban areas have complex (especially hilly urban area) and heterogeneous features, high-resolution imagery provides better information by mapping these areas.
- Consistent multi-temporal Landsat satellite data for each year provides a detailed comparison of images.
- Incorporating socio-economic environmental data, land policy, biophysical and human factors (population density, technology, political) could improve the performance of land use analysis for future predictions.

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Short Communication

EFFECTS OF PLANT GROWTH REGULATORS ON YIELD AND YIELD ATTRIBUTES OF TOMATO (*SOLANUM LYCOPERSICUM*)

B. Ahmed[1*], M. Sultana[1], M. Sumi[1], A.S. Mitu[2], R. Biswas[3] and M.A.M. Hussen[4]

[1]Bangladesh Agricultural Research Institute (BARI), Gazipur; [2]Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna; [3]Khulna Agricultural University (KAU), Khulna; [4]Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka. Bangladesh

Abstract

A field experiment was carried out at Tuber Crops Research Sub Center, Seujgari, Bogura, Bangladesh to assess the effect of plant growth regulators on tomato during the winter season of 2020-2021. Four Plant Growth Regulators (PGRs) available in market viz., PGR_1 = Flora @ 20 ppm, PGR_2= Protozim @ 20 ppm, PGR_3= Vagimax and PGR_4= Miraculan@ 20 ppm were used, and there was a control no use of PGR was used as control in the study. The experiment was conducted in RCBD with three replications. The growth and yield contributing characters significantly differed due to plant growth regulators. The maximum number of fruits/plant (65) was recorded from PGR treatment (application of Flora @ 20 ppm) while the minimum number of fruits/plant (25) was recorded from the control treatment (no application of plant growth regulators). Plant growth regulators had significant influence on growth and yield of tomato. The highest yield (36.21 t/ha) and highest Photosynthesis (Chlorophyll a, Chlorophyll b and Total Chlorophyll) was obtained from the application of PGR_1 = Flora @ 20 ppm plant growth regulator. The maximum Benefit Cost Ratio (BCR) (3.34) was also recorded from PGR_1 treatment, while the minimum BCR (1.66) was recorded from control (no application of plant growth regulators). Among the four PGRs i.e., application of Flora @ 20 ppm showed the best result in tomato production.

Keywords: Benefit cost ratio, Growth regulators, Tomato, Yield

Introduction

Tomato (*Solanum lycopersicum*) belonging to *Solanaceae* family is a vegetable crop grown in Bangladesh during winter. Its food value is very rich because of higher contents of vitamins A, B, and C including calcium and carotene (Alam *et al.*, 2010). It is much popular as salad in the raw state and is made soups, juice, ketchup, pickles, sauces, conserved puree, paste, powder and other products. In Bangladesh, there is a great possibility of increasing tomato yield per unit area with proper use of fertilizer (Kayum *et al.*, 2008; Khan *et al.*, 2014). Tomato requires large quantity of readily available fertilizer nutrient (Khayyat *et al.*, 2007). In absence of other production constraints, nutrient uptake and yield are very closely related. PGRs are chemicals which are used to modify plant

* Corresponding Author: kbdahmed@gmail.com

growth such as increasing branching, suppressing shoot growth, increasing return bloom, removing excess fruit, or altering fruit maturity (Uddin *et al.,* 2009). PGRs have the positive and essential role for building up protoplasm and protein, which induce cell division and initial meristematic activity when applied in optimum quantity.

PGRs have largest effect on yield and quality of tomato. It also promotes vegetative growth, flower and fruit set of tomato. It significantly increases the growth and yield of tomato. Application of PGRs to the plants produces high tomato fruit yield and improves fruit quality whereas excessive application leads to luxuriant development of vegetative parts of the plant at the expense of reproductive growth (Mehraj *et al.,* 2014). In the local market, various companies sell their PGRs. However, studies on the market available PGRs for physiological efficiency, apparent growth recovery and their relation to yield potentiality on tomato are scanty. With the above background, the present study was undertaken to investigate the effect of PGRs on the yield, yield attributes and Benefit Cost Ratio (BCR) of tomato.

Materials and Methods

The experiment was carried out in Tuber Crops Research Sub Center (TCRSC) research field of BARI, Seujgari, Bogura, during the winter season (November 24, 2020 to March 30, 2021) to find out the effect of selected four plant growth regulators (PGR_0 = Control, PGR_1 = Protozim @ 20 ppm, PGR_2= Flora@ 20 ppm, PGR_3= Vagimax @ 20 ppm and PGR_4 = Miraculan @ 20 ppm) available in market of Bogura on BARI Tomato-14. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Twenty four days old seedlings were transplanted at a spacing of 60 cm × 40 cm in the experimental plot on 24 November 2019. Manures and chemical fertilizers were applied at the rate of cow dung 20 t/ha, Urea 250 kg/ha, Triple Superphosphate (TSP) 200 kg ha, and Murate of Phosphate (MP) 150 kg/ha. Later the stock solution was diluted in distilled water to prepare the working solutions just before application. Spraying was performed early in the morning to avoid rapid drying of the spray solution due to transpiration. Data were collected from ten randomly selected plants from each plot viz., plant height (cm), number of fruits/plant, fruit length and diameter, average fruit weight (g) and yield/ha. The means were separated at 5% level of significance.

Chlorophyll determination

1. Preparation of the reaction solution: Pure acetone, pure ethanol and distil water (4.5:4.5:1) mix up them.
2. The RS and sample of fresh leaves (small pieces) in small tubes (100:1) moxed up and placed the tubes in dark until the color of leaf pieces converted into white.
3. Reading taken at 663 and 645nm for chlorophyll while for caroteniods at 470nm.
4. Calculation of Chlorophyll Determination (mg/g FW):

   Chl. (a) = (12.71×OD663–2.59×OD645)/100

   Chl. (b) = (22.88×OD645–4.67×OD663)/ 100

   Total chlorophyll = Chl. (a) +Chl. (b)

The benefit cost ratio (or benefit-to-cost ratio) compareed the present value of all benefits with that of the cost and investments. These benefits and costs were treated as monetary cash flows or their equivalents. The BCR was calculated to find out the comparison between each treatment. The BCR of tomato was calculated by using the following formula:

$$BCR = \frac{PV_{benefits}}{PV_{costs}}$$

Where,

$PV_{benefits}$ = present value of benefits

PV_{costs}= present value of costs

Results and Discussion

Plant height

Statistically significant variation was found in the plant height (cm) of tomato due to application of plant growth regulators (Table 1).The maximum plant height (52.66 cm) was recorded by application of Plant Growth Regulator (Flora @20 ppm), while the minimum plant height (24.45 cm) was recorded from control (no application of plant growth plant growth regulators). It might be due to the effect of plant growth regulators on plant growth which is supported by Choudhury *et al.*, 2013 and Ali *et al*., 2015.

Table 1. Effect of PGR on yield and yield attributes of tomato

Treatment	Plant height (cm)	No. of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Yield (t/ha)
T_1	52.66	65	2.86	3.25	40.35	36.21
T_2	45.36	60	3.05	2.61	39.25	26.38
T_3	44.59	55	3.21	2.57	36.89	32.31
T_4	48.24	49	2.05	3.21	45.58	31.38
T_5 (Control)	24.45	25	1.59	2.39	29.68	18.98
CV (%)	1.56	4.21	2.31	1.75	7.24	3.58

T_1=PGR_1 (Flora @ 20 ppm), T_2= PGR_2 (Protozim @ 20 ppm,), T_3= PGR_3 (Vagimax @ 20 ppm),T_4= PGR_4 (Miraculan @ 20 ppm) and T_5= No PGR(Control)

Number of fruits per plant

Statistically significant variation was found in the number of fruits per plant of tomato due to application of plant growth regulators (Table 1). The maximum number of fruits per plant (65) was recorded from PGR treatment (application of Flora @ 20 ppm) while the minimum number of fruits per plant (25) was recorded from no application of plant growth regulators. It might be due to that flora enhanced fruit setting in tomato.

Fruit length

In case of fruit length (cm), statistically significant variation was found of tomato due to application of plant growth regulators (Table 1).The highest fruit length (2.86 cm) was recorded from PGR treatment (application of Flora @ 20 ppm) while the minimum fruits length was recorded from no application of plant growth regulators (Control).

Fruit diameter

In respect of fruit diameter (cm), statistically significant variation was found in tomato due to application of plant growth regulators (Table 1).The highest fruit diameter (3.25 cm) was recorded from PGR treatment (application of Flora @ 20 ppm) while the minimum fruit diameter (2.39 cm) was recorded from Control.

Individual fruit weight

Average individual fruit weight of tomato revealed statistically significant variation due to application of plant growth regulators (Table 1). The maximum average weight of individual fruit (45.58 g) was recorded from PGR treatment (application of Miraculan @ 20 ppm), while the minimum average weight of individual fruit (29.68 g) was recorded from Control.

Photosynthesis

It is observed that the photosynthetic element Chlorophyll-a, Chlorophyll-b and total chlorophyll was higher in treatment of PGR than the control treatment (Fig. 1). Among the PGRs, application of Flora @ 20 ppm gave the higher photosynthetic element production than other. Higher photosynthetic rate results in higher yield performance (Ahmed *et al*., 2021 (a), Ahmed *et al*, 2020, Ahmed *et al*, 2021(b)

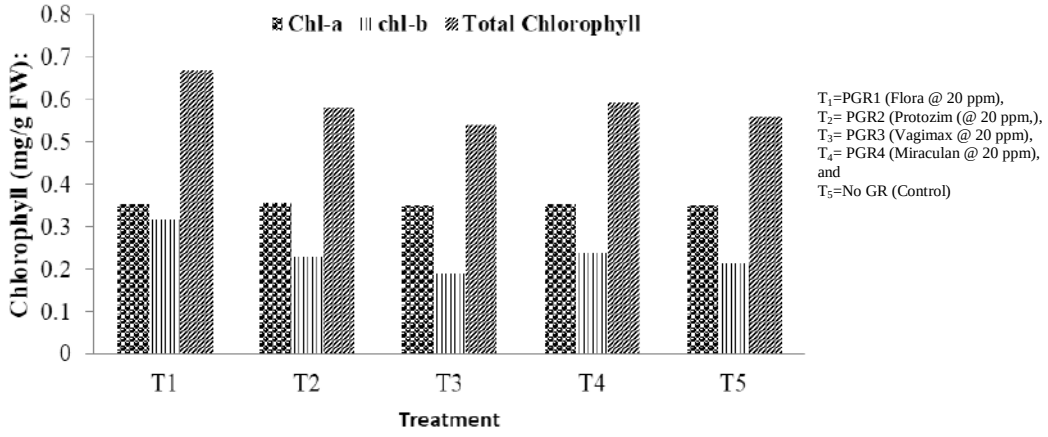

Fig. 1. Effects of different PGR_5 on photosynthesis of tomato

Yield

Statistically significant variation was found due to application of plant growth regulators in respect of yield of tomato (Table 1). The maximum yield (36.21 t/ha) was recorded from PGR treatment (application of Flora @20 ppm), while the minimum yield (18.98 t/ha) was recorded from no PGR application (Control) PGRs increased the number and weight of fruits/plant and thus increased yield of tomato (these findings were supported by Akand *et al*, 2016; Mehdizadeh *et al*., 2013; Isah *et al.*, 2014)

Benefit Cost Ratio (BCR)

The maximum Benefit-Cost Ratio (BCR) (3.34) was recorded from PGR treatment (application of Flora @20 ppm), while the minimum BCR (1.66) was recorded (Table 2) from Control treatment (no application of Plant Growth Regulators). Plant growth regulators increased yield and weight of fruit per plant and thus increased BCR of tomato (these findings were supported by Ahmed *et al.*, 2018).

Table 2. Effect of PGRs on the Benefit-Cost Ratio (BCR) of tomato

Treatment	Production Cost (ha^{-1})	Selling cost (Market price @ 40 tk kg^{-1})	Profit (Tk)	BCR
T_1	650,000	2801,500	2151,500	3.34
T_2	670,000	2391,900	1721,900	2.57
T_3	660,000	2607,000	1947,000	2.95
T_4	650,000	1904,500	1254,500	1.93
T_5	600,000	1756,000	1156,000	1.66

T_1=PGR_1 (Flora @ 20 ppm), T_2= PGR_2 (Protozim @ 20 ppm,), T_3= PGR_3 (Vagimax @ 20 ppm),T_4= PGR_4 (Miraculan @ 20 ppm) and T_5= No PGR (Control)

Conclusion

Plant growth regulators had significant influence on the growth and yield of tomato, Flora @ 20 ppm gave the highest yield, yield attributes and Benefit-Cost Ratio (BCR).

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